APPENDIX 12-C

Water Balance and Water Quality Model Report

GOLDCORP

Appendix 12-C

Coffee Gold Project

Water Balance and Water Quality Model Report

Project No. A362-2
29 March 2017

LORAX ENVIRONMENTAL

2289 Burrard Street
Vancouver, BC, V6J 3H9
Canada
1-604-688-7173

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1. Introduction

1. Introduction

A site wide water balance model (WBM) and water quality model (WQM) has been developed for the Coffee Gold Project and is described in the following report. The report describes the WBM and WQM, key inputs and assumptions of each model, and presents model outputs, including a summary of the streamflow and surface water quality output.

The WBM and WQM is used to provide quantitative estimates of changes to surface water flow and quality as a result of mine operation and closure. Quantifying the degree to which streamflow and surface water quality are predicted to change informs the environmental assessment process that is mandated by the Yukon Environmental and Socio-Economic Assessment Act (YESAA, 2003). An estimation of the potential alterations to baseline streamflow and water quality condition informs site-wide water management planning and focuses mitigation strategies core to Project design. Further, WBM and WQM outputs are direct inputs to valued and intermediate component assessments central to the Application (*i.e.*, surface hydrology, surface water quality, groundwater, fish and aquatic biota and valued components related to human health and social well-being).

1.1 *Report Objectives*

The specific objectives of this report are as follows:

- Describe the inputs and assumptions employed in the modeling exercises, including those inputs from relevant baseline studies:
    - Hydro-meteorology (Appendix 8-A);
    - Hydrogeology (Appendix 7-A);
    - Geochemistry (Appendix 12-D);
    - Water Quality (Appendix 12-A); and
    - Heap Leach Facility Water Balance Model (Appendix 12-C-1 and Appendix 12-C-2).
- Describe the WBM and WQM and introduce the modeling platform and architecture that have been used to represent the Project and adjacent receiving environments;
- Discuss the calibration approach and present the calibration results for the WBM and WQM respectively;

- Summarize the sensitivity scenarios that have been evaluated for the Coffee Gold Mine as part of the YESAA application; and
- Present and synthesize the results from the GoldSim model, including discussion of results for predicted streamflows and surface water quality.

1.2 *Report Structure*

The data sources incorporated into the WBM and WQM are presented in Section 2 of this report. The WBM is informed by a hydro-climate assessment that has been undertaken for the Project (Appendix 8-A), and baseline hydrogeology studies (Appendix 7-A) which include the construction and calibration of a site-wide groundwater model. Water quality predictions require both baseline water quality and facility-specific (*e.g.*, pit walls, waste rock, stock piles) geochemical source term information. This information is presented in detail in the Application (Surface Water Quality Baseline Report, Appendix 12-A; Geochemical Characterization Report, Appendix 12-D), but summarized briefly in Section 2 as well.

Streamflow and surface water quality predictions were derived from two linked models. First, a WBM was configured to estimate monthly surface water flows at a number of facilities and locations, on and adjacent to, the Project. Next, water quality signatures were assigned to each flow term and a WQM was used to estimate surface water quality conditions at ten locations (model 'nodes') downstream of the Project. Section 3 provides a description of the WBM, describes how the WBM was constructed and calibrated, and also presents a summary of streamflow results from the model. Section 4 focuses on the WQM and shares a similar structure (*i.e.*, description, construction, calibration, results) to Section 3. The report concludes in Section 5 with a discussion and summary of next steps for water modelling at the Coffee Gold Mine.

Ultimately, results from the WBM support the hydrological assessment for the Project, which is described in detail in the Surface Hydrology Intermediate Component (IC) Report (Appendix 8-B). Outputs from the WBM and WQM, in turn, are direct inputs to the Surface Water Quality Valued Component (VC) Report (Appendix 12-B), which describes the anticipated effects of the Project on surface water quality. Streamflow and surface water quality changes also affect other VC and IC valued and intermediate components, as noted above. WBM and WQM outputs are direct inputs to the Fish and Fish Habitat VC Report (Appendix 14-B), but also relevant to human health and social studies (*e.g.*, Appendix 18-B).

2. Data Sources

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2. Data Sources

This section of the report presents foundational information for the WBM and WQM, including information from the Coffee Gold Mine Plan and Water Management Plan, and data sources from water-related baseline studies (*i.e.*, meteorology, hydrology, surface water quality, groundwater and geochemistry).

2.1 *Coffee Gold Mine Plan*

A complete description of the Coffee Gold Mine Plan is provided in the YESAB Project Proposal. Notably, Section 2 (Project Description**)** presents temporal and spatial information relevant to the conceptualization and construction of the WBM and WQM. Figure 2-1 below shows the End-of-Mine (EOM, Yr-12) General Arrangement in relation to local catchments and WBM/WQM predictive nodes for general reference.

2.1.1 Project Phases and Activities

The Project comprises four distinct time-frames: construction, operation, reclamation and closure and post-closure Phases, as presented in Table 2-1 and Figure 2-2. Table 2-1 also describes primary activities associated with each Project phase and that are incorporated into the WBM/WQM for the Coffee Gold Mine. Figure 2-3 shows the Project layout at the point of maximum mine infrastructure buildout.

2.1.1.1 *Mine Phases Selected for Assessment*

The Project phases selected for assessment include late operations (*e.g*. starting in mine-year 7 or 2027); post-mining closure; active closure and post-closure (Figure 2-2). The Post-Closure Phase has been modelled out to the year 2100, although monitoring activities are not expected to continue for the duration of this Project phase. This end-point was selected because the climate change projections that were incorporated into the WBM terminate in this year.

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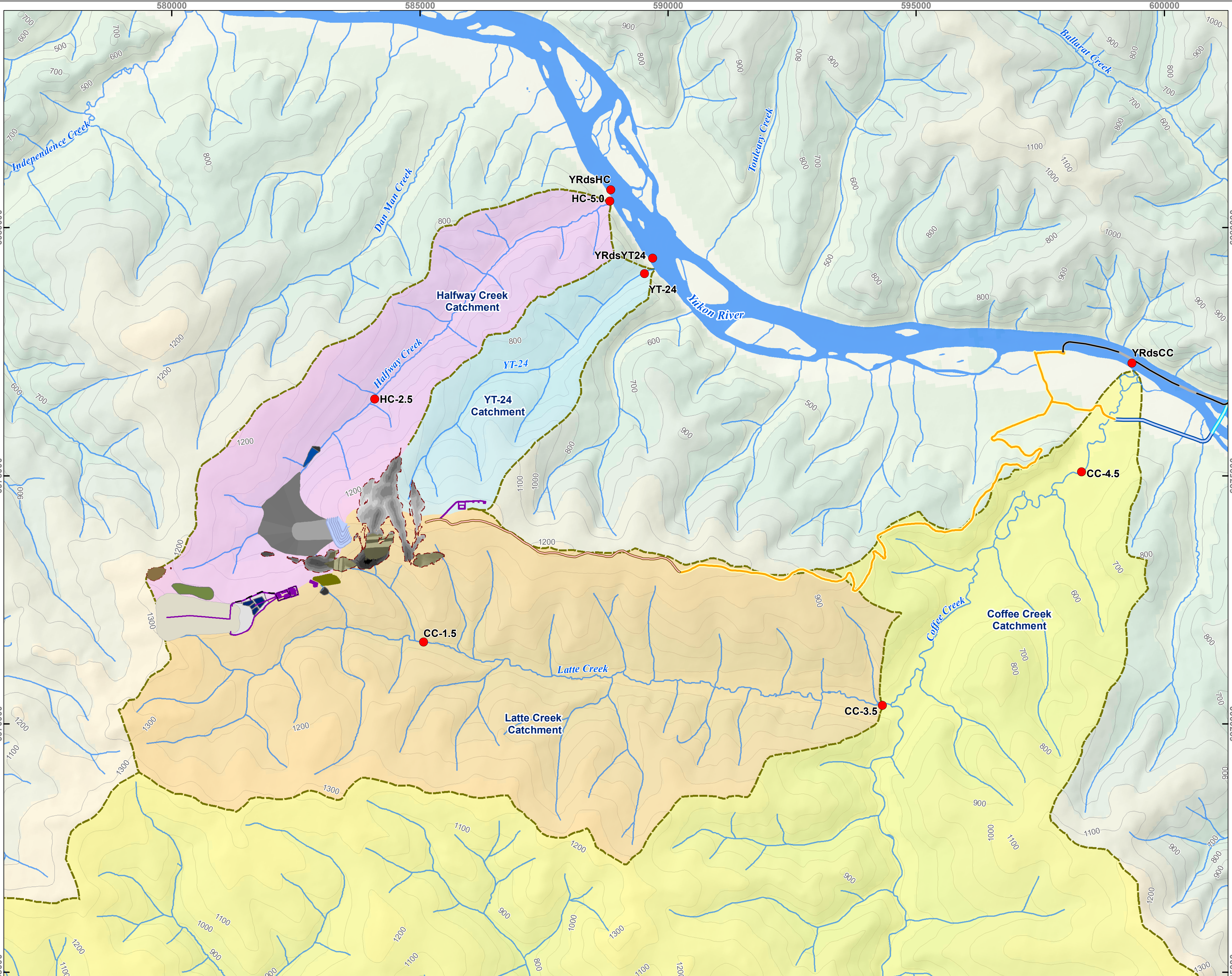
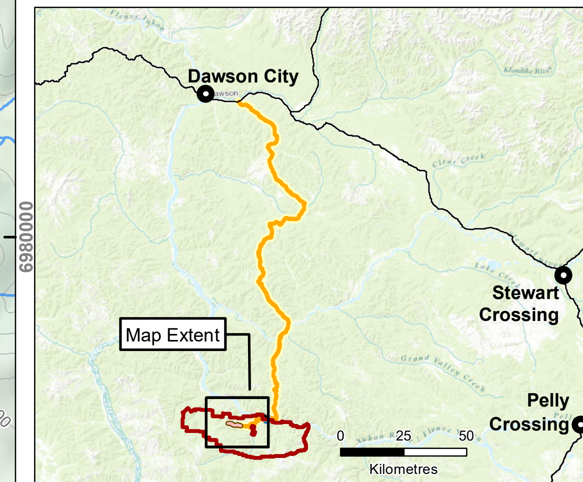
End-of-Mine General Arrangement and WBM-WQM Nodes





Legend

- Surface Water Quality Monitoring Location
- City/Community
- Catchment Boundary
- Coffee Property Claims Boundary
- Waterbody
- Watercourse
- Elevation Contours (100m)
- Yukon River Barge Route
- Yukon River Ice Road
- Winter Road
- Mine Site Access Route
- Northern Access Route

Pre-Mine Catchment Area

- Halfway Creek
- Latte Creek
- YT-24 Creek
- Coffee Creek

Proposed Infrastructure

- WRSF
- Backfill
- Total Pit Outline
- ROM Stockpile
- Organics Stockpile
- Frozen Soil Storage Area
- Event Pond
- Heap Leach Access Disturbance Footprint
- Heap Leach Pad Base
- Support Infrastructure

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NAD 1983 UTM Zone 7N

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Figure 2-1	Date: Mar 28, 2017	Drawn by: GM	Reviewed: AS

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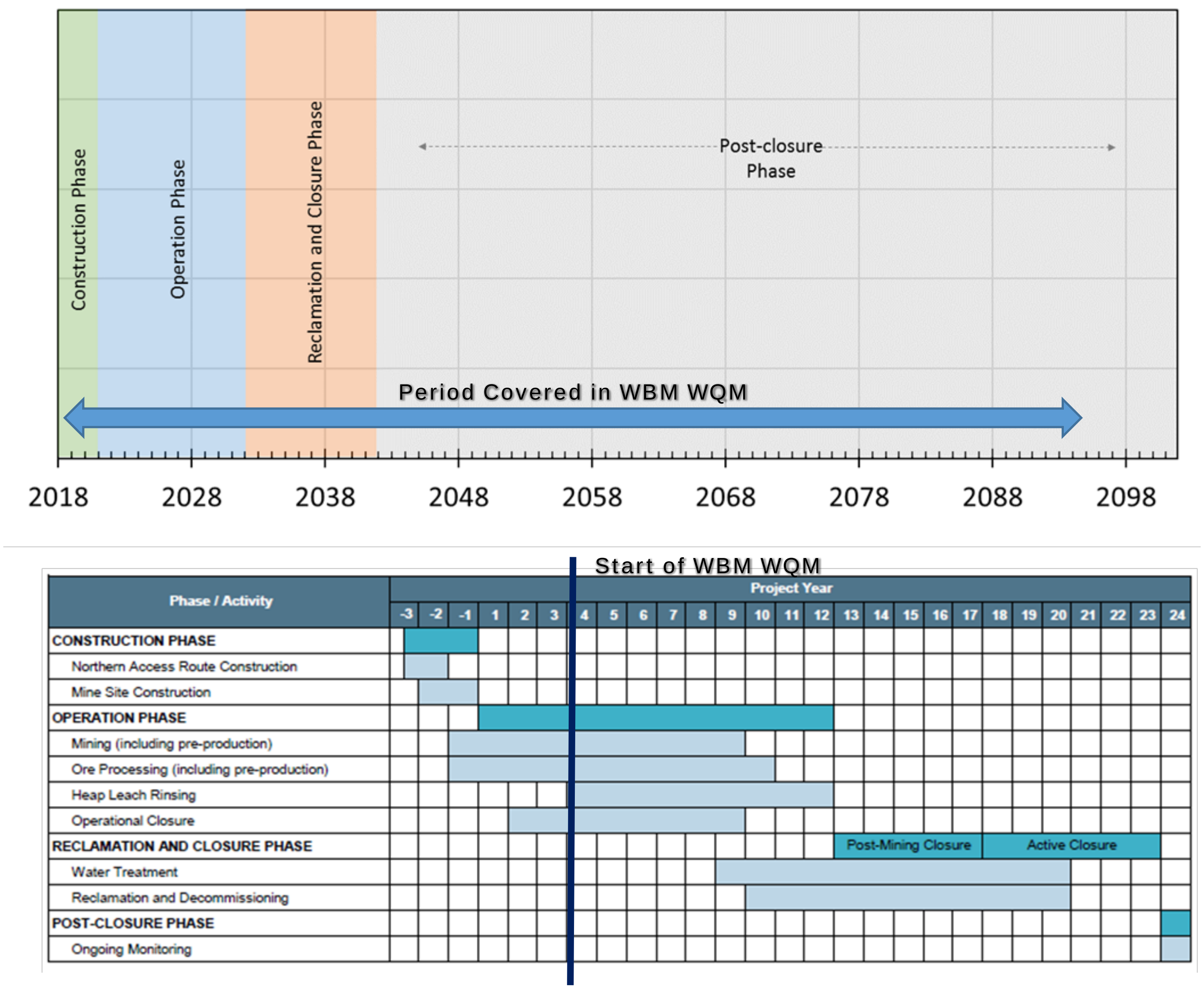


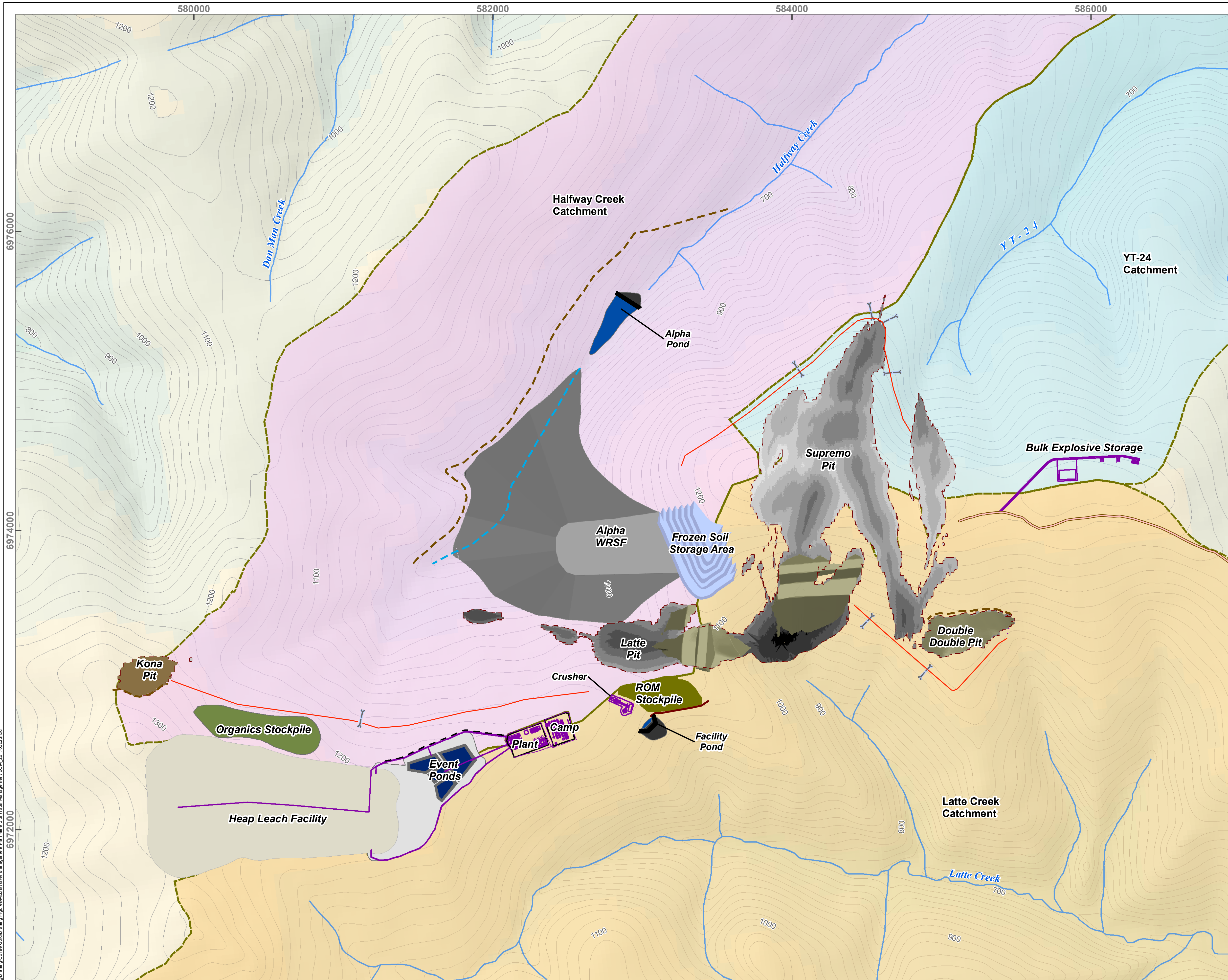
Figure 2-2: Proposed Project timeline for the Coffee Gold Mine

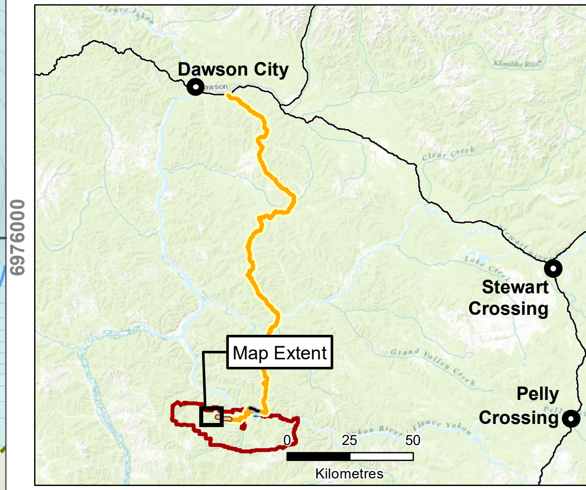
Table 2-1:
Coffee Gold Mine Project Activites by Phase

Phase	Mine Years	Calendar Year	Duration	Activities
Construction	Years -3 to -1	2018 to 2020	16 months	• Clearing and grubbing of mine infrastructure areas; • Development and dewatering (as required) of Latte and Double Double pits; • Development and use of Alpha WRSF; • Development of stockpiles for temporary storage of organics/topsoil and remaining overburden, run-of-mine (ROM) ore and crushed ore; • Heap Leach Facility (HLF) construction, including water management infrastructure; • Loading of ore on HLF pad and initial makeup water withdrawal (if required); • Development and use of water management infrastructure external to HLF (*e.g.*, diversion ditches, sediment control ponds);
Operation	Years 1 to 12	2020 to 2032	12 years	• Development of Kona Pit and Supremo Pit, and continued development of the Double Double and Latte Pits (and associated temporary closures); • Backfilling of waste rock to open pits; • Continued use of Alpha WRSF and development and use of temporary Beta WRSF; • Continued use of all stockpiles; • Operation of crusher and process plant, and continued staging of HLF construction (including a 3rd event pond in or before Year 6); • Progressive closure and reclamation of the HLF; • Ongoing contact and non-contact water management, pit dewatering as required; • Installation of water treatment facility for HLF before Year 9, and; • Treatment of closed HLF stages drain-down rinse water.
Post-Mining Closure and Reclamation	Years 13 to 23	2033 to 2042	11 years	• Progressive reclamation of disturbed areas within mine site footprint; • Progressive reclamation of Alpha WRSF, Beta WRSF footprint and HLF; • Closure of Supremo and Kona Pits; • Closure of HLF and related water management structures, including operation of water treatment facility for HLF rinse water (Year 9 to 20); • Decommissioning of sediment ponds and HLF water treatment facility;
Post-Closure	Year 24 onwards	2043 to 2099	Indefinite	• Monitoring activities to track performance of remediation work completed for the closed mine site.

COFFEE GOLD MINE

Mine Site General Arrangement, EOM





Legend

- City/Community
- Mine Site Access Route
- Catchment Boundary
- Elevation Contour (20m)

End of Year 9 Catchment Areas

- Halfway
- Latte Creek
- YT-24 Creek

Proposed Infrastructure

- WRSF
- Backfill
- Total Pit Outline
- ROM Stockpile
- Organics Stockpile
- Frozen Soil Storage Area
- Event Pond
- Heap Leach Access Disturbance Footprint
- Heap Leach Pad Base
- Support Infrastructure

Water Management

- Culverts
- Pond Berm
- Diversion Channel
- Road Drainage Ditch
- Rock Drain
- Collection Channel
- Settling Pond Dam
- Settling Pond

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Meters

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Figure 2-3	Date: Mar 27, 2017	Drawn by: GM	Reviewed: AS

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2.1.2 Open Pits

The mineral resource is accessed via Latte, Double Double, Supremo and Kona pits, and will be mined by open-pit shovel and truck methods. Open pit mining will progress as follows: Double Double pit will be mined out first in Year 1, followed by Latte and Kona pits in Years 3 to 5 of the mine plan, with Supremo pit being completed finally in Year 12. With the exception of Latte Pit, the lowest mined elevation of the open pits will be situated above the groundwater table, and as such, groundwater inflows to pits through the Operation Phase are expected to be minimal. All water that accumulates in the Kona pit during operations (this water will only be meteoric water entering the pit and not groundwater) will be used in the process plant as make-up. In Year 11, Kona pit will be backfilled during winter when the waste rock is frozen so that the backfill process will re-establish permafrost to depth. Upon cessation of mining, several pit lakes are expected to form as a result of surface runoff and meteoric water inputs reporting passively to pits, with the time elapsed to maximum fill point, or spillover, being pit specific.

2.1.3 Waste Rock Storage Facilities

Most waste rock from the open pits is planned to be deposited in the Alpha waste rock storage facility (WRSF) in the Halfway Creek catchment. Additionally, some waste rock will be backfilled into pit exposures at Latte, Supremo and Double Double to create causeways for vehicles and to minimize ex-pit WRSF footprints overall. A smaller, temporary Beta WRSF will be located adjacent to the Kona pit (Figure 2-3). Total waste material removed from the pits, including that used for construction and placed as backfill is estimated to be approximately 300 Mt. Additional detail on the WRSFs in contained in Appendix 31-D – Waste Rock and Overburden Facility Management Plan.

2.1.4 Stockpiles

Three types of stockpile will be present at the Project site (Figure 2-3):

- a temporary organics stockpile, located north of the HLF that will be used for reclamation purposes;
- a frozen soil storage area located adjacent to the Alpha WRSF, and;
- a Run-of-mine (ROM) ore stockpile located adjacent to the crusher that will be used during the months of January through March in the Operation phase when ore is not being stacked on the HLF.

All stockpiles are temporary, and the ROM stockpile will have a capacity of 1.5 Mt and may be used when mined ore exceeds the crusher throughput rate. All stockpiles have been incorporated into the site-wide WBM/WQM.

2.1.5 Heap Leach Facility

The construction, operation, progressive reclamation, water management infrastructure and proposed operating practices related to the HLF are outlined in detail in Appendices 2-C-1 and 2-C-2 of the Project Proposal. Updated HLF water balance modeling work for operation and draindown was completed in support of the Project Proposal, as well as the current WBM and WQM, and are provided in Appendix 12-C-1 and Appendix 12-C-2, respectively.

The HLF will be located at ridge-top elevation, straddling the headwaters of the Latte and Halfway Creek watersheds and has a design capacity of 61.4 Mt. The long axis of the heap leach pad will align with the ridgeline, and is designed to allow ore stacking to a height of 80 m. The heap leach pad will be constructed in five stages, each of which will provide capacity for 1.5 to 3 years of mined ore to be stacked on the pad. The leach pad is divided into a total of 38 cells, with 1-2 Mt of ore scheduled per cell. The total surface area of the Stage 5 heap leach pad designed to accommodate 61.4 Mt of stacked ore will be 971,700 m^2.

The HLF water balance model is described in the Feasibility Study, and the assumptions and outputs described there are incorporated into the site-wide WBM/WQM. The HLF will essentially operate as a closed loop from a site-wide water balance perspective, to ensure the highest possible gold recovery, as well as protecting the downgradient waterbodies from releases of process water. Further information on the water management infrastructure and associated water management strategies associated for the site- and the HLF are provided in Section 2.2.1 and Section 2.2.2 of this report.

2.2 *Water Management Plan*

This section outlines the water management information used to delineate the portions of each watershed that contain mine infrastructure, and inform the assumptions made in the site-wide WBM/WQM. Water management at the Coffee Gold Mine is described in more detail in Appendix 31-E.

2.2.1 Site Water Management

The Water Management Plan (Appendix 31-E) outlines the infrastructure design criteria, location, operation and maintenance principles for the proposed mine water management system. Briefly, the water management infrastructure proposed for the Project is comprised of three components:

- Diversion channels (for mine contact and non-contact water);

- Rock drains in the Alpha WRSF and Supremo in-pit backfill (to route flow through the base of the WRSF).
- Sedimentation ponds (to collect contact water and reduce sediment loads in discharged water), and;

The water management plan is structured to separate contact and non-contact waters where possible, and to effectively route contact water to central collection points where total suspended solids (TSS) may be managed and water quality samples taken before the water is released to the receiving environment.

The separation of contact and non-contact water requires the construction of diversion channels that route runoff from undeveloped portions of each watershed directly to the receiving creeks. The largest potential source of contact runoff/seepage will be the Alpha WRSF and runoff from exposed pitwalls.

Two sedimentation ponds (Alpha Pond and Facility Pond) will be constructed down-gradient of mine infrastructure to retain the 10-year, 24-hour storm event, with a 48-hour retention time to allow suspended solids to settle out of the water column (refer to Appendix 31-E). Volumes in excess of such events will be routed through a pond outlet or riser and runoff volumes that exceed this threshold will be routed via a spillway that is designed to pass a 200-year, 24-hour storm. The sedimentation ponds will also serve to attenuate peak discharge events emanating from the mined area.

As the open pits are mined out and closed, they are expected to fill with water over time (with the exception of the Kona pit). The rate at which in-pit lakes will develop varies with the pit, but all pits are anticipated to fill to their spill elevations eventually. Notably, the SU1 pit is expected to fill to its spill elevation during the Operation phase, and will be routed via a spillway to upper Latte Creek. Other pits (or portions of pits) will fill and begin to spill during the Closure or Post-closure phase.

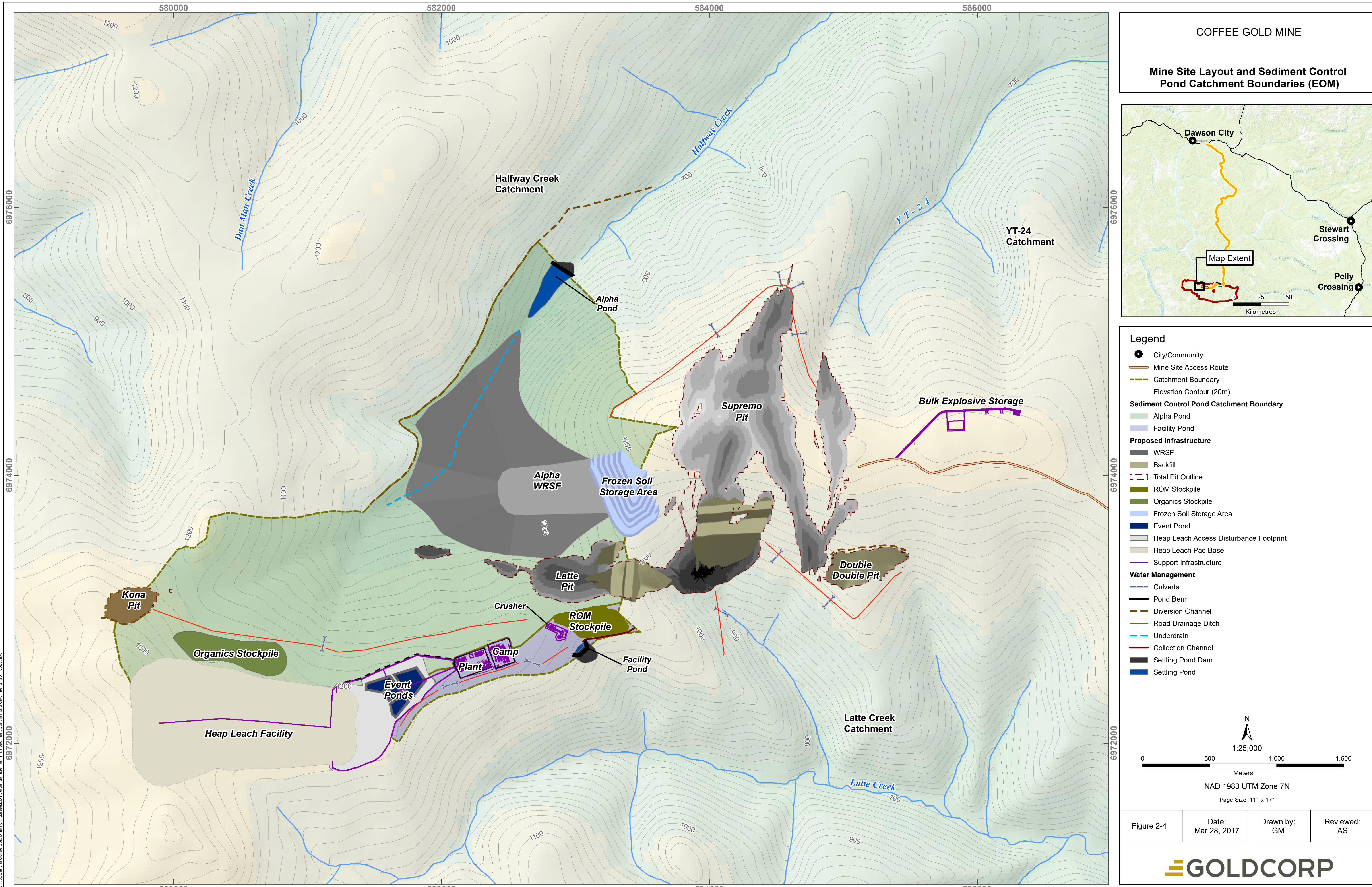
Rock drains will be constructed prior to waste rock placement at the base of the Alpha WRSF and the Supremo in-pit backfill. These structures will route undiverted drainage from upgradient areas through the base of the waste rock. The drains will be sized to route flows equal to the peak runoff generated from a storm four times larger than the 100-year, 24-hour event. The potential for ice formation in these drains has been considered, and while it is unlikely that the drains will completely freeze, diversion channels sized to accommodate the 100-year, 24-hour event will be located at the pit lake spill points as a contingency measure. More detail on the design of the rock drains are presented in the Water Management Plan (Appendix 31-E)

2.2.2 Summary of Water Management

For the purposes of water management, the mine site is divided into seven distinct areas. A summary of the key water management components related to each of these areas is described below:

1. *Alpha Waste Rock Storage Facility (WRSF) and Alpha Pond*. The Alpha WRSF is the primary storage facility for waste rock generated from the Coffee Project (Figure 2-3). The Alpha WRSF is situated in the upper Halfway Creek catchment and includes an rock drain to safely convey flow beneath the facility into the Alpha Pond. Precipitation and snowmelt that infiltrates the Alpha WRSF will report to the rock drain and be collected in the Alpha Pond. Contact water collected in the Alpha Pond is discharged to Halfway Creek during operations and early closure (Figure 2-4and Figure 2-5). A diversion channel exists on the west slope of the Halfway catchment that diverts clean runoff away from the Alpha WRSF and into Halfway Creek, downstream of the Alpha Pond. Ultimately, the Alpha Pond is decommissioned during Post-Closure (Figure 2-6) and water conveyed through the rock drain discharges directly into Halfway Creek.

2. *Kona Pit and Beta Waste Rock Storage Facility (WRSF).* Water that collects in the Kona Pit while during mining will be pumped to the HLF process plant as make-up water. Runoff and seepage infiltration from the Beta WRSF is passively discharged to the Alpha WRSF rock drain and is collected in the Alpha Pond (Figure 2-4). At the beginning of closure, the Kona pit is backfilled with rock from the Beta WRSF. Backfill will occur during winter to facilitate re-establishment of permafrost in the Kona pit by using frozen waste rock. Upon completion of backfill, surface runoff from the Kona backfill is passively discharged to the Alpha WRSF rock drain and collected in the Alpha Pond (Figure 2-5).



COFFEE GOLD MINE
Mine Site Layout and Sediment Control Pond Catchment Boundaries (EOM)
Dawson City
Stewart Crossing
Pelly Crossing
Map Extent
0 25 50
Kilometres
Legend
City/Community
Mine Site Access Route
Catchment Boundary
Elevation Contour (20m)
Sediment Control Pond Catchment Boundary
Alpha Pond
Facility Pond
Proposed Infrastructure
WRSF
Backfill
Total Pit Outline
ROM Stockpile
Organics Stockpile
Frozen Soil Storage Area
Event Pond
Heap Leach Access Disturbance Footprint
Heap Leach Pad Base
Support Infrastructure
Water Management
Culverts
Pond Berm
Diversion Channel
Road Drainage Ditch
Underdrain
Collection Channel
Settling Pond Dam
Settling Pond
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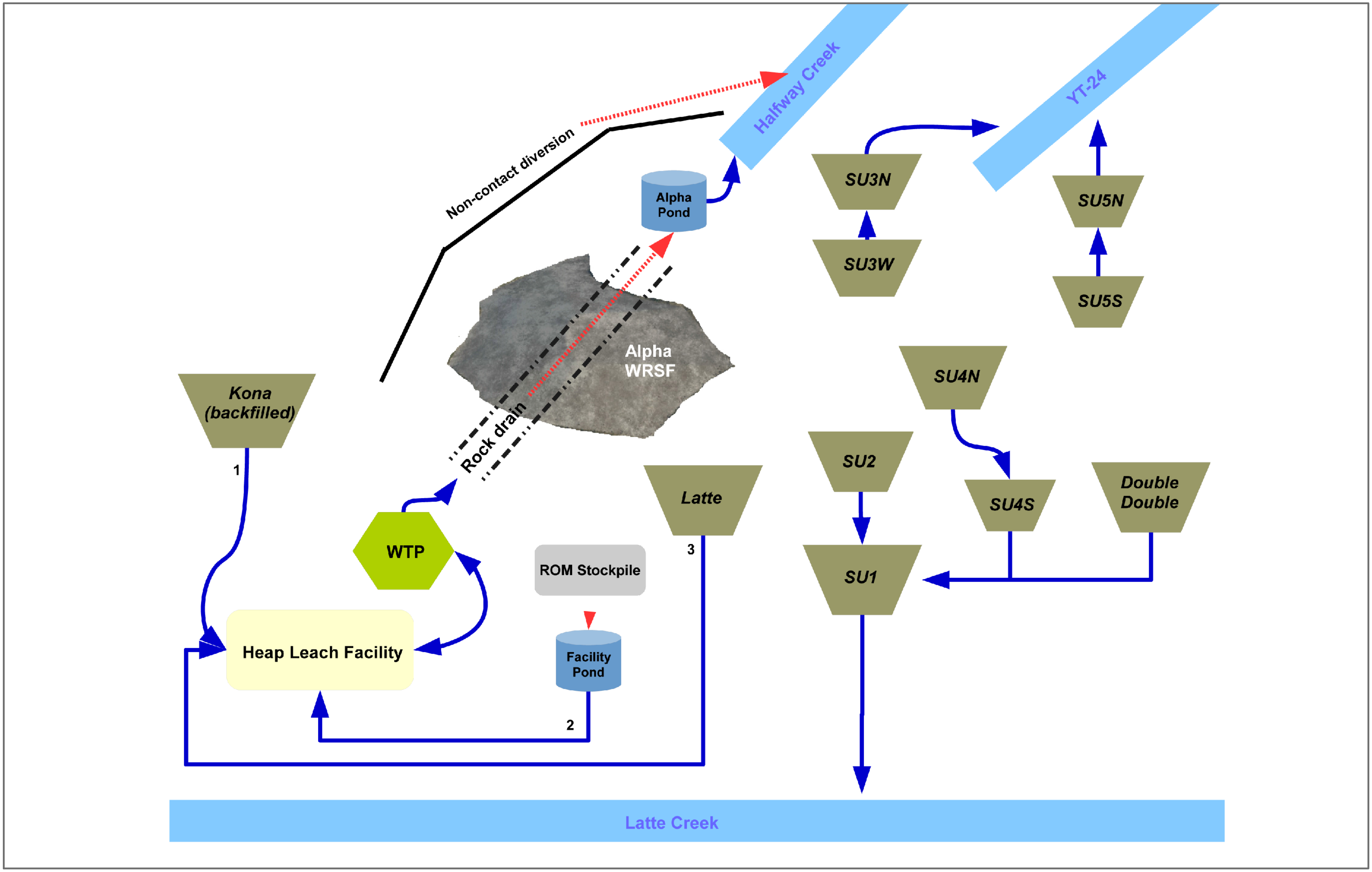
Halfway Creek Catchment
YT-24 Catchment
Latte Creek Catchment
Dan Man Creek
Halfway Creek
YT-24
Latte Creek
Alpha Pond
Alpha WRSF
Frozen Soil Storage Area
Supremo Pit
Bulk Explosive Storage
Double Double Pit
Latte Pit
Kona Pit
Crusher
ROM Stockpile
Facility Pond
Organics Stockpile
Camp
Plant
Event Ponds
Heap Leach Facility



LEGEND

- Pumped
- Passive
- 1 HLF Makeup Water Priority

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PROJECT: **Coffee Gold Project**

TITLE: End of Mine Water Management Schematic

PROJECT #: A362-2

FIGURE: 2-5

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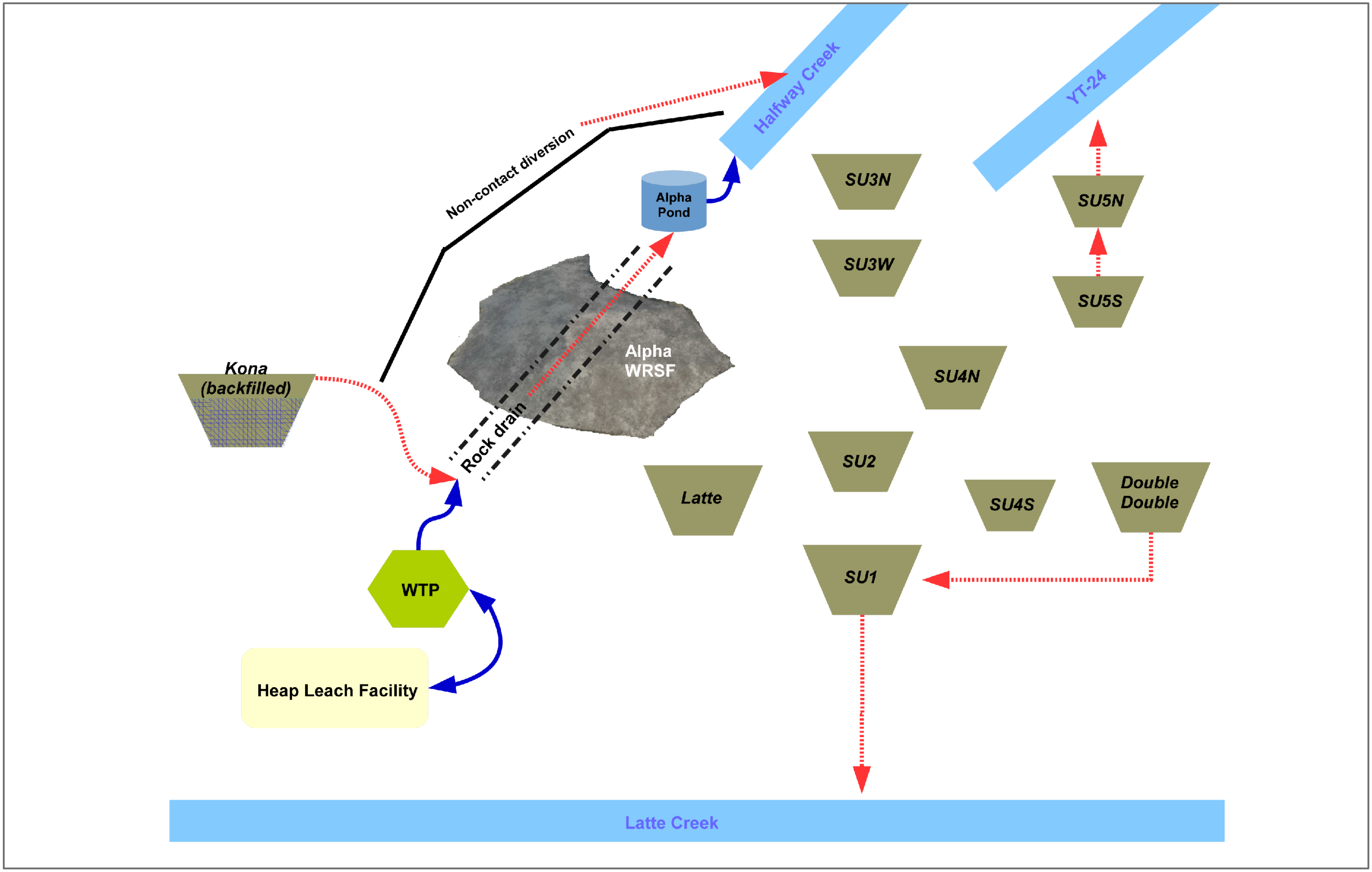

LEGEND

- Pumped
- Passive
- Permafrost

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CLIENT: GOLDCORP

LORAX ENVIRONMENTAL

PROJECT: **Coffee Gold Project**

TITLE: Closure Water Management Schematic

PROJECT #: A362-2

FIGURE: 2-6

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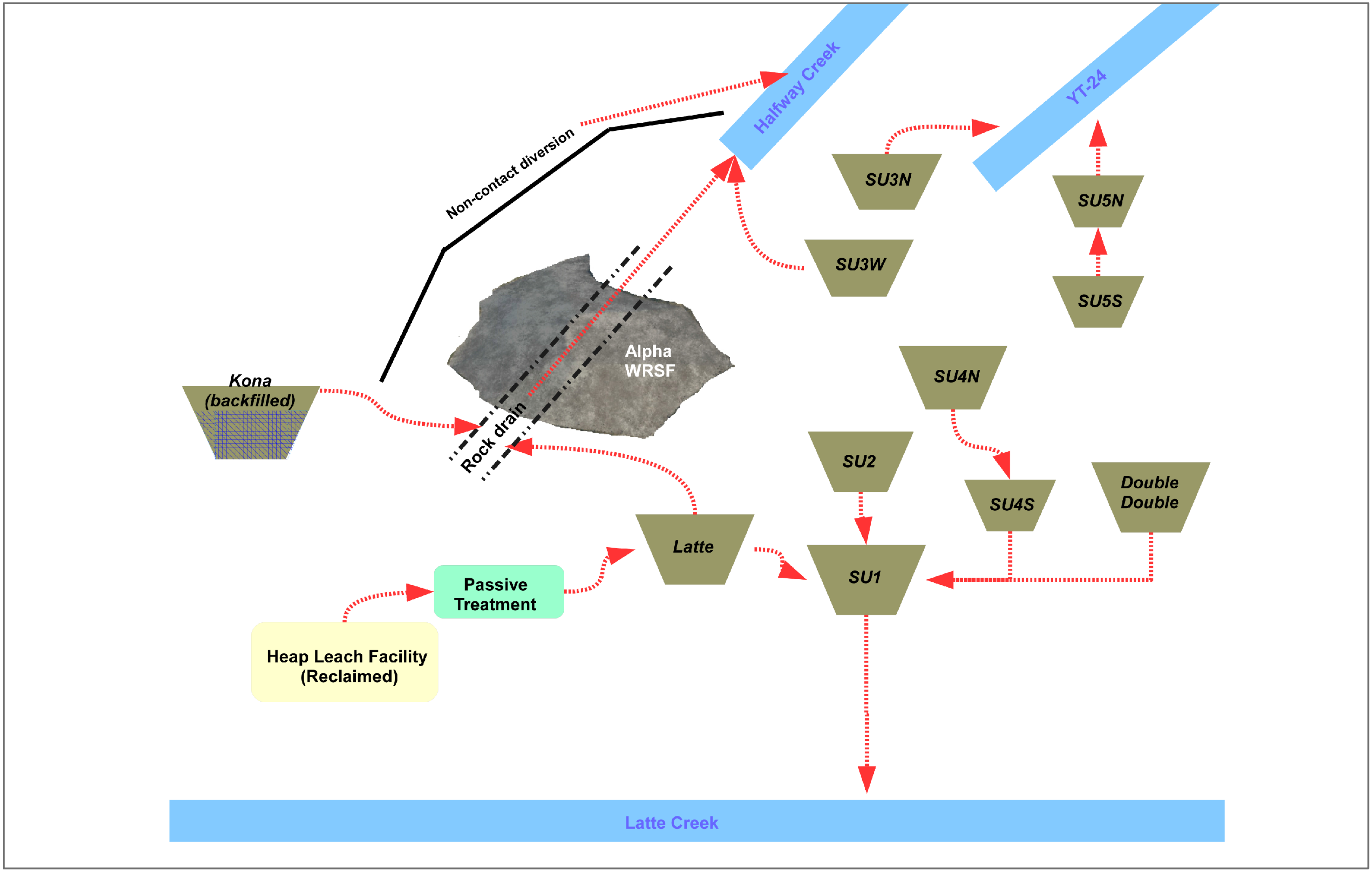

LEGEND

Passive

Permafrost

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CLIENT: GOLDCORP

LORAX ENVIRONMENTAL

PROJECT: **Coffee Gold Project**

TITLE: Post-closure Water Management Schematic

PROJECT #: A362-2

FIGURE: 2-7

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3. *Heap Leach Facility (HLF)*. The HLF will be operated predominantly as a closed system from a water management perspective for most of the operation phase. Outside makeup water demand only appears in year 1 and 2 after the initial water recruited for startup in year -1 and early year 1 is used up in charging the system with water and wetting the ore after stacking begins in mid-year -1. The heap will be free draining with no in-heap storage of solution other than retained moisture. The leach pad will be divided into 4 or 5 stages and each stage will be further divided into cells. During operations and the early stages of closure, geomembrane covers (raincoats) will be used over the heap to reduce the amount meteoritic water infiltrating into the heap and entering the process solution. The raincoats will remain in use over portions of the heap until closure is complete. The heap will be rinsed and capped in stages (progressive closure) and as each stage is capped the raincoats for that area will be removed and used in other areas or incorporated as part of the closure capping. Heap solution management is addressed through rinsing of the heap and collection and treatment of rinse solutions. Under the current HLF water balance, treatment of excess rinse water will be required in year 9. Excess water is treated to remove residual cyanide with hydrogen peroxide followed by a bioreactor treatment system to reduce nitrogen, metalloids and metal concentrations to acceptable concentrations. Treated water of acceptable quality will be released to the Halfway Creek drainage during operations and early closure (Figure 2-4 and Figure 2-5). At post-closure, and upon cessation of active water treatment (~ Year 20) the water treatment plant is decommissioned and HLF seepage water is directed through events ponds that have been converted to passive treatment cells and ultimately into Latte pit (Figure 2-6).

4. *Plant Site*. The Plant site which collectively includes the process plant, camp, associated facilities and Run-of-Mine (ROM) ore stockpile. Contact water from the Plant Site will be collected and discharged to the Facility Pond. Water collected in the Facility Pond will be used for the Heap Leach Facility. Excess water will be discharged into the Latte Creek Catchment (Figure 2-4.

5. *Latte Pit*. Latte pit is one of the first pits developed. Meteoric water that collects in the Latte pit during mining is used as make-up water in the HLF (Figure 2-4). Once mining is complete, meteoric water accumulating in the Latte pit is allowed to passively fill in the pit. The Latte pit also receives overflow from the passive treatment system during post closure. Upon complete filling, Latte pit water overflows into the Alpha rock drain and reports to Halfway Creek (Figure 2-6).

6. *Supremo South and Double Double Pit Complex*. The Supremo South and Double Double pit complex comprises pits SU4N, SU2, SU4S, Double Double and SU1

(Figure 2-4). During operations, meteoric that accumulates in pits SU4N, SU2, SU4S and Double Double will be pumped to SU1. Water in SU1 will be settled in an in-pit sump designed to ensure settling of suspended solids to a maximum of 15 mg/L. Water that meets this criterion will be discharged to the small ephemeral drainage that discharges to Latte Creek (Figure 2-4). At closure and post-closure, SU1 fills to the pit spill point and water will be allowed to passively discharge to the Latte drainage. Contact water from the Double Double backfilled pit at closure and post-closure will passively discharge to the Latte drainage (Figure 2-5 and Figure 2-6).

7. *Supremo North Pit Complex*. The Supremo North pit complex comprises pits SU3W, SU3N, SU5S, and SU5N (Figure 2-4). During operations, meteoric that accumulates in pits SU3W and SU3N will be settled in in-pit sumps designed to ensure settling of suspended solids to a maximum of 15 mg/L. Water that meets this criterion will be discharged from SU3N to the YT-24 drainage. Similarly, meteoric water that accumulates in SU5S and SU5N will be settled in in-pit sumps to meet suspended solids discharge criteria and discharged via SU5N to the YT-24 drainage (Figure 2-4). At closure, SU5S and SU5N fill to their respective spill points and passively discharge to YT-24. SU3W and SU3N are larger pit voids and do not fill to their respective fill points until the post-closure stage. At that time, SU3W will passively spill to Halfway Creek and SU3N will passively spill to YT-24. (Figure 2-5 and Figure 2-6).

2.2.3 Heap Leach Water Management

The heap leaching process involves the dissolution of the target metals via the application and circulation of a dilute cyanide solution through the ore. Following the crushing process, the ore is stacked on a lined pad and all solution exiting the heap (pregnant solution containing the target metals) is collected and routed to the process plant.

It is noteworthy that the HLF water balance is most sensitive to the delivered ore moisture content value, as the pore volume in the delivered ore represents a significant storage component in the system. A higher initial ore moisture content value results in lower solution application requirements to bring the ore moisture content up to the specific retention value. Therefore, it is necessary to maintain a positive water balance for the heap pad to ensure that the barren solution continues to move through the stacked ore and pick up the target metals. However, since the HLF, as a whole, cannot discharge to the receiving environment without treatment, the larger HLF must operate in a neutral water balance.

To maintain the balance between a net positive condition within the leach pad and a net neutral condition in the facility as a whole, two event ponds are proposed to be constructed to manage the excess solution from the leach pad. These ponds are sized to ensure that contact water from the pad is contained within a closed loop system and contain the sum of a 72-hour heap drain-down resulting from a prolonged power outage or pump failure, all HLF contact water generated by the probable maximum precipitation (PMP) event, and incident water accumulation during a wet-climatic cycle.

During the first year of mine life, the areal extent of the HLF is small, and therefore additional makeup water (*i.e.*, beyond those volumes harvested from the HLF footprint) will be pumped from the following sources, listed in order of priority:

- Kona Pit sump
- Facility Pond
- Alpha Pond or Latte Pit
- Raincoat Ponds

Owing to the net positive water balance at the mine site, this is expected to be necessary at the beginning of the Operation Phase, and only occasionally and during extended dry periods of the Operation Phase thereafter. As the HLF area expands, the volume of contact water will increase in tandem, and therefore the makeup water requirements will drop accordingly.

The volume of contact water generated by the HLF will be reduced by the use of covers (or raincoats) that limit infiltration of meteoric water to the HLF and route non-contact water from the surface of the leach pad to the Rainwater Collection Pond. This water will also be available for makeup, and will be discharged to the Alpha WRSF rock drain (which drains to Halfway Creek) when not required. All other non-contact water from the areas surrounding the HLF will drain passively to the Alpha WRSF rock drain, and then into the Alpha Pond before being discharged to Halfway Creek, or will drain passively to Latte Creek on the south side of the HLF.

2.3 *Summary of Baseline Conditions*

This section presents a summary of the baseline information collected by the hydro-meteorology, groundwater, surface water quality and geochemistry programs initiated by Kaminak Gold in 2010, through to end of 2015.

2.3.1 Meteorology

Monitoring locations, climate data sources, methods and meteorology results are presented in their entirety in Appendix 8-A. A brief summary of the baseline meteorology program findings is presented below.

2.3.1.1 *Site Climate Monitoring*

Air Temperature

For the relatively short period of record at the Coffee Gold Mine, measured average annual temperature is -2.5°C, and monthly average air temperatures range from -19°C (December) to +13°C (July) (Table 2-2). At the elevation of the Coffee Gold Mine climate station, a notable departure from the regional temperature signal occurs during winter months. Valley bottom temperature inversions during winter months are apparent and local ridgetop temperatures may be 10°C higher than measurements recorded at valley bottom stations. These inversions result in a reversal of the normal lapse rate (decreasing temperature with increasing elevation) and are commonly caused by cold Arctic air masses pooling in the valley bottoms from late October to early March.

Precipitation

Mean annual precipitation (MAP) at the Coffee Gold Mine (*i.e.*, 1,300 m above sea level) is estimated to be 485 mm, with 65% of this total precipitation realized as rain during the months of May through September, and the remaining 35% occurring as snow from October through April (Table 2-2). This estimate of MAP was arrived at using site-measurements of rainfall and snow accumulation that were assessed in combination with regional precipitation data (*i.e.*, from Federal/State weather stations, snow courses, snow pillows).

It is common in areas with high topographic relief for precipitation amounts (annual, low-frequency/high-magnitude events, *etc.*) to increase with elevation due to orographic effects - primarily cooling of the air mass as it is forced upward by topography and subsequent condensation of the entrained water vapour. Precipitation gradients were ascertained through an inspection of site- and regional precipitation data, and were established at the Project as follows: 4%/100 m elevation gain for rainfall; and 9%/100 m elevation gain for snow.

Evaporation, evapotranspiration

Annual potential evaporation (PE) for the Project area is estimated to be ~500 mm with monthly rates being highest in May, June, July and August (roughly 70 to 110 mm per month) and considerably lower for autumn, winter and spring months. Consistent with other studies in the Yukon, an evapotranspiration estimate for the Coffee Gold site is roughly 40% of the assumed PE value or 182 mm per year (Table 2-2).

Table 2-2:
Monthly measured and synthetic climate parameters for 1,300 m asl.

	Air Temperature (°C)		Precipitation (mm)		Potential Evaporation (mm)	
	Measured (2012-2015)	**Reconstructed (1986-2014)**	**Measured (2012-2015)**	**Reconstructed (1986-2014)**	**Measured (2012-2015)**	**Reconstructed (1986-2014)**
Jan	-14.6	-19.7	38.8	35.9	0.4	0.2
Feb	-15.2	-14.9	22.3	22.7	5.0	0.4
Mar	-10.1	-9.0	16.3	20.0	22.6	3.4
Apr	-2.7	0.8	13.5	14.3	46.2	26.7
May	8.3	6.9	40.7	36.2	103.0	59.5
Jun	12.3	11.3	41.5	53.0	112.2	84.4
Jul	13.3	12.6	101.9	76.8	91.9	95.8
Aug	11.2	10.1	48.3	58.1	71.2	79.7
Sep	4.8	5.0	38.7	49.8	36.9	48.3
Oct	-3.2	-2.4	21.6	37.0	10.4	14.5
Nov	-15.3	-13.2	19.2	43.7	1.0	0.5
Dec	-18.4	-17.2	16.2	37.2	0.2	0.1
Annual	-2.5	-2.5	419.0	484.6	500.8	413.5
May-Sep	10.0	9.2	271.1	273.8	415.1	367.6
Oct-Apr	-11.4	-10.8	147.9	210.8	85.7	45.9

2.3.1.2 *Extension of the Baseline Climate Record*

As described in Appendix 8-A, site- and regional hydrometric data were analyzed in combination to: place the relatively short period of record for Coffee Gold Mine into a broader context; generate a long-term (*i.e.*, 28 year) synthetic climate record for the Project area, and; to compute climate metrics (*e.g.*, extreme rainfall depths for various return periods) from the combined site- and regional information. Appendix 8-A outlines the methods adopted to produce a long-term synthetic climate record.

Year-over-year synthetic daily climate data are plotted on a common calendar year X-axis (refer to Figure 2-8, Figure 2-9 and Figure 2-10) for air temperature, precipitation and potential evaporation, respectively. Synthetic data are presented in this format as the charts clearly show the range of variability inherent in the synthetic time series. Also shown in the plots are time series data for one calendar year (Year 2022), to give indication of a typical year (*i.e.*, range in variability, timing of changes) for these three parameters. To place the reconstructed precipitation record in context of the annual recurrence interval estimates presented in Appendix 8-A, the minimum (maximum) annual precipitation in the 28-year climate series falls between a 1:50 and 1:100 dry (wet) precipitation year.

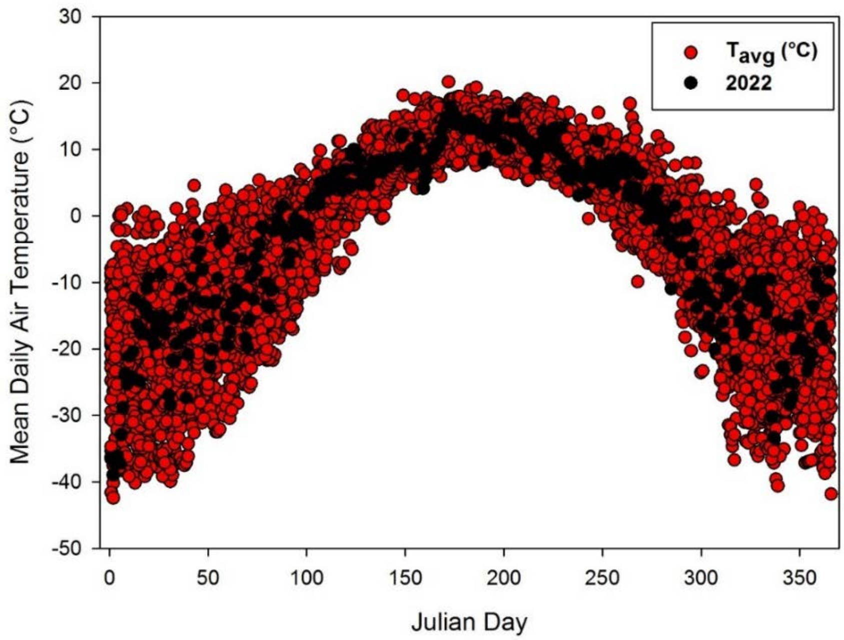


Figure 2-8: Year-over-year synthetic daily temperature data plotted on a common calendar year X-axis. Daily data for the 30-year dataset are shown in red and data for Calendar Year 2022 data are shown in black.

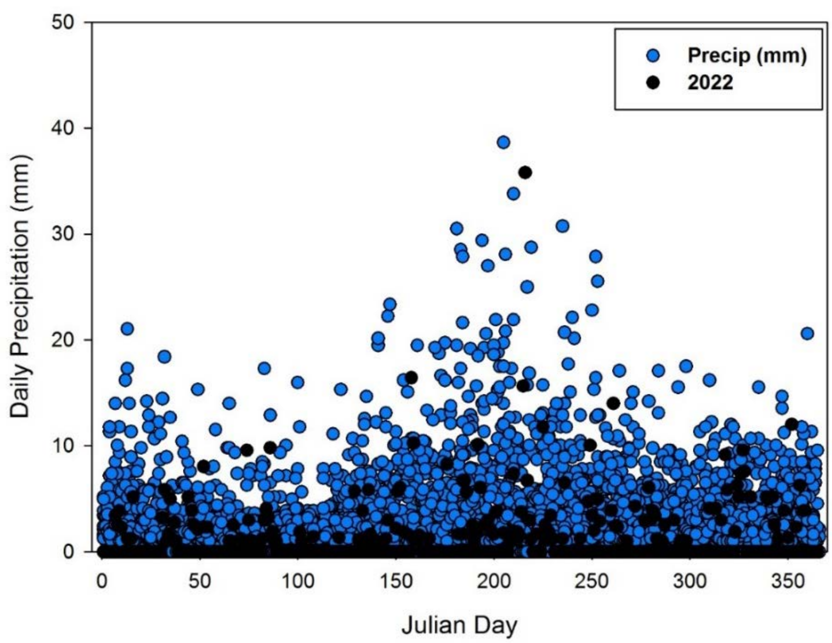


Figure 2-9: Year-over-year synthetic daily precipitation data plotted on a common calendar year X-axis. Daily data for the 30-year dataset are shown in blue and data for Calendar Year 2022 data are shown in black.

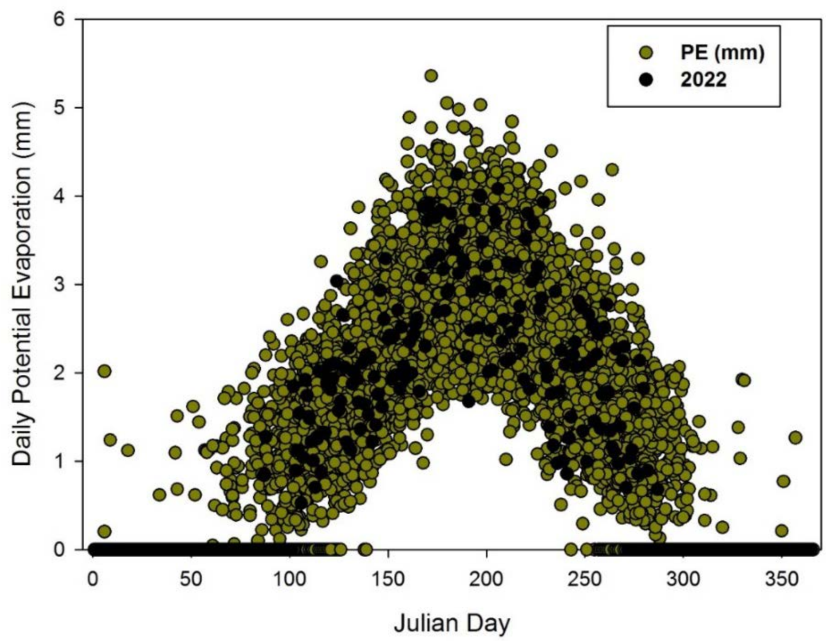


Figure 2-10: Year-over-year synthetic daily potential evaporation data plotted on a common calendar year X-axis. Daily data for the 30-year dataset are shown in green and data for Calendar Year 2022 data are shown in black.

2.3.2 Hydrology

The baseline hydrology datasets and their description are also presented in full in Appendix 8-A, and the reader is referred there for any specific information on the measurement methods, regional data sources and supporting analyses that apply to measured and synthetic data presented in this report. A summary of the baseline data is presented herein to provide context for WBM construction, core assumptions and eventual calibration.

2.3.2.1 *Project Hydrometric Stations*

A baseline surface hydrology monitoring study was initiated at the Project site in autumn 2010. At eight locations, spot flow measurements were recorded monthly and at three stations (HC-5.0, CC-3.5 and IC-4.5), stilling wells, metric staff gauges and instrumented stations with continuously recording water level recorders were established. The network was expanded in 2014, with a focus on instrumenting the spot flow stations that gauge headwater basins that are expected to contain the majority of the Project infrastructure. All baseline hydrometric stations are listed in Table 2-3, and those that were explicitly included as predictive nodes in the WBM/WQM are highlighted in bold.

Table 2-3:
Coffee Creek Surface Water Monitoring Stations – Station IDs and Drainage Basin Characteristics

Station ID	Drainage Area (km^2)	Mean Elevation (m asl)	Min Elevation (m)	Max Elevation (m)
CC-0.5	385.6	1,023	446	1,707
CC-1.0	3.4	1,017	732	1,302
CC-1.5	23.1	1,120	712	1,379
CC-3.5	69.8	969	447	1,379
CC-4.5	484.0	993	427	1,708
CC-6.0[1]	9.6	1,225	1,042	1,394
HC-2.5	14.8	1,043	664	1,343
HC-5.0	27.0	885	428	1,344
IC-1.5	81.1	1,077	522	1,708
IC-2.5	17.3	1,003	493	1,344
IC-4.5	222.3	989	427	1,708
YT-24	11.8	838	428	1,293

The extensive hydrometric network at the Project site, combined with the monthly sampling trips conducted since autumn 2010, has allowed a high-quality and high-resolution streamflow dataset to be assembled. These data are presented in Appendix 8-A, and have been used to inform project feasibility studies, complete design and engineering studies related to the Project, and to build and calibrate the WBM/WQM described in this report.

2.3.2.2 *Project Site Watershed Characteristics*

Gauged watersheds at the Project site range in size from ~3 to 500 km^2, noting that eight of the watersheds being monitored have drainage areas of less than 25 km^2 (Table 2-3). Watercourses potentially affected by the Project, including Halfway Creek, Latte Creek, Independence Creek, Coffee Creek and YT-24 (Unnamed tributary to Yukon River), were gauged as part of the baseline study. In addition to capturing a range of drainage areas, the watersheds gauged for the baseline hydrology study differ in elevation characteristics (*i.e.*, mean catchment elevations range 800 to 1,300 m asl) and represent varying aspects as well.

2.3.2.3 *Project Site Streamflow Regime*

Local patterns of streamflow are dominated by a snowmelt freshet that typically occurs late-April to mid-June, and punctuated by multiple rainfall-induced high flow events that occur throughout the summer and autumn. In general, these high flow events are short lived, often persisting for a duration of 1 or 2 days.

Annual Unit Yields

Average unit yields across the Project site are 9 L/s/km^2 for the open water season (May to October), ranging from 4.5 to 15 L/s/km^2, depending on the drainage. The YT-24 and CC-1.0 drainages that drain the proposed north and south waste rock catchments respectively have lowest yields, while Upper Latte Creek (CC-6.0 and CC-1.5) and Independence Creek at the Mouth (IC-4.5) have the highest yields.

Runoff-Elevation Relationship

In Appendix 8-A, Coffee Gold hydrometric data are tabled in runoff depth format. A robust relationship between runoff and elevation is present at the Project site, which is consistent with the precipitation gradients discussed in Section 2.3.1.1. This relationship is shown for Project site drainages in Figure 2-11, noting that, with the exception of the CC-1.0 basin, a small (3.4 km^2) catchment in the headwaters of Latte Creek, mean annual runoff (MAR) was determined to increase at the Coffee Gold property as the median basin elevation increases. Proposed mine infrastructure for the Coffee Gold Project will be situated at high elevation within Project site basins, underscoring the importance of capturing any dependence of runoff on elevation in the WBM.

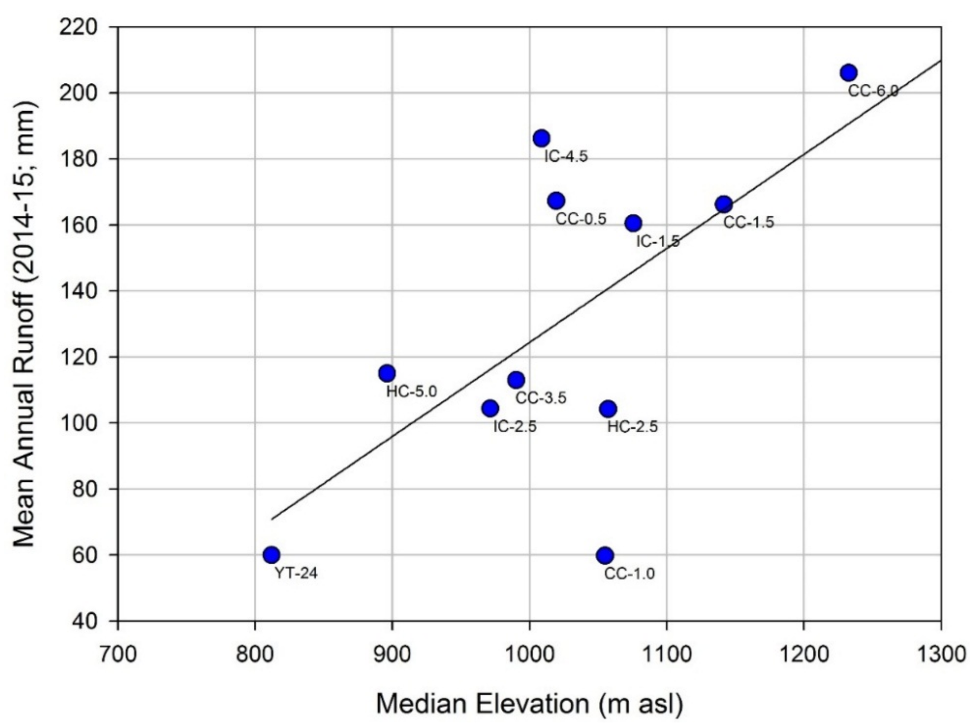


Figure 2-11: Mean annual runoff for the open water season plotted against median basin elevation (2014-2015)

Peak Flows

Peak flows at Coffee Gold are driven primarily by the intense convective rainfall events that are common in the summer months, with secondary peaks occurring in late-May, as a result of melting snowpacks. Instantaneous peak flows (as unit yields) are typically between 120 and 200 L/s/km^2 at Coffee Gold, although some drainages have recorded peak flows that are much lower and in the 60 L/s/km^2 range (*e.g.*, CC-1.0, HC-2.5 and IC-2.5). Instantaneous peak flows recorded in Upper Latte Creek (*e.g.*, CC-6.0 and CC-1.5) are larger in magnitude with measurements on the order of 300 to 400 L/s/km^2 recorded.

Low Flows

The accurate characterization of the low flow regime at the Project site is critical – particularly with regards to predictions of mine-influenced water quality during periods of limited natural dilution. More information on the relationship between streamflows, groundwater discharge and water quality in the Project area creeks is presented in Section 4 (Water Quality) of this report, but the baseline low flow information is presented here to set the context.

During the open water season, the recession limbs of local hydrographs are often steep following the passage of a large rain event and the associated peak flows. Low flow conditions can occur intermittently during the summer and early autumn across the Project site, with unit yields during early summer often approaching those measured during the winter months. Measured low flows are summarized in Appendix 8-A (refer to Section 3.2.1.4 Low Flows).

As summer progresses, baseflows are enhanced by active layer melt and soil moisture recharge. However, by November unit yields typically drop to 0.5 to 1.5 L/s/km^2 in Project site drainages, and zero flow conditions become widespread by January and are accompanied by extensive aufeis formation. Aufeis (*i.e.*, frozen groundwater seepage that accumulates within and adjacent to local watercourses) is pervasive in creeks and streams at the Project site. This ice impedes subsequent flow, which is forced on top of the existing ice sheet, where it freezes. This process repeats continuously throughout the winter, and results in laminated ice sheets that can approach 2 m in thickness and 50+ m in width in the Project stream channels. The aufeis process also acts as a storage reservoir for winter baseflows, and can store up to a third of the cumulative annual baseflow in sub-Arctic watersheds (Yoshikawa *et al.*, 2007).

2.3.2.4 *Extending the Baseline Streamflow Records*

In order to effectively generate predictions of the potential Project induced alterations to the streamflow and water quality regime, the WBM/WQM has to be run for a much longer period than the existing baseline data currently spans. This requires that the short-term site data be placed in context of the longer regional record, so that longer period climatic cycles (*e.g.*, the Pacific Decadal Oscillation) and any persistent trends are incorporated into the WBM predictions. To meet this requirement, the discharge records available for the Project site were extended using statistical relationships with a nearby Water Survey of Canada (WSC) discharge record for the Indian River above the Mouth (09EB003). The record period for this station is of sufficient length and completeness to capture the full-range of inter-annual streamflow variability over the last 30 years; and the data provides a complete representation of all relevant components of the site hydrographs (*i.e.*, rapid freshet, multiple rainfall driven peaks during the summer and early fall, and extended winter base flows of <1 L/s/km^2).

This extension process resulted in the creation of synthetic hydrographs and 34-year records (1982-2015) of daily discharge being created for the Project site drainage basins. These long-term synthetic records were then used as the calibration targets for the WBM, discussed further in Section 3.2.6. Figure 2-12 depicts the reconstructed long-term annual runoff time-series for stations CC-1.5, HC-2.5 and YT-24. Given the general arrangement for the proposed mine (refer to Figure 2-3), these three basins are likely to see the highest degree of modification and/or alteration to surface flow, surface water quality and/or groundwater condition (quantity, quality) as project footprints advance. Runoff data in Figure 2-12 show that overall, range in inter-annual variability for each station is substantial, and the relative magnitude of variation differs between basins. The differences in magnitude are assumed attributable to site-specific differences in median basin elevation (Figure 2-11) that have been correctly embedded into the respective synthetic discharge series. The reader is referred to Appendix 8-A for a complete description of the derivation of these long-term streamflow records.

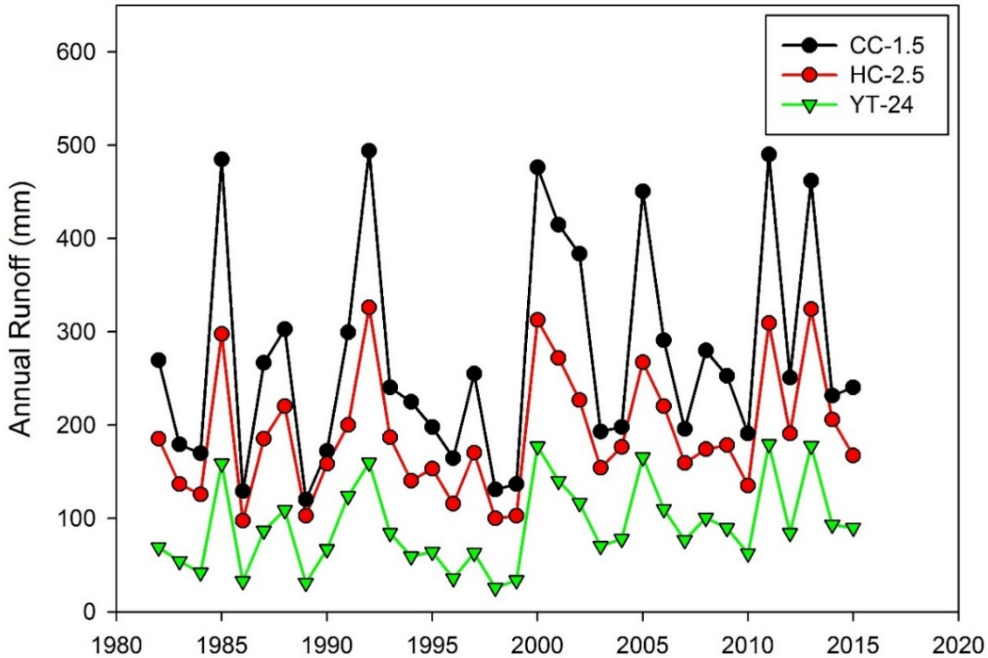


Figure 2-12: Annual runoff time-series for stations CC-1.5, HC-2.5 and YT-24.

2.3.2.5 *Streamflow Record for Coffee Creek at the Mouth (CC-4.5)*

The Coffee Creek watershed is represented by the CC-4.5 station, located upstream of the confluence with the Yukon River (Figure 2-1). Manual flow measurements have been made at this site coincident with water quality sample collection since 2010. However, no continuous discharge record is available for this station, and therefore no synthetic discharge record was created. However, long-term records exist for stations CC-0.5 (Upper Coffee Creek) and CC-3.5 (Latte Creek at the Mouth; Table 2-3). The difference in area between the larger watershed represented by CC-4.5 and the sum of CC-0.5 and CC-3.5 is 28.5 km^2. Given the known dependence of runoff on elevation, streamflow for the ungauged portion of Coffee Creek was scaled from the CC-3.5 record, as the median elevation of this basin more closely matches that of the entire Coffee Creek watershed (990 m and 1,000 m, respectively). Upper Coffee Creek (CC-0.5) does not contain any proposed mine infrastructure, and therefore the natural streamflow record was carried through the entire analysis.

2.3.2.6 *Yukon River Discharge Data*

Contact waters associated with the Coffee Gold Project will report passively to either Latte Creek, YT-24 or Halfway Creek. Ultimately, these three receiving creeks report to the Yukon River, and therefore, an understanding of the Yukon River flow regime is important.

The Yukon River is gauged at a number of locations in the Yukon and State of Alaska. The Water Survey of Canada hydrometric station Yukon River above White River (09CD001) is situated a short distance downstream of the Project (~15 km downstream). The period of record for this station is 61 years (1956-2016), and the drainage area for the basin at the location of the gauge is 149,000 km^2. The drainage areas of the Yukon River at locations relevant to the Project are essentially identical in magnitude. For example, the estimated drainage of the Yukon River above Coffee Creek is 147,317 km^2 (*i.e.*, an area 1.2% less than that area at 09CD001). The Yukon River downstream of Halfway Creek compares within 0.8% of the drainage at 09CD001 and is 147,839 km^2.

Average, minimum and maximum discharge data (period of record, daily) for the Yukon River above White River are shown in Figure 2-13. These data show that winter flows for the Yukon River are typically 400-500 m^3/s, but may reach winter minima on the order of 250 m^3/s upon occasion. In contrast, flows for months May through November can reasonably be expected to range between 1,000 and 3,000 m^3/s at the Project site. Maximum peak flows on the Yukon River may be expected in May, June and July, with discharges ranging from 4,000 to 8,000 m^3/s.

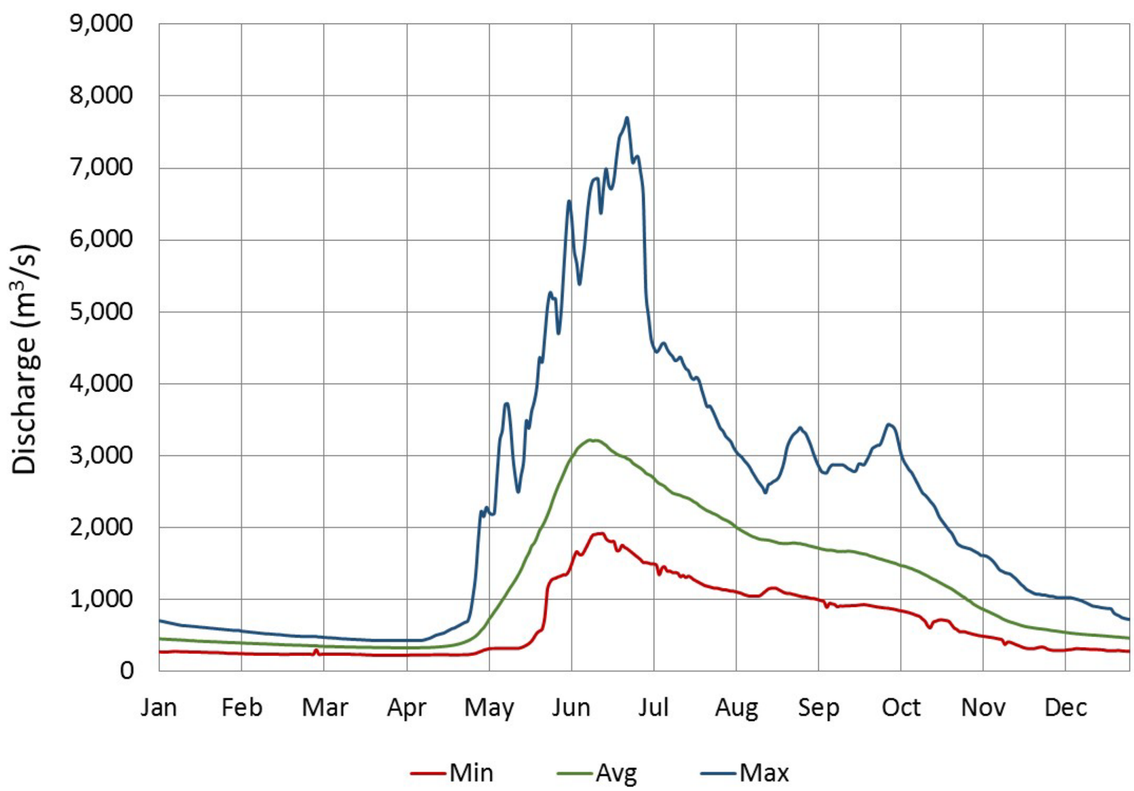


Figure 2-13: Daily average-, minimum- and maximum discharge data for the Yukon River above the White River (09CD001).

2.3.3 Surface Water Quality

The surface water quality baseline program for the Project area creeks was initiated at the same time as the hydrology program, in autumn of 2010. Multiple sampling points were established on Latte, Coffee, YT-24 and Independence Creeks, as well as two reference points on the Yukon River. In total, 18 stations were sampled on a monthly basis where possible. Several sites were not sampled during the winter months, as many streams experience extensive channel icing during the winter months.

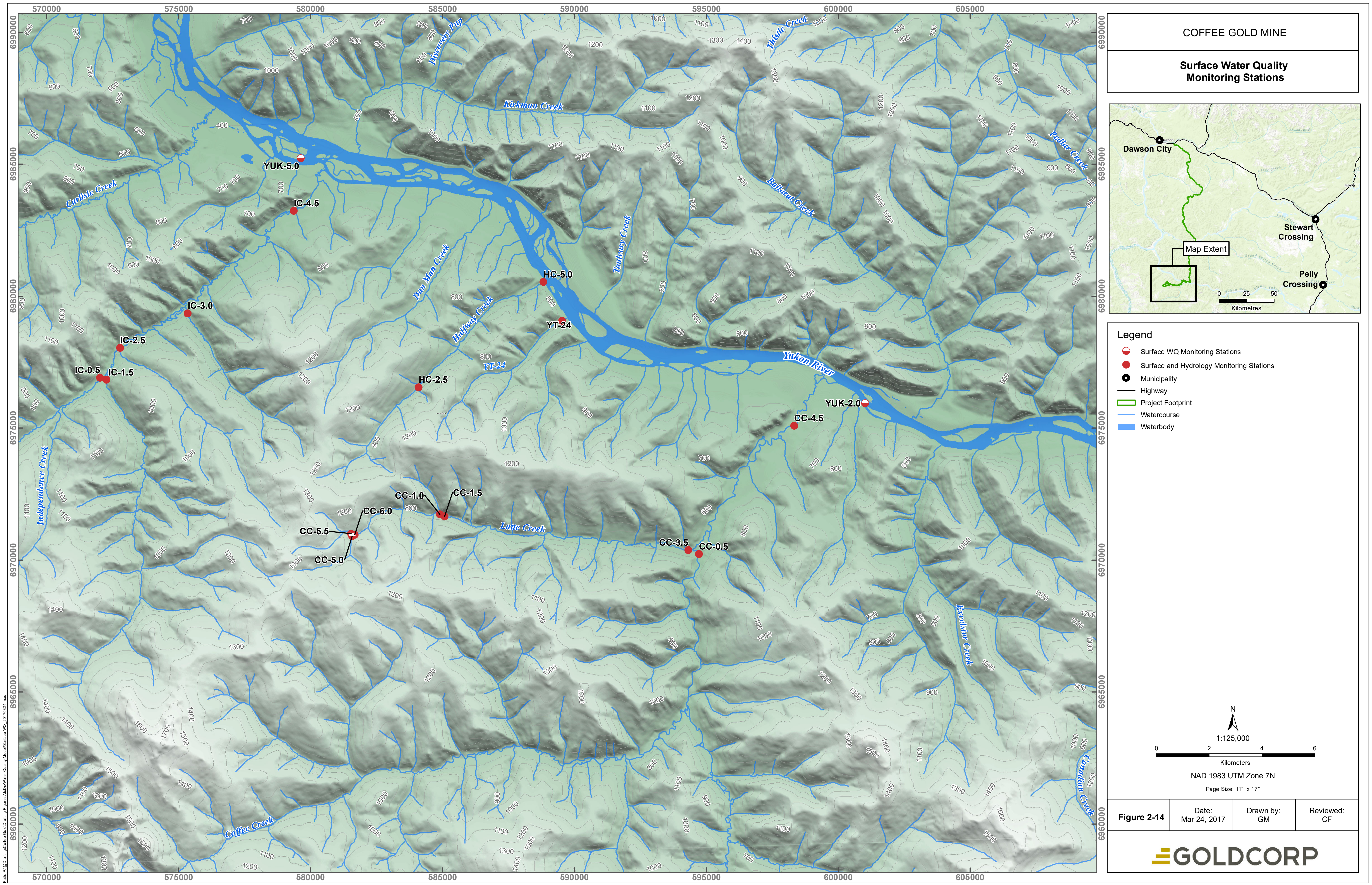
The water quality sampling points are illustrated in Figure 2-14 and metadata is presented in Table 2-4. Stations that were carried forward as WQM inputs are denoted in bold. Summaries of the water quality information gathered to date are presented by watershed in the following sections, and the reader is referred to the water quality baseline report presented in Appendix 12-A of the Project Proposal for a more detailed synopsis. This section will only present the summaries for the primary PCOCs included in the WBM/WQM.

Note that while an extensive baseline water quality and streamflow dataset exists for the Independence Creek watershed, these data are not summarized in this report. No Project influence is expected in this watershed, and therefore Independence Creek was not included in the WBM/WQM. It is expected that these data will be used as a reference point going forward, to place any trends or alterations in the Project area surface water quality in context.

The following section provides an overview of existing surface water quality conditions by catchment for Latte Creek, Coffee Creek, YT-24, Halfway Creek, Independence Creek, and Yukon River based on the results of the baseline monitoring program described above. Because there were no major developments or discharges to any of the Project area catchments through the baseline monitoring period to present, the terms “existing” and “baseline” within the context of surface water quality conditions in this section are used interchangeably.

Further information on existing surface water quality conditions in the project area and the baseline monitoring program can be found in Appendix 12-A, which is accompanied by tabulated water quality summary statistics for the baseline period, monthly data summaries, and raw monitoring data.

For the purposes of the present assessment, data are summarized for nine primary stations out of the 18 stations sampled under the water quality monitoring program. The data presented reflect trends in seasonal variability for each water course and reflect parameters naturally elevated within each catchment.



COFFEE GOLD MINE
Surface Water Quality Monitoring Stations
Dawson City
Stewart Crossing
Pelly Crossing
Map Extent
Kilometres
Legend
Surface WQ Monitoring Stations
Surface and Hydrology Monitoring Stations
Municipality
Highway
Project Footprint
Watercourse
Waterbody
YUK-5.0
IC-4.5
IC-3.0
IC-2.5
IC-0.5
IC-1.5
HC-5.0
YT-24
HC-2.5
YUK-2.0
CC-4.5
CC-1.0
CC-1.5
CC-6.0
CC-5.5
CC-5.0
CC-3.5
CC-0.5
Yukon River
Kirkman Creek
Discovery Pup
Thistle Creek
Pedlar Creek
Ballarat Creek
Carlisle Creek
Dan Man Creek
Halfway Creek
Touleary Creek
Independence Creek
Latte Creek
Excelsior Creek
Canadian Creek
Coffee Creek
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Table 2-4:
Water Quality Sampling Stations, Coordinates and Rationale

Site	**Drainage**	**Coordinates**		**Site**	**Sampling**	**Rationale**
		North	**East**	**Type**	**Start Date**	
Independence Creek						
IC-0.5	Independence Creek – main stem	6976911	572012	Reference	Oct-2010	Outside Project influence
IC-1.5	Un-named larger tributary to Independence Creek	6976835	572260	Reference	Oct-2010	Outside Project influence
IC-2.5	Small un-named tributary to Independence Creek	6978044	572771	Reference	Oct-2010	Outside Project influence
IC-3.0	Small un-named tributary to Independence Creek	6979357	575334	Reference	Oct-2010	Outside Project influence
IC-4.5	Independence Creek - mouth	6983237	579358	Reference	Oct-2010	Outside Project influence
Latte Creek						
CC-6.0	Upper Latte Creek	6971061	581317	Potential exposure	June-2014	Below Project influence
CC-5.5	Small tributary from northwest to upper Latte Creek	6971100	581061	Potential exposure	June-2014	Below Project influence
CC-5.0	Small tributary from south to upper Latte Creek	6970905	581079	Potential exposure	June-2014	Below Project influence
CC-1.0	Small tributary to Latte Creek draining the SU1 and Double Double pits	6971733	584890	Exposure	June-2014	Below Project influence
CC-1.5	Latte Creek downstream of CC-1.0 drainage	6971654	585071	Exposure	Oct-2010	Below Project influence
CC-3.5	Latte Creek immediately upstream of confluence with Coffee Creek	6970375	594319	Exposure	Oct-2010	Below Project influence
Halfway Creek						
HC-2.5	Halfway Creek midway	6976548	584089	Exposure	Oct-2010	Below Project influence
HC-5.0	Halfway Creek mouth	6980536	588823	Exposure	Oct-2010	Below Project influence
YT-24						
ML-1.0 (YT-24)	Mouth of YT-24, small tributary to Yukon River	6979073	589526	Exposure	June-2014	Below Project influence
Coffee Creek						
CC-0.5	Coffee Creek immediately upstream of confluence with Latte Creek	6970225	594719	Reference	Oct-2010	Above Project influence
CC-4.5	Coffee Creek	6975084	598330	Exposure	Oct-2010	Below Project influence
Yukon River						
YUK-2.0	Yukon River upstream of Coffee Creek confluence	6975946	601011	Reference	Oct-2010	No Project influence
YUK-5.0	Yukon River downstream of Independence Creek confluence	6985228	579624	Exposure	Oct-2010	Below Project influence

Water quality data for each catchment and corresponding stations are presented in the following order:

- Latte Creek stations CC-1.5, mid-catchment, and CC-3.5, lower-catchment (Section 2.4.2.7);
- Coffee Creek stations CC-0.5, upstream of project influence, and CC-4.5, downstream of confluence with Latte Creek (Section 2.4.2.7);
- YT-24 station ML-1.0, lower-catchment near outlet (Section 2.4.2.8);
- Halfway Creek stations HC-2.5, mid-catchment, and HC-5.0, lower-catchment (Section 2.4.2.9), and;
- Yukon River stations YUK-2.0, upstream of Coffee Creek confluence and project influence, and YUK-5.0, downstream of Independence Creek confluence and all project influence (Section 2.4.2.10).

2.3.3.1 *Latte Creek and Coffee Creek*

Baseline water chemistry are presented in this section for Latte Creek stations CC-1.5 and CC-3.5, and for Coffee Creek stations CC-0.5 and CC-4.5 for the period of October 2010 to January 2016. Latte Creek is a tributary of Coffee Creek that shares groundwater and surface hydrology components with the latter, which strongly influence surface water quality throughout the system. During mine operations, stations CC-1.5, CC-3.5, and CC-4.5 will reflect mining-related loading, while CC-0.5 will remain a background station representative of the upper Coffee Creek catchment.

Water chemistry in the Latte Creek and lower Coffee Creek drainages is driven by varying proportions of snow-melt driven surface runoff (lower ionic strength, higher organic content) and groundwater inputs (higher ionic strength, lower organic content) to surface flow, based on the seasonal water balance. This seasonality in water chemistry is more pronounced the higher a station occurs in the catchment.

Of the four stations presented here, station CC-1.5 is furthest upstream in the Coffee Creek/Latte Creek catchment. As such, this station is characterized by soft water low in major ions during freshet periods, and hard to very hard waters with high levels of major ions during winter low flow periods (Figure 2-15). Lower in the Latte Creek catchment at station CC-3.5, water chemistry shows a similar seasonality although annual minima and maxima are less pronounced compared to CC-1.5. Both CC-0.5 and CC-4.5 are characterized by soft to moderately-soft waters (between 35 mg/L and 75 mg/L; Figure 2-16) with lower levels of dissolved major ions (*e.g.*, alkalinity, hardness, sulphate) during the open water period of May to September. During low flow periods, water chemistry at both stations is dominated by hard to very hard waters with high levels of dissolved solids, although annual maxima at CC-4.5 are less pronounced compared to CC-0.5. In contrast, pH remains relatively uniform throughout the Latte Creek and Coffee Creek drainages on an annual basis (7.0 to 8.0).

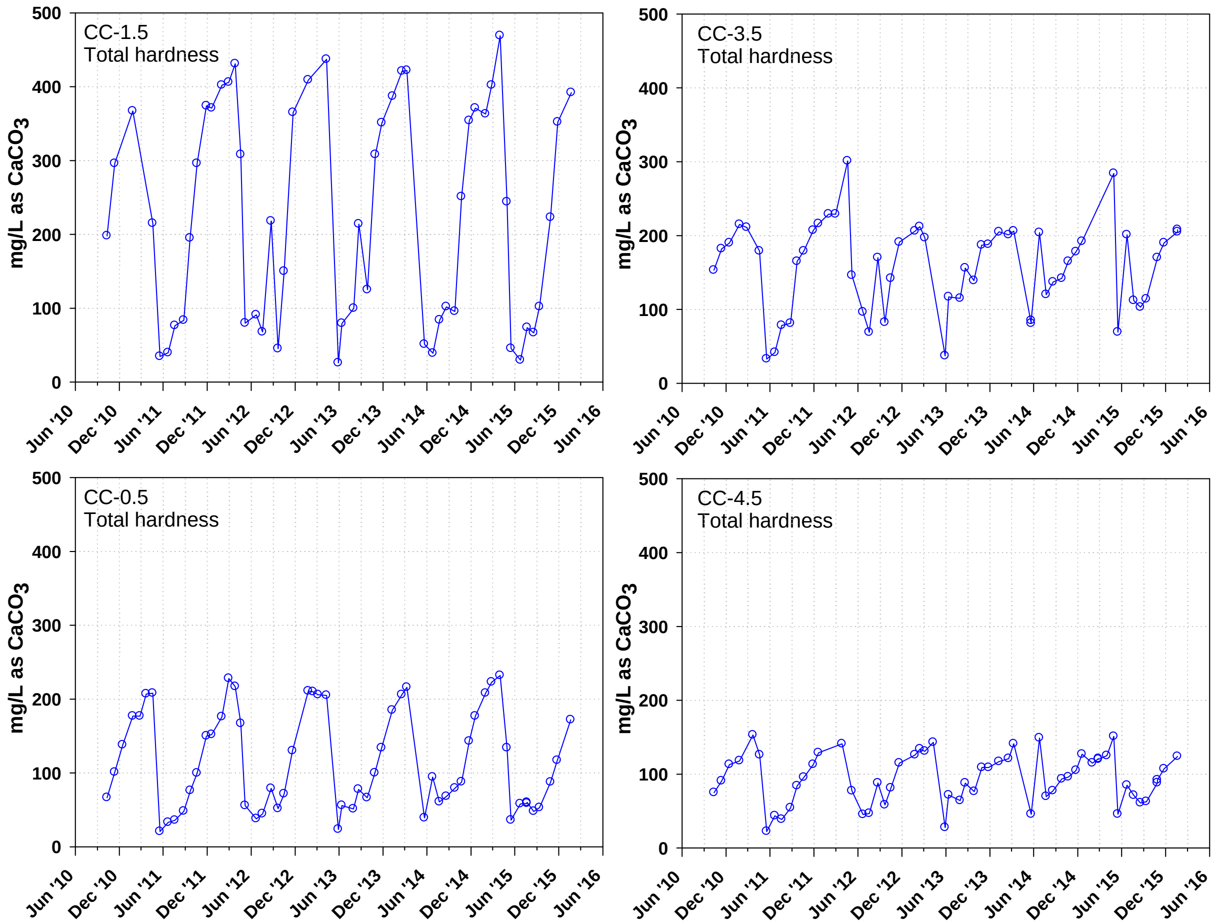


Figure 2-15: Time series for total hardness at stations CC-1.5, CC-3.5, CC-0.5, and CC-4.5 for October 2010 to January 2016.

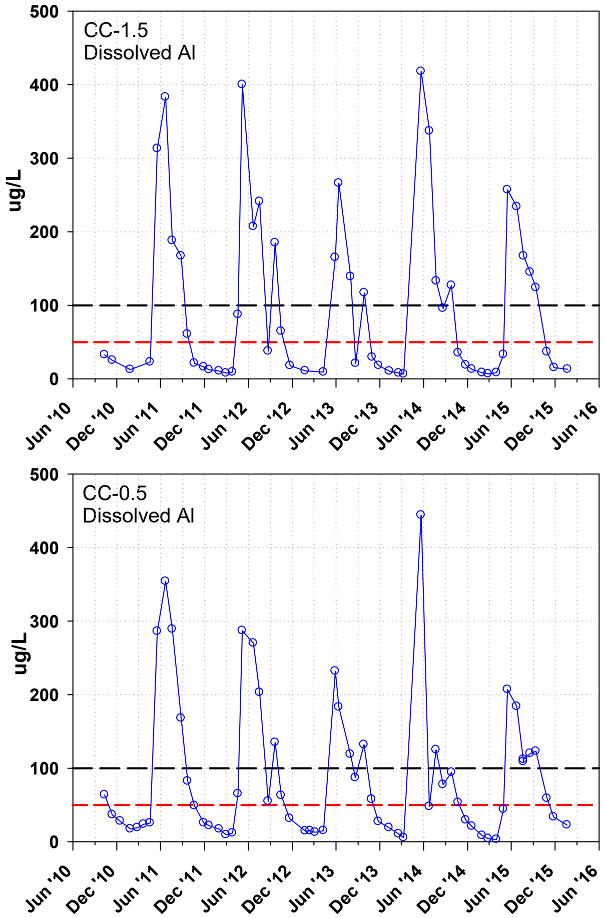


Figure 2-16: Time series for dissolved aluminum at stations CC-1.5, CC-3.5, CC-0.5, and CC-4.5 for October 2010 to January 2016. BC maximum (black dashed line) and 30-day (red dashed line) water quality guidelines assume pH <6.5.

The influence of snow-melt driven surface runoff during the open water season and groundwater inputs during winter months is also reflected in time series for organic and trace element parameters. Peak summer flows typically coincide with annual maxima in TSS, dissolved organic carbon, dissolved aluminum, total Fe, and particulate-bound metals (*e.g.*, T-As, T-Cd, T-Cu, T-Cr, and T-Zn). In contrast, the dominance of groundwater inputs during winter contributes to annual peaks in several dissolved metals, most notably U. Despite seasonally-associated concentration peaks that have been measured for many parameters, mean monthly concentrations of total and dissolved trace elements are typically low (*e.g.*, As, Sb, Co, Cr, Pb, Hg, Ni, Se, and Zn).

Several parameters are naturally elevated throughout the Coffee Creek catchment and commonly exceed corresponding CCME or BC WQGs on an annual basis. In Latte Creek, D-Al, T-Fe and T-Cu regularly exceed their corresponding CCME long-term water quality guidelines during the open water season (Figure 2-17), with T-Cd and T-Cr commonly approaching or exceeding guidelines as well. During winter low flow periods, total U consistently occurs well above its CCME long term guideline on an annual basis (Figure 2-18). Notably, total As and total Se typically below their WQGs year-round, although sporadic increases are observed in association with high-TSS events. Similar exceedances occur in the baseline monitoring dataset for Coffee Creek stations CC-0.5 and CC-4.5, with the exception of total U at CC-4.5, which has remained below the CCME guideline throughout the baseline period (Figure 2-18).

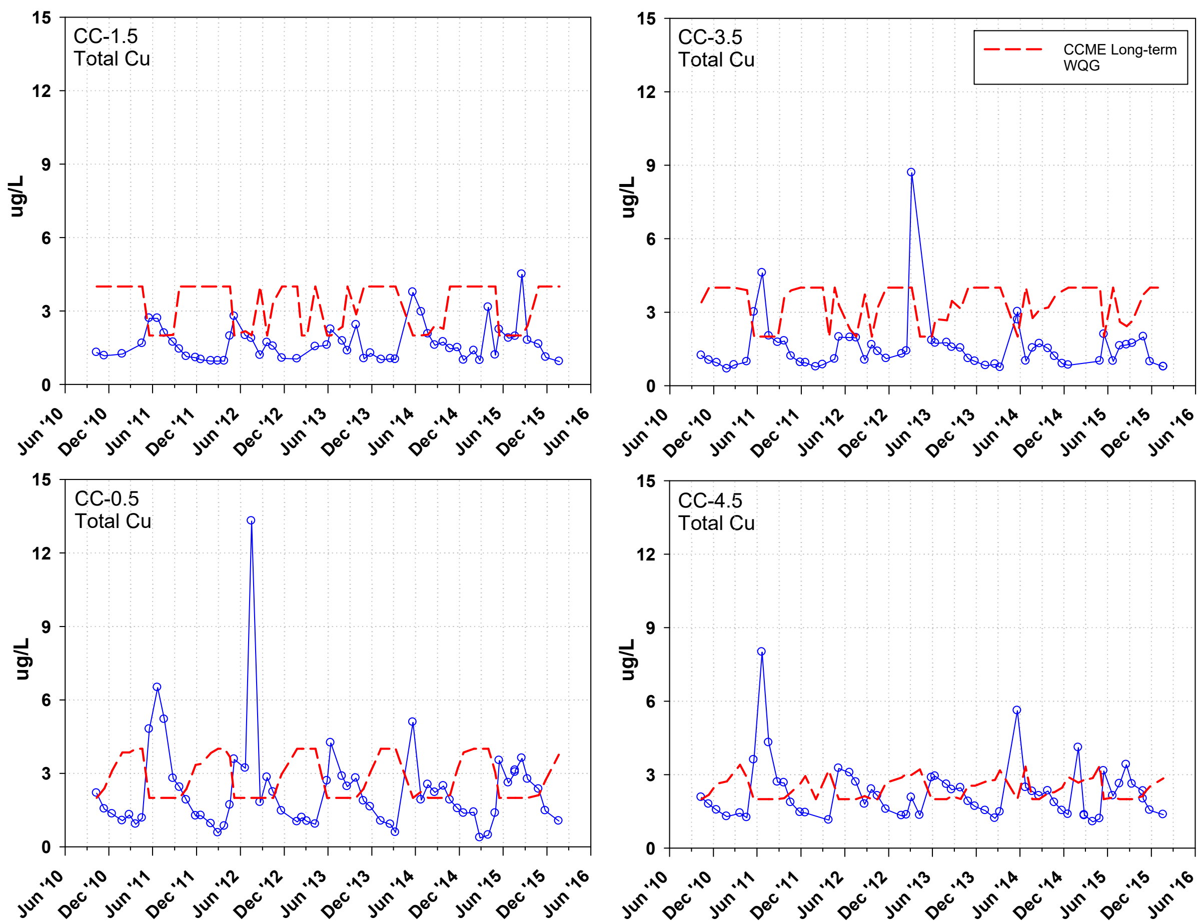


Figure 2-17: Time series for total copper at stations CC-1.5, CC-3.5, CC-0.5, and CC-4.5 for October 2010 to January 2016. CCME long-term water quality guideline (red dashed line) calculated from measured total hardness.

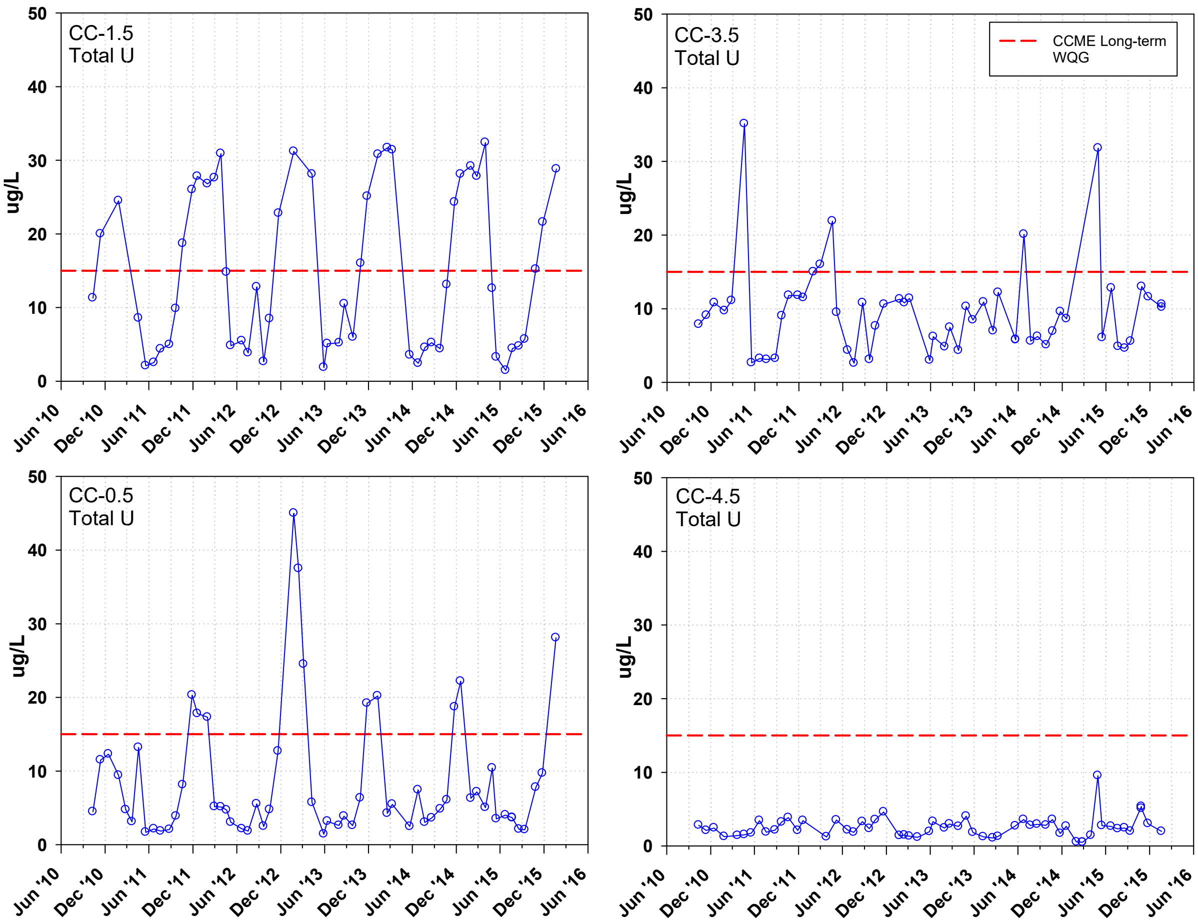


Figure 2-18: Time series for total uranium at stations CC-1.5, CC-3.5, CC-0.5, and CC-4.5 for October 2010 to January 2016. CCME long-term water quality guideline shown as red dashed line

2.3.3.2 *YT-24 Tributary*

Baseline water chemistry data are presented in this section for YT-24 tributary station ML-1.0 for the period of June 2014 to October 2016. Station ML-1.0 was renamed to YT-24 but the original naming convention is retained herein as all laboratory report the station as ML-1.0. Although baseline monitoring in the YT-24 catchment was initiated later compared to other catchments, the current baseline dataset reflects over one year of baseline monitoring. Due to the ephemeral nature of flow in this catchment, monthly samples have been collected at ML-1.0 during months of the open water period (April to October).

Certain parameters naturally exceed their corresponding CCME or BC WQGs at ML-1.0, including dissolved Al and total Cu (Figure 2-19). Total Cd occasionally occurs near its CCME guideline as well (Appendix 12-A).

2.3.3.3 *Halfway Creek*

Baseline water chemistry data are presented in this section for Halfway Creek stations HC-2.5 and HC-5.0 for the period of October 2010 to January 2016. Although HC-5.0 is located lower in the Halfway Creek catchment compared to HC-2.5, monthly sampling at HC-5.0 during winter was not possible due to the inability to locate flow.

Similar to the Coffee Creek catchment, water chemistry in Halfway Creek is driven by varying proportions of melt-water surface runoff (lower ionic strength, higher organic content) and groundwater inputs (higher ionic strength, lower organic content) to surface flow. Owing to the seasonal water balance, several water quality parameters show a distinct seasonal signature.

Halfway Creek is characterized by soft water and low levels of major ions during freshet periods (Figure 2-20). During winter low flow periods, no flow is evident at HC-5.0, while HC-2.5 is characterized by hard to very hard waters with high levels of major ions. pH remains relatively uniform throughout the Latte Creek and Coffee Creek drainages on an annual basis, typically occurring between 7.0 and 8.0.

Several parameters are naturally elevated throughout the Halfway Creek catchment and exceed their CCME or BC WQGs on an annual basis. For example, D-Al, T-Fe and T-Cu regularly exceed their corresponding CCME long-term water quality guidelines during the open water season (Figure 2-20 and Figure 2-21. During winter low flow periods, total U consistently occurs well above its CCME long term guideline on an annual basis at station HC-2.5 as well as during lower flow periods in the open water period (Figure 2-21**.**).

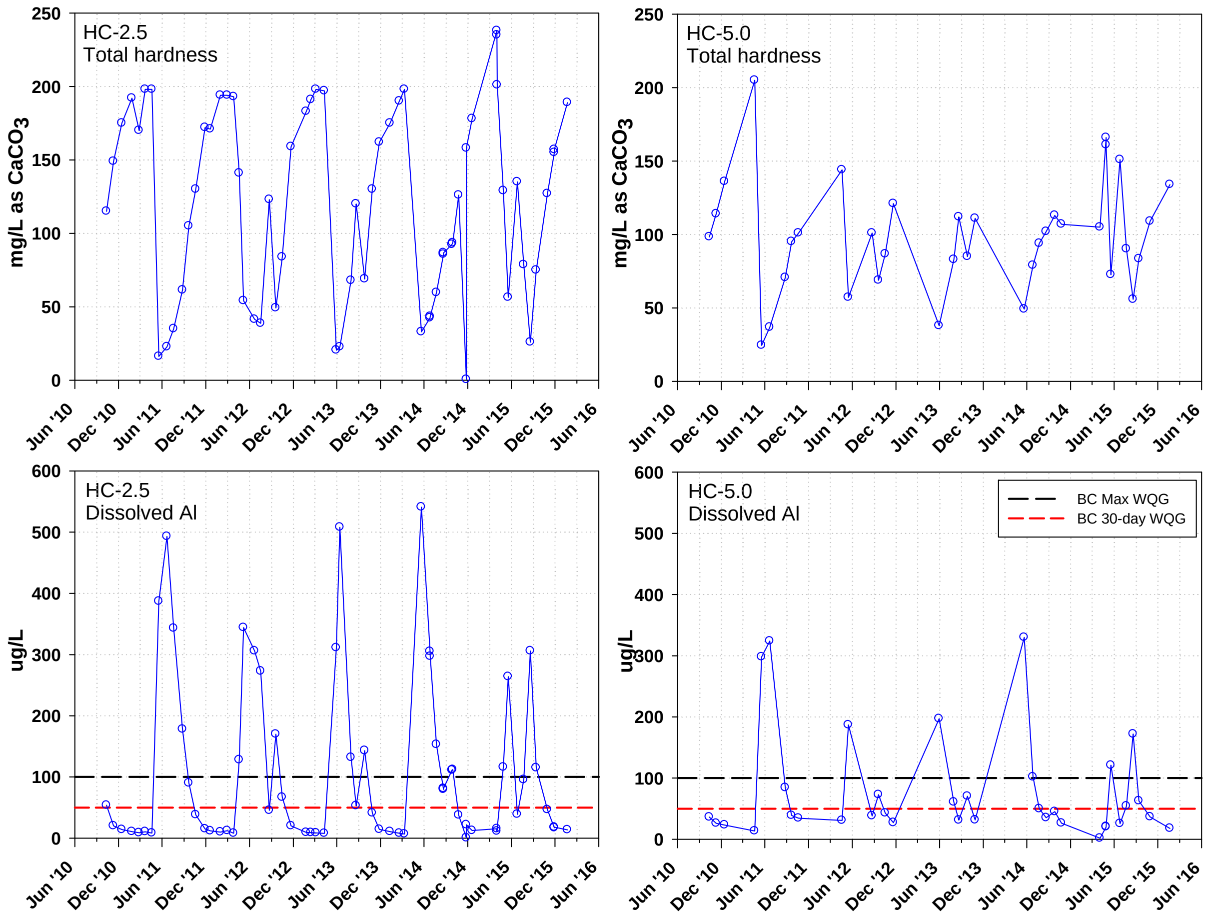


Figure 2-20: Time series for total hardness and dissolved aluminum at stations HC-2.5 and HC-5.0 for October 2010 to January 2016. CCME long-term and short-term water quality guidelines shown as red and black dashed lines, respectively

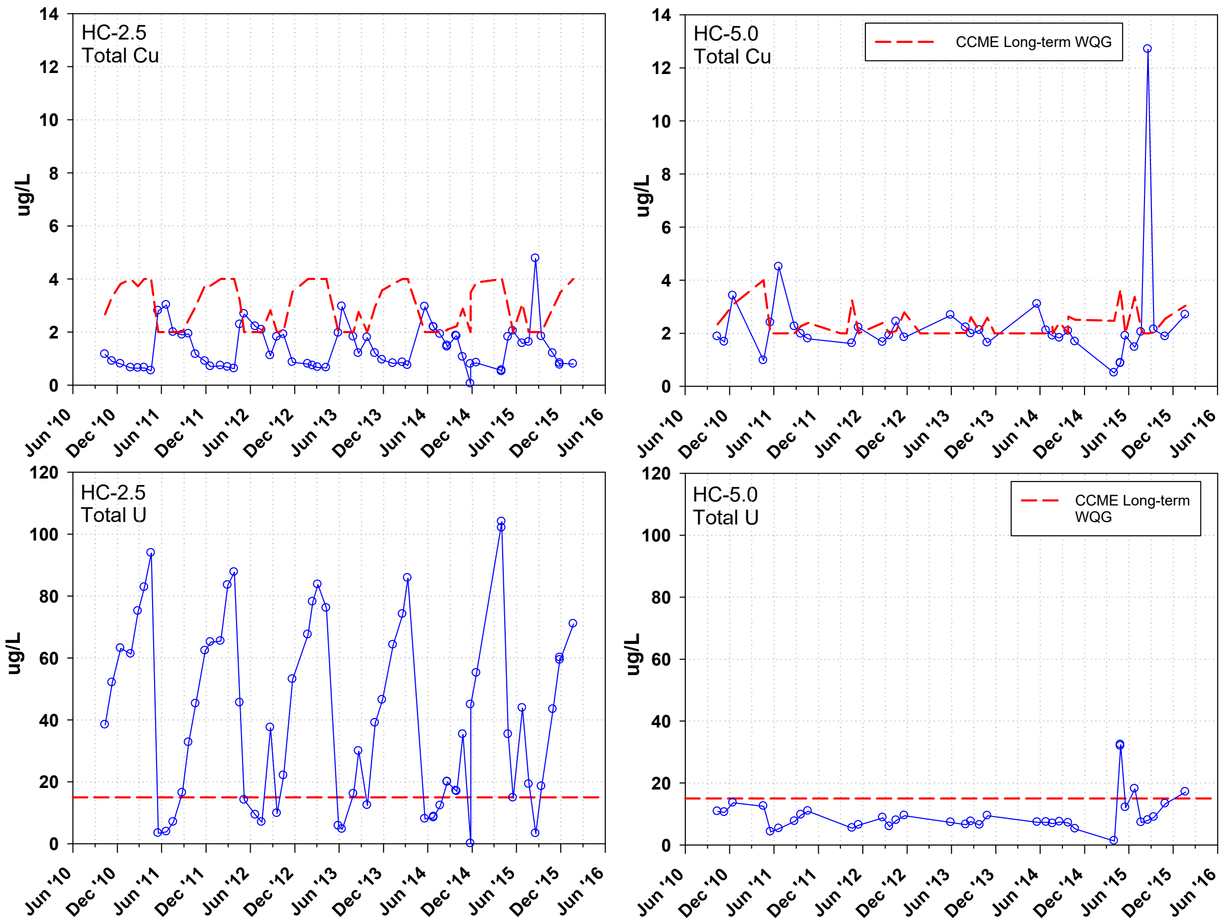


Figure 2-21: Time series for total copper and total uranium at stations HC-2.5 and HC-5.0 for October 2010 to January 2016. CCME long-term water quality guideline shown as red dashed lines.

2.3.3.4 *Yukon River*

Baseline water chemistry data are presented in this section for Yukon River stations YUK-2.0 and YUK-5.0 for the period of October 2010 to January 2016. YUK-2.0 occurs immediately upstream of all mine-related discharges. YUK-5.0 occurs downstream of all potential Project-related surface and groundwater discharges that may report to the Yukon River via the Coffee Creek catchment (including Latte Creek), the YT-24 catchment, and the Halfway Creek catchment. Monitoring data at the Yukon River stations are presented for the period of October 2010 through to January 2016.

Yukon River stations YUK-2.0 and YUK-5.0 are characterized by consistently hard waters with low to moderate levels of major ions (Figure 2-22). pH levels are generally circum-neutral to slightly basic, which is attributed to bicarbonate alkalinity. The strong seasonal water quality signature observed in smaller creeks in the Project area associated with winter groundwater inputs is largely absent from the Yukon River, owing to its larger relative catchment size.

During summer high flow, however, the Yukon River shows concentration peaks for certain organic parameters (*e.g.*, DOC), nutrients (T-P), TSS, and metals, including D-Al, T-Cd, T-Cr, T-Cu, T-Fe, T-Mn, T-Ni, T-Pb, and T-Zn. Mean monthly total arsenic concentrations at both YUK-2.0 and YUK-5.0 are typically well below 1.0 µg/L for most flow periods of the year with maximum values coincident with elevated TSS. Total U concentrations are also low; while mean monthly dissolved Al concentrations at stations YUK-2.0 and YUK-5.0 were also lower relative to stations in other project-area tributaries (but commonly exceed the BC 30-day WQG during summer flows).

Interestingly, concentrations of total Cu in the Yukon River at station YUK-2.0 and YUK-5.0 routinely exceeded the CCME hardness-based Cu guideline, despite consistently elevated hardness (Figure 2-22 and Figure 2-23). Mean monthly total Cu concentrations at both Yukon River stations indicate that elevated total Cu concentrations are associated with the peak flow months of May and June (Figure 2-23). Similar to Cu, total Cd concentrations typically slightly exceeded the CCME long term guideline during peak flow periods. Despite annual concentration peaks for certain parameters during summer high flows, mean monthly concentrations of total and dissolved trace elements are typically low, falling below CCME and BC long term guidelines (*e.g.*, Al, As, Sb, Co, Cr, Pb, Hg, Ni, Se, and Zn), and most notably for U (Figure 2-23).

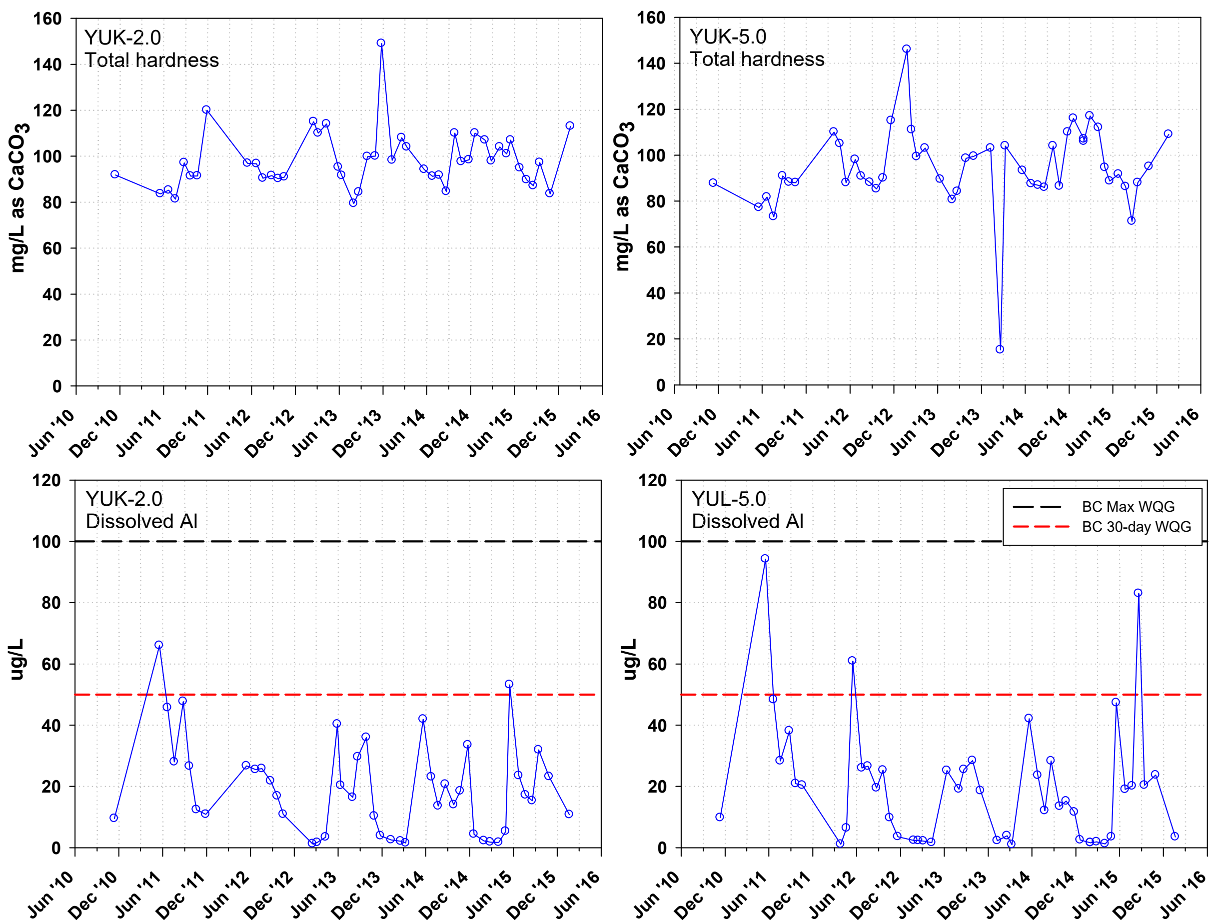


Figure 2-22: Time series for total hardness and dissolved aluminum at stations YUK-2.0 and YUK-5.0 for October 2010 to January 2016. CCME long-term and short-term water quality guidelines shown as red and black dashed lines, respectively.

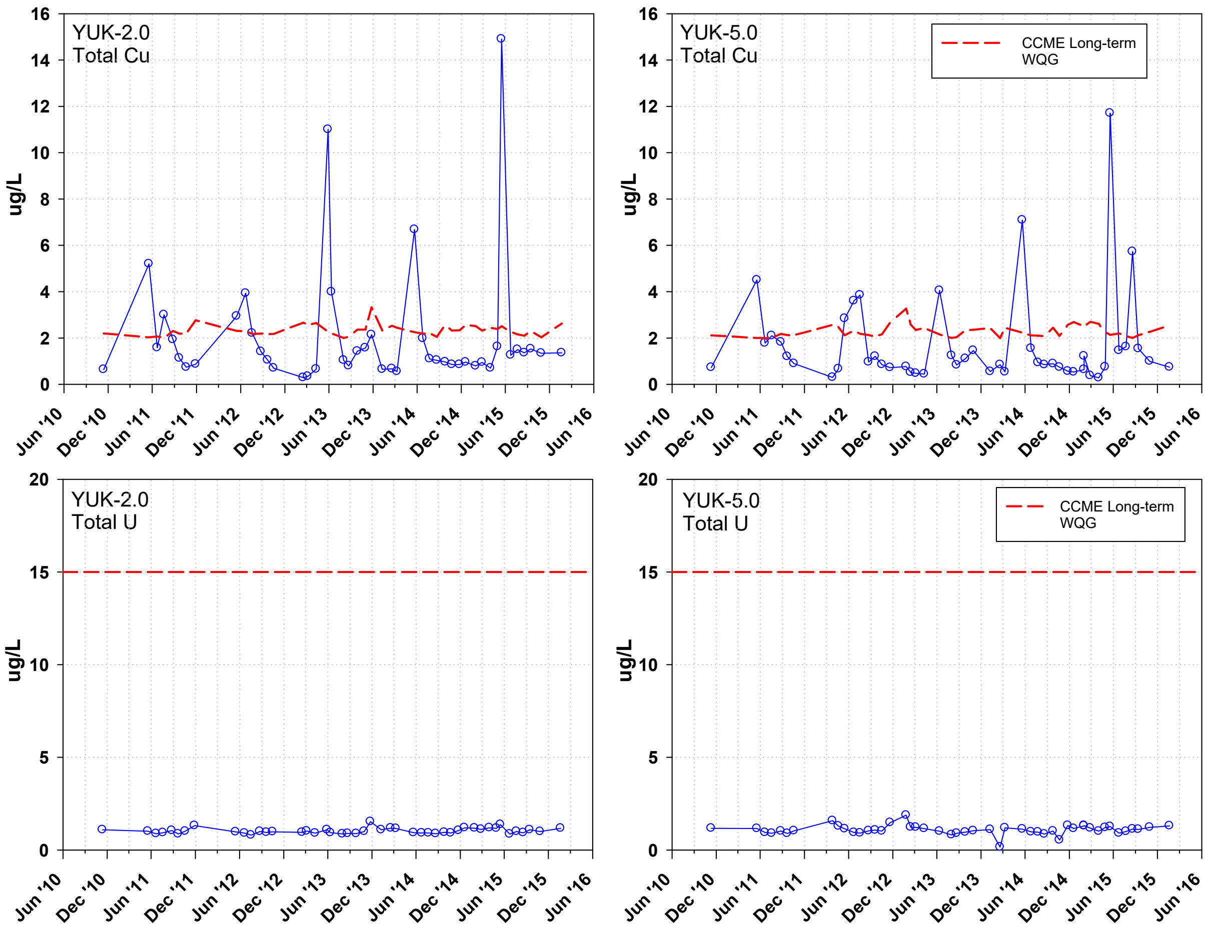


Figure 2-23: Time series for total copper and total uranium at stations YUK-2.0 and YUK-5.0 for October 2010 to January 2016. CCME long-term water quality guideline shown as red dashed lines

2.3.4 Groundwater

The following sections present the baseline conditions for groundwater quantity and quality in the Project area. The information presented in this section is summarized from the full baseline report, presented in Appendix 7-A of the Project Proposal. A summary of the groundwater model setup and findings are also presented in this section; this information is presented in full in the Appendix 7-B-1 of the Project Proposal.

2.3.4.1 *Baseline Data*

Multiple hydrogeological field programs have been undertaken at the Coffee Gold Mine Site since 2013. The results speak to a complex hydrogeological system influenced by discontinuous permafrost and fracturing.

Gold mineralization is associated with an extensional deformation event that resulted in formation of steep-to-vertical brittle fractures and normal faults cross-cutting all lithologies at Coffee. Structural features rather than rock type impart the dominant control on bedrock hydraulic conductivity. A hydrogeological investigation that focussed on hydraulic testing of these fracture systems, which intersect proposed pits, reported a narrow range of hydraulic conductivity with arithmetic mean value of $7x10^{-7}$ m/s. High hydraulic conductivity values (on the order of 10^{-6} m/s) were also measured in boreholes advanced in valley locations (*i.e.* Halfway Creek, YT-24 Drainage, Upper Latte Creek) and supports the inference that valley traces represent fault structures. The geometric mean of intact bedrock hydraulic conductivity is on the order of $5x10^{-8}$ m/s.

Ground temperature data obtained from thermistors, as well as observations from drilling and monitoring well sampling, indicate that permafrost is extensive, but discontinuous across the project area. Permafrost extends to greatest depths in ridge areas and appears to decrease in thickness with declining elevation. North facing slopes tend to have thicker permafrost than south-facing slopes, with the thickest permafrost (~165 metres) encountered in the area of the Supremo Phase 3 North Pit. Permafrost is absent in the lower reaches of the Upper Latte Creek drainage. Permafrost in the project area is warm (between 0 and -2^{o}C) and is coolest (-1.4^{o}C to -2^{o}C) on north facing slopes.

The active zone, the supra-permafrost layer that seasonally thaws, is generally shallow across the site (less than 2 m deep), except in areas where insulating vegetation has been stripped (i.e. road cuts). Overall, the period of thaw for shallow temperature sensors within 5 m of ground surface is highly variable across the site in both timing and duration. Selected instruments recorded above zero shallow subsurface temperatures between mid-May and the end of October 2015. Therefore, creek baseflow measured during the winter (October to May), when the active zone is frozen, is most representative of deeper groundwater discharge. Where groundwater discharge freezes in the stream channels through the winter, extensive aufeis forms.

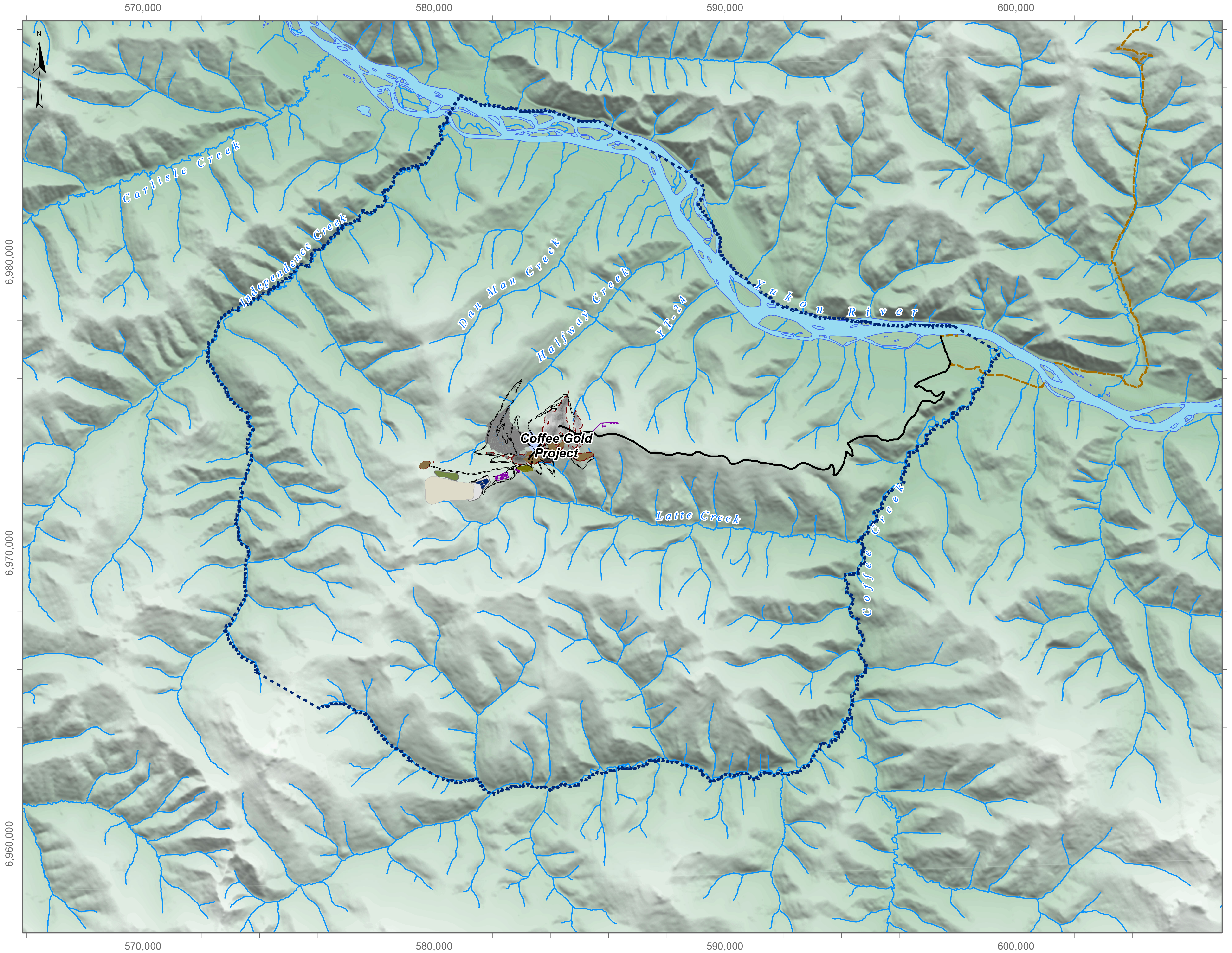
Water levels generally follow topography, with the deepest water levels (ranging from approximately 130 metres to over 220 metres below ground surface) found in ridge areas, and confined/artesian pressures encountered at low to moderate elevations. Permafrost in combination with higher quality rock is believed to act as a confining unit in some areas. Vertical hydraulic gradients are highly variable across the site (ranging from negligible to 40% upward or downward) and speak to a complex groundwater system influenced by both permafrost and fracturing. Groundwater level responses to seasonal recharge vary anywhere from a few metres to tens of metres.

Groundwater in the Project area is predominantly circum-neutral (pH 6 to 8), with most groundwater samples between pH 7 and 8. Groundwater quality shows variable influence from weathering of sulphide minerals and/or dissolution of sulphate minerals, either from the deposits or other disseminated mineralization across the Project area. This is evidenced by low to substantial sulphate concentrations and variable salinity. Groundwater quality at the Mine Site is characterized the presence of elevated dissolved arsenic and uranium. Dissolved arsenic ranges from 0.27 to 1860 µg/L and is highest in deeper groundwater in the vicinity of Kona pit. Uranium ranges from 7.6 to 589 µg/L and is highest in groundwater in the YT-24 and Halfway Creek catchments.

2.3.4.2 *Groundwater Model*

A 3-D, steady-state, numerical groundwater model has been constructed predict potential Project changes to groundwater using the Groundwater Vistas platform (Rockware®), operating the finite difference groundwater modeling code MODFLOW-2005 (Harbaugh, 2005). A detailed account of the Groundwater Model can be referenced in Appendix 7-B1. The groundwater modeling exercise has been undertaken in three stages simulating baseline (pre-mine) conditions, end of Operation Phase (Year 12) conditions and a long-term Post-Closure condition.

The groundwater model domain is illustrated in Figure 2-24. The model is truncated to the west by Independence Creek, to the north by the Yukon River and to the east and south by Coffee Creek. The groundwater model incorporates permafrost thickness and high hydraulic conductivity features such as the pit structures and creek traces. Otherwise, bedrock hydraulic conductivity has been assigned based on depth and whether it is observed/inferred to be frozen. Overburden is not modeled, save a package of colluvium at the base of the Upper Latte Creek drainage and the alluvium flanking the Yukon River. Recharge rates are varied by elevation and whether the bedrock is frozen. Calibrated groundwater recharge rates on unfrozen ground correspond to 15% MAP; recharge rates on permafrost are either 0 mm/yr or 5 mm/yr, depending on elevation. The recharge rates applied in the Groundwater Model are summarized in Table 2-5.



LEGEND

- Model Domain Boundary
- Access Road
- Proposed Dawson Route
- Waterbodies
- Watercourses

Coordinate System: *NAD 1983 UTM Zone 7N*
Projection: *Transverse Mercator*
Datum: *North American 1983*
Units: *Meter*

1:125,000

0 2 4 Km

DATE SAVED:	Mar 28, 2017
DRAWN BY:	GM
REVIEWED:	LF
VERSION:	1

CLIENT:

GOLDCORP

LORAX ENVIRONMENTAL

PROJECT:

Coffee Gold Hydrogeology

TITLE:

Model Domain

PROJECT #:	*FIGURE:*
A362-5	2-24

P:\@Drafting\Coffee Gold\Drafting Figures\MxDs\Water Balance\Fig 2-21_GW Model Domain_20170327.mxd

During the baseline model calibration, recharge rates and hydraulic conductivity were varied until simulated water levels and creek baseflow matched observed targets. The creek baseflow rates used as calibration targets correspond to 0.4 to 0.9 L/s/km^2 except at YT-24 and CC-1.0, where June 23rd, 2015 low flows used as lower bound. Hydraulic head targets were largely measured in late June, 2015.

Table 2-5:
Pre-Mine Recharge Rates used in Groundwater Model

	Applied Recharge Rate (mm/y)	
Elevation Range (masl)	**Unfrozen Ground**	**Permafrost**
400 to 600	0	0
600 to 800	53.8	0
800 to 1000	59.3	0
1000 to 1200	65.5	0
1200 to 1400	71.1	5.0

Operation Phase and Post-Closure Model

The main drivers of groundwater quantity changes are pit development, placement of waste rock and implementation of large, lined areas (i.e. under the HLF and associated facilities). Removal or ponding of water that discharges to and/or collects in pits can increase or decrease recharge to the groundwater system and this may manifest as changes in water levels and creek baseflows. Changes that occur in one pit complex may enhance or diminish changes resulting from development of another pit complex. These changes are further confounded by diminished recharge under WRSFs and HLF facilities.

An iterative exercise between the Groundwater Model and Water Balance Model was conducted to integrate groundwater flowpaths and rates into the Water Balance Model. This integration was manifested through the iterative evaluation of pit lake elevations. Leakage versus pit lake stage curves were determined for all of the pits using the Groundwater Model. These leakage curves were coded into the Water Balance Model along with meteoric water inputs and other diversions.

The baseline model was modified to represent conditions at end of Operation Phase (Year 12) and late Post-Closure. The maximum pit lake elevations computed for these years in the Water Balance Model were applied in the Groundwater Model as a boundary condition in the lake footprint areas (Table 2-6). For the Operation Phase model, the type of boundary condition used for the pit lake depends on whether the base of the pit lies in permafrost and whether the pit is backfilled with waste rock. The Post-Closure model was modified to represent the formation of saturated through-taliks under all pit lakes residing on permafrost. This condition is assumed to occur once all pit lakes have reached their spill elevation. This was achieved through applying a higher hydraulic conductivity (reflective of shallow, unfrozen ground) underneath the pit lakes and simulating the lakes as constant heads. These changes force the deeper water table to rise to the level of the pit lake. While the changes create enhanced communication between pits, pit seepage losses to receiving drainages remain small. This is due to vertical and lateral seepage from the pits being limited by low conductivity deep bedrock and surrounding permafrost. The reader is referred to Appendix 7-B-1 for further detail on this modelling exercise. The primary effect of talik formation is expected to be greater groundwater fluxes between pits, with minimal (*i.e.*, < 0.5 L/s) alterations to the estimated leakage rates reporting to the receiving environment nodes compared to a Post-Closure case where permafrost is left intact. As site-specific thermal modeling has not been conducted to estimate the time until talik development occurs, this condition is not tied to a specific Mine Year, and instead is assumed to occur at some long-term point during post-closure. Given the minimal differences in leakage rates reporting to the receiving environment between the talik/ no talik condition, the site-wide WBM assumes that taliks do not form beneath the pit lakes.

Pit boundary conditions, along with approximate pit floor elevation, simulate pre-mine water table and permafrost elevation is summarized in (Table 2-6).

With exception to the Double Double pit, all in-pit and ex-pit waste rock storage areas were assigned a recharge rate of 0 mm/yr, to account for steep footprint areas, rock drains and/or the presence of permafrost which all limit infiltration of waste rock seepage into the underlying bedrock. The recharge rate applied to the backfilled Double Double pit (151 mm/yr) corresponds to 35% MAP, which is consistent with the infiltration rate applied to this facility in the Water Balance Model. Finally, zero recharge has been applied in the footprint area of the HLF and associated event ponds in consideration of the liner system that will be installed.

Ultimately, the Groundwater Model has indicated that creek baseflows at end of Operation Phase and Post-Closure are relatively insensitive to mining activities. During Operation Phase, some of the pits are developed above the water table and contact water infiltration rates are limited by low bedrock hydraulic conductivity associated with permafrost.

Table 2-6:
Boundary Conditions Applied to Pits in Groundwater Model

Pit	Pit Advanced Through Permafrost	Pit Lake Elevation Year 12 (m asl)	Pit Lake Elevation Post-Closure (m asl)	Groundwater Model Boundary Condition (Year 12)	Groundwater Model Boundary Condition (Post-Closure)
SU1[1]	Permafrost Absent	942	942	Constant Head	Constant Head
SU2	Yes	1061	1081	Constant Head	Constant Head
Latte[1]	Yes	998	1040	Constant Head	Constant Head
SU3W[2]	No	1176	1200	General Head	Constant Head
SU3N	Yes	1050	1090	Constant Head	Constant Head
SU4N[1]	Yes	1083	1105	Constant Head	Constant Head
SU4S	Permafrost Absent	1013	1048	Constant Head	Constant Head
SU5S[2]	No	1165	1165	General Head	Constant Head
SU5N[2]	No	1140	1140	General Head	Constant Head
Double Double[3]	Permafrost Absent	Not specified	Not specified	Recharge = 151 mm/yr	Recharge = 151 mm/yr
Kona[3]	No	None	None	Recharge = 0 mm/yr	Recharge = 0 mm/yr

Notes:
1. Pit partially backfilled with mine waste, recharge = 0 mm/yr in footprint of mine waste
2. In Post-Closure, bedrock hydraulic conductivity underlying pit is converted from a permafrost value to a shallow bedrock value.
3. Pit completely backfilled with mine waste, recharge as indicated.

The highest seepage rates from the pits to groundwater Post-Closure are encountered at Latte and SU4S pits and are on the order of 3 L/s and 1.7 L/s, respectively. Conversely, leakage to the SU1 pit is ~4 L/s Post-Closure. Resultant changes to creek baseflow are summarized in Table 2-7. Most of the predicted changes to baseflow amount to less than a 10% from simulated baseline baseflows. The exception is HC-2.5, which increases beyond 10% as a result of discharge from Latte and SU3N/SU3W pits.

Table 2-7:
Simulated Creek Baseflows for Baseline, End of Operation and Post-Closure Conditions.

Drainage	Hydrometric Station	Basin Area km²	Creek Baseflow[1] Calibration Target (L/s)		Simulated Creek Baseflow						
					Baseline	End of Operation Phase			Post-Closure Phase		
			Lower Bound	Upper Bound	L/s	L/s	ΔL/s[2,3]	% Change[2,3]	L/s	ΔL/s[2,3]	% Change[2,3]
Independence Creek	IC-2.5	17.3	6.9	16	4.7	4.6	-0.1	-3%	4.6	-0.1	-3%
	IC-3.0	18.3	7.3	16	10	10	0.0	0%	10	0.0	0%
Halfway Creek	HC-2.5	14.8	5.9	13	8.2	8.4	0.2	3%	10.0	1.8	22%
	HC-5.0	27.0	11	24	17.4	17.7	0.2	1%	19	1.9	11%
YT-24 Drainage	YT-24	11.8	3.8	11	7.3	7.4	0.1	1%	7.6	0.3	4%
Latte Creek	CC-6.0	9.6	3.8	8.6	4.4	4.3	-0.1	-2%	4.4	-0.1	-2%
	CC-1.0	3.4	0	3.1	2.1	1.2	-0.8	-40%	1.9	-0.1	-5%
	CC-1.5	23.1	9.3	21	14	12	-1.2	-9%	14	0.2	1%
	CC-3.5	69.8	28	63	48	47	-1.1	-2%	50	1.3	3%

Notes:
1. Lower and upper bound values computed from a basin yield of 0.4 to 0.9 L/s/km², respectively, except at YT-24 and CC-1.0, where June 23rd, 2015 low flows used as lower bound.
2. Change in flows (ΔL/s) computed as *ΔL/s = simulated mine phase baseflow - simulated baseline baseflow; n*egative changes indicate a decrease in baseflow from simulated baseline levels, positive changes indicate an increase in baseflow from simulated baseline levels.
3. Change in flows (%) computed as *% Change* = (*simulated mine phase baseflow - simulated baseline baseflow)/(simulated baseline baseflow);* negative changes indicate a decrease in baseflow from simulated baseline levels, positive changes indicate an increase in baseflow from simulated baseline levels.

2.3.5 Geochemistry

Geochemical characterization testwork has been conducted to evaluate the acid rock drainage and metal leaching (ARD/ML) of geologic material that will be disturbed during mine life. The purpose of this testwork is to inform mine waste management and monitoring, and to provide an assessment of the geochemical behaviour of proposed mine facilities (*e.g.*, pit walls, waste rock facilities, heap leach facility and borrow sources). The complete results and data interpretation can be found in the Geochemical Characterization Report provided in Appendix 12-D.

The geochemical program included a variety of static tests, kinetic tests and detailed mineralogical analysis to characterize the ML/ARD potential. The characterization program demonstrates that most rock types have little or no potential for acid generation, with the exception of granite ore produced form the Kona pit which constitutes only a minor fraction of mine rock (1.9% of total ore). Despite neutral pH conditions some metal leaching may still occur, with As and U being the primary parameters of concern in most rock types. A summary of the ML/ARD potential from ore and waste rock is provided below.

2.3.5.1 *Ore*

Ore at the project site is highly oxidized, primarily being classified as oxide with a minor amount of transition material. As a result of in-situ weathering, sulphide and carbonate minerals have largely been removed from the ore. There is some variation in residual carbonate and sulphur content between the different lithologies and weathering facies. Transitional ore has elevated sulphur and carbonate content compared to oxide ore. However, the differences between lithologies are generally more distinguishing than weathering zone. The schist lithology has the highest sulphur (median – 75^{th} percentile of 0.07 – 0.49 wt.%), the gneiss has an intermediate sulphur content (median – 75^{th} percentile of 0.01 – 0.04 wt.%) and the granite has the lowest Sulphur content (median – 75^{th} percentile of 0.01 – 0.03 wt.%).

Due to the low sulphur content, relatively minor quantities of acid neutralizing carbonate minerals present in the ore, in the form of calcite and dolomite, can maintain a neutral drainage pH. The schist and gneiss ore are classified as non-potentially acid generating (non-PAG) or non-reactive and have neutral to alkaline rinse pH (6.7 – 8.7). This shows that oxidation of sulphide minerals during in-situ weathering has produced insufficient acidity to deplete carbonate minerals. Conversely, granite ore has a mildly acidic rinse pH (4.4 - 6.8) and acid base accounting indicates that 39% of granite ore is potentially acid generating (PAG). While the rinse pH is only mildly acidic, similar to that of rain water (pH 5.6), kinetic testing on granite ore indicates that these mildly acidic conditions will lead to a significant increase in metal leaching potential. Therefore, granite ore is classified as PAG for the purposes of mine waste management.

Analysis of solid phase metal abundances show that all lithologies of ore are enriched in Sb, As, Bi, Hg, Se and Ag with respect to average continental abundances (ACAs). Gneiss and granite ore are also enriched in U, with a median value of 14 ppm in the oxide weathering zone of both lithologies. Conversely, schist ore shows little or no U enrichment, with median values being similar to that of average continental abundance (median value of 2.9 ppm compared to ACA of 2.7 ppm). There is a significant variation in As enrichment between lithologies, with gneiss having significantly lower concentrations (median of 966 ppm) compared to schist and granite ore types (median values of 2450 and 2040 ppm, respectively).

Kinetic testwork indicates that although pH neutral conditions are expected from all mine facilities containing ore, there still remains potential for neutral pH metal leaching. The primary elements of concern in ore are As and U, and to a lesser extent Sb, Se, Cr and Hg.

2.3.5.2 *Waste Rock*

Geochemical testwork indicates that all lithologies and weathering facies of waste rock have little or no potential for acid generation. The low potential for acid generation is, in part, related to the lack of sulphur mineralization, with median total S values in gneiss, granite and schist being 0.01, <0.01 and 0.03 wt.%, respectively. There is some variation in sulphur content between weathering facies within each lithology, with the fresh weathering zone typically showing greater sulphur content then the transition and oxide zones. However, the sulphur content remains relatively low even in unweathered (fresh) waste rock, with median values ranging from <0.01 to 0.11 wt.%. Regardless of the lithotype or weathering facies, pyrite is the primary sulphur mineral. Similar to sulphur, carbonate mineral abundance can be related to both lithology and weathering zone. The highest carbonate abundances and NP are exhibited by the schist lithology, followed by the gneiss and granite units, with unweathered 'fresh' waste rock generally showing greater carbonate content then transition or oxide weathering zones. The primary carbonate minerals identified are calcite and dolomite, with lower concentrations of ankerite and siderite also present. Due to the low sulphur concentrations and the presence of carbonate minerals, all waste rock is classified as non-reactive or non-PAG.

Analysis of solid phase metal concentrations show that the granite and gneiss lithologies are enriched in U and all lithologies of waste rock are enriched in Sb, As, Bi, Hg and Se (relative to ACA). The observed metal enrichments for waste rock is consistent with that observed for ore, with concentrations in the ore samples generally higher than that measured for waste rock of the same lithology and weathering group. In particular, Sb and As are one to two orders of magnitude lower in waste rock compared to ore of the same lithology and weathering. The difference in U concentrations is less pronounced, with gneiss and granite ore having approximately twice the U content as waste rock (median values of 14 ppm in ore versus median value of 6.0 to 7.0 ppm in oxide waste rock). Uranium shows no enrichment in schist, with concentrations being below the ACA (2.7 ppm) in all weathering facies.

Kinetic testing based on humidity cells, unsaturated columns, and field bins indicated that U and to a lesser extent As, Se, and Zn are the primary metal leaching concerns in waste rock. Geochemical source terms for these parameters for all waste rock facilities are provided in Appendix 12-D.

3. Water Balance Model

GOLDCORP

3. Water Balance Model

This section of the report outlines the following with respect to the WBM used to characterize the baseline flow regime and estimate any flow alterations associated with the Project: the software used to compile the site-wide water balance model; a discussion of the inputs and assumptions required to assemble the model; WBM calibration and validation; and presentation of WBM results.

In Sections 3.1 and 3.2, over-arching assumptions and common inputs to the WBM are introduced, followed by a detailed summary of the model architecture, inputs, assumptions and calibration procedures for each of the three watersheds that will contain mine infrastructure – Latte Creek/Coffee Creek, Yukon Tributary 24 and Halfway Creek (Section 3.3, 3.4 and 3.5). Relevant information for the drainages are presented in this order, and as Latte Creek is introduced first, the majority of the modeling assumptions related to mine components will be presented in the Latte Creek section (Section 3.3). As the model descriptions progress through to the other two drainages, any assumptions specific to these drainages, or any alterations to those presented in the Latte Creek section, will be brought forward. Section 3 concludes with a presentation of results for the three main drainages (Section 3.6).

3.1 *Model Overview*

A critical component of both the environmental assessment and licensing process is the prediction of potential changes to water quantity resulting from mine development and closure. These predictions inform the mine plan and water management strategies, and form inputs into the fisheries and aquatic habitat impact assessments as well. It is common convention to index the magnitude of predicted flow changes attributable to the Coffee Gold Mine (Base Case, With Project) by comparing Base Case flows to a Baseline (or Pre-development) flow record:

$$\%\Delta Flow = \left(\frac{Base\ Case\ Flow - Baseline\ Flow}{Baseline\ Flow}\right) x\ 100$$

In this regard, necessary outputs from the Coffee Gold Mine WBM are Base Case and Baseline Flow records that are of long-duration and span the main phases of the Project (*i.e.*, Construction, Operation, Closure, Post-closure).

For the Coffee Gold Mine, the site-wide WBM has been configured to estimate baseline flow conditions within local watersheds that may be affected by the Project (*i.e.*, Latte Creek/Coffee Creek, YT-24 Tributary, Halfway Creek). In parallel, the WBM is also configured to include all relevant Base Case Project infrastructure, including the HLF, open pits, WRSFs, ore and overburden stockpiles, and water management infrastructure (*e.g.*, sediment ponds, diversion ditches, event ponds, *etc*.). Within the Base Case module of the WBM, each mine component is spatially defined by year of the Project life, which allows the footprints (sub-catchments) and /or volumes of each component to expand as the mine development progresses. Each sub-catchment represents a single land cover type (*e.g.*, WRSF, open pit, natural ground, pit lake, *etc*.)

Overall, daily temperature and precipitation data are used to drive the WBM, with meteoric water being converted to runoff using assumptions and coefficients specific to the land surface type represented in each sub-catchment. All sub-catchments are assembled in hierarchical order, with runoff tracked and aggregated across the Coffee Gold Mine and downstream into the receiving environment. The assembly of a long-term climate dataset is presented briefly in Section 3.2.4, and in complete detail in Appendix 8-A.

Baseline and Base Case flow data are the main outputs of the site-wide WBM, with outputs provided on a monthly basis for all phases of the Project, from Year -3 to Year 80 of the Project life. Ultimately, these modelled data are used as the inputs to the flow change assessment (Section 3.6) for Project site locations and provided to related disciplines (*e.g.*, hydrogeology, water quality, fisheries) for IC and VC assessments.

3.1.1 Site-wide WBM Approach and Assumptions

This section presents the inputs and assumptions employed in the assembly, calibration and running of the site-wide WBM. Briefly, the guiding assumptions are listed below:

- The WBM produces monthly discharge data for Project site stations for two conditions: Baseline Condition (*i.e.*, Pre-development, Natural Case) and Base Case (*i.e*., With Project). The Baseline (or 'Natural') module of the WBM considers no mine footprints and/or water-related management activities, whereas the Base Case module of the WBM has mine plan and water management activities associated with the Project fully encoded.
    - This approach allows for a direct comparison to be made between the current and undisturbed flow regime and the predicted flow regime, for any location and/or time-period of interest, or for the entire model domain (all watersheds containing and downstream of mine infrastructure) and the full Project life span (Construction Phase through Post-closure).
- Given the highly dynamic nature of streamflows at the Project site, the WBM is set-up to run on a daily time-step. This was made possible by the availability of high-quality daily- synthetic climate data and synthetic daily- streamflow records that the WBM was driven by and calibrated to, respectively. All WBM runs were

completed at a daily time-step with flow outputs from the WBM aggregated to a monthly time-step.

- The use of a synthetic daily climate record as an input to the model facilitates WBM runs on a daily time-step from the start of Construction through the Post-closure phase of the Project. This is desirable for tracking temporally variable flows (*e.g.*, freshet) and rapidly changing storage in smaller ponds and pit lakes, as well as to remain coordinated with the modelling approach adopted for the HLF.
    - Climate data used to drive the site-wide WBM were adjusted to account for potential future climate change. As described in Sections 3.2.1 and Section 3.2.4, the 28-year synthetic climate record presented in Appendix 8-A was looped three times (*i.e.*, 84-year record to represent calendar years 2018 through 2100), then adjusted for temperature and precipitation increases forecast by an A2 emission scenario.
    - The HLF water balance model described in the Feasibility Study forms a sub-component of the site-wide water balance model, and the climate data inputs and assumptions are notably consistent between the two models to ensure discrepancies are not introduced by differing architecture or inputs.
- The Baseline module of the WBM, and many of the mine sub-catchments within the Base Case module generate runoff from climate data with a watershed model. The architecture of the watershed model is predicated on the concept that streamflow is comprised of three components: quickflow, interflow and baseflow (Maidment, 1993).
    - The WBM was assembled using three reservoirs to represent these components (Section 3.2), and the factors governing the rates at which these reservoirs fill via precipitation and snowmelt were varied by basin and/or mine component type (*e.g.*, natural ground, WRSFs, open pits). In essense, this allowed the WBM to be accurately calibrated to the Baseline flow condition, or consistent with professional practices (*e.g.*, waste rock seepage runoff coefficient) in the case of the Base Case module, over a wide range of flow conditions and at high-resolution time-step (Section 3.2 for generic discussion).
    - This foundational WBM architecture is used consistently within each natural watershed of mine sub-watershed to convert meteoric water into runoff based on sub-watersheds characteristics (*e.g.*, elevation, surface type, water management infrastructure; Section 3.2.1).
- Flows are aggregated within each sub-watershed, and combined again at the next level in the watershed heirarchy. This allows the predicted flows to be derived for

any sub-watershed in the WBM, or aggregated and reported for a collection point of interest (*e.g.*, sediment collection pond discharge, or receiving environment node). Arguably, this may have little relevance when assessing flow alterations at a major basin scale, but aggregation is highly important for the WQM and the interpretation of water quality predictions under the Base Case condition.

- Mine facilities are assumed to be developed according to the development schedules and timelines set out in the Coffee Gold Mine Plan, as described in Section 2 (the Project Description).
- For both the Baseline and Base Case modules of the WBM, outputs include time-series of monthly streamflow for all points of interest on Latte and Coffee Creeks, Yukon Tributary 24, Halfway Creek and the Yukon River at nodes located upstream and downstream of the Project area.
  - Specifically for the Base Case output of the WBM, these time-series outputs capture predicted mine-related impacts such as: the dewatering of actively mined open pits; storage of water within mined out pits; flow attenuation by waste rock storage areas; supply of make-up water for operation of the plant and HLF; and any routing of water, within and between watersheds, by the proposed water management infrastructure.
- The Independence Creek watershed was excluded from this analysis, given that none of the proposed Project infrastructure is located within this drainage basin. The potential for a groundwater connection between Kona Pit and Kona tributary (a tributary of Independence Creek) was assessed (refer to Section 2.3.4 and Appendix 7-B-1 for more detail) as part of the Project Proposal. It is noted that the existing groundwater table is approximately 130 m below the ground surface at Kona Pit, and the maximum depth of excavation at Kona Pit will be 86 m below ground surface. Therefore, the current water table is approximately 45 m below the maximum depth of the pit.

3.1.2 Delineation of Mine Affected Watersheds

In order to generate estimates of streamflow ([volume (L^3)]/[time (T)]) from precipitation inputs ([depth (L)]/[time (T)]), the delineation of both the natural and mine-altered watershed areas (L^2) was necessary for modelling locations of interest. Pre-mine drainage areas for surface water monitoring stations were generated primarily using Surfer 12. For this exercise, the 1:50,000 Grid NRCAN Canadian Digital Elevation Model was the source of topographic data utilized for drainage basin delineations. Mine sub-catchments were manually drawn in AutoCAD with base layers being the mine footprints and water management layouts presented in Appendix 31-E, and mine sub-catchment were then combined with the pre-mine catchments as appropriate. Hypsometric curves were calculated for each basin (Appendix 8-A) and mine sub-catchment were computed then used to delineate the elevation bands within each basin/sub-catchment to scale the climate inputs (Section 3.2.2).

3.1.3 Baseline (Natural) WBM Run

The Baseline WBM module is first run to produce baseline streamflow time-series for modelling locations of interest. Main assumptions and inputs to the Baseline (Natural) WBM are outlined in Table 3-1 below with Figure 3-1 showing the location of WBM nodes (*i.e.,* points of flow and water quality prediction) for which time-series of baseline flows are produced.

The Natural, or Baseline condition was calculated in the following way:

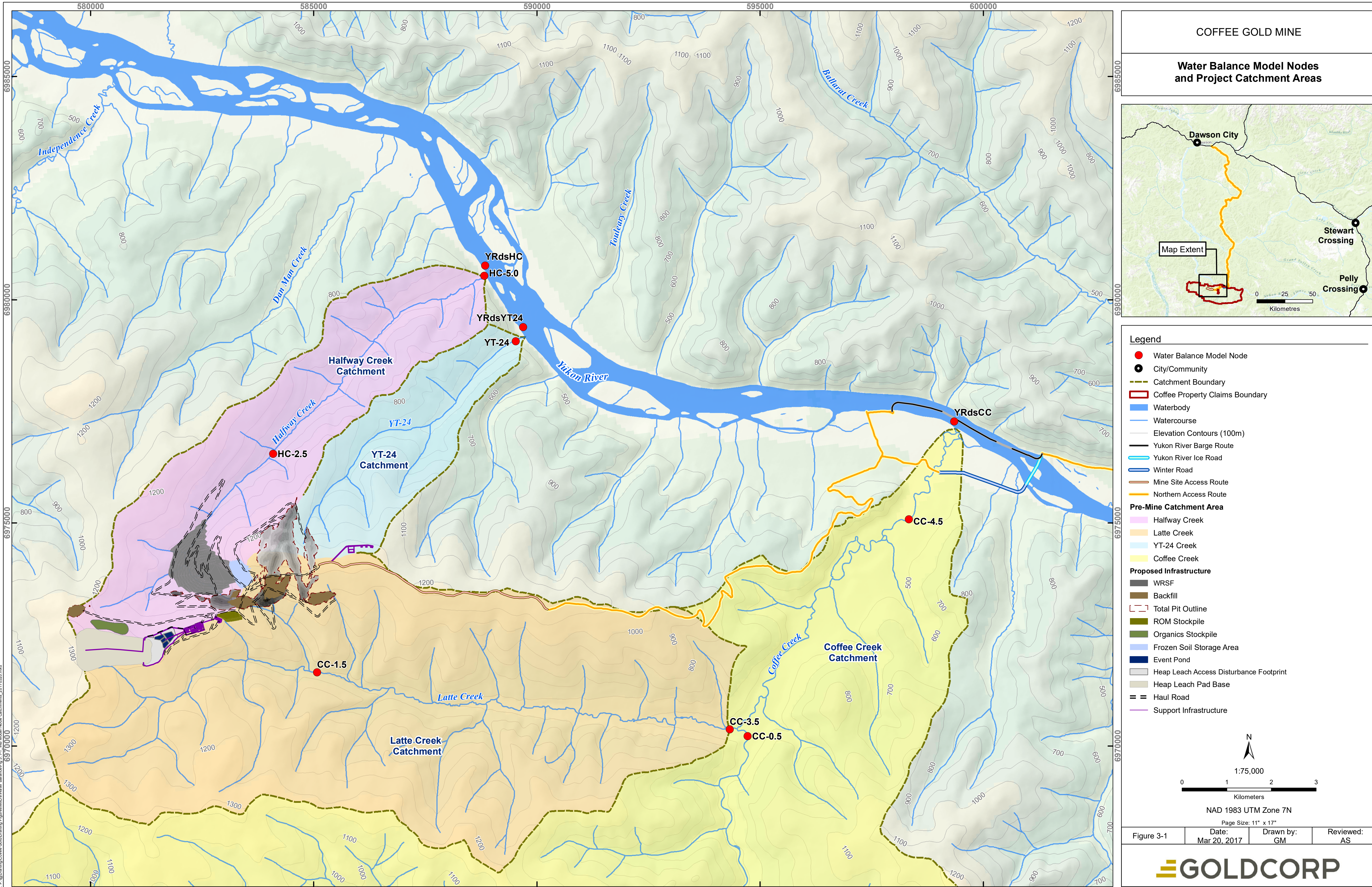
- Baseline streamflow is computed in all catchments for the undisturbed areas (this is 'Natural' background, which is the full station catchment minus all mine areas, including non-contact within the pond catchments).
- The background is then scaled up from the "undisturbed" area to the full station catchment – this now represents the 'Natural' or baseline flow to the station.
- The natural flow is then carried downstream and added to the additional flow from the downstream natural catchments.
- For example, the natural flow in CC-1.5 would be scaled-up from the undisturbed background in that catchment, then added to the incremental background between CC-1.5 and CC-3.5. Downstream, they would be added to the natural flow from CC-0.5 and the incremental natural flow between the confluence of Coffee/Latte Creek and station CC-4.5.

For the Baseline Case, 84-year, monthly- predicted streamflow records are generated by the WBM for seven local tributaries and three WBM nodes on the Yukon River (Figure 3-1).

The flow regime of Latte Creek is represented by two stations (*i.e*., CC-1.5 and CC-3.5), whereas monitoring station CC-4.5 represents the larger Coffee Creek basin. There are two stations on Halfway Creek (HC-2.5 and HC-5.0) and one hydrometric station on Yukon Tributary 24 (YT-24). In addition, three Yukon River nodes are encoded in the WBM to assess potential alterations to baseline water quantity and quality resulting from Project development. The Yukon River nodes are situated downstream of Coffee Creek, YT-24 and Halfway Creek, with the latter representing the final point at which cumulative Project related changes are anticipated.

Table 3-1: Coffee Gold Mine Water Balance Model Description – Natural Flow Module

Natural (Baseline) Module	
Purpose	• To estimate monthly, natural (*i.e.*, baseline, no Project) streamflows and water quality at nodes on local watercourses (Latte, Coffee, YT-24 and Halfway Creek) and the Yukon River.
Modelling Platform	• GoldSim (v.11) is a graphical and object-oriented modelling platform.
GoldSim WBM Module	• The Coffee Gold Mine WBM was constructed using a three reservoir watershed model. • Surface runoff, baseflow, snowfall/melt processes and aufeis production from winter baseflow are all represented in the Coffee Gold Mine WBM which is a modified version of the Birkenes model (Christophersen and Seip, 1982; Seip *et al.*, 1985; Stone and Seip, 1989). • The natural flow module of the Coffee Gold Mine WBM was calibrated at daily time-step using long-term, daily- synthetic streamflow data as the calibration target.
Catchment Boundaries, Elevation Data	• Watershed boundaries and hypsometric outputs (*i.e.*, curves and representative bands of elevation data) for local catchments were generated from 1:50,000 mapping data. • To encode elevation dependent climate parameterizations into the WBM, drainages were separated into three elevation bands (400-800 m, 800-1200 m and >1200 m).
Climate	• The natural flow module of the Coffee Gold Mine WBM was driven by a 28-year daily precipitation, air temperature and potential evaporation record. • Precipitation and air temperature inputs are scaled by elevation using gradients reported in Appendix 8-A. • To represent the Project timeline (2018-2099), the 28-year climate record was looped three times to produce an 84-year record. • Monthly climate change scenario data (from the Scenario Network for Arctic Planning) for the A2 emission scenario (2-km resolution) were used to scale precipitation and air temperature inputs over the long term (Closure and Post-closure phases).
Hydrology	• Baseline hydrology data from autumn 2010 to December 2015 were combined with regional streamflow data to generate long-term synthetic streamflow records. • Long-term synthetic streamflow records for Latte, Coffee, YT-24 and Halfway Creek served as targets for the natural flow module WBM calibration.
Outputs	• For the natural flow condition (*i.e.*, no project, baseline), 84-year long predicted streamflow records are generated by GoldSim. Flow records are produced for seven local tributaries and three WBM nodes on the Yukon River at a monthly time step.


COFFEE GOLD MINE
Water Balance Model Nodes
and Project Catchment Areas
Dawson City
Stewart Crossing
Pelly Crossing
Map Extent
0 25 50
Kilometres
Legend
Water Balance Model Node
City/Community
Catchment Boundary
Coffee Property Claims Boundary
Waterbody
Watercourse
Elevation Contours (100m)
Yukon River Barge Route
Yukon River Ice Road
Winter Road
Mine Site Access Route
Northern Access Route
Pre-Mine Catchment Area
Halfway Creek
Latte Creek
YT-24 Creek
Coffee Creek
Proposed Infrastructure
WRSF
Backfill
Total Pit Outline
ROM Stockpile
Organics Stockpile
Frozen Soil Storage Area
Event Pond
Heap Leach Access Disturbance Footprint
Heap Leach Pad Base
Haul Road
Support Infrastructure
N
1:75,000
0 1 2 3
Kilometers
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GOLDCORP
Yukon River
Independence Creek
Dan Man Creek
Halfway Creek
Ballarat Creek
Touleary Creek
Latte Creek
Coffee Creek
YT-24
Halfway Creek Catchment
YT-24 Catchment
Latte Creek Catchment
Coffee Creek Catchment
YRdsHC
HC-5.0
YRdsYT24
YT-24
HC-2.5
YRdsCC
CC-4.5
CC-1.5
CC-3.5
CC-0.5
580000
585000
590000
595000
600000
6985000
6980000
6975000
6970000

3.1.4 Base Case WBM Run

Next, the model is run with the mine plan turned on (Base Case), and the same set of monthly time-series outputs are generated as was done for the Natural model. The Base Case (Mine) WBM module is described at high level in Table 3-2 and discussed in more detail in the following sections. The general arrangement of mine facilities at the Coffee Gold Project is shown in Figure 3-1 and in greater detail in Figure 2-1.

Table 3-2:
Coffee Gold Mine Water Balance Model Description – Base Case Module

Base Case (With Project) Module	
Purpose	• To estimate monthly, base case (*i.e.*, Project affected) streamflows and water quality at nodes on local watercourses (Latte, Coffee, YT-24 and Halfway Creek) and the Yukon River.
Overview	• The modelling platform and WBM/WQM module used to estimate Base Case conditions were fundamentally the same as those described for the natural module. o The same catchment boundaries, water quality, climate and hydrology inputs described for the natural flow module were used to populate the undisturbed portions of local watersheds in the Base Case module. • Mine plan, water management details and outputs from the Coffee Gold Mine Groundwater Model were encoded into the Base Case module to represent future conditions at the Project site with development.

Mine Plan	• Mine footprints for proposed open pits, WRSFs, the HLF, soil and ROM stockpiles and related Project infrastructure were encoded into the Base Case module.
	• The end-of-mine plan described in Section 2.1 was used to populate the Base Case module. This includes:
	  o Open pits – Kona, Latte, Supremo and Double
	  o Backfilled pits and causeways
	  o WRSFs – Alpha, Beta (temporary)
	  o HLF, including water management ponds

Water Management Layout	• Sediment control ponds and conveyance structures (*e.g.*, toe drains, interception ditches) described within the Coffee Gold Mine Water Management Plan (refer to Appendix 31-E) were also encoded into the Base Case model. • Conceptually, the Water Management Plan conveys contact waters associated with Project footprints to one of three watersheds: Latte/Coffee Creek drainage, YT-24 drainage and Halfway Creek drainage.
Groundwater	• A 3D numerical groundwater model was constructed and calibrated for the Project (Appendix 7-B-1). • The groundwater model was first calibrated for baseline conditions, then run with Project footprints (dumps, open pits) in place to look at long-term patterns of recharge and discharge from pits. • Estimates of recharge/discharge to/from pits predicted by the groundwater model were incorporated into the base case module of the WBM.
Outputs	• As per the natural flow module, 84-year predicted flow and water quality records for seven local tributaries and three nodes on the Yukon River are outputted from the base case module of the WBM.

The creeks that have Project infrastructure situated within their drainage boundaries are:

- Latte Creek (a portion of the HLF footprint and camp/processing facilities, Latte Pit, portions of Supremo Pit and Double Double Pit).
- Yukon Tributary 24 (portions of Supremo Pit); and
- Halfway Creek (Kona pit and temporary WRSF, Alpha WRSF, a portion of the HLF footprint, camp/processing facilities and Latte Pit).

As per the Baseline Case, 84-year, monthly- predicted streamflow records are generated by the WBM for the Base Case. Base Case flow outputs are produced for the seven local tributaries and three WBM nodes on the Yukon River (Figure 3-1).

3.1.5 GoldSim Modeling Platform

The WBM for the Coffee Gold Mine was developed in GoldSim, a flexible, object-oriented software tool for the numerical simulation of complex natural or engineered systems. GoldSim was specifically designed for tracking flows through advective and diffusive media and can also simulate the fate of chemical species within that flow using an integrated contaminant-transport module.

The management of flows is handled in GoldSim through computational elements that represent the diverse components of a flow system:

- Data elements: constant or time-dependent scalar and vector quantities
- Expressions: mathematical formulae linking flow elements
- Reservoirs: finite (or infinite) volume storage facilities with user-specified addition, withdrawal and leakage rates
- Flow logic: flow splitting, allocation and flow demand

In GoldSim, elements are assembled and connected using an intuitive graphical user interface. Unit conversion is handled automatically between elements, and automated error checking is invoked during execution to ensure unit and logical consistency between calculations. GoldSim can be run either in a deterministic or stochastic mode, depending on the required outcome of the simulation.

3.2 *GoldSim Watershed Model*

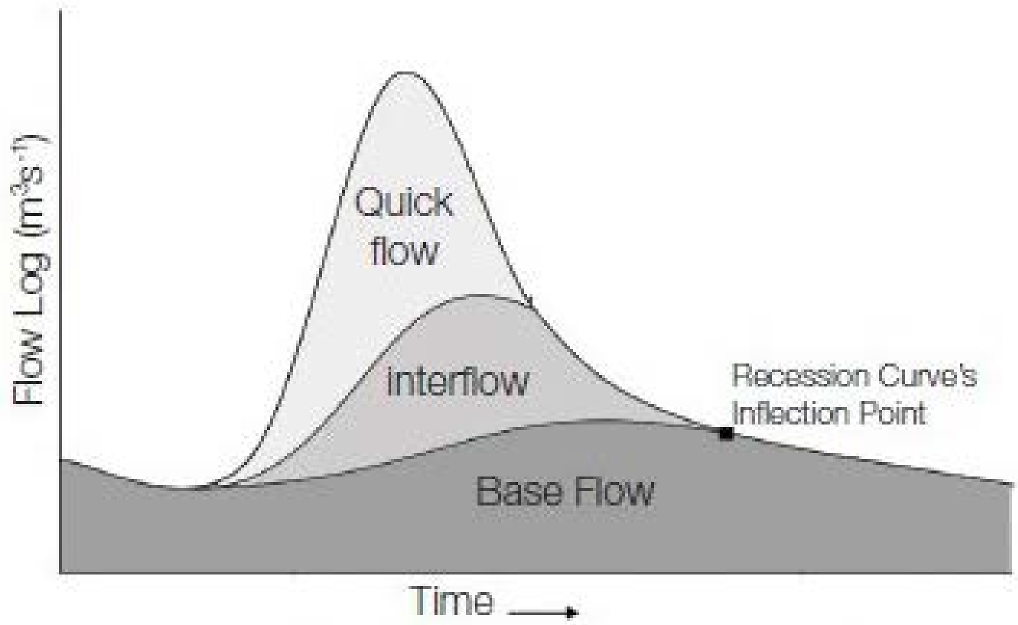
The streamflow regime at the Project site is highly dynamic, with multiple peak flow events common place and driven by an initial freshet and/or following convective rainfall events in the summer. Significant volumes of water may be delivered to the local creeks in the span of 2 days, yet may subsequently be followed by prolonged dry periods where surface flows diminish to the point where groundwater discharge is the main determinant of streamflow.

As the open water season progresses, active layer melt contributes increasing amounts of discharge to local creeks, which is expressed as an increasing low flow signature throughout the summer. Finally, average winter temperatures are well below zero, and surface flow in all local watersheds is reduced to zero as the stream channels freeze in during winter. In winter, the only moving water at the site is generated by discharging groundwater, which will freeze in laminae (aufeis) as cold conditions progress. This icing phenomenon continues throughout the winter, and results in ice sheets that greatly exceed the existing channel width. A customized site-wide water balance model was constructed in the GoldSim modeling environment to allow baseline conditions at the Project site, which are highly variable on a seasonal basis, to be accurately represented.

Figure 3-2 shows the commonly accepted components of streamflow with surface volumes of water reporting from with one of three signatures:

- Quick flow – generated by storm or snowmelt events and often resulting in peak flow events. For tributaries local to the Coffee Gold Mine, water contributed via this mechanism may report to creeks in less than 2 days time;
- Interflow – this refers to the lateral movement of infiltrated meteoric water through the shallow overburden to the stream channel. Flow reporting to creeks along this pathway is often referred to as vadose or unsaturated zone flow, and;
- Baseflow – the portion of surface flow derived from groundwater discharge. At the Project site, this composes the majority of streamflow during summer low flow periods and through the winter season.

The watershed model assembled to replicate the streamflow regime at the Project site incorporates this understanding of streamflow composition and response directly into the model architecture. Accordingly, surface runoff, baseflow, snowfall/melt processes and aufeis production from winter baseflow are all represented in the site-wide WBM, which is a modified version of the Birkenes model. This model was developed as part of a research program to understand linkages between stream chemistry and flow in a small (< 1 km^2) catchment in southern Norway (*e.g.*, Christophersen and Seip, 1982; Seip *et al*., 1985; Stone and Seip, 1989). The modelling approach is depicted as a conceptual diagram in Figure 3-3 and as encoded in GoldSim in Figure 3-4.



Source: http://turmalina.igc.usp.br/img/revistas/guspsc/v13n1/a01fig07.jpg

Figure 3-2: Conceptual hydrograph showing runoff partitioning.

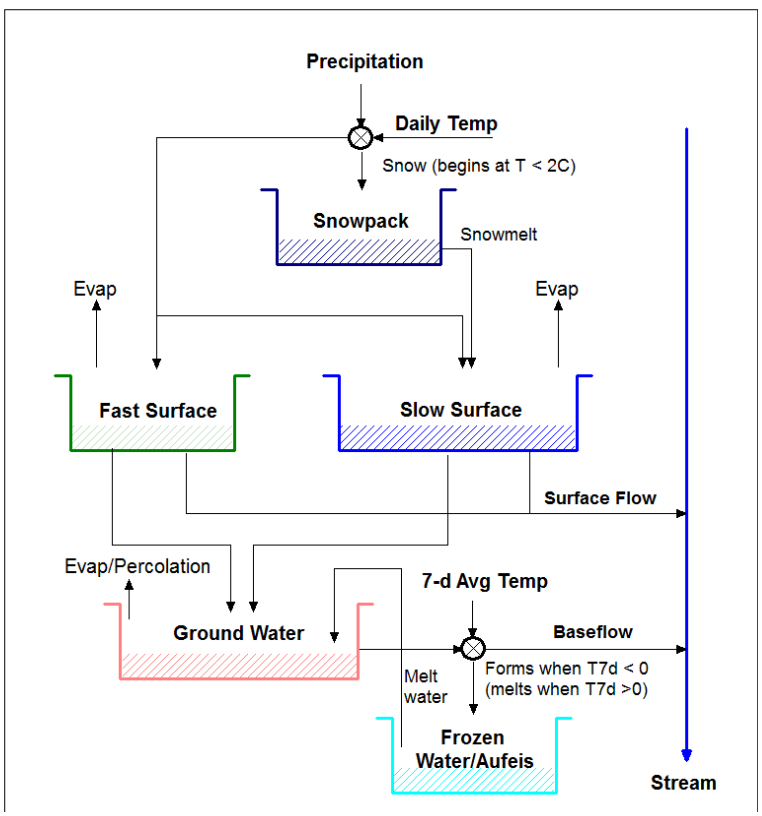


Figure 3-3: Schematic presenting an overview of the three-reservoir water balance model in conceptual format

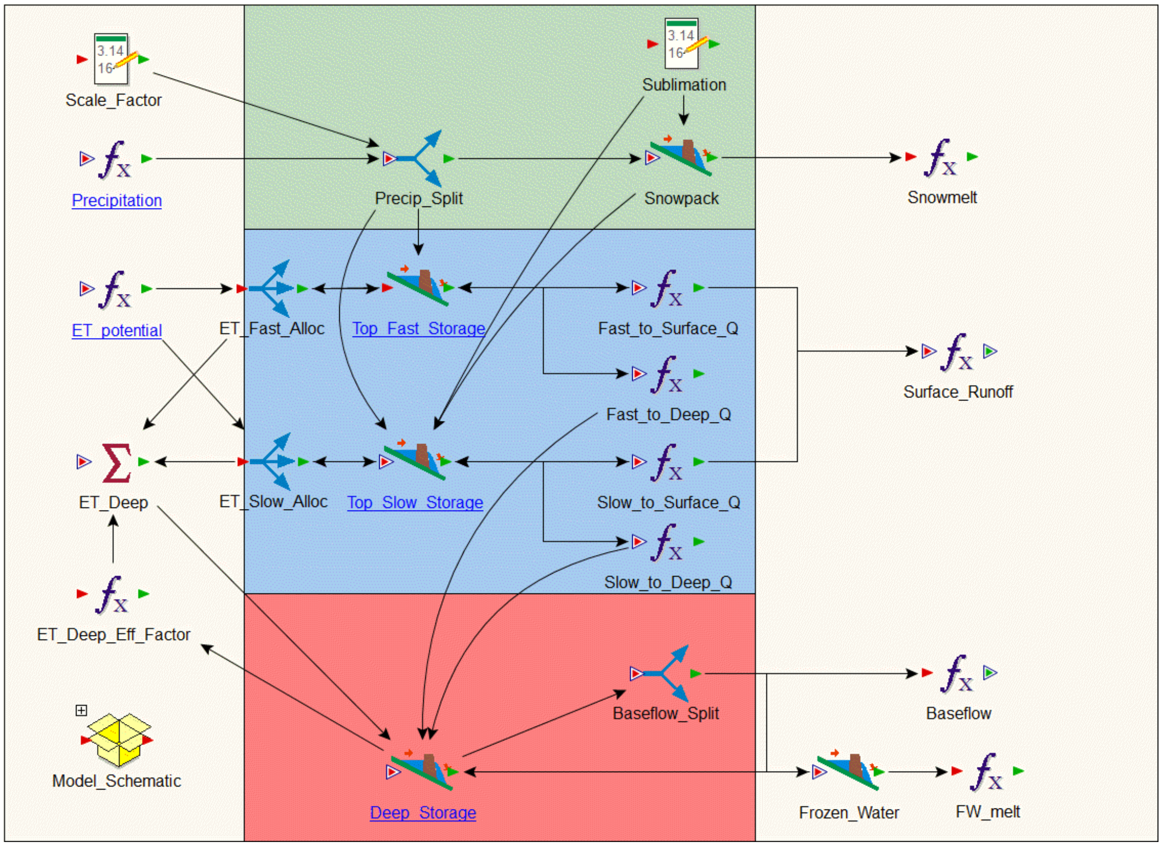


Figure 3-4: Schematics presenting an overview of the three-reservoir water balance model as encoded in a GoldSim environment

Conceptually, incoming precipitation is partitioned in the WBM to rain or a snow reservoir based on air temperature thresholds. As shown in Figure 3-3, all precipitation falls as snow at -2°C and rain at +2°C, with the proportions of each changing linearly between these thresholds. Rainfall is then directed into Fast and Slow Surface reservoirs, which represent areas of fast runoff response, and slower-draining soil areas respectively. Fast and slow surface recession flow from the surface storage reservoirs can go directly to surface discharge, or to the Deep Surface Water reservoir, depending on the fraction of remaining available storage in the latter. Figure 3-3 shows that when the Deep Surface Water reservoir fills, slow recession flow from the reservoir reports to baseflow (and fractionally to aufeis in winter). Where aufeis has been modeled (based on air temperature) to freeze completely during the winter months, streamflow is zero. In the model, evaporation is withdrawn from both surface reservoirs (Fast and Slow), and from the Deep Surface reservoir but at a lower rate. The deepest water in the Deep Surface Reservoir is protected from evaporation, and provides a source for winter baseflow. Only when both the Fast and Slow surface reservoirs are empty may evaporation occur from the Deep Reservoir, and at a much reduced rate, which is calibrated uniquely by watershed. Finally, snowmelt and melting of aufeis are indexed to the rolling 7-day average air temperature. Aufeis is assumed to melt at 10% of the snowmelt rate, due to its higher density and location in the shaded valley bottoms.

Additional information pertaining to the three reservoir watershed model, including specific parameter values and assumptions are detailed in Section 3.2.6.

3.2.1 Climate Inputs

The climate inputs that are used to drive both the Natural and Base Case WBMs are outlined below in Sections 3.2.2 through 3.2.4. The Natural and Base Case models perform a deterministic 84-year simulation using a reconstructed synthetic precipitation and temperature record as driving data. Climate inputs for the period 2018 through 2100, which amount to three loops of the 28-year synthetic climate record (described in Appendix 8-A and introduced in Section 2.3.1.2), were prepared for entry into the WBM. The first 28-year series is the same as that described in Appendix 8-A, while the second two 28-year series were modified to account for the projected influence of future climate change. This adjustment is presented formally in Section 3.2.4.

To account for the inherent uncertainty in the measurement and modeling of streamflows and any potential alterations to the existing streamflow regime, the site-wide WBM was run with many iterations of the input climate data series. This dataset includes several prolonged wet- and dry-periods and accounts for future climate change. This climate series was iterated through the model, by stepping forward one year in the climate record for each iteration. For example, Run #1 of the model set Year 1 of the climate series as Year -2 in the mine life, Run #2 set Year 2 of the climate series as Year -2 in the mine life, and moved Year 1 to the end of the 28-year time-series, and so on. In this way, 28 separate realizations of the model were run so that each year of the mine life is run with all possible combinations of the natural climate series.

No assumptions are necessary regarding which year of the mine life will be most sensitive to a wet- or dry-year are necessary because every year of the mine life is modeled with every year of the climate record. This approach is similar to the stochastic methods that are often employed to quantify the variability in model outputs resulting from variable climate inputs, but the progression of years in the input series is not randomized in this method, nor are *a priori* assumptions required for the statistical distribution of the input series. The natural progression of dry- and wet-periods and the inter-annual variability associated with long-term climate cycles (*e.g.*, the Arctic Oscillation and the Pacific Decadal Oscillation) is retained in the model inputs. Therefore, resulting outputs per WBM node consists of 28 sets of streamflow prediction – each extending for the 84-year time period.

3.2.2 Precipitation and Temperature

Precipitation at the Coffee Gold Mine and therefore runoff, are understood to increase with elevation at the Project site and this is necessarily incorporated into the WBM as well. Air temperature patterns on the other hand, generally decreases with increasing elevation, with the exception of persistent and prolonged inversions that occur during the winter that given a reversal of the air temperature lapse rate. In order to effectively represent climatic variations with elevation in the WBM, each watershed is broken into 100 m elevation bands and the reconstructed climate series described in Section 2.3.1.2 (generated for 1,300 masl) is scaled accordingly. The scalars used in the WBM for precipitation and air temperature are presented in Table 3-3 and Table 3-4.

Table 3-3:
Precipitation scalars by month using base elevation of 1,300 m. To scale inputs to the WBM, daily precipitation values are multiplied by scalars for each elevation band

Elevation (m)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
300	0.4	0.4	0.4	0.4	0.7	0.7	0.7	0.7	0.7	0.4	0.4	0.4
400	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.7	0.5	0.5	0.5
500	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.7	0.5	0.5	0.5
600	0.5	0.5	0.5	0.5	0.8	0.8	0.8	0.8	0.8	0.5	0.5	0.5
700	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	0.8	0.6	0.6	0.6
800	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	0.8	0.6	0.6	0.6
900	0.7	0.7	0.7	0.7	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.7
1000	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.8
1100	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.8
1200	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9
1300	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1400	1.1	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1
1500	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2
1600	1.3	1.3	1.3	1.3	1.1	1.1	1.1	1.1	1.1	1.3	1.3	1.3
1700	1.4	1.4	1.4	1.4	1.2	1.2	1.2	1.2	1.2	1.4	1.4	1.4
1800	1.5	1.5	1.5	1.5	1.2	1.2	1.2	1.2	1.2	1.5	1.5	1.5
Average gradient	**9%**	**9%**	**9%**	**9%**	**4%**	**4%**	**4%**	**4%**	**4%**	**9%**	**9%**	**9%**

Table 3-4:
Temperature scalars by month using base elevation of 1,000 m. Summer gradient is -0.46°C/100 m increase in elevation wherease the prescribed winter gradient is +0.65°C/100 m increase in elevation

Elevation (m)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
300	-4.6	-4.6	0.0	3.2	3.2	3.2	3.2	3.2	3.2	-4.6	-4.6	-4.6
400	-3.9	-3.9	0.0	2.8	2.8	2.8	2.8	2.8	2.8	-3.9	-3.9	-3.9
500	-3.3	-3.3	0.0	2.3	2.3	2.3	2.3	2.3	2.3	-3.3	-3.3	-3.3
600	-2.6	-2.6	0.0	1.8	1.8	1.8	1.8	1.8	1.8	-2.6	-2.6	-2.6
700	-2.0	-2.0	0.0	1.4	1.4	1.4	1.4	1.4	1.4	-2.0	-2.0	-2.0
800	-1.3	-1.3	0.0	0.9	0.9	0.9	0.9	0.9	0.9	-1.3	-1.3	-1.3
900	-0.7	-0.7	0.0	0.5	0.5	0.5	0.5	0.5	0.5	-0.7	-0.7	-0.7
1000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1100	0.7	0.7	0.0	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	0.7	0.7	0.7
1200	1.3	1.3	0.0	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	1.3	1.3	1.3
1300	2.0	2.0	0.0	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	2.0	2.0	2.0
1400	2.6	2.6	0.0	-1.8	-1.8	-1.8	-1.8	-1.8	-1.8	2.6	2.6	2.6
1500	3.3	3.3	0.0	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	3.3	3.3	3.3
1600	3.9	3.9	0.0	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	3.9	3.9	3.9
1700	4.6	4.6	0.0	-3.2	-3.2	-3.2	-3.2	-3.2	-3.2	4.6	4.6	4.6
1800	5.2	5.2	0.0	-3.7	-3.7	-3.7	-3.7	-3.7	-3.7	5.2	5.2	5.2

3.2.3 Potential Evapotranspiration

Potential Evapotranspiration (PE) for the Project site is derived from daily reconstructed air temperature record using the following regression:

$$PE\ (mm) = (-0.0000002*T^4) + (0.00005*T^3) + (0.0042*T^2) + (0.1064*T) + 0.9537 + \Delta PE$$

where T is temperature in °C, and ΔPE is a normally-distributed random offset (mean 0°C) truncated to +/- 1 °C with an effective standard deviation of 0.44°C (the offset was calculated outside of GoldSim and exists as a fixed random daily record for all simulations). In the WBM, PE is set to 0 mm when the temperature is below 0°C at which point sublimation becomes effective over the snowpack. The daily PE (T > 0°C) for the first 28 years of the GoldSim simulation are shown in Figure 2-10. The final PE record for the complete 84-year run includes the effects of climate change (discussed in Section 3.2.4), as the PE estimates are indexed to temperature in the WBM. Note that there are disproportionately more occurrences of T > 0°C in the winter when considering the entire 84-year record due to increases in temperature imposed by the inclusion of expected climate change effects, and therefore PE values greater than 0 mm are more frequent during the shoulder seasons (*i.e.,* spring, autumn) during the Post-closure phase of the Project.

3.2.4 Climate Change

The influence of a changing climate on the hydrologic regime of the discontinuous permafrost zone is well documented (see Appendix 8-A for a detailed summary). Average annual temperatures are projected to rise significantly in the region over the next century. Present day annual average temperature is roughly -3°C at the Project site, and the annual average is forecasted to rise by 3 to 5°C by the end of the century. Net precipitation in the vicinity of the Coffee Gold Mine is projected to increase roughly 20% over the course of this century, where summer and winter can be expected to be slightly wetter in the future, and spring and fall seasons are projected to see little net change in precipitation abundance.

Often, the effects of rising temperatures and alterations in the precipitation regime owing to climate change are assessed for major projects as a sensitivity analyses. However, given the fact that current trends in hydro-climatic parameters (*i.e.*, Yukon Territory instrumental record) align closely with climate projections for the region, it was deemed appropriate to incorporate the influence of climate change explicitly in the WBM.

To accomplish this objective, the 28-year, daily- synthetic climate record were looped three times then trended upward for air temperature and precipitation as dictated by 2-km resolution down-scaled climate change scenario data for the Project. Trending of the climate data was governed by datasets produced by the Scenario Network for Arctic Planning, and for an aggressive and worst case climate change scenario (A2 emission scenario). Climate change projections, observed and predicted trends and the rationale for the selection of the A2 emission scenario for Base Case is described in Appendix 8-A (refer to Appendix D, Climate Change in that document). Air temperature and precipitation inputs entered into the WBM (both the Baseline/Natural Flow and Base Case modules of the WBM) sub-models are shown in Figure 3-5, superimposed on top of the temporal boundaries assumed for the modeling exercise.

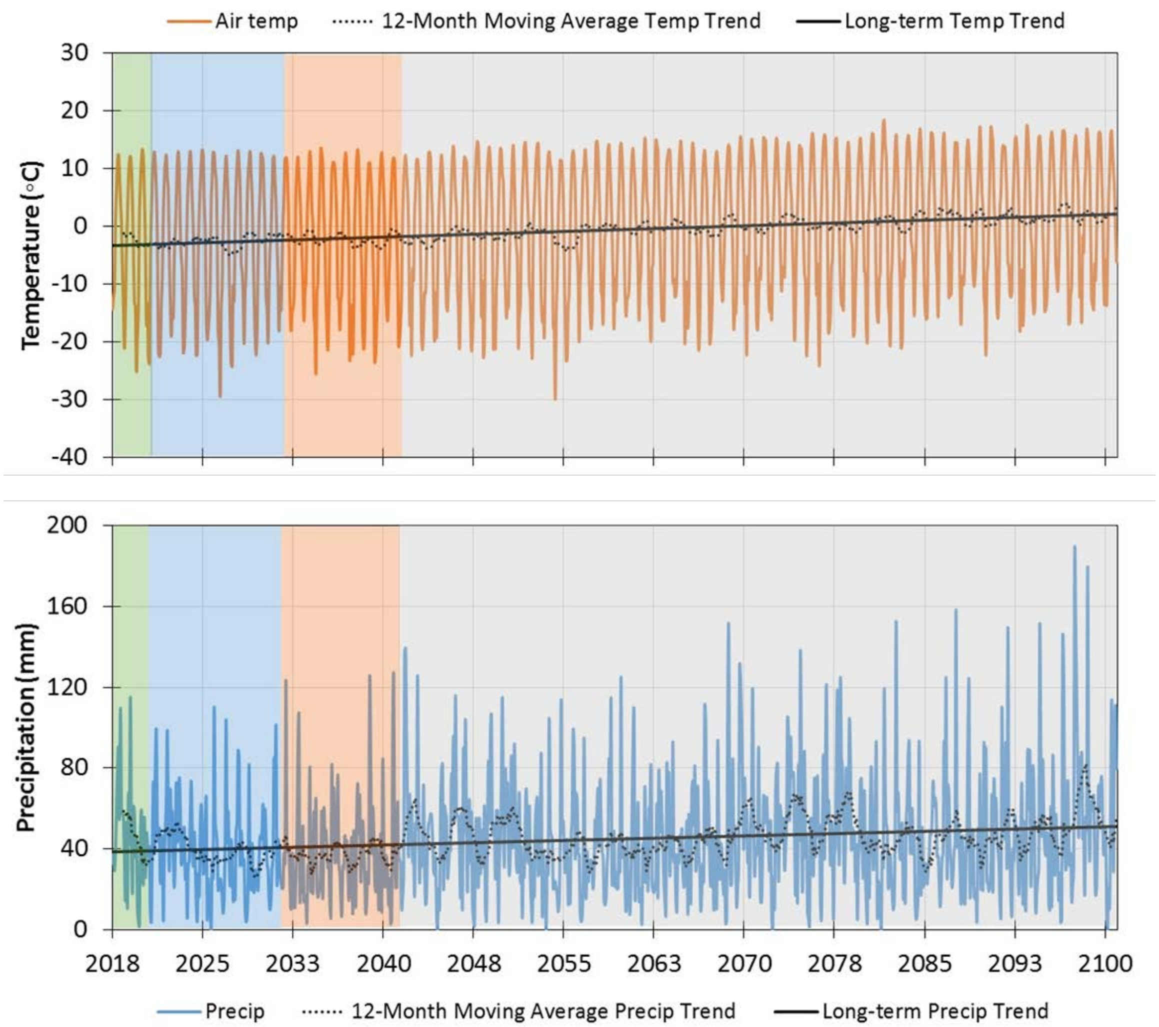


Figure 3-5: Air temperature and precipitation inputs (shown at monthly time step, with long-term and 12-month rolling averages) to the Coffee Gold Water Balance Model. Temperature and precipitation variables were trended using 2-km gridded climate change scenario for the A2 emission scenario. Shading on the plot (i.e., grey, blue, pink and green) correspond to temporal boundaries introduced in Section 2.1.1.

3.2.5 Water Balance Model Output Nodes

The current configuration of the site-wide water balance also considers ten receiving environment nodes (Figure 3-1), each situated downstream of mine infrastructure in the N1 (YT-24), N3 (Upper Latte) and Alpha Pond (Halfway Creek) sub-catchments which are depicted coarsely in Figure 3-1, but with finer detail in Figure 2-1.

Listed below are descriptions of these receiving environment water balance nodes:

- Latte/Coffee Creek – proposed mine footprints report in the direction of Latte Creek, a headwater drainage to Coffee Creek. Coffee Creek is a large watershed (~500 km^2) that reports to the Yukon River.
    - CC-1.5 – The CC-1.5 water balance node is situated immediately downstream of the SU1 and Double Double pits. The N3 catchment is located in the headwaters of Upper Latte Creek, and collects all drainage from mine infrastructure in Upper Latte Creek.
    - CC-3.5 - The CC-3.5 water balance node is situated immediately upstream of the Latte Creek-Coffee Creek confluence. Mine water discharges that report to CC-1.5 (drainage area ~23 km^2) will become more dilute by the time they reach CC-3.5 (drainage area ~70 km^2) given that the drainage between CC-1.5 and CC3-5 is undisturbed and for all intents and purposes considered pristine.
    - CC-0.5 – The Project does not influence flow (or water quality) at this water balance node. Therefore, the flows represented by this node are background or natural flows only in both the Natural Flow and the Base Case sub-models.
    - CC-4.5 - The CC-4.5 water balance node is situated on Coffee Creek proper, upstream of the confluence with the Yukon River. The combined drainage area reporting to this location is approximately 500 km^2.
- Yukon Tributary 24 (unnamed tributary that reports directly to the Yukon River)
    - YT-24 (Yukon Tributary #24) - proposed mine footprints in the N1 sub-catchment report in the direction of Yukon Tributary 24, a tributary to the Yukon River. This water balance node is situated immediately upstream of the confluence with the Yukon River. The N1 catchment is located in the headwaters of YT-24 and collects all drainage from proposed mine infrastructure. The drainage area of the watershed reporting to the YT-24 node is ~12 km^2.
- Halfway Creek - proposed mine footprints in the Alpha Pond and Kona pit sub-watersheds report in the direction of Halfway Creek. Halfway Creek reports directly to the Yukon River.
    - HC-2.5 - The HC-2.5 water balance node is situated roughly mid-drainage on Halfway Creek (catchment area ~15 km^2). The water balance node is downstream of the principle points of discharge from the Alpha WRSF and Kona Pit/temporary Beta WRSF.
    - HC-5.0 - The HC-5.0 water balance node is situated immediately upstream of the Halfway Creek-Yukon River confluence. Drainage area reporting to HC-5.0 is approximately 30 km^2.

- Yukon River - The WBM accounts for flow and tributary mixing at three locations on the Yukon River: Yukon River downstream of Coffee Creek, Yukon River downstream of YT-24 and Yukon River downstream of Halfway Creek.
    - YR ds CC-4.5 – This water balance node represents the Yukon River immediately downstream of the confluence with Coffee Creek. With respect to the Yukon River, this is the upstream extent that potential flow effects (and/or water quality effects) attributable to the project may be realized.
    - YR ds YT-24 - This water balance node represents the Yukon River immediately downstream of the confluence with Yukon Tributary 24 (YT-24).
    - YR ds HC-5.0 - This water balance node represents the Yukon River immediately downstream of the confluence with Halfway Creek. With respect to the Yukon River, this is the furthest downstream extent that potential flow and/or water quality effects attributable to the project may be realized.

A screenshot of the major mine components as represented in the GoldSim model is presented in Figure 3-6.

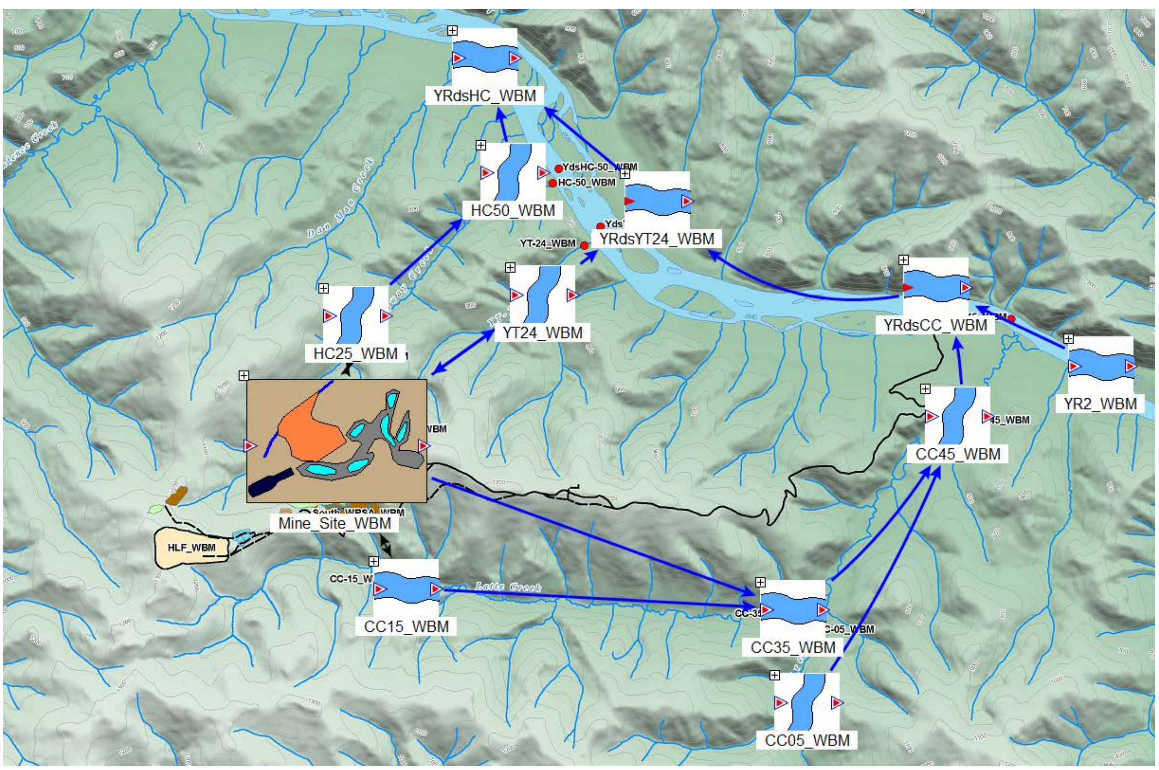


Figure 3-6: Overview of the Coffee Gold Site-wide Water Balance Model. In the schematic, WBM elements identified with grey/black icons are the WRSF model nodes, and the blue river icons represent the receiving environment nodes

3.2.6 Watershed Model Calibration/Validation

This section presents the general approach used to calibrate the WBM, and example summary tables and figures to illustrate the degree to which the model is able to replicate the existing streamflow regime. A robust approach to calibration and subsequent documentation of the process is necessary to provide confidence that the model is adequately parameterized, and therefore able to produce reasonable estimates of the existing streamflow regime prior to modelling any alterations that may result from mine development. Outputs for HC-2.5 are presented in this section for discussion, noting that identical calibration exercises were carried out at daily time step for key WBM nodes.

3.2.6.1 *Calibration Approach*

As with any modeling exercise, the WBM was first calibrated to the existing baseline data set. During the initial model conceptualization and build phase, the WBM was parameterized, run and then output was compared to measured streamflow data for the CC-1.5, CC-3.5, CC-0.5, YT-24, HC-2.5 and HC-5.0 monitoring locations. Measured daily data from these locations spanned a period of 2 to 5 years and provided a high-resolution record of streamflow for the open water season for initial calibration. By trial-error-comparison, final architecture of the WBM was confirmed per basin and a second stage of the calibration process commenced.

In the second phase of calibration several calibration targets were selected, but the primary targets were the reconstructed (synthetic) daily streamflow records that were derived using the Indian River above the Mouth (Water Survey of Canada, 09EB003) predictor station (refer to Section 2.3.2.4 and Appendix 8-A). The model calibration effort first focused on accurately replicating the flow distribution curves for all months of the year, with an emphasis on the open water period (*i.e.,* April to end-October) when streamflows are reliably expected to exceed yields of approximately 0.5 to 1.0 L/s/km^2.

Due to the importance of the freshet in the context of annual streamflow volumes and the inherent uncertainty in measurements of winter precipitation, a supplementary calibration metric was employed to ensure that the balance between end-of-winter (peak) snow water equivalent (SWE) and freshet runoff volumes was appropriately represented in the WBM. A combination of site-specific and regional analyses indicated that approximately 30% of peak SWE is converted to runoff during freshet, and this value was carried forward as a calibration metric for the WBM.

Owing to comparatively more limited winter flow and water quality data for Project area creeks and the challenges associated with accurately gauging streamflow under aufeis, the second phase of the calibration process focused primarily on replicating the measured water quality during the winter months, particularly for concentrations of As and U in the surface water. This process is outlined in considerable detail in Section 4 (Water Quality Model) of this report and is considered to be an appropriate and conservative approach overall for several reasons:

- Naturally occuring concentrations of the primary PCOCs reach annual maxima during the winter months when flows are for all intents and purposes negligible;
- The winter season has the lowest available dilution capacity in the receiving environment, and therefore this is the most sensitive time of year from a PCOC concentration and loading perspective;
- Fish habitat is the primary ecosystem component that is likely to be affected by alterations in the streamflow regime and Project area creeks naturally freeze to bed during the winter months, precluding fish use of almost all local creeks during this season, and;
- The relative precision for water quality sampling is higher than that for measurements of streamflow and this is particularly true for gauging done under ice.

For these reasons, replicating winter water quality signatures over water quantity signatures was given higher priority (for the winter season) in the model calibration process.

WBM parameter descriptions are provided in Table 3-5, with final parameter values that were assigned for each watershed model node listed in Table 3-6. These descriptions and values may be cross-referenced with terms referenced in Figure 3-4. Note that recession constants that govern the rate of water removal from the various model reservoirs are dependent on the chosen model time-step (1 day) and are represented mathematically as (using the fast bucket [*Kf*] as an example):

$$Vol\_current\_day = Kf * Vol\_previous\_day$$

The higher the recession constant, the greater the volume retained in the model reservoir from one day to the next, and therefore, the lower the rate of drainage from this reservoir. Values differ by watershed, but *Kf* for example is usually 0.2 to 0.4, whereas *Kb* (the recession for the deep storage) is 0.98 to 0.995.

Table 3-5:
WBM parameter descriptions

Parameter	Description
Kf	Recession constant for the fast-draining surface bucket (see above for supporting equation).
Ks	Recession constant for the slow-draining surface bucket.
Kb	Recession constant for the deep surface bucket.
%Fast	Fraction of catchment surface area presumed to report as fast-draining.
%Slow	Fraction of catchment surface area presumed to report as slow-draining.
%Fast to Deep	Fraction of fast-surface bucket storage that reports to the deep surface bucket (per time-step) - this represents downward infiltration.
% Slow to Deep	Fraction of slow-surface bucket storage that reports to the deep surface bucket (per time-step) - this represents downward infiltration.
Deep Retained (mm)	Depth of deep surface bucket that cannot be affected by evaporation/upward percolation. Water below this depth is protected from evaporation to provide water for winter baseflow.
%PE Deep	The percent of the full evaporation rate that can act upon deep surface storage (only activates when surface buckets are dry). This represents deep evaporation or upward percolation during times of low precipitation.
%Aufeis Frozen	Fraction of winter baseflow that converts to Aufeis (normally 40-100%).
Aufeis Melt Rate/Snowmelt rate	Factor applied to scale snowmelt rate (which is a function of temperature) to melt aufeis (normally 10%, meaning that aufeis melts at 1/10 the rate of snow).

Table 3-6:
Natural Case Watershed Model Parameters

Catchment	*Kf*	*Ks*	*Kb*	%Fast	%Slow	%Fast ToDeep	%Slow ToDeep	Deep Retained (mm)	%PE Deep	%Aufeis frozen	Aufeis melt rate/ Snow melt rate
CC-1.5	0.2	0.75	0.980	50%	50%	60%	30%	10	40%	60%	0.1
CC-3.5	0.5	0.94	0.995	40%	60%	50%	50%	0.5	100%	60%	0.1
CC-0.5	0.2	0.88	0.995	40%	60%	20%	20%	8	40%	90%	0.1
CC-4.5	0.2	0.92	0.985	50%	50%	40%	10%	10	40%	70%	0.1
YT-24	0.4	0.97	0.990	40%	60%	60%	60%	0.5	100%	80%	0.1
HC-2.5	0.2	0.92	0.985	20%	80%	60%	10%	20	40%	50%	0.1
HC-5.0	0.2	0.92	0.985	20%	80%	60%	10%	20	40%	50%	0.1

3.2.6.2 *Calibration Results*

A watershed model is considered to be well calibrated if percent bias is +/-25% for streamflow (*e.g.*, Moriasi *et al.* 2007), on a monthly time-step. Percent bias (PBIAS) measures the tendency of the modeled data to be higher or lower than their observed counterparts. The PBIAS metric is calculated as follows:

$$PBIAS = \left[\frac{\sum_{i=1}^{n}\left(Y_i^{obs} - Y_i^{sim}\right) * 100}{\sum_{i=1}^{n}\left(Y_i^{obs}\right)}\right]$$

The optimal value of PBIAS is 0.0 (*i.e.*, modeled values show no deviation from measured values). Positive values indicate model underestimation bias and negative values indicate model overestimation bias. Note that the ± 25% PBIAS threshold provided by Moriasi *et al*. (2007) was for a monthly time-step. The site-wide WBM was run at a daily time-step, and so the variability of flows, and thus the modeled results are expected to show bias higher than would be expected for a monthly time step. Therefore, if the PBIAS metrics calculated from a daily data set remain mostly within this threshold, it adds further confidence in the models ability to accurately represent the Project area streamflow regime.

To display model calibration results, the daily data for the open water season from both the WBM and the reconstructed streamflow records were first ranked, exceedance probabilities were calculated for each value, and then data were plotted. Presented this way (*i.e.*, percent exceedance plot or flow duration curve format), the highest daily flow value therefore has a probability of exceedance equal to zero, the median streamflow has an exceedance probability equal to 0.5, and the lowest value in the record has an exceedance probability equal to 1. Next, percent bias statistics were then calculated for six of the modeled nodes (CC-0.5, CC-1.5, CC-3.5, YT-24, HC-2.5 and HC-5.0).

The calibration results for the HC-2.5 node are presented below as an example of this process. The first plot for HC-2.5 (Figure 3-7) shows the daily progression of precipitation and streamflow for this station for a series of years that overlaps with the baseline data set. Overall, these outputs show the magnitude of the spring freshet, number and magnitude of rainfall driven peak flow events and the duration of the annual low-flow periods are well represented by the model when a comparison to the synthetic record is made. The daily flow exceedance plot (or flow duration curve) for the HC-2.5 node is presented for all months of the first 28 years of a WBM run in Figure 3-8, and for the open water season only (April to October, open water period) in Figure 3-9. Finally, Figure 3-10 shows average reconstructed, modeled (Natural Case) and measured (baseline) streamflows for the overlapping period of baseline record at HC-2.5 at a monthly time-step.

From the flow duration curves, it is apparent that the watershed model is able to accurately represent the natural streamflow regime at this node for the highest 75% of all daily flows, over the 28-year calibration run (Figure 3-8, flow duration curve showing all data). This is approximately equal to a slightly longer duration than that covered by the open water season at the Project site, which is equal to 7 months, or 60% of the year. When only the open water season model results are examined, the watershed model calibration improves substantially (Figure 3-9) and model-target flow match is robust over more than 90% of the flow conditions experienced in the open water season at HC-2.5.

When the percent bias is plotted against the probability exceedance for the open water period (Figure 3-11), the PBIAS results indicate that the modeled flows for exceedances <8% are underestimated compared to the reconstructed record. It should however be noted that the highest flows in the reconstructed record are extrapolated beyond the highest flows measured during the baseline period (2 to 5 years), and thus are subject to a higher degree of uncertainty (Appendix 8-A). In contrast, the remaining portion of the daily streamflow record is well represented by the WBM, with almost all data points for flows with a probability of exceedance of 0.92 and lower showing PBIAS values that lie within the +/-25% thresholds.

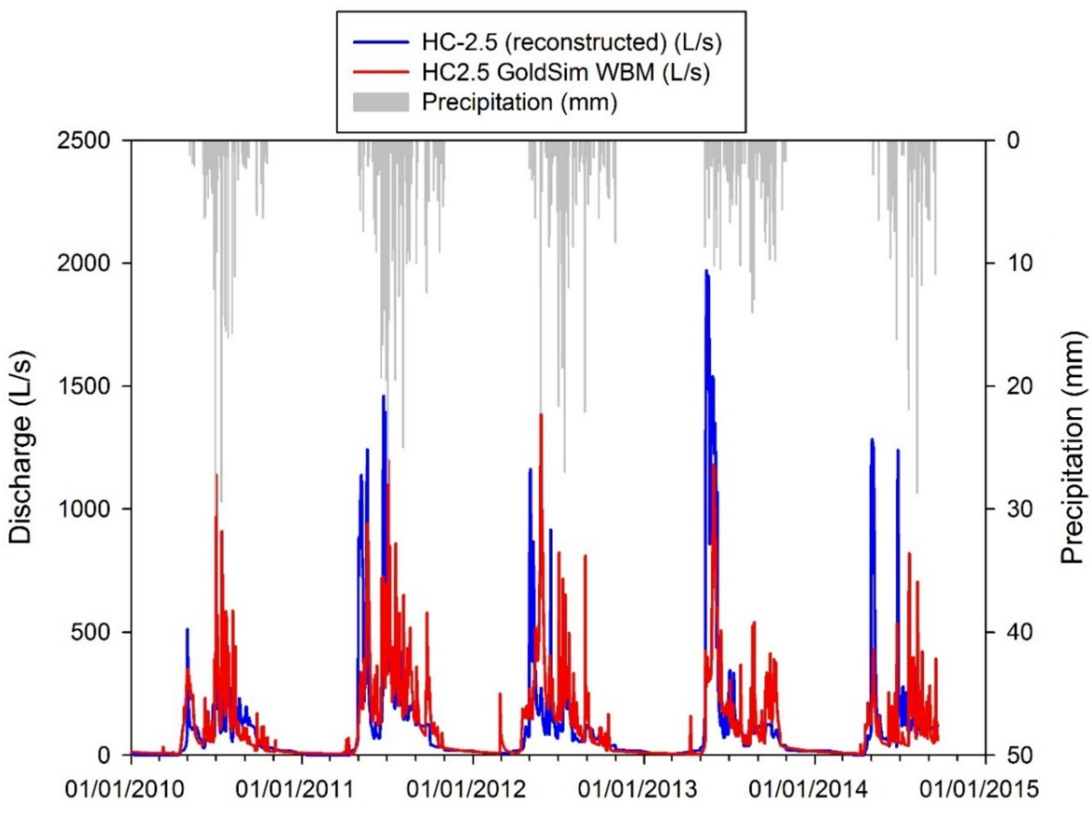


Figure 3-7: Daily WBM output for HC-2.5, compared to reconstructed streamflow time-series

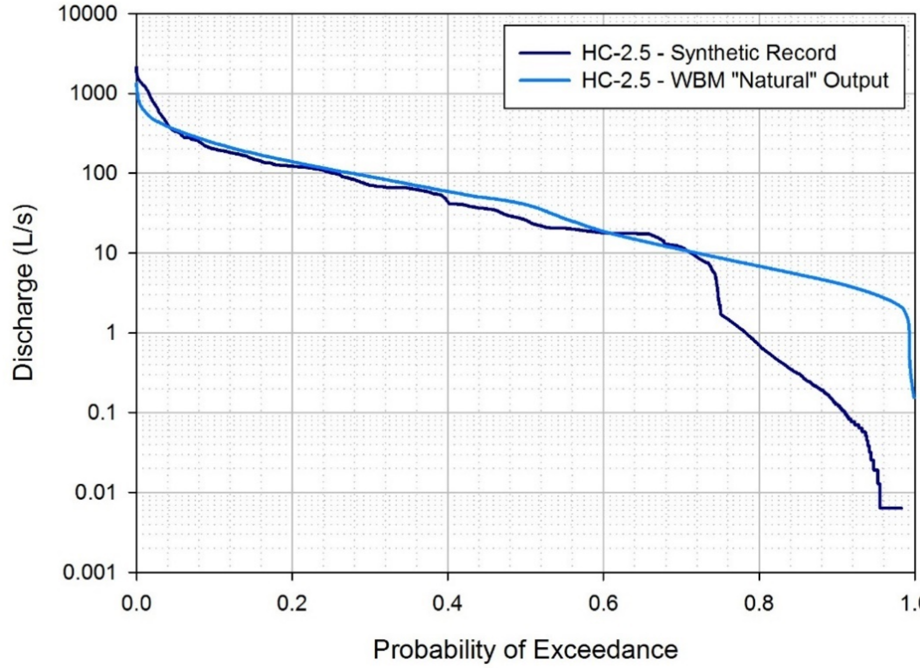


Figure 3-8: Flow duration curves for the HC-2.5 node showing the daily reconstructed discharge series and the WBM Natural run output, for all months.

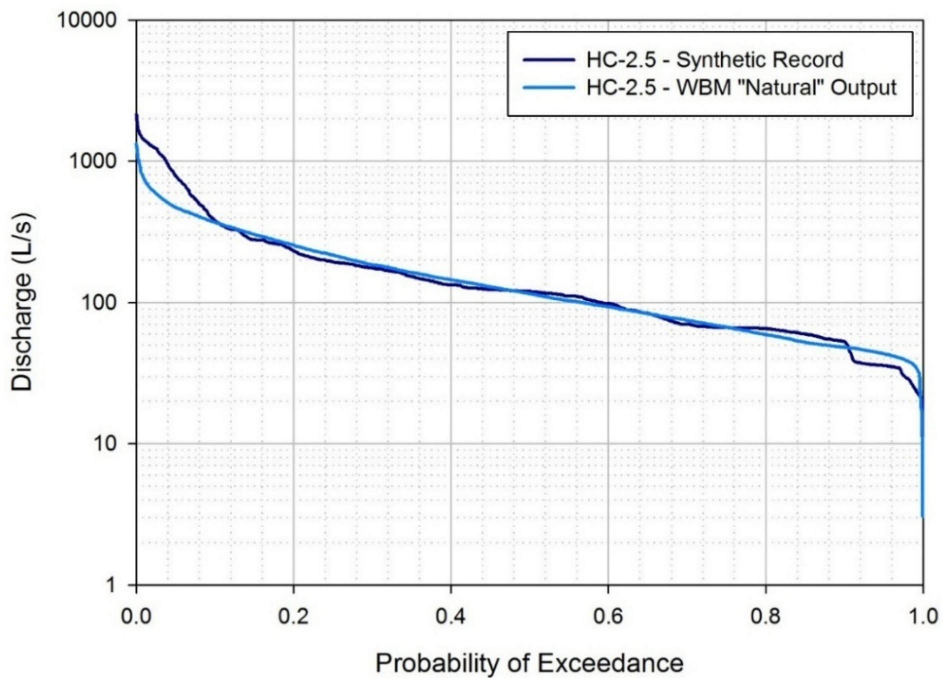


Figure 3-9: Flow duration curves for the HC-2.5 node showing the daily reconstructed discharge series and the WBM Natural run output, for the open water season (April to October).

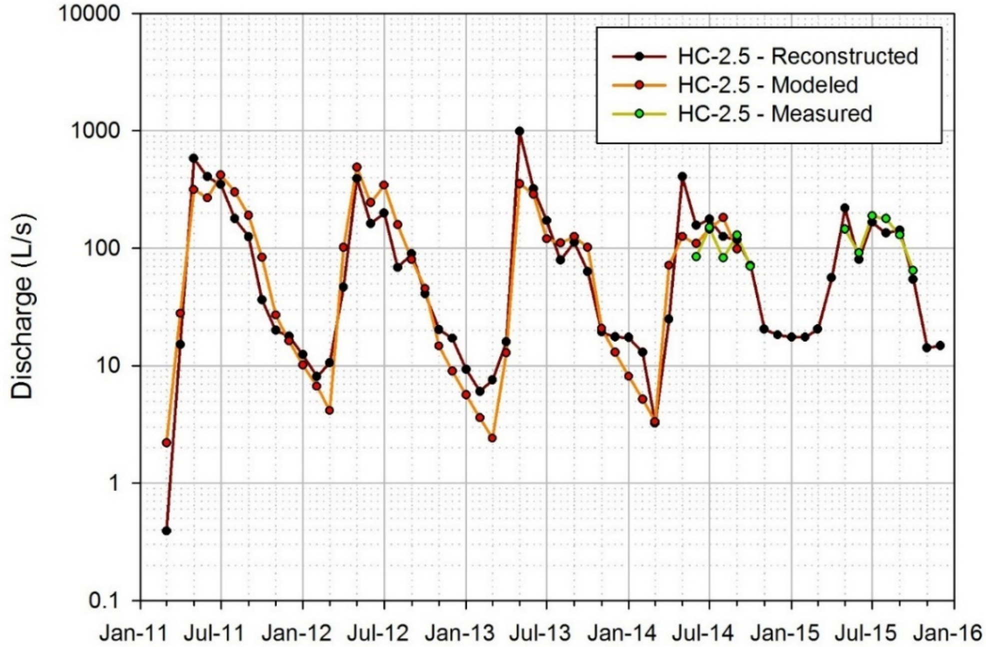


Figure 3-10: Time-series plot for the HC-2.5 node showing the reconstructed, modeled (Natural Case) and baseline streamflows. Y-axis is log scale to highlight low-flow calibration.

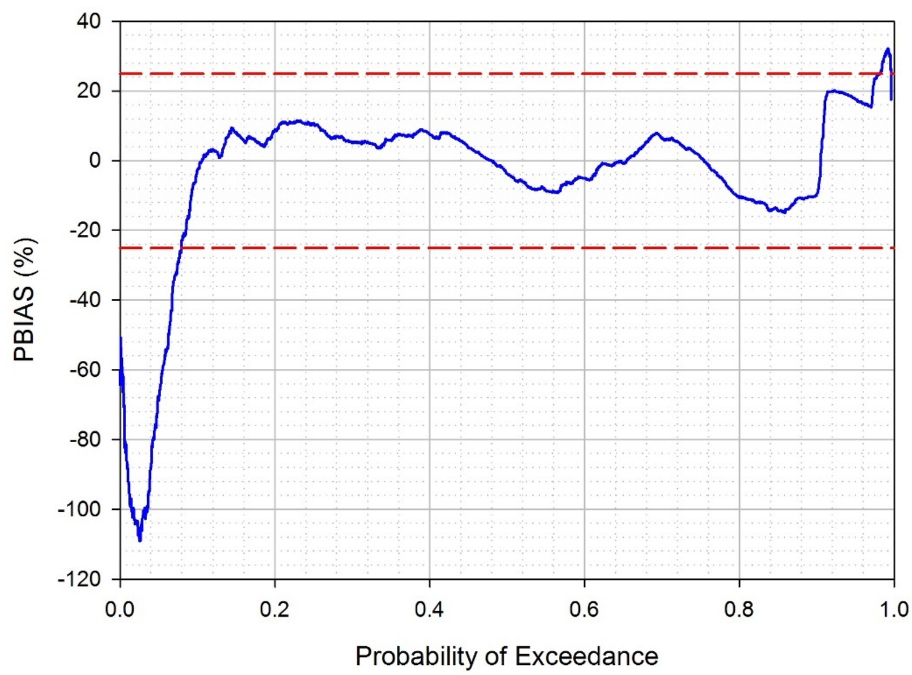


Figure 3-11: Percent bias plotted against the probability of exceedance for the HC-2.5 node, for the open water season (April to October). The red lines represent the +25% and -25% percent bias.

3.2.7 Inputs and Assumptions – Latte Creek and Coffee Creek

The next three sections (*i.e.*, Section 3.3 through 3.5) discuss each watershed containing mine infrastructure associated with the proposed Coffee Gold Mine. Discussion begins with the climatic data that was used as input to the model, then introduces detailed descriptions of each mine component, starting at the height of land and moving downgradient to the sediment collection ponds that will gather all contact water prior to discharge to the receiving environment.

Latte Creek watershed is presented first (Section 3.3), followed by Yukon Tributary 24 (Section 3.4) and finally Halfway Creek (Section 3.5). Parameterization of mine components within each drainage (*e.g.*, open pits and WRSFs) is generally consistent between watersheds and all relevant infrastructure and any related WBM assumptions will be presented once and as they first appear in the three watersheds. In this way, all components of the WBM will be presented in the order that they appear in each watershed, allowing the reader to better understand how the model inputs, assumptions and linkages are combined to generate estimates of flows for contact, non-contact and receiving environment areas of the Project site.

3.3 *Latte Creek and Coffee Creek*

This section outlines the input data and assumptions used to drive the Base Case WBM in detail for the Latte Creek watershed (nodes CC-1.5, CC-3.5 and CC-4.5, presented in downstream order). Overall, the water management layout for the Coffee Gold Mine envisions several types of water conveyance and storage structures (ditches, rock drains and sediment ponds), proposed to divert non-contact water around mine features or to divert contact waters efficiently to downstream sediment collection ponds. As illustrated in Figure 2-1, a single sediment collection pond will be constructed in the Latte Creek drainage (Facility Pond). The modeled flows in Latte Creek and Coffee Creek will be presented sequentially from the highest to lowest points in the watershed as follows:

- All inputs to the Facility Pond (HLF, non-contact areas, process plant and camp site and the ROM stockpile; Figure 3-12);
- All inputs to Upper Latte Creek (N3 watershed in Figure 3-13), (Supremo pit, Latte pit, Double Double pit and all non-contact flows reporting to Upper Latte Creek);
- Additional non-contact flows reporting to the CC-1.5 node;
- Additional natural flows provided by the basin between CC-1.5 and CC-3.5, and;
- The natural flows generated by the Upper Coffee Creek watershed (node CC-0.5), and the incremental natural flows generated by the watershed area between the confluence of Latte and Coffee Creeks (below CC-1.5 and CC-0.5) to the outlet of Coffee Creek above the Yukon River (node CC-4.5).

3.3.1 Facility Pond

The Facility Pond is located on the southern side of the ridgeline that contains the HLF, camp and process plant site and the ROM stockpile (Figure 2-1 and Figure 3-12). This pond is anticipated to receive both contact and non-contact runoff, has a design capacity of 8,900 m^3 and is assumed to function as designed. The catchment area that contributes to the Facility Pond, including all mine components and non-contact areas, is presented in Figure 3-12, which is a screen-shot of the model architecture as assembled in the GoldSim platform.

This pond is assumed to fill as driven by the modeled flows reporting to the pond, and the pond volumes and storage changes resulting from evaporation and discharge to the receiving environment are assumed to be driven solely by the pond water balance. In other words, the model assumes that once the pond level reaches the spill elevation, water is released to the environment without active management. This includes an assumption that for Base Case, water is not withdrawn from the pond for use in dust control at the mine site. Water from this pond will be directed to the HLF to fulfill external process water requirements that are not met by water pumped from the Kona pit. The Facility Pond is assumed to be decommissioned at closure.

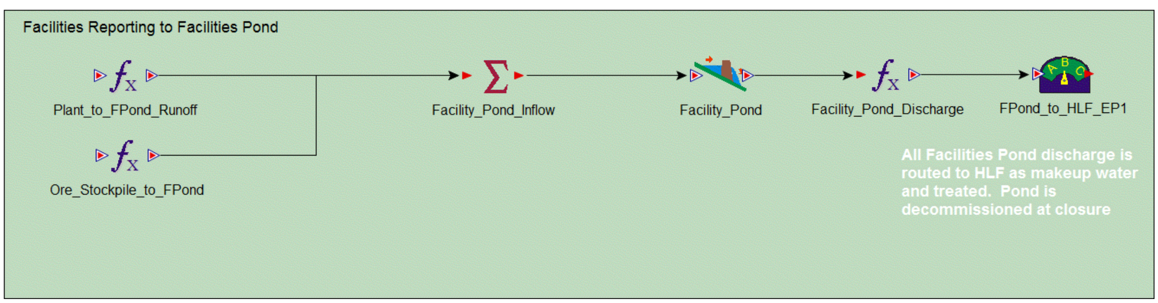


Figure 3-12: Facility Pond conceptual diagram from GoldSim WBM.

3.3.1.1 *Heap Leach Facility*

As shown in Figure 2-1, the HLF is situated at the ridgetop, and straddles both the Upper Latte and Upper Halfway Creek watersheds, with 73.1 ha of the HLF located in the headwaters of Latte Creek. The operation of the HLF is driven by the movement of solution through the leach pad. The timing and volume of water requirements and excesses at this facility are critical to both the efficient extraction of target metals, and protection of local watercourses. Given the importance of the HLF water balance to both the efficient extraction of the targeted resource and the overall mine site water balance, a deterministic water balance model was assembled to predict the volume and timing of water that the system will have to manage.

The HLF specific modeling exercise was done in two steps – a first model was set-up to predict the water balance throughout the Operation Phase to the end of active leaching (detailed in Appendix 2), and a second model was used to describe the period following active leaching, when the heap will be rinsed and drained-down during Closure (Appendix 3). The mine plan assumptions selected as the operating case from both the Operation and Drain-down HLF WBMs were carried over into the GoldSim site-wide water balance model to ensure consistency between all modeling efforts. Specific details of the Operation and Drain-down HLF WBMs follow.

Operation HLF WBM

The Operation Phase of the HLF WBM is fully described in Appendix 1 of this report. The HLF WBM is a deterministic water balance model based on the SCS (Soil Conservation Service) Curve Number model, where the proportion of precipitation converted to runoff is calculated based on the curve number approach (USDA, 1986). Briefly, curve numbers are empirical factors assigned based on the soil type, land cover and antecedent soil moisture conditions of the area being modeled. The HLF WBM operates on a monthly time-step, and tracks all water that is input and output from the lined pad, as well as stored volumes (*e.g.*, water retained in heap, event pond and raincoat pond volumes).

Input water sources in the HLF water balance include:

- Pore water contained in ore delivered to the leach pad;
- Meteoric water (rain and snow);
- Make-up water from external sources (*e.g*., pit dewatering, sediment ponds, local creeks);

System losses are summarized by three basic categories:

- Evaporative losses from areas not covered by rain covers (*i.e.*, directly from solution application system, from pond surfaces and from the actively leached portion of the ore heap);
- Losses to surface tension between ore particles (during heap irrigation), and;
- Extraction losses (draining or pumping water out of the system to treatment).

As the HLF must operate as a closed system for a good portion of the Operation Phase (*i.e.*, no untreated discharge from the HLF), a robust representation of the water balance is essential to confirm that the HLF design supports this requirement. The Operation HLF

WBM was used to run various scenarios, including delivered ore moisture content, raincoat coverage and treatment rates and timing (Appendix 2).

The Operation HLF WBM uses the same reconstructed climate data set as the site-wide WBM (described in Section 2.3.1.2) for consistency between all modeling exercises. In addition to the processes and fluxes briefly described above, the Operation HLF WBM also tracks any excess water that may be generated, that exceeds the storage capacity of the proposed event ponds. Since the event ponds are designed to contain the sum of a 72-hour heap drain-down, the PMP and expected incident water accumulation, an exceedance at the facility is most likely to result from an ongoing excess accumulation of water over time. Nonetheless, this volume must be estimated, and the model tracks it by routing any excess to a reservoir labeled 'treatment and discharge', to estimate the timing and rate of treatment that will be required.

The heap leach pad will be constructed in five stages and closed progressively as gold has been extracted from the ore in each cell. The progressive closure of the HLF begins in Year 5, and the Operation HLF WBM reflects this plan.

In general, the site-wide water balance model makes the following assumptions regarding the fluxes of water to- and from the HLF:

- During the Construction Phase, the meteoric water that falls on the lined area of the HLF is collected for use as eventual process water;
- During the development and dewatering of the Kona pit, any excess water is directed to Event Pond 1 (EP1), where it is then used preferentially as process water;
- Similarly, water collected in the Facility Pond is directed to EP1, and then used as process water, as required;
- Latte pit water is assigned third priority for makeup water requirements;
- Any additional process water requirements are withdrawn from the raincoat pond as needed, and;
- Zero recharge to the groundwater system is assumed to occur from the HLF footprint (including event and storage ponds) owing to the robust liner system proposed for HLF water infrastructure.

Leach Pad Drain-down WBM

The heap leach pad drain-down model is described in Appendix 2 of this report, and is briefly summarized here for context. The drain-down WBM tracks the dewatering of the ore stack during the reclamation and closure (of portions of the leach pad) during the latter portion of the Operation Phase, carrying through into the Closure Phase. This model is also set up to run on a monthly time-step, and for the initial scoping runs, average monthly climate inputs were used instead of the time-series used in the Operations HLF WBM. Several sensitivity analyses were run to examine the effect of varying the reclamation schedule, effective Curve Number of the cover, raincoat coverage and water treatment rates. The model was found to be most sensitive to the water treatment rates applied.

During operations, the heap leach facility is predicted to reach a net positive water balance sometime by Year 9 of the mine plan, which given the expected quality of the water contained in the heap pore space, will require treatment prior to discharge. For the Project, discharge of treated water is assumed to begin in Year 9, at a rate of 2 L/s in April, 4 L/s for May through September during Operations. Immediately after the cessation of ore stacking, treatment rates ramp up to 5 L/s for April and 11 L/s for May through September for an additional 3 to 4 years, as dictated by the Operation and Drain-down heap leach water balance model (see Appendices 1 and 2).

Currently, this treated water is assumed to be directly discharged to the Alpha WRSF rock drain, above the HC-2.5 node. Treatment and discharge are assumed to only occur during the 6 month open-water period. Further, it is assumed that water treatment capabilities will no longer be required by Year 20, at which point discharge from the detoxified HLF will be directed to the Alpha WRSF rock drain at flow rates dictated by variable meteoric inputs that report to the reclaimed HLF. The ore heap is assumed to be covered at this point in time and overall the WBM targets an infiltration rate through the cover of the HLF at 25% of MAP.

The mine plan assumptions selected as the operating case from both the Operation and Drain-down HLF WBMs were carried over into the GoldSim site-wide water balance model to ensure consistency between all modeling efforts.

3.3.1.2 *Process Plant, Camp Site and ROM Stockpile*

In a departure from the majority of contact areas associated with the site-wide WBM, these three mine components are modeled using a simple runoff coefficient approach, whereby daily volumes of meteoric inputs are modified by a factor of 0.7 to generate runoff from these areas. This approach was taken based on the limited disturbance and residence time on the landscape of these components. A runoff coefficient of 0.7 is higher than the targeted value for other mine components with the exception of pit wall runoff, and therefore the runoff generated from these areas is biased higher to compensate for the simplified approach. This results in a conservative estimation of runoff from these components.

The Process Plant and Camp Site are situated at the ridgetop and straddle both the Upper Latte and Upper Halfway Creek watersheds, with 3.4 ha of the process plant and camp site located in the headwaters of Latte Creek, and 3.8 ha located in the headwaters of Halfway Creek. The ROM Stockpile is located entirely within Upper Latte Creek and shows an area of 9.1 ha at its maximum extent. All runoff from these components is directed to the Facility Pond.

3.3.1.3 *Non-Contact Runoff*

There are many undisturbed areas that will be located within the mine area. These areas are often small in extent, and located between two or more mine components. The baseline watershed model (as described in Section 3.1.3) is used for these catchments, with one main difference - zero recharge to groundwater is assumed to occur below these areas. In other words, all non-contact water is captured and routed to the nearest surface collection point. All site water will be managed according to the Project's Water Management Plan (Appendix 31-E). Non-contact water is diverted around pits and WRSFs, and it is assumed that there is no leakage from the collection ditches.

3.3.2 N3 Sub-catchment

The N3 sub-catchment captures all drainage from the Supremo pit and Double Double pit that reports to Upper Latte Creek, in a small tributary that joins Latte Creek right above the CC-1.5 node (Figure 2-1 and Figure 3-13). The catchment area that contributes to the N3 sub-catchment, including all mine components and non-contact areas, is presented in Figure 3-13, which is a screen-shot of the model architecture as assembled in the GoldSim platform. The N3 catchment contains a substantial proportion of the proposed mine infrastructure, including the Double Double pit and waste rock backfill and portions of the Latte and Supremo pits. The assumptions and parameterizations that informed the representation of these components are outlined in the following sections.

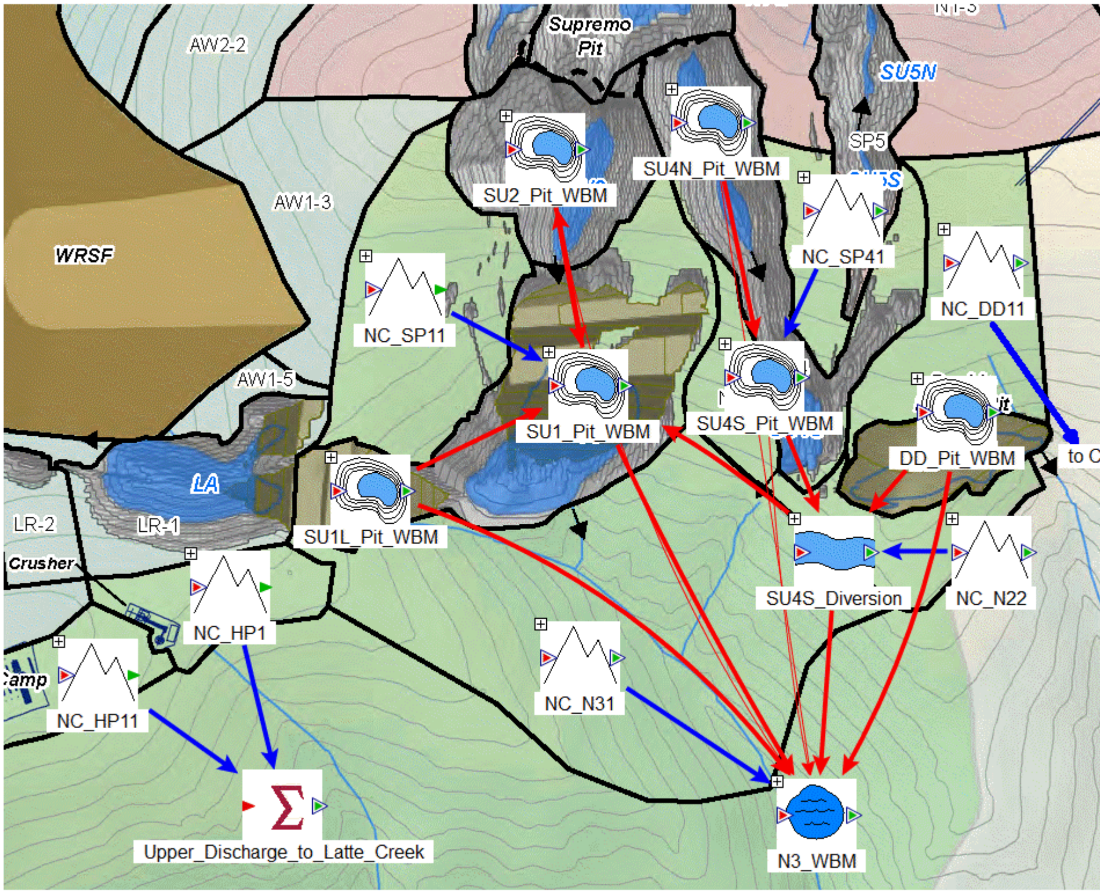


Figure 3-13: N3 catchment area. In this schematic, colour coding refers to the following cover types: light grey polygons with green boundary (non-contact, undisturbed terrain), grey (exposed pit wall/surface), light blue (pit lake), and beige (waste rock, in-pit backfill.

3.3.2.1 *Double Double and Latte Pit Backfill*

The WRSFs (including pit backfill) associated with the Coffee Gold Mine are expected to modify the natural runoff regime by attenuating the hydrograph, and abstracting flows during the initial wetting-up period. The total backfilled area at EOM is 44.4 ha. The causeways in Latte pit and Supremo pit are scheduled to be constructed in Mine Year 2 and Mine Year 5, respectively. The Double Double pit is slated to be backfilled by Mine Year 8. Typically, freshly placed waste rock is not fully saturated, and wetting fronts driven by meteoric inputs will progress slowly through the waste rock pile. The rate at which this process occurs is driven by the amount of incident precipitation, the proportion of fines within the pile, and the presence and connectivity of macro-pores which allow preferential flow paths to develop (Nichol *et al.*, 2005). As a result, and in reality, it can take several years for a waste rock pile to “wet-up”, but the WBM conservatively assumes that the

WRSFs are fully saturated upon placement, and water moves freely through the WRSFs once waste accumulates in the facility.

All WRSFs are assumed to have annual infiltration rates averaging 35% of MAP over the full model run, which is equal to, or slightly higher than the natural runoff coefficients per baseline watershed, depending on the watershed of interest. This value was selected as the target based on a review of the available literature on waste rock dump hydrology in cold climates (*e.g.*, Carey *et al.*, 2005, Janowicz *et al.*, 2007 and Neuner *et al.*, 2013). A time-series plot of the annual variation in the modeled percentage of annual precipitation that infiltrates the WRSFs (expressed as a runoff coefficient) located within the N3 sub-catchment is provided in Figure 3-14. The specific WRSF catchments listed in the legend can be cross-referenced to Figure 3-13 above.

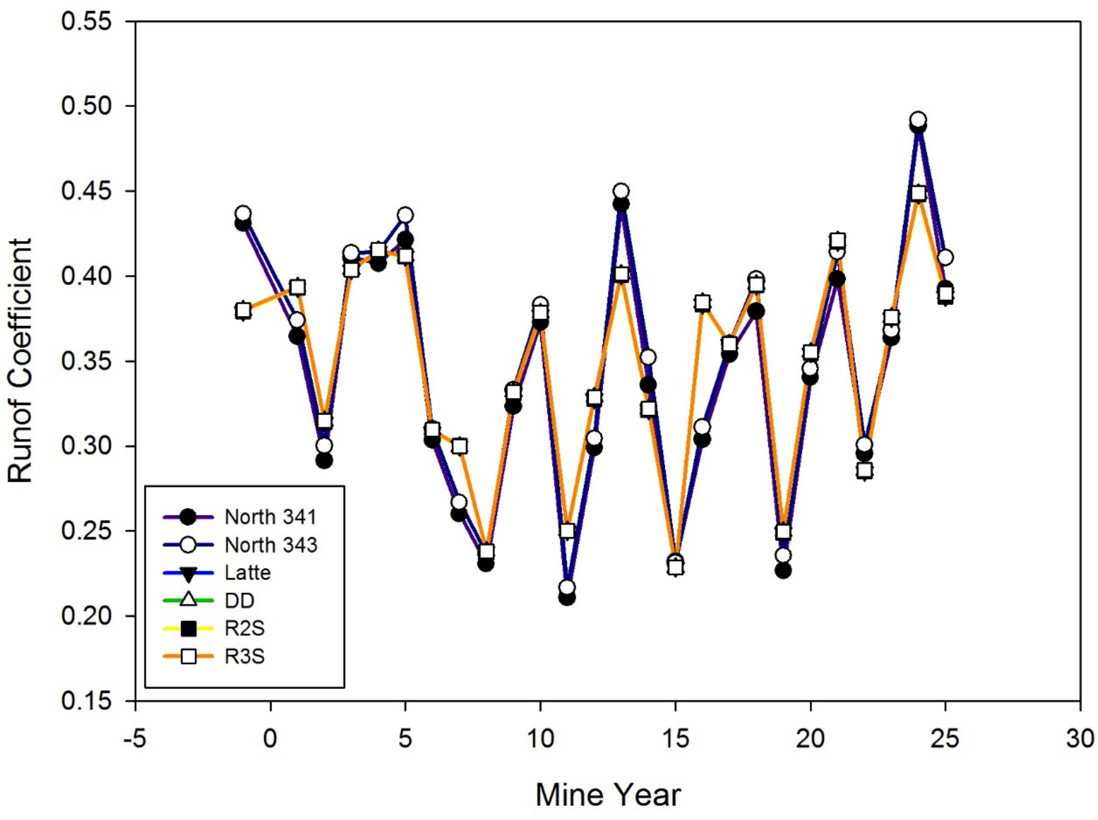


Figure 3-14: Annual variation in the modeled percentage of annual precipitation that infiltrates the WRSFs located in the N3 catchment.

Note that while the long-term average infiltration for the Coffee Gold WRSFs is 35% of MAP, it varies substantially from year-to-year, with maximums approaching 50% of annual precipitation and minimum values of 21% respectively. A summary of the available literature on waste rock dump infiltration that was used in the parameterization of the WRSFs in the site-wide WBM is presented in Table 3-7.

Table 3-7:
Waste Rock Pile Infiltration in Cold Climates – Summary of Research

Site	Location	Study	Type	MAP (mm)	ET (mm)	Infiltration (mm)	Infiltration Coefficient
Key Lake	Saskatchewan	Carey *et al.* (2005)	Measured	236	145	91	0.39 (*81 day period*)
Diavik	NWT	Neuner *et al.* (2013)	Measured	280			0.37 (0.10 to 0.42)
Faro Mine	Yukon	Janowicz *et al*. (2006[1])	Modeled	398	146	219	0.55 (*wet year*)
Faro Mine	Yukon	Janowicz *et al*. (2007)	Modeled				0.45 (*average year*)
Red Dog Mine	Alaska	SRK (2005)	Modeled	470		193	0.41
Rabbit Lake Mine	Saskatchewan	Ayres *et al*. (2005)	Modeled	540	400 (PET)	200	0.37
Cluff Lake	Saskatchewan	Nichol *et al*. (2005)	Measured	455			0.44 to 0.55

[1]Precipitation, ET and infiltration values are the average of the Faro, Grum and Vangorda dumps

The WBM also assumes that no surface runoff is generated from the WRSFs – all incident precipitation/snowmelt is assumed to either evaporate or infiltrate to the piles, which is consistent with the literature reviewed on northern waste rock dumps (*e.g.*, Carey *et al*., 2005 and Neuner *et al*., 2013). This is conservative, in that the final volume of water reporting from the WRSFs is assumed to have infiltrated the pile, and has therefore picked up the available loads from the source terms assigned to the WRSFs rather than a non-contact or hybrid chemical signature.

3.3.2.2 *Open Pits – Operational Dewatering*

As the open pits are developed, incident meteoric water will be actively managed via dewatering from the pit sumps. In the WBM, no pumping rate limit is applied for the dewatering rates, and no constant dewatering rate is assumed. Essentially, the water that reports to an actively mined pit is assumed to be removed in full during the current time-step. The pit walls are expected to convert meteoric water to runoff much more effectively than natural ground or other mine components, and total 68 ha in area at EOM. To reflect this, the target runoff coefficient for pit walls was set as 0.7 for the complete model run, noting that pitwall runoff is generated in the WBM with a modified three-reservoir model as used for baseline watersheds and WRSFs. The actual values vary from 0.65 to 0.73, depending on the model iteration and year.

Runoff generated from the pit sub-catchments is assumed to be pumped preferentially to the HLF as makeup water (Latte pit) and to the SU1 pit at EOM (SU4N, SU4S, SU2 and Double Double pits; see Figure 2-5). Once mining (and for some pits, backfill) operations end, pits are assumed to be decommissioned and the dewatering requirement in the WBM ceases. Meteoric and groundwater inputs to pits result in the formation of pit lakes over time and these lakes are assumed to be situated over unfrozen ground. As a result, final pit lake level is expected to influence the local hydraulic gradient, and depending on the local groundwater table elevation, the pit lake will either act as a sink (local discharge zone), or a source (local recharge zone).

Some of the pit lakes expected to form in the future switch from the former to the latter, as the lake level rises and the local hydraulic gradients reverse direction. This interaction with the groundwater system required definition of the relationship between the pit lake elevation and the rate of discharge/recharge to/from the local groundwater system. In turn, this required an iterative process between the groundwater and WBM models, where the estimated pit lake elevation over time would be used as input to the groundwater model as a constant head boundary, which would then inform the recharge/discharge rates. This process was repeated until both models converged on a common solution, and this is reflected in the output from the final site-wide WBM runs.

Any leakage from the groundwater system that reports to the pit lakes is assumed to be stored as ice overwinter, then is released similar to aufeis melting at freshet. This simulates the expected hydraulic resistance in the pit lake to groundwater infiltration when it's frozen, and is consistent with the assumptions made in the numerical groundwater model.

Overall, the modelling process (*i.e.*, the convergence of the Site WBM and the Coffee Gold Groundwater Model) provided the leakage rates associated with pit lakes, but the direction of travel was also necessary to determine which catchment the leakage is routed to. This was accomplished in the groundwater model by using a particle tracking routine to estimate the areas where pit leakage was expected to daylight. Further information on this exercise and the results is presented in Appendix 7-B-1. Finally, once the pit lake reaches the spill elevation (taken from an encoded volume-elevation curve), any excess water is assumed to report to the downstream catchment via the sub-WRSF rock drains. Figure 3-15 below shows modelled timelines for pit development, management (dewatering), filling and spilling. For the Latte Creek/Coffee Creek watershed, those assumptions made in the WBM that are specific to the water balance of relevant open pits are outlined below for the periods when they are being actively mined, and therefore dewatered.

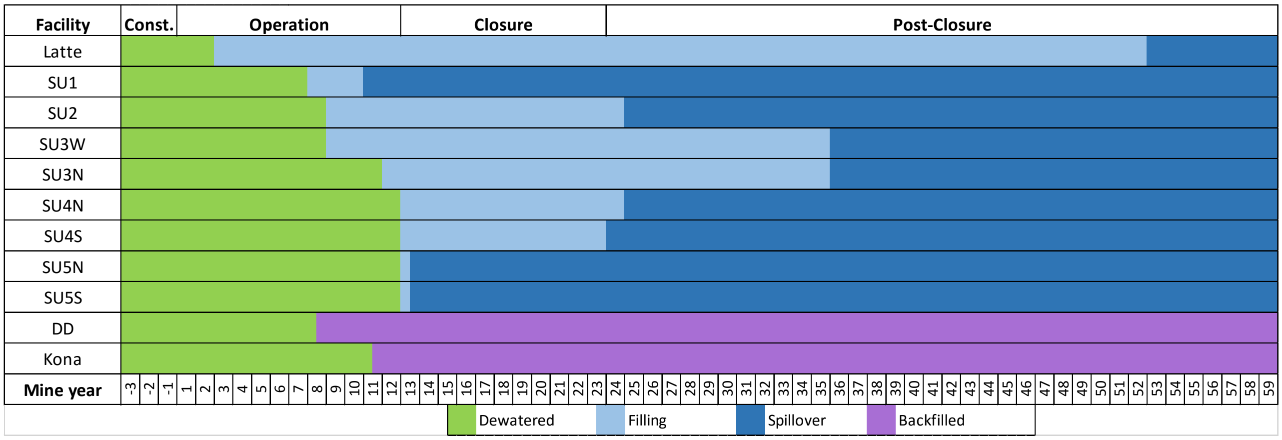


Figure 3-15: Proposed Timelines for Pit Development, Management, Filling and Spillover at Coffee Gold Mine. Green bars represent active mining and therefore pit dewatering, light blue represents the pit filling period, dark blue bars indicate that the pit is spilling, and purple bars represent pit backfill with waste rock.

Double Double pit

The Double Double pit is mined out in the first year of Operations (Year 1), and then begins to fill with meteoric water in Year 2. By Year 8, the pit is backfilled with waste rock, and the pit lake has not completely formed by this point.

Latte Pit

The Latte pit is mined out in the 3rd year of Operations (Year 4), and is partially backfilled with waste rock during Years 2 to 4 to form a causeway.

Supremo Pit

Zero recharge to the groundwater system was applied to waste rock placed in the Supremo pits. Given the steep slope of the Supremo pits, it is assumed any recharge that infiltrates the mine waste will immediately drain towards the lowest point in the pit, where it will form a lake or be dewatered. By the end of Year 3, non-contact water enters the SU1 pit from several locations directions, but prior to that non-contact water (including that from the SU4S/Double-Double diversion ditch) flows directly to the N3 sub-catchment.

3.3.2.3 *Open Pits – Filling and Spillover*

As per Figure 3-15, once the open pits situated wholly or partially within the N3 catchment have been mined out, dewatering is assumed to cease. At this point, the pits fill passively from meteoric inputs and then pit lakes form. Some pits (*e.g.*, Latte and Supremo) are connected to the groundwater system and the leakage to (or seepage from) the local groundwater system is described in the WBM. Once a pit lake begins to form and a ponded water surface exists in the bottom of the pit, the pit lakes are represented in the WBM using a simple water balance equation.

$$\Delta S = P - E + GW$$

Where:

ΔS = change in pit lake storage volume

P = precipitation inputs (rain + snowmelt)

E = evaporation

GW = groundwater inputs and/or losses

A summary of the open pit characteristics that were used to parameterize the WBM is provided in Table 3-8.

Table 3-8:
Pit Lake Characteristics – N3 Drainage

Pit Lake Name	Pit Water Capacity(m^3)	Bottom Elevation (m, asl)	Spill Elevation (m, asl)	Peak Pit Lake Water Elevation (masl)		
				End of Mine (Year 12)	Long-Term Monitoring	LTM Spill Date (Year 1 = 2020)
Latte	3,197,925	950	1,040	998	Spill	Jun 2052
SU1	2,995,642*	871	942	942	Spill	EOM
SU2	611,020	1,031	1,081	1,061	Spill	May 2044
SU4N	518,881	1,061	1,105	1,083	Spill	May 2043
SU4S	668,880	990	1,048	1,013	Spill	Aug 2043
DD	888,977	985	1,035	Backfilled		

* Total pit shell volume including backfill areas

Double Double Pit

Once development in Double Double ceases and dewatering stops, the pit is backfilled. When the Double Double pit fills, the pore space volume that is assumed to be available for water storage is 30% of the total pit volume. There is sufficient pore volume in the backfilled waste rock such that an initial displacement and spilling of the existing pit lake is not predicted to occur. As discussed in Section 3.3.3.1, the average annual infiltration rate equivalent to 35% of MAP was applied to the backfilled Double Double pit, and this sub-catchment switches to being represented by the WRSF parameterization (*i.e.*, less flashy flow generation, and no surface runoff). Once full, the pit lake spills toward Pit SU1, which then reports to the N3 sub-catchment. Note that the Double Double pit is advanced in unfrozen and saturated ground where infiltration through the mine waste is not expected to freeze. Leakage of water from this pit is predicted to report to Latte Creek at a constant rate of 0.76 L/s at EOM and continuing in perpetuity.

Latte Pit

A time-series of WBM output for the Latte pit water balance is shown in Figure 3-16. Similar to the pore space assumption made for the waste rock backfill in Double Double pit, the assumed volume is 30% of the pit volume (backfilled areas only) prior to backfilling. A summary of additional specific assumptions related to the behaviour of the Latte open pit and associated pit lake are as follows:

- The Latte pit begins to fill in Year 3 via meteoric inputs and groundwater discharge at low lake levels, when the pit lake is 5-10 m deep the groundwater flux switches to from net inflow (recharge) net outflow (discharge) as the pit lake level increases and the local hydraulic gradient is reversed.
- When stage is highest, the Latte Pit leakage rate to the CC-1.5 node is predicted to be 0.21 L/s at EOM, and 0.71 L/s (net) during the post-closure phase, which is a balance of the groundwater inflows and outflows from the pit (net discharge to groundwater).
- At maximum pit lake levels, the Latte Pit reports via passive spill to Halfway Creek, Latte Creek and SU1.

The rate of inflow/outflow to the local groundwater system is dependent on the elevation of the pit lake surface, as outlined in Table 3-9.

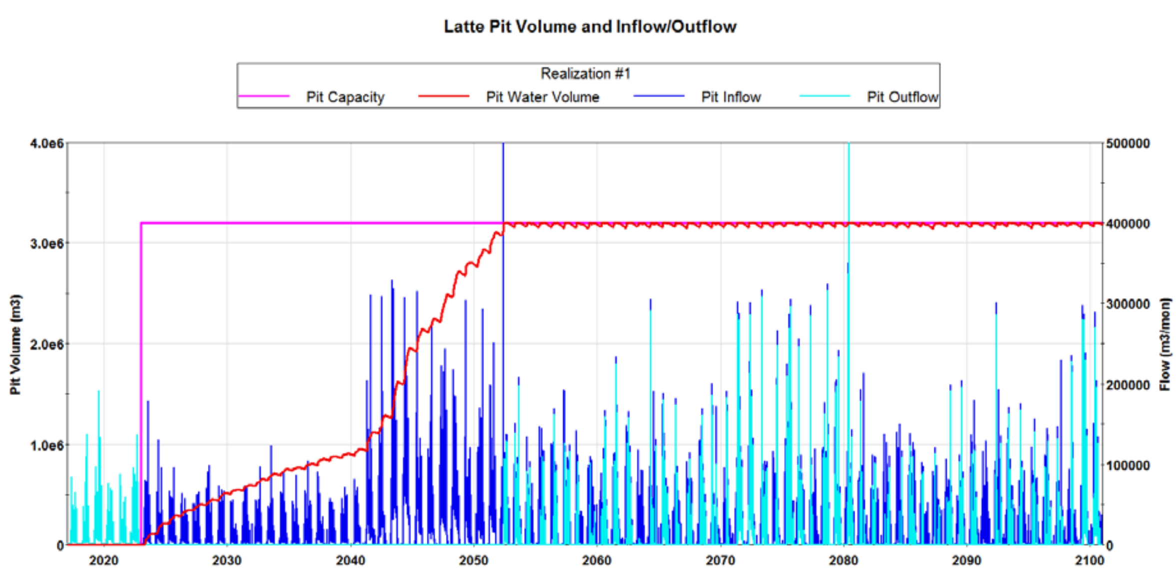


Figure 3-16: Latte pit lake volumes, inflows and outflows for the full WBM run

Table 3-9:
Latte Pit lake leakage rates. Negative values indicate losses to groundwater.

Latte pit Lake Elevation (m)	Latte pit outflow to groundwater (L/s)	Latte pit lake flux to Halfway Creek (L/s)	Latte pit lake flux to Latte Creek (L/s)	Latte pit lake flux to SU1 pit lake (L/s)
965	0.19	0.00	0.00	0.00
975	-0.09	0.15	0.00	0.00
985	-0.43	0.38	0.05	0.00
995	-0.82	0.61	0.21	0.00
1009	-1.48	0.88	0.39	0.00
1015	-1.79	1.16	0.63	0.00
1022	-2.21	1.39	0.83	0.00
1030	-2.72	1.62	0.87	0.17
1034	-2.99	1.83	0.88	0.27

Supremo Pit

Due to the relative size and variable depth of the Supremo Pit, a total of eight lakes are expected to form in this pit once mining operations have ceased. Of these, three are predicted to report to the N3 sub-catchment with assumptions and flow paths outlined below (in order of highest to lowest position in the catchment):

SU2

This pit lake sits in the topographic high of the N3 sub-catchment. Base Case WBM results indicate that this pit is expected to fill and spill by Mine Year 25. Groundwater modelling confirms that rates of inflow/outflow to the local groundwater system, to Halfway Creek and the SU1 pit lake from SU2 are dependent on the elevation of the pit lake surface, as outlined in Table 3-10. Leakage from this pit lake is predicted to report to CC-1.5 at a rate of 0.001 L/s during the post-closure phase. The SU2 pit water balance output for a full model run is presented in Figure 3-17.

Table 3-10:
SU2 Pit lake leakage rates. Negative values indicate losses to groundwater

SU2 Lake Elevation (m)	SU2 outflow to groundwater (L/s)	SU2 to Halfway Creek (L/s)	SU2 Leakage to SU1 (L/s)
1071	-1.15	0.00	1.40
1078	-1.44	0.00	1.67
1085	-1.89	0.39	1.72
1092	-2.71	0.55	2.33

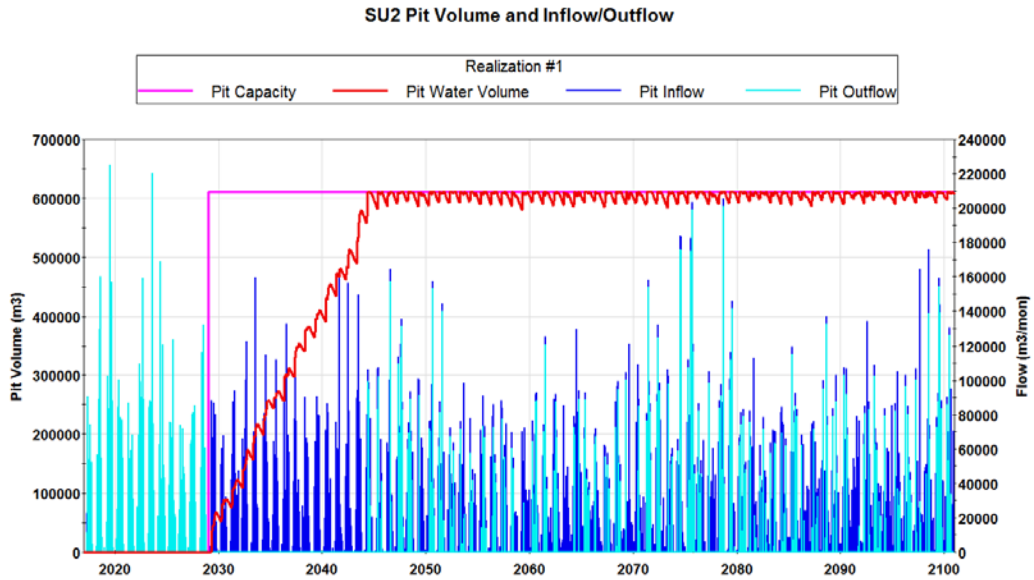


Figure 3-17: SU2 pit lake volumes, inflows and outflows for the full WBM run

SU4S

This pit lake sits adjacent and just to the west of the backfilled Double Double pit. This pit is predicted to fill and spill by Mine Year 24 and report to the interception ditch that flanks Double Double. SU4S therefore reports to SU1 pit. It is notable that the rate of inflow/outflow to the local groundwater system and Latte Creek is dependent on the elevation of the pit lake surface, as outlined in Table 3-11. Leakage from this pit lake is predicted to report to CC-1.5 at a rate of 0.47 L/s at EOM, and 1.67 L/s during the post-closure phase. The pit lake water balance for the full model run at this location is presented in Figure 3-18.

Table 3-11:
SU4S Pit lake leakage rates. Negative values indicate losses to groundwater.

SU4S Lake Elevation (m)	SU4S outflow to groundwater (L/s)	SU4S flux to Latte Creek(L/s)
1030	-0.20	0.23
1033	-0.21	0.30
1036	-0.24	0.36

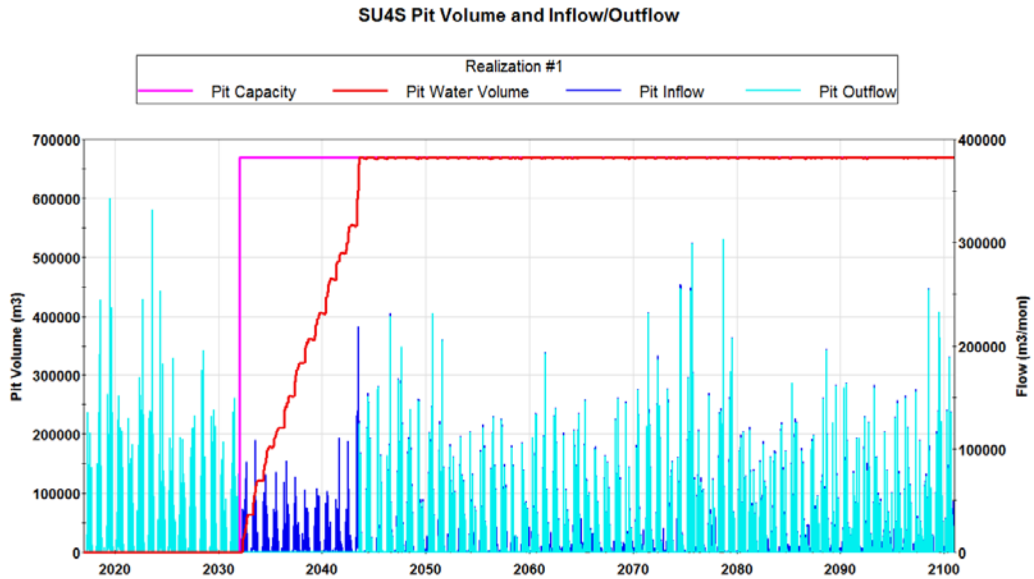


Figure 3-18: SU4S pit lake volumes, inflows and outflows for the full WBM run

SU4N

Once at the spill elevation, this pit lake will drain passively to the SU4S pit, and then out to the N3 sub-catchment. Leakage from this pit to the CC-1.5 node is minimal, with a predicted rate of 0.003 L/s during post-closure. The pit lake water balance over time is presented in Figure 3-19. Flow rates per pit lake elevation are presented for SU4N in Table 3-12.

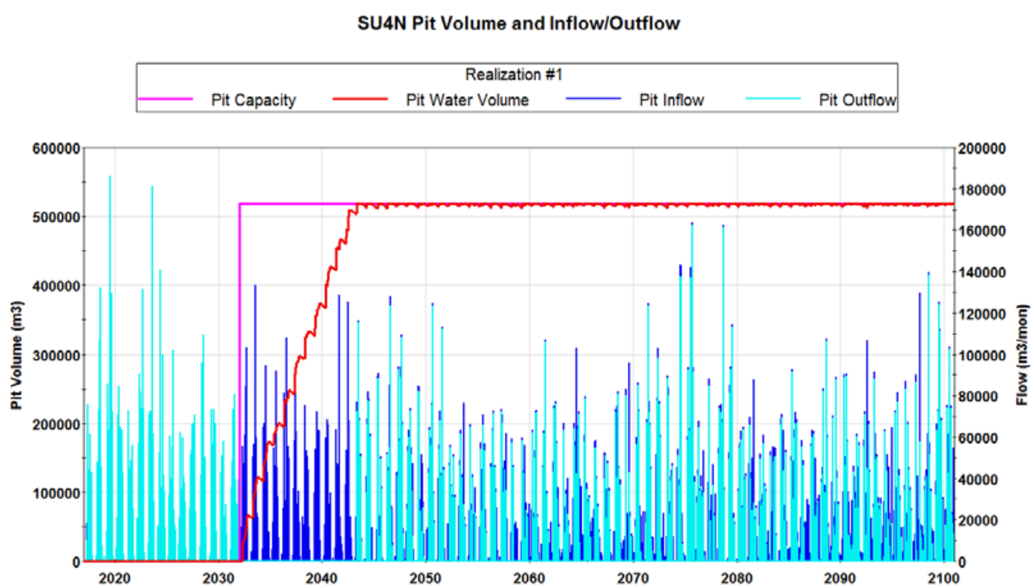


Figure 3-19: SU4N pit lake volumes, inflows and outflows for the full WBM run

Table 3-12:
SU4N Pit lake leakage rates. Negative values indicate losses to groundwater system

SU4N Lake Elevation (m)	SU4N outflow to groundwater (L/s)	SU4N to Halfway Creek (L/s)	SU4N to YT-24 (L/s)
1078	-0.23	0.17	0.09
1084	-0.31	0.24	0.13
1087	-0.37	0.28	0.15
1090	-0.44	0.31	0.19

SU1

This pit lake will be situated in the topographic low of the N3 sub-catchment. This pit lake receives runoff from non-contact and contact areas (including SU2, in pit WRSF infiltration, contact runoff from Double Double pit, seepage from the Latte pit lake, and any spillover from SU4S and SU4N).

All future seepage from SU1 pit is predicted to report directly to Latte Creek. Leakage from this pit lake is predicted to report to CC-1.5 at a rate of 0.65 L/s at EOM, and 0.49 L/s during the post-closure phase. A time-series of WBM output for the SU1 pit lake is shown in Figure 3-20. Further, Figure 3-21 shows the relative balance of non-contact and contact runoff reporting to Latte Creek once the SU1 pit begins to spill for a representative year (2024; Mine Year 4).

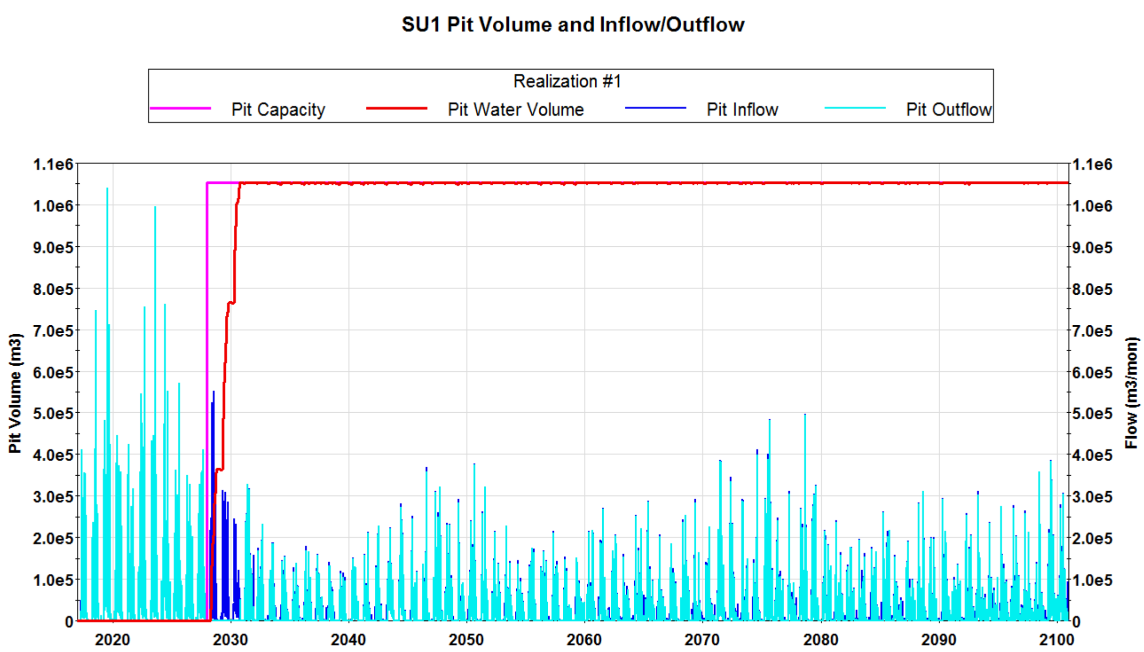


Figure 3-20: SU1 pit lake volumes, inflows and outflows for the full WBM run.

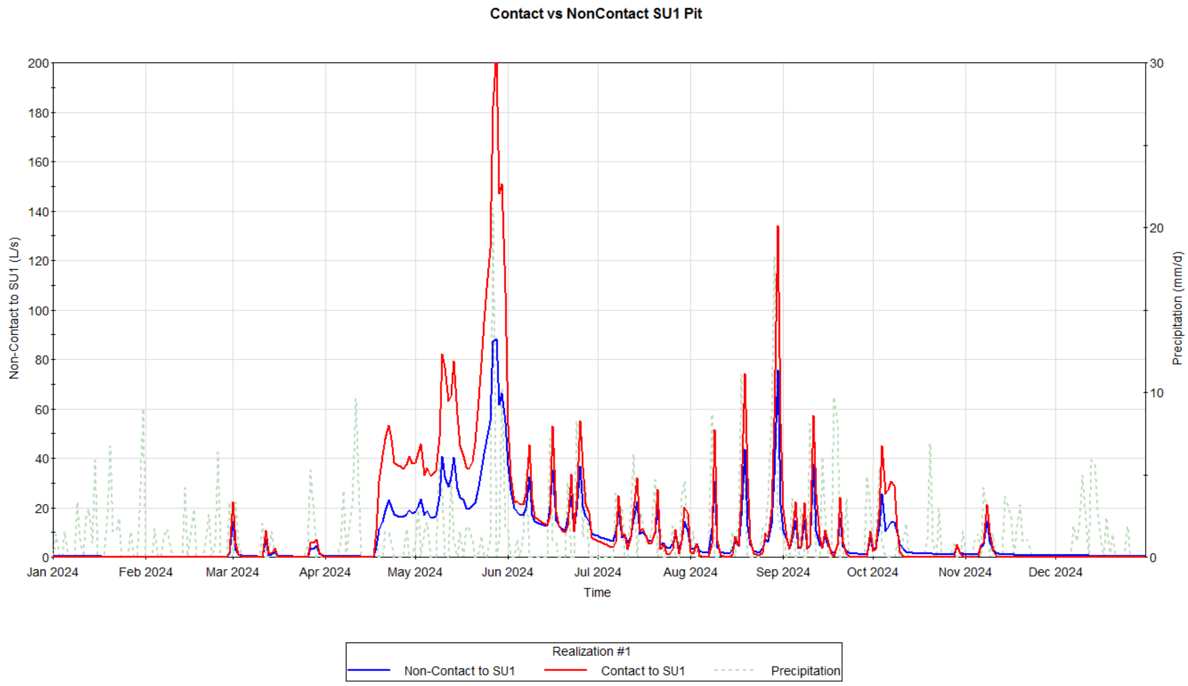


Figure 3-21: Non-contact and contact runoff to SU1 pit – output from the WBM.

3.3.2.4 *Non-contact Runoff*

WBM assumptions applied to the non-contact areas in the N3 sub-catchment are the same as those described in Section 3.3.2.3. In addition, the WBM is configured assuming that approximately 70% of the natural catchment up-gradient of the Double-Double pit bypasses the pit and diversion channel, and reports to Latte Creek downstream of CC-1.5 but upstream of CC-3.5.

3.3.3 CC-1.5

The CC-1.5 WBM node represents the first receiving environment prediction point for Latte Creek (Figure 3-1), and encompasses a watershed of 23 km^2. All flows emanating from the Facility Pond, the N3 sub-catchment, and natural drainage areas (*i.e.*, headwater drainages) report to this node. Table 3-13 provides a summary of the mine affected areas located within the Latte Creek drainage (and therefore the larger Coffee Creek watershed.

The information presented in Table 3-13 indicates that the total area occupied by mine infrastructure in the Latte Creek watershed is 2.0 km^2. At the spatial scale of CC-1.5 watershed, this results in a percent reduction of the un-impacted watershed areas for the CC-1.5 node of approximately -9% (Table 3-14).

Table 3-13:
End of Mine (EOM) areas by mine footprint type for the Latte/Coffee Creek watersheds.

Footprint	Latte/Coffee
Exposed Pitwall Area	68.0
WRSF Area	-
Backfilled Waste Rock	44.4
Frozen Soil	5.4
Camp/Plant Site	3.4
Soil Stockpile	-
ROM Stockpile	9.1
Heap Leach Facility	73.1
Total Mine Area	203.4
Total Mine Area (km^2)	2.0

Note: All values are in hectares except where noted.

Table 3-14:
Existing and mined (Year 12) watershed areas and median elevations for Latte/Coffee Creek watersheds.

Station	Pre-mine area	Max mine area (Yr 12)	Yr 12 natural watershed area	Change in natural watershed area	Median elevation	Median elevation – mine infrastructure
	(km^2)	(km^2)	(km^2)	%	(m asl)	(m asl)
CC-1.5	23.13	2.03	21.1	-9%	1,142	1,158
CC-3.5	69.83	2.03	67.8	-3%	990	1,158
CC-4.5	483.97	2.03	481.9	0%	1,000	1,158

Table 3-15 summarizes the parameters used in the watershed model to represent the various mine components and natural drainage areas within the Latte Creek, and larger Coffee Creek catchments. These parameters may be cross-referenced to the conceptual diagram and GoldSim model architecture figure in Section 3.2 (refer to Figure 3-3 and Figure 3-4).

Table 3-15:
Watershed model parameters for Latte Creek catchment

Catchment	Kf	Ks	Kb	%Fast	%Slow	%Fast ToDeep	%Slow ToDeep	Deep Retained (mm)	%PE Deep	%Aufeis frozen	Aufeis melt rate/ Snow melt rate
Pitwalls	0.2	0.2	0.200	60%	40%	20%	20%	0	25%	100%	0.1
Backfill*	0.2	0.92	0.960	60%	40%	70%	70%	0	40%	100%	0.1
HLF Closure*	0.4	0.97	0.990	40%	60%	90%	90%	0.5	50%	100%	0.1
CC-1.5	0.2	0.75	0.980	50%	50%	60%	30%	10	40%	60%	0.1
CC-3.5	0.5	0.94	0.990	40%	60%	50%	50%	0.5	100%	60%	0.1
CC-0.5	0.2	0.88	0.995	40%	60%	20%	20%	8	40%	90%	0.1
CC-4.5	0.2	0.92	0.985	50%	50%	40%	10%	10	40%	70%	0.1

*Runoff is masked to zero.

3.3.3.1 *Contribution from Facility Pond*

The WBM assumes that all water accumulating in this pond is used as makeup water for the HLF as required, and no untreated water from the Facility Pond is released to the environment. During Closure and Post-closure, all water from this drainage reports to Latte Creek upstream of CC-1.5 monitoring location.

3.3.3.2 *Contact Groundwater (Pit Leakage)*

As outlined in Section 3.3.3.3, leakage from the Latte pit lake, Double Double backfill and the four Supremo pit lakes that fall within the N3 sub-catchment *(i.e.*, SU1, SU2, SU4S and SU4N) are assumed to report directly to Latte Creek at CC-1.5. Maximum total seepage rate from all pit lakes reporting to CC-1.5 is approximately 2.1 L/s at EOM, and 4.0 L/s at closure, though a requirement for leakage of this magnitude is that all pit lakes reach their maximum elevation and begin to spill.

3.3.3.3 *Calibration of Natural Watershed Model to Baseline Conditions at CC-1.5*

In Figure 3-22, Figure 3-23 and Figure 3-24, three calibration plots are shown for CC-1.5 WBM node. Figure 3-22 shows daily flow duration curves at the CC-1.5 node for the open water season (*i.e.,* Apr to Oct) and compares WBM output to the synthetically generated discharge records assembled for this location. Percent bias results (*i.e.*, PBIAS metric; WBM output *vs.* Synthetic time series) are plotted against probabilities of exceedance for the CC-1.5 node in Figure 3-23, and overall these data show that for exceedance probabilities between 0.15 and 1.0, PBIAS results computed from modeled and target flows fall within the +/-25% threshold adopted as being acceptable for a watershed model (Moriarsi *et al.*, 2007). For exceedance probabilities between 0 and 0.15, Figure 3-23 indicates that a portion (approximately a third) of the PBIAS results fall within the +/-25% acceptance threshold, though results also show model under-estimation of highest flows at this location (*i.e.*, PBIAS results are in the range -30 to -60%). At monthly time step, all available flow outputs (*i.e.*, measure, synthetic and modelled) are shown in Figure 3-24. Like the PBIAS results at daily time step, monthly time series data give a strong indication of the reasonableness of modelled flow outputs for this node and the strength of the watershed calibration used.

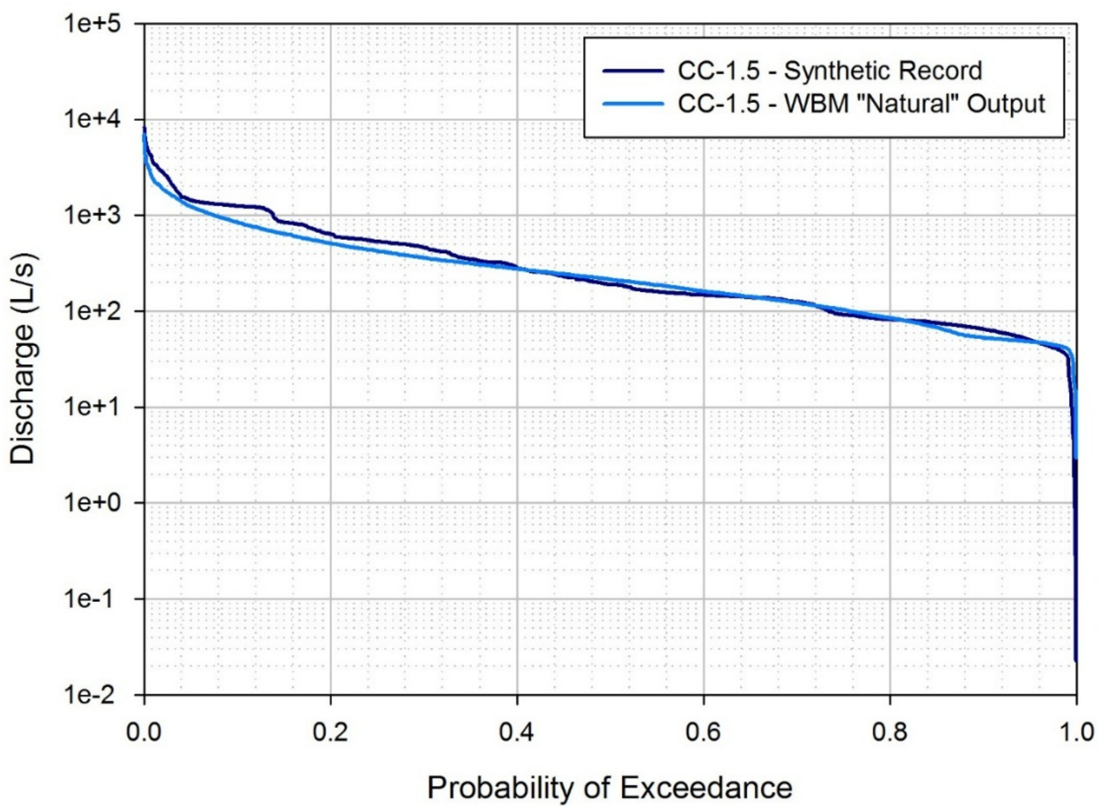


Figure 3-22: Flow duration curves for the CC-1.5 node showing the daily reconstructed discharge series and the WBM Natural run output, for the open water season (April to October).

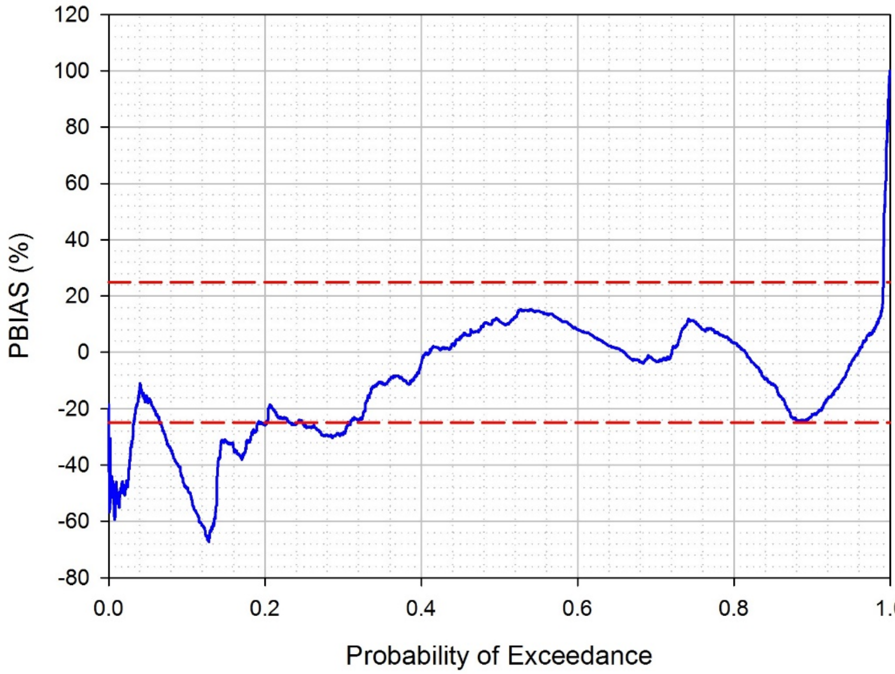


Figure 3-23: Percent bias plotted against the probability of exceedance for the CC-1.5 node, for the open water season (April to October). The red lines represent the +25% and -25% percent bias.

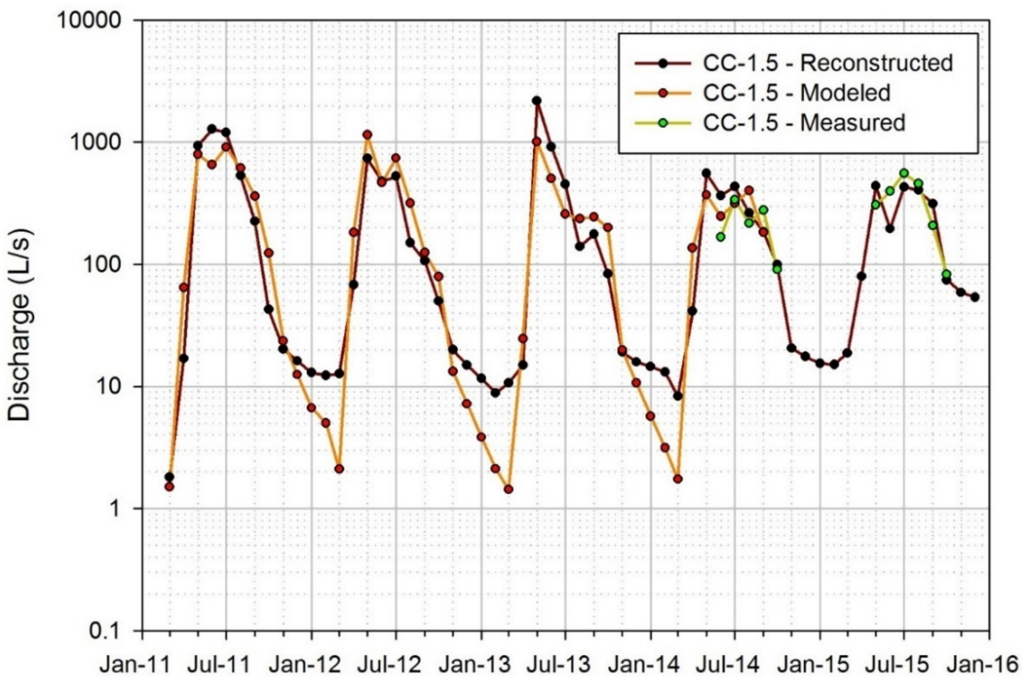


Figure 3-24: Time-series plot for the CC-1.5 showing the reconstructed, modeled (Natural Case) and baseline streamflows. Y-axis is log scale to highlight low-flow calibration

3.3.4 CC-3.5

The CC-3.5 node is located on Latte Creek just above the confluence with Coffee Creek. In the WBM, all flows reporting to CC-1.5 report to CC-3.5, which has a total watershed area of 69.8 km^2, 67.8 km^2 of which (or approximately 97% of the watershed area) is undisturbed and contributes non-contact runoff to the CC-3.5 modelling node.

WBM calibration plots are shown for CC-3.5 in Figure 3-25, Figure 3-26 and Figure 3-27. For the open water period, flow duration curves (Figure 3-25) and PBIAS output (Figure 3-26) show robust WBM calibration for nearly the full range of flow and exceedance conditions at CC-3.5. PBIAS results for exceedance values greater than 0.95 are indicative of WBM over-estimation under low flow conditions. However, the magnitude of these flows are very low (<50 L/s), translate to yields that are less than 1 L/s/km^2, and are understood to rarely occur.

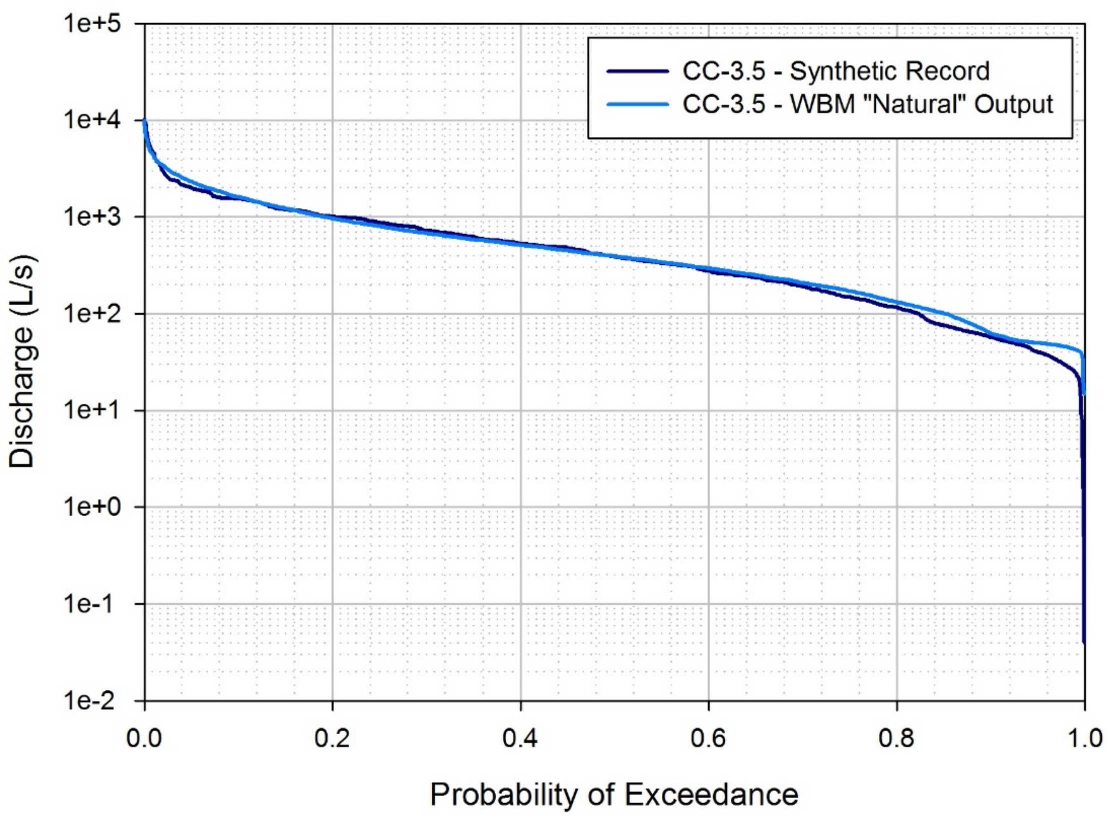


Figure 3-25: Flow duration curves for the CC-3.5 node showing the daily reconstructed discharge series and the WBM Natural run output, for the open water season (April to October).

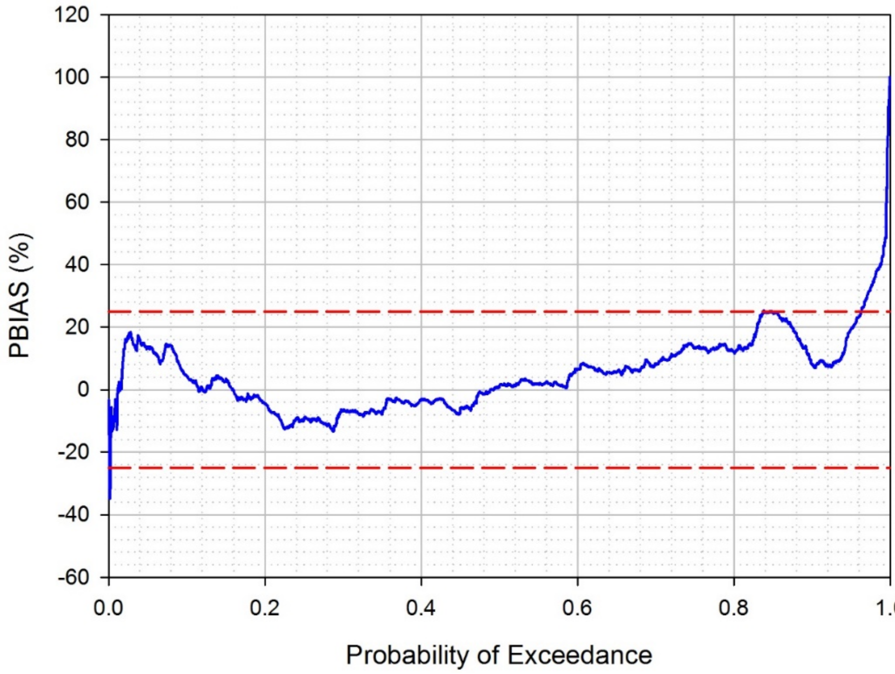


Figure 3-26: Percent bias plotted against the probability of exceedance for the CC-3.5 node, for the open water season (April to October). The red lines represent the +25% and -25% percent bias.

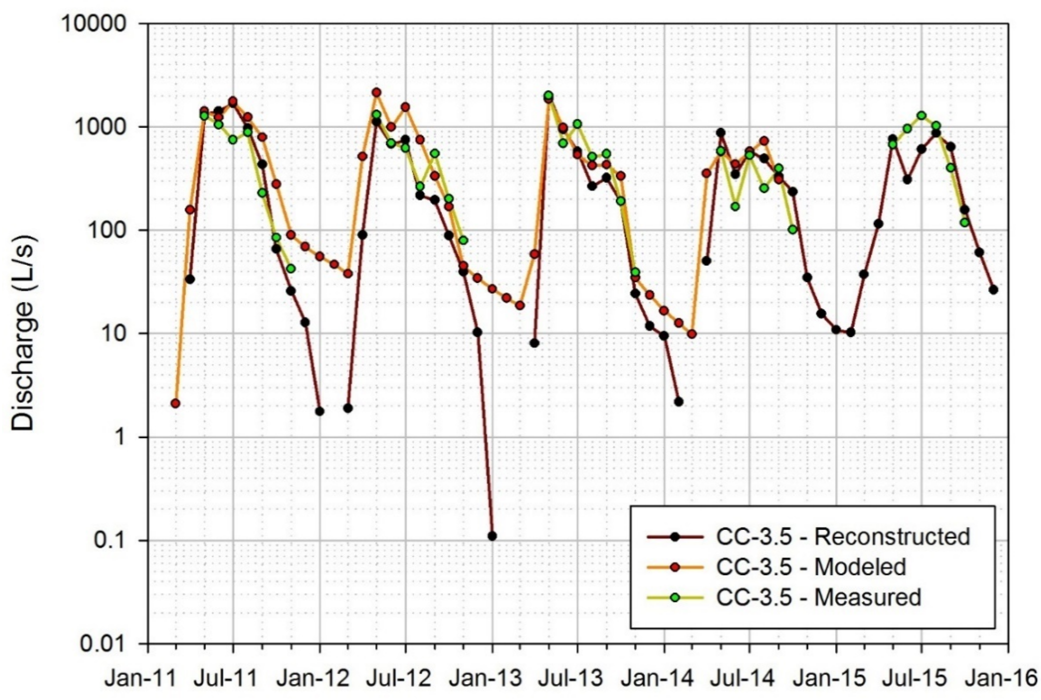


Figure 3-27: Time-series plot for the CC-3.5 showing the reconstructed, modeled (Natural Case) and baseline streamflows. Y-axis is log scale to highlight low-flow calibration

3.3.5 CC-0.5 and CC-4.5

The CC-4.5 node is located on Coffee Creek, just above the confluence with the Yukon River. All flow that reports to CC-3.5 mixes with non-contact flows reporting to the CC-0.5 node, which has a drainage area of 385.6 km^2 (Figure 3-1). Flows reporting to CC-4.5, which has a total watershed area of 484 km^2 (*i.e.*, 481.9 km^2 (or 99.6%) of which is undisturbed and contributes non-contact runoff to the CC-4.5 node), eventually report to the Yukon River.

WBM calibration plots are shown for CC-0.5 in Figure 3-28, Figure 3-29 and Figure 3-30. For the open water period, flow duration curves (Figure 3-28) and PBIAS output (Figure 3-29) show consistent WBM underestimation of the flow at CC-0.5, which is a conservatism built into the current version of the WBM. With the exception of very high and low flow conditions, PBIAS results for this modelling node range from -20 to -40% (Figure 3-30). Monthly results (*i.e.*, measured, synthetic and modelled) for CC-0.5 are shown in Figure 3-30.

In the WBM, CC-4.5 is represented as the sum of CC-3.5 and CC-0.5 flows. As noted in the Coffee Gold Mine Baseline Hydro-meteorology Report (Appendix 8-A), streamflow data show measured reductions in surface runoff between the confluence of Latte and Coffee Creeks (represented by stations CC-3.5 and CC-0.5, respectively) and CC-4.5 near the mouth of Coffee Creek from expectation. In the Coffee Creek area, losing reaches of local watersheds are hypothesized to occur owing to flow abstraction through the structural lineament that cross-cuts both Halfway and Coffee Creeks (refer to Appendix 7A). These flow abstractions are most readily measurable during periods of low streamflow, both during the open water season and the winter. In addition, these losing reaches appear to influence the concentrations of certain PCOCs (*e.g.*, uranium and arsenic).

The quality of the baseline hydrometric data set allows these abstractions to be represented in the WBM with a reasonable level of confidence. The model handles the losing reach in Coffee Creek as follows. The flow from CC-3.5 and CC-0.5 are added, then routed to a GoldSim splitter (*i.e.*, type of modelling tool built into the GoldSim software) year-round where the first 200 L/s of surface flow bypasses CC-4.5 and reports to the Yukon River directly.

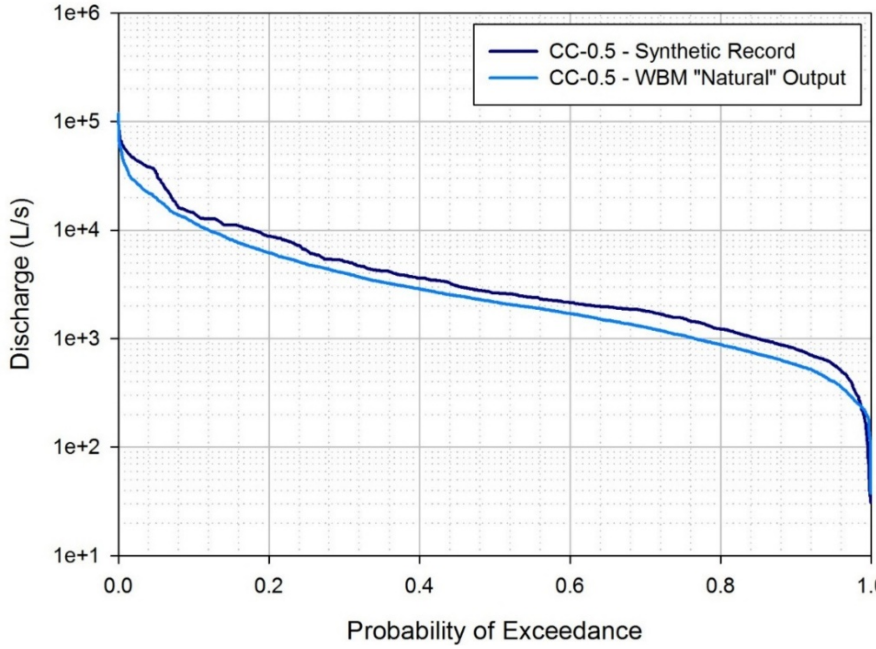


Figure 3-28: Flow duration curves for the CC-0.5 node showing the daily reconstructed discharge series and the WBM Natural run output, for the open water season (April to October).

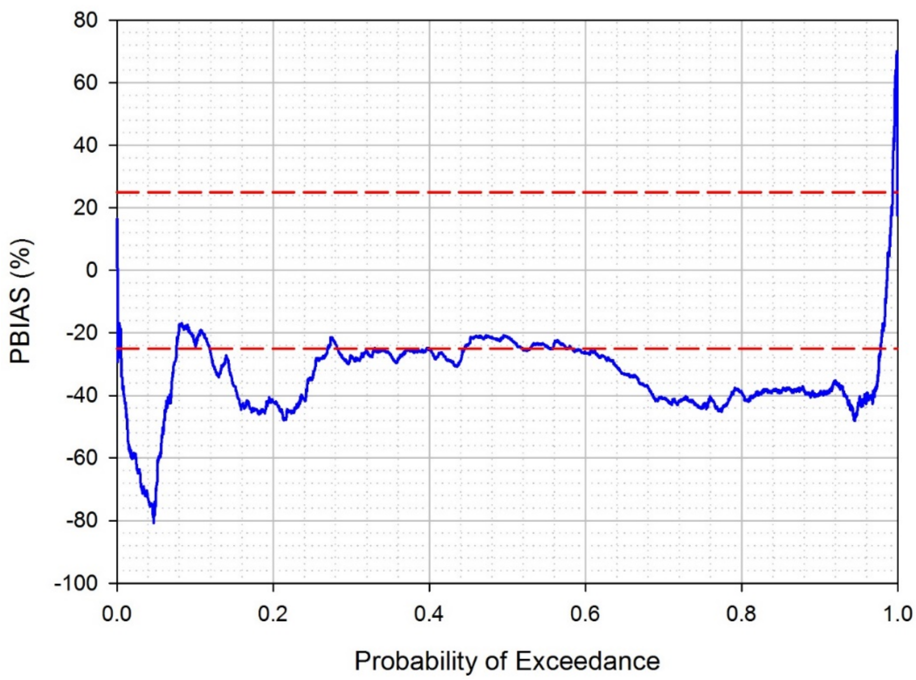


Figure 3-29: Percent bias plotted against the probability of exceedance for the CC-0.5 node, for the open water season (April to October). The red lines represent the +25% and -25% percent bias

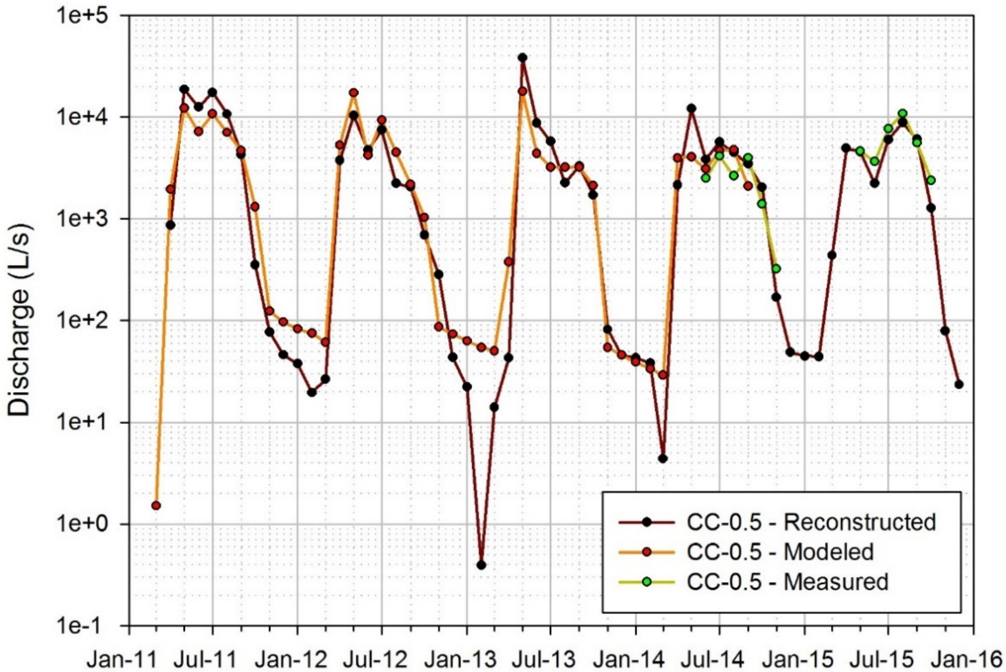


Figure 3-30: Time-series plot for the CC-0.5 showing the reconstructed, modeled (Natural Case) and baseline streamflows. Y-axis is log scale to highlight low-flow calibration.

3.4 *Inputs and Assumptions – Yukon Tributary 24*

This section outlines the input data and assumptions used to model the Yukon Tributary 24 watershed (node YT-24). As illustrated in Figure 3-31, all mine contact drainage will report to the N1 sub-catchment. As per Section 3.3, modeled flows in Yukon Tributary 24 are presented in the following sub-sections sequentially from the highest to lowest points of interest in the watershed as follows:

- All inputs to the N1 sub-catchment (Supremo pit and all non-contact flows reporting to this node) will first be described;
- Additional non-contact flows reporting to the YT-24 node will be described.

3.4.1 N1 Sub-catchment

The N1 sub-catchment node will receive both contact and non-contact runoff, and aggregates the various inputs within the WBM in the same way as the N3 sub-catchment is configured. The catchment areas that contributes to the N1 sub-catchmen, including all mine components and non-contact areas, are presented in Figure 3-31, which is a screen-shot of the model architecture as assembled in the GoldSim platform. The assumptions and parameterizations that informed the representation of these components are outlined in the following sections.

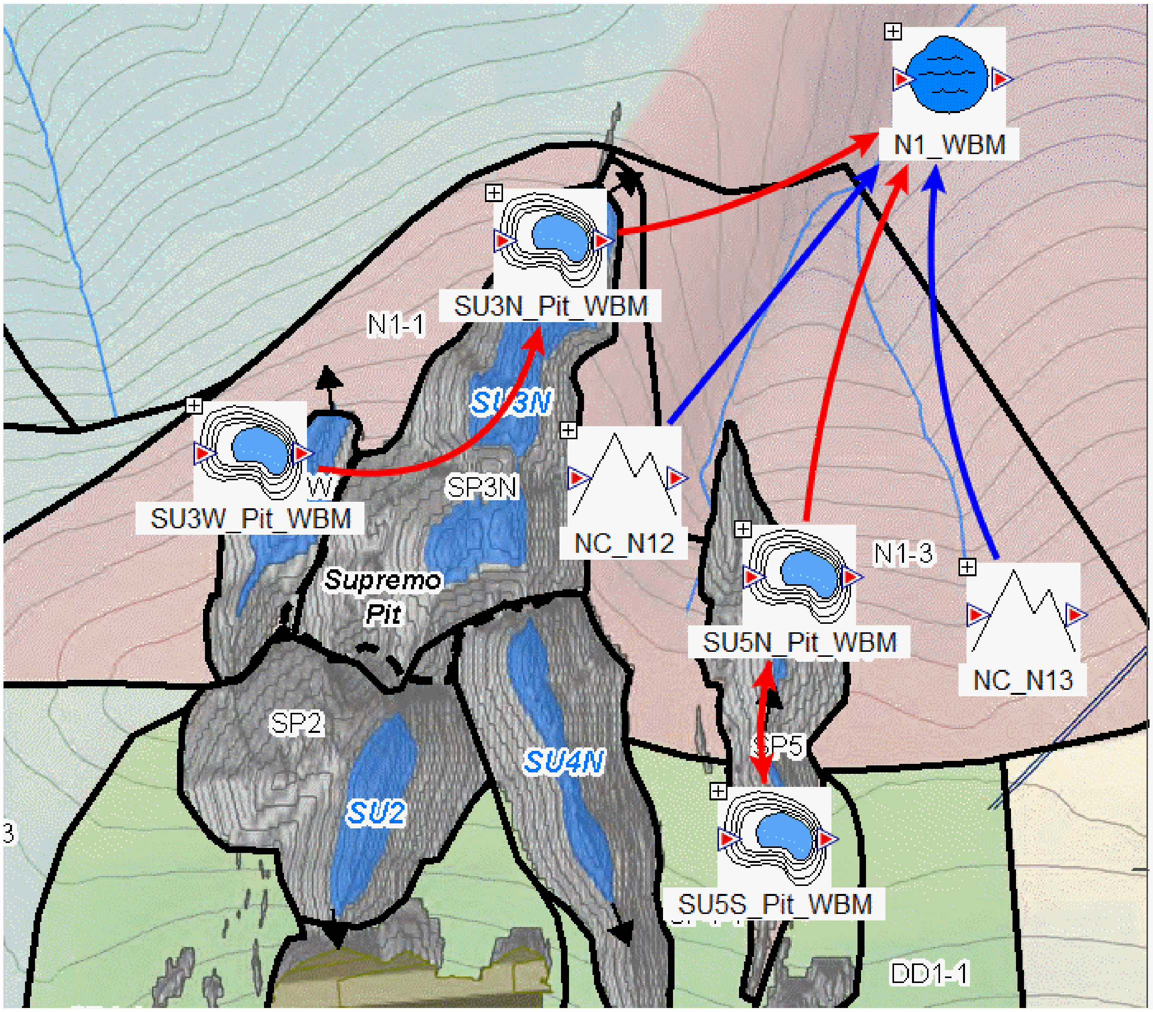


Figure 3-31: N1 catchment area. In this schematic, colour coding refers to the following cover types: light grey polygons (non-contact, undisturbed terrain), grey (exposed pit wall/surface), light blue (pit lake) and beige (waste rock, in-pit backfill).

3.4.1.1 *Supremo Pit – Operational Dewatering*

Zero recharge to the groundwater system was applied to waste rock placed in the Supremo pits. Given the steep slope of the Supremo pits, it is assumed any recharge that infiltrates the mine waste will effectively drain towards the lowest point in the pit, where during the Operation phase it will be dewatered, with the pumped flows directed to the N1 sub-catchment. Overall, the modeling assumptions used for the open pit dewatering are the same as those presented in Section 3.3.3 for the N3 sub-catchment, and the schedule for the pits/pit lakes discussed in the N1 sub-catchment drainage have been presented previously in Figure 3-15.

SU5S

This is a large pit in the headwaters of the N1 sub-catchment. During the Operation phase, dewatering capability is turned on in the WBM for this and other pits associated with the Project for the duration of active mining. Volumes of water associated with pit dewatering are assumed to report first to the SU5N pit in the WBM, and then to the YT-24 node for the duration of the Operation phase.

SU5N

This is a small pit situated down-gradient of SU5S. Dewatering is enabled in the WBM for the duration of active mining, which reports to the YT-24 node.

SU3W

Like other pits, dewatering is enabled in the WBM for the duration of active mining. Water is pumped to the SU3N pit, and then on to the YT-24 node.

SU3N

This is a small pit situated down-gradient of SU3W. Dewatering is enabled in the WBM for the duration of active mining, which reports to the YT-24 node.

3.4.1.2 *Supremo Pit – Filling and Spillover*

As indicated in Figure 3-15, after the Supremo Pit has been mined out, dewatering of respective pits is assumed to cease. After these points in time, pits fill passively via meteoric inputs (snow, rain) and losses (evaporation), and pit lakes form. Due to the relative size and variable depth of the Supremo Pit, a total of eight lakes are expected to form in this pit once mining operations have ceased. Of these, four will report to the N1 sub-catchment with assumptions and flow paths outlined below (in order of highest to lowest position in the catchment) for these four pit lakes.

The future Supremo pit is understood to show connection to the groundwater system, and the leakage to (or seepage from) the local groundwater system is described below for relevant pits. As presented in Section 3.3.2.3, the pit lake water balance is represented by a precipitation/evaporation balance. Further, a summary of the open pit characteristics that were used to parameterize the WBM is provided in Table 3-16, and pit lake water balances are presented in Figure 3-32, Figure 3-33, Figure 3-34 and Figure 3-35 for the filling and spilling periods relevant to the N1 sub-catchment.

Table 3-16:
Pit Lake Characteristics – N1 sub-catchment

Pit Lake Name	Pit Water Capacity (m3)	Bottom Elevation (masl)	Spill Elevation (masl)	Peak Pit Lake Water Elevation (masl)		
				End of Mine (12/31/2032)	Long-Term Monitoring	LTM Spill Date (Year 1 = 2020)
SU5S	20,252	1150	1165	1165	1165	EOM
SU5N	28,386	1120	1140	1140	1140	EOM
SU3N	2,207,000	1011	1090	1050	1090	11/01/2054
SU3W	1,091,104	1150	1200	1176	1200	04/01/2055

SU5S

The capacity of the SU5S pond is 20,252 m^3, the lowest of the four pit lakes presented in (Table 3-16). At the end of mining, the SU5S pit lake is assumed to be full and spilling passively. Pit lake water balance results for SU5S are provided in Figure 3-32 and show the pit lake spilling by EOM (2032). Spill from SU5S is assumed in the WBM to be toward the SU5N pit. Leakage from this pit lake is predicted to YT-24 at a rate of 0.33 L/s during the post-closure phase.

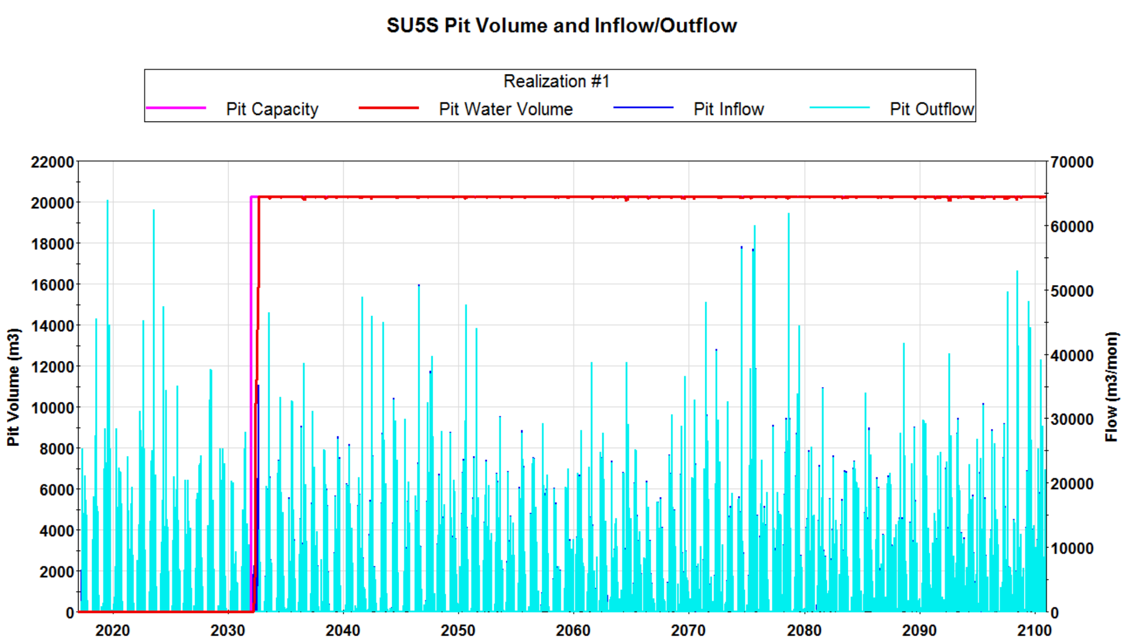


Figure 3-32: SU5S pit lake volumes, inflows and outflows for a WBM run.

SU5N

At ~28,386 m^3 (Table 3-16), the SU5N pit lake is small compared to other pit lakes in the N1 sub-catchment. As such, spill from this pit lake is predicted to occur by the end of active mining operations (*i.e.*, spillover by 2032). Rates of spillover from the SU5N pit lake to YT-24 increase appreciably when SU5S is full and begins to spill toward SU5N. Fill and spill patterns for the SU5N pit lake are shown in Figure 3-33. Leakage from this pit lake is predicted to report to the YT-24 node at a rate of 0.06 L/s during the post-closure phase.

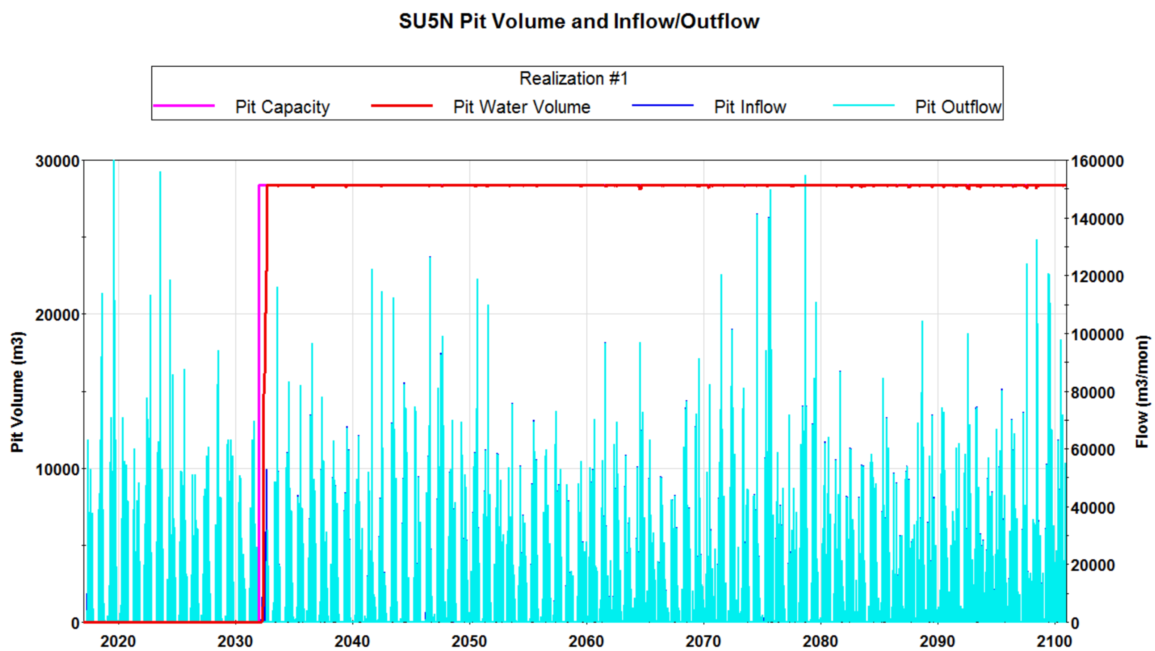


Figure 3-33: SU5N pit lake volumes, inflows and outflows for a WBM run.

SU3W

A pit lake water balance is shown for SU3W in Figure 3-34. The SU3W pit lake is relatively large (1,091,104 m^3; Table 3-16) and fill time is predicted to be ~30 years. Once full, spillover from SU3W is directed toward SU3N pit lake which is situated down-gradient from SU3W, and then on to the YT-24 node.

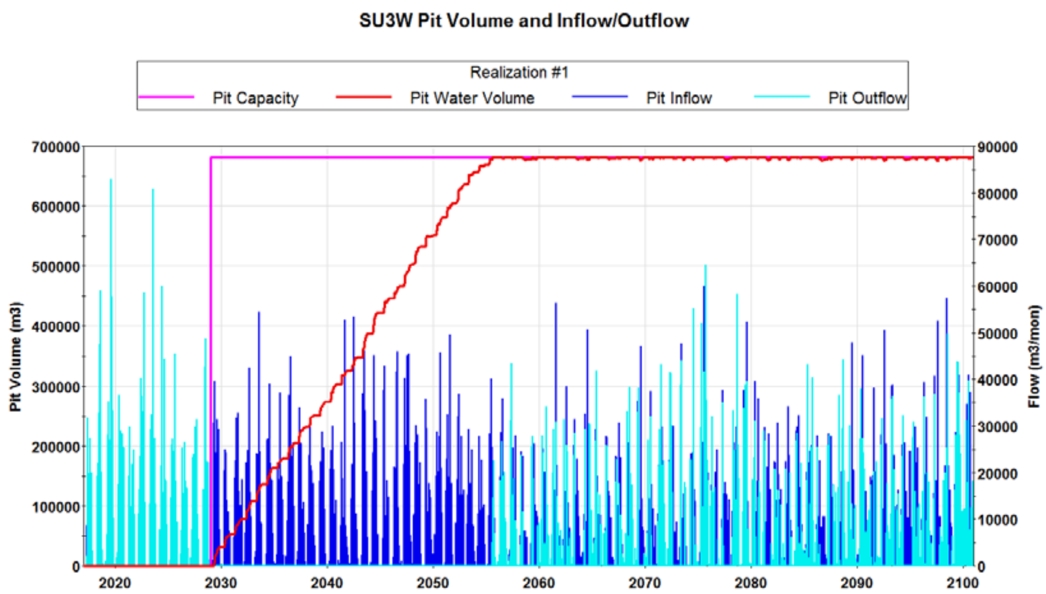


Figure 3-34: SU3W pit lake volumes, inflows and outflows for a WBM run

SU3N

This is the largest pit lake predicted to form in the N1 sub-catchment, with an estimated volume of 2,207,000 m^3 (Table 3-16). As shown in Figure 3-35, approximately 30-years is required before the SU3N pit lake is predicted to spill over to the YT-24 tributary. Groundwater modelling indicates connection between this facility and local tributaries, with rates of inflow/outflow to the local groundwater system, Halfway Creek and YT-24 represented in the WBM using depth-dependent relationships. At EOM, leakage from this pit lake reports to Halfway Creek at approximately 0.24 L/s. During the closure and post-closure phases, this pit lake is predicted to leak to Halfway Creek at 0.43 L/s, and YT-24 at 0.1 L/s.

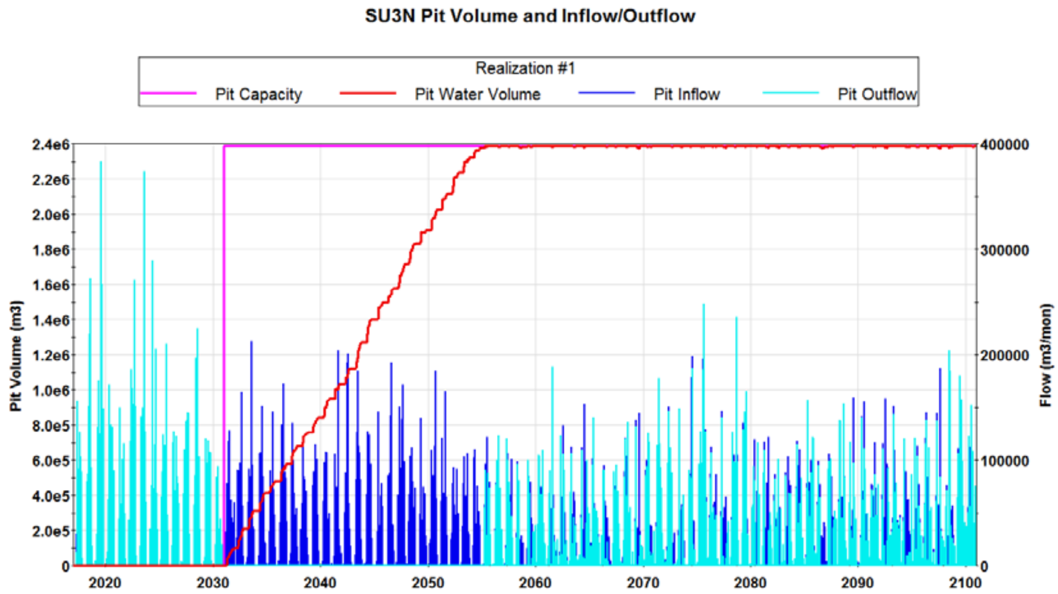


Figure 3-35: SU3N pit lake volumes, inflows and outflows for the full WBM run

3.4.1.3 *Non-contact Runoff in the N1 sub-catchment*

The WBM assumptions applied to non-contact areas delineated within the N1 sub-catchment are applied consistently with the methods and assumptions described in Section 3.3.2.4 for the N3 sub-catchment.

3.4.2 YT-24

The YT-24 WBM node represents the first receiving environment point incorporated into the WBM below the N1 sub-catchment (Figure 3-1), and represents a watershed area of approximately 12 km^2. Conceptually, all flows emanating from the N1 sub-catchment and any natural drainage areas located downgradient report to this node. Table 3-17 provides a summary of the mine affected areas located within the YT-24 drainage (a tributary that reports directly to the Yukon River), with mine footprint totalling 0.4 km^2 in the basin.

The information presented in Table 3-18 indicates that the reduction of the un-impacted watershed area for the YT-24 node is -3%.

Table 3-17:
End of Mine (EOM) areas by mine footprint type for the Yukon Tributary 24 watershed

Footprint	YT-24
Exposed Pitwall Area	39.6
WRSF Area	-
Backfilled Waste Rock	-
Frozen Soil	-
Camp/Plant Site	-
Soil Stockpile	-
ROM Stockpile	-
Heap Leach Facility	-
Total Mine Area	39.6
Total Mine Area (km^2)	0.4

Note: All values are in hectares except where noted.

Table 3-18:
Existing and mined (Year 12) watershed areas and median elevations for the Yukon Tributary 24 watershed

Station	Pre-mine area	Max mine area (Yr 12)	Yr 12 natural watershed area	Change in natural watershed area	Median elevation	Median elevation – mine infrastructure
	(km^2)	(km^2)	(km^2)	%	(m asl)	(m asl)
YT-24	11.83	0.396	11.43	-3%	812	1,140

Table 3-19 summarizes the parameters used in the watershed model to represent the pitwall runoff and natural drainage areas within the Yukon Tributary 24 catchment. The parameters can be cross-referenced to the conceptual diagram and GoldSim model architecture figure in Section 3.2, and the parameter descriptions presented in Table 3-5.

Table 3-19:
Watershed model parameters for the Yukon Tributary 24 watershed

Catchment	Kf	Ks	Kb	%Fast	%Slow	%Fast ToDeep	%Slow ToDeep	Deep Retained (mm)	%PE Deep	%Aufeis frozen	Aufeis melt rate/ Snow melt rate
Pitwalls	0.2	0.2	0.200	60%	40%	20%	20%	0	25%	100%	0.1
YT-24	0.4	0.97	0.990	40%	60%	60%	60%	0.5	100%	80%	0.1

3.4.2.1 *Contact Groundwater (Pit Leakage)*

Leakage from the SU3N, SU5S and SU5N pit lakes is assumed to report directly along with surface flows at YT-24. The maximum groundwater seepage rate that reports directly to YT-24 is approximately 0.5 L/s, occurring when the SU5S pit lake reaches the maximum elevation and begins to spill sometime in the Post-closure phase.

3.4.2.2 *Non-contact Runoff*

The WBM assumptions applied to the non-contact areas in the N1 sub-catchment are the same as those described in Section 3.3.2.4 for the N3 sub-catchment.

3.4.2.3 *Calibration of the Natural Watershed Model to Baseline Conditions for YT-24*

In Figure 3-36, Figure 3-37 and Figure 3-38 calibration plots are shown for the YT-24 WBM node.

Figure 3-36 shows daily flow duration curves at for the YT-24 node for the open water season (*i.e.*, April to October) and compares WBM output to results to the synthetically generated discharge records assembled for this location. Percent bias results (*i.e.*, PBIAS metric; WBM output *vs*. Synthetic time series) are plotted against probabilities of exceedance for the YT-24 node in Figure 3-37. Overall data in this figure show that for exceedance probabilities between 0.15 and roughly 0.8, PBIAS results computed from modeled and target flows are within the +/-25% threshold adopted as being acceptable for a watershed model (Moriarsi *et al.*, 2007). For exceedance probabilities between 0 and 0.15, Figure 3-37 indicates model under-estimation of highest flows at this location (*i.e*., PBIAS results are typically in the range -25 to -50%). Similarly, for low flow conditions the model shows under-estimated flows compared to the synthetic flow targets for exceedance probabilities greater than 0.8. It is noted though that for YT-24, flows corresponding to exceedances of >0.8 equate to flows that are less than 10 L/s and correspond to yields being less than 1 L/s/km^2. At monthly time step, all available flow outputs (*i.e*., measure, synthetic, modelled) are shown in Figure 3-38.

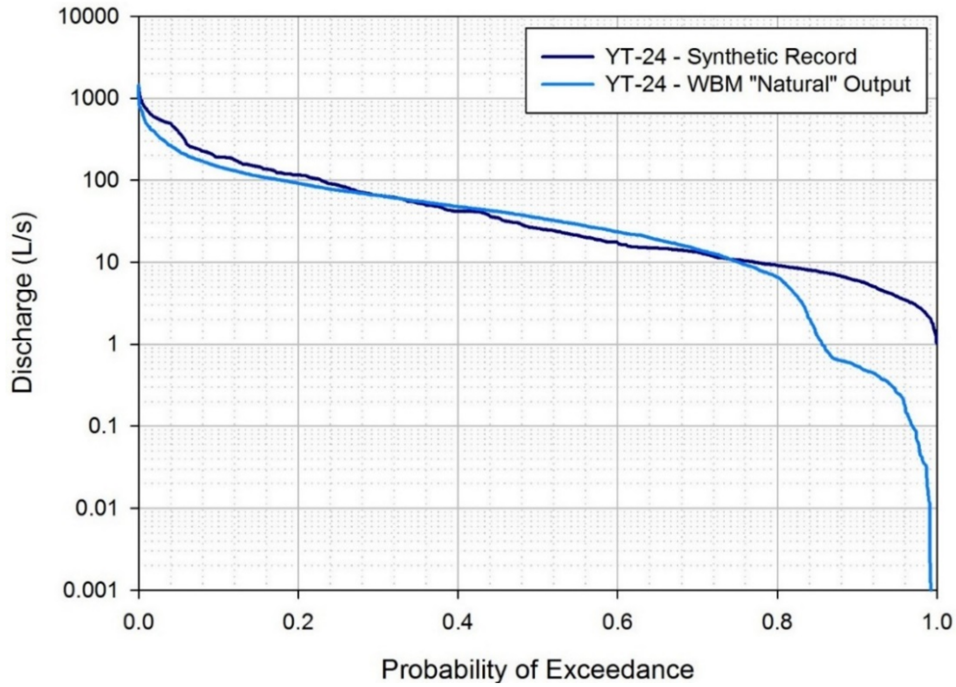


Figure 3-36: Flow duration curves for the YT-24 node showing the daily reconstructed discharge series and the WBM Natural run output, for the open water season (April to October).

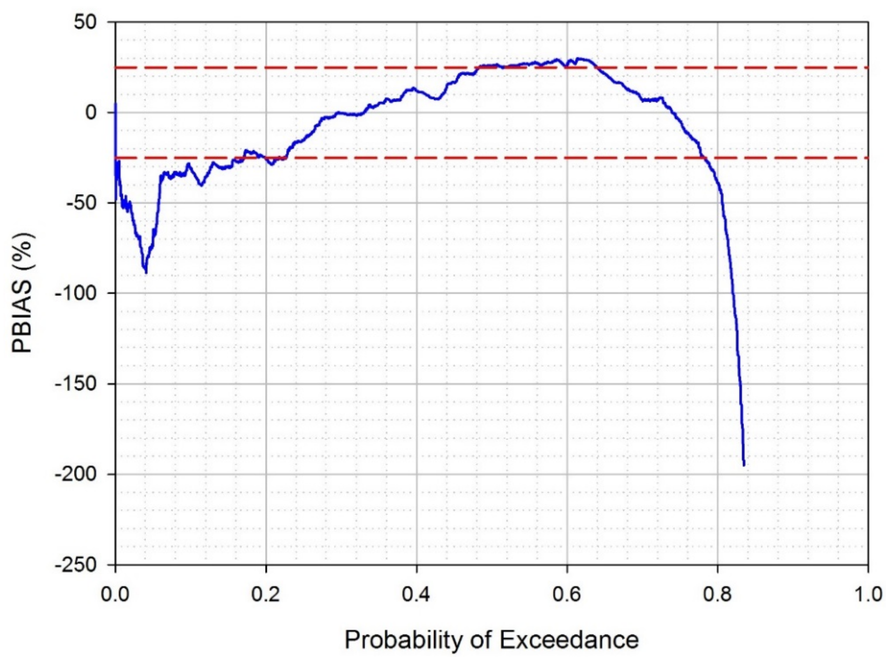


Figure 3-37: Percent bias plotted against the probability of exceedance for the YT-24 node, for the open water season (April to October). The red lines represent the +25% and -25% percent bias

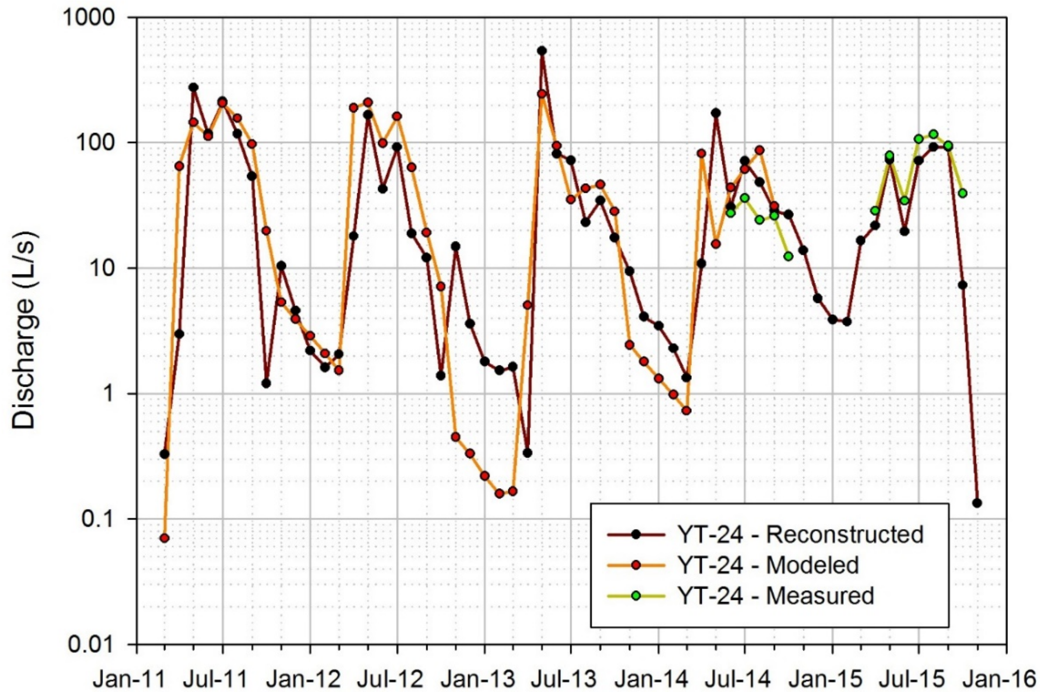


Figure 3-38: Time-series plot for the YT-24 showing the reconstructed, modeled (Natural Case) and baseline streamflows. Y-axis is log scale to highlight low-flow calibration

3.5 *Inputs and Assumptions – Halfway Creek*

This section outlines the input data and assumptions used to drive the Base Case WBM for the Halfway Creek watershed and nodes HC-2.5 and HC-5.0. As illustrated in Figure 2-1, a single large sediment collection pond will be constructed in this drainage downgradient of the toe of the Alpha WRSF, and upstream of the HC-2.5 node. In the sections below, WBM assumptions and inputs for Halfway Creek will be presented sequentially from the highest to lowest points in the watershed as follows:

- All inputs to the Alpha Pond;
    - Kona Pit and waste rock backfill;
    - Alpha WRSF infiltration;
    - Frozen soil stockpile;
    - Upgradient non-contact runoff not captured by the diversion channel;
    - Treated HLF draindown water;
- Additional non-contact flows reporting to the HC-2.5 node, and;
- Additional natural flows provided by the basin between HC-2.5 and HC-5.0.

3.5.1 Alpha Pond

The Alpha Pond is located to the north of the HLF and is situated in the headwaters of Halfway Creek above the HC-2.5 node. This pond will receive both contact and non-contact runoff, has a design capacity of 357,500 m^3, and is represented within the WBM in the same way as the other sediment collection ponds. The catchment area that contributes to the Alpha Pond, including all mine components and non-contact areas, is presented in conceptual form in Figure 3-39. The assumptions and parameterizations that informed the representation of these components are outlined in the following sections.

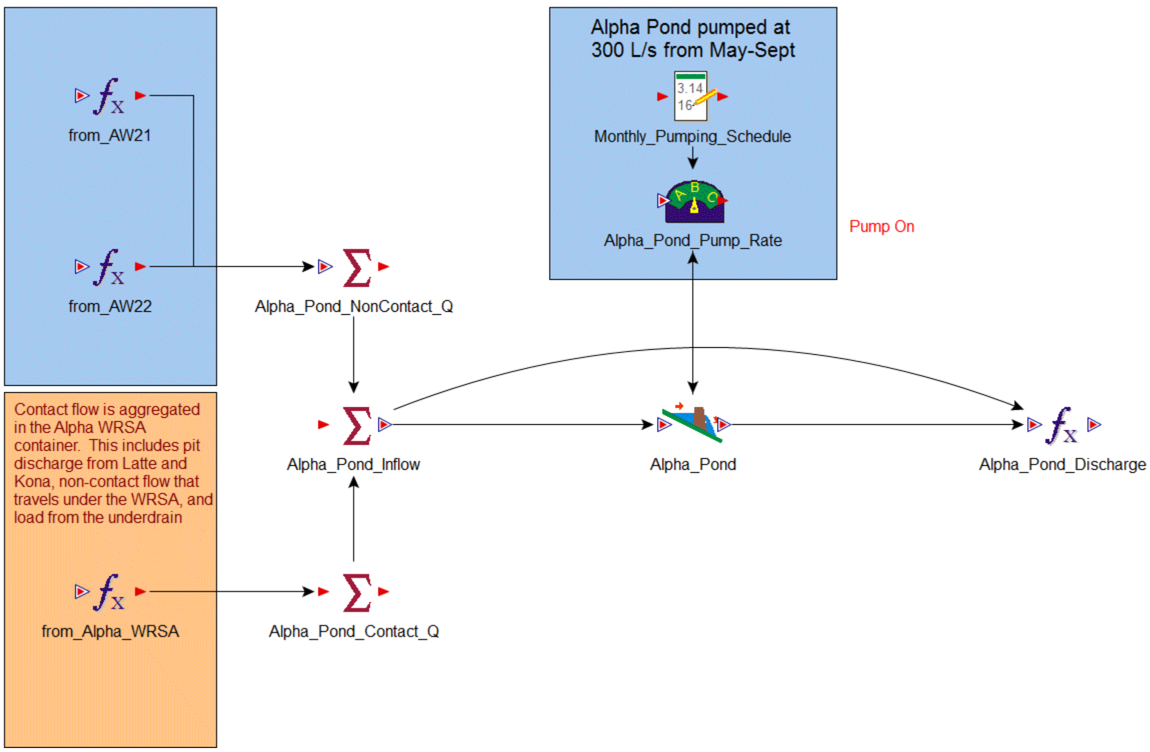


Figure 3-39: Alpha Pond conceptual diagram from GoldSim WBM.

3.5.1.1 *Kona Pit and Waste Rock Backfill*

All waste rock from this pit will be placed in a temporary WRSF (Beta) located adjacent to the pit. This waste rock is classified as potentially acid generating (PAG), and therefore it will be backfilled to the Kona pit in Year 11 of the Operations Phase. The EOM WBM assumes that all infiltration to the backfilled waste rock reports to the Alpha WRSF rock drain efficiently (*i.e.*, no infiltration is abstracted to fill the pit). All water that accumulates in the Kona pit during the Operation phase (this water will only be meteoric water entering the pit and not groundwater, as the base of the pit is above the local groundwater table) will be used in the process plant as make-up. Kona pit will be backfilled during winter, when the waste rock is frozen so that the backfill process will re-establish the permafrost. As such and in the future, water will not enter the backfilled pit voids but rather run off the waste rock in the active zone. This assumption has been incorporated into the WBM, and any waste rock runoff is routed directly to the Alpha WRSF rock drain accordingly, once the pit has been backfilled.

3.5.1.2 *Frozen Soil Stockpile*

The frozen soil stockpile is situated to the east and upgradient of the Alpha WRSF, occupies an area of 16 ha, and lies entirely within the Upper Halfway Creek watershed. This stockpile is modeled using a simple runoff coefficient approach, whereby the daily volume of meteoric inputs is modified by a factor of 0.7 to generate runoff from these areas.

3.5.1.3 *Heap Leach Facility*

The HLF is situated at the ridgetop, and straddles both the Upper Latte and Upper Halfway Creek watersheds, with 70.8 ha of the HLF located in the headwaters of Halfway Creek. All assumptions and flow volumes and routing are consistent with those described in Section 3.3.1.1. As outlined in Section 3.3.1.1, once treatment of the surplus HLF contact water begins, this treated water is assumed to be directly discharged to the Alpha WRSF rock drain, above the HC-2.5 node in Halfway Creek. Treatment and discharge are assumed to only occur during the 6 month open-water period. Further, it is assumed that water treatment capabilities will no longer be required by Year 20, at which point water from the detoxified HLF will be directed to passive treatment, then to the Latte pit lake, and then to the Alpha WRSF rock drain (see Figure 2-7). The ore heap is assumed to be covered at this point in time and overall the WBM targets an infiltration rate through the cover of the HLF at 25% of MAP.

3.5.1.4 *Non-contact Runoff*

The WBM assumptions applied to the non-contact areas in the Alpha Pond drainage are the same as those described in Section 3.3.2.4, noting that non-contact water from the raincoat ponds will be available for use as makeup water or will be discharged to the Alpha WRSF rock drain when not required. All other non-contact water from the areas surrounding the northern side of the HLF will drain passively to the Alpha WRSF rock drain.

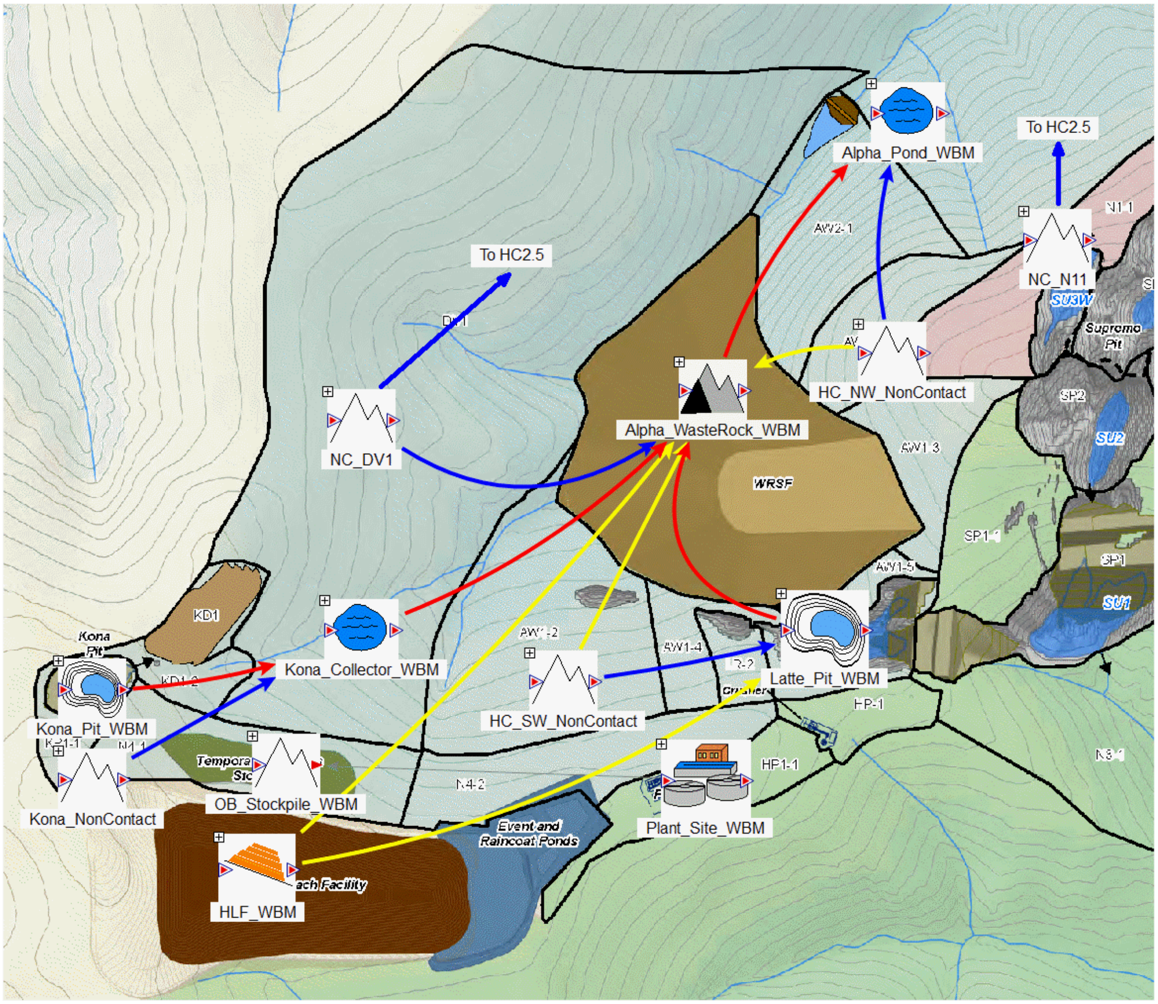


Figure 3-40: Alpha Pond catchment area. In this schematic, colour coding refers to the following cover types: light grey polygons (non-contact, undisturbed terrain), grey (exposed pit wall/surface), light blue (pit lake), beige (waste rock, in-pit backfill) and dark blue (sedimentation pond – Alpha Pond).

3.5.1.5 *Latte Pit – Operational Dewatering*

The modeling assumptions used for the open pits in the Alpha Pond drainage are the same as those presented in Section 3.3.2. The schedule (mining, dewatering, filling) for the Latte pit has been presented previously in Figure 3-15. The Latte pit is mined out in the 3rd year of Operations (Year 4), and is partially backfilled with waste rock during Years 2 to 4 to form a causeway.

3.5.1.6 *Open Pits – Filling and Spillover*

The sequence of pit lake formation and subsequent spill from Latte Pit is outlined in Section 3.3.2.3, and the lake elevation dependent fluxes into/out of the pit lake have been presented previously (refer to Table 3-9). The Supremo pit fluxes have also been presented previously in Sections 3.3.2.3 and 3.4.1.2. In the future, the Latte pit lake will spill to the Alpha WRSF rock drain, and this is predicted to occur in approximately 2052 – with WBM results showing some intermittent losses from the pit lake by the late 2040s (Figure 3-16). Predicted leakage rates for the pit lakes that report to Halfway Creek are outlined below.

Latte

At EOM, leakage from this pit lake reports to Halfway Creek at approximately 0.85 L/s. During the closure and post-closure phases, this pit lake is predicted to leak to Halfway Creek at 2.3 L/s, and YT-24 at 0.1 L/s. These leakage rates are approximately four times higher than those predicted to report to Latte Creek from this pit lake (see Section 3.3.2.3).

SU2

At EOM, leakage from this pit lake reports to Halfway Creek at approximately 0.03 L/s. During the closure and post-closure phases, this pit lake is not predicted to leak to Halfway Creek via the groundwater system.

SU3W

At EOM, leakage from this pit lake to Halfway Creek is predicted to be minimal (0.01 L/s). During the closure and post-closure phases, this pit lake is predicted to leak to Halfway Creek at 0.28 L/s.

SU3N

At EOM, leakage from this pit lake to Halfway Creek is predicted to be minimal (0.24 L/s). During the closure and post-closure phases, this pit lake is predicted to leak to Halfway Creek at 0.43 L/s – a rate approximately four times the leakage expected to report to the YT-24 node from this pit lake during closure (see Section 3.4.1.2).

SU4N

Leakage from this pit lake to Halfway Creek is predicted to be minimal, ranging from 0.02 L/s at EOM, to 0.008 L/s during the closure and post-closure phases.

SU5S

Leakage from this pit lake to Halfway Creek is predicted to be minimal (0.01 L/s) at OM, and non-existent during closure and post-closure.

SU5N

Leakage from this pit lake to Halfway Creek is predicted to be minimal (0.002 L/s) at OM, and non-existent during closure and post-closure.

3.5.1.7 *Alpha WRSF*

The assumptions employed in the WBM to represent the Alpha WRSF are consistent with those described in Section 3.3.2.1 for the Double Double waste rock backfill. The expected attenuation of streamflows by the Alpha WRSF is of particular relevance to the Halfway Creek drainage.

On a sub-annual time-scale, the WRSFs are also assumed to attenuate streamflow locally, as the high pore space volume and higher than natural proportion of fines acts to slow runoff generation as meteoric water works its way through the WRSFs. Specifically, a review of the available literature indicates that placement of waste rock typically attenuates the peak flows in the watershed, and enhances summer low flows. This process is driven mainly by matrix flow within the fines content of the waste rock pile, which was found to be the main component of the runoff regime by Nichol *et al*. (2005) and Neuner *et al*., 2013. An example of how this process was incorporated into the WBM is shown in Figure 3-41, for the Alpha WRSF. Note that this figure shows the contact and non-contact flows that report to the Alpha Pond for the year 2024 (Year 4 of mine life).

The mine plan currently states that where possible, the first lift (approximately 5 m) of all new WRSF areas will be placed during the winter season to ensure that the foundation soils remain frozen. This step is intended to avoid deformation due to creep of frozen soil or a potential sliding failure through the frozen overburden. Accordingly, the WBM assumes that due to the presence of permafrost beneath the WRSFs, and the construction of the rock drains beneath each WRSF, there is no infiltration to the underlying groundwater system. Given the topographic relief of the WRSF sites and prevalence of permafrost, it is understood that the rock drains will be highly effective and that WRSF seepage will report to the water collection systems and sedimentation ponds and not to groundwater. Furthermore, it is more conservative from a surface water quality effects standpoint to assume that WRSF seepage reports to the sediment ponds rather than groundwater. Overall, this is consistent with the assumptions in the numerical groundwater model (Appendix 7-B-1).

A time-series plot of the annual variation in the modeled percentage of annual precipitation that infiltrates the WRSFs located within the Alpha Pond drainage is provided in Figure 3-42. As per other WRSFs represented in the WBM, while the long-term average infiltration is 35% of MAP, infiltration varies substantially from year-to-year for the Alpha WRSF, with maximums approaching 50% of annual precipitation and minimum values being 21% in comparison.

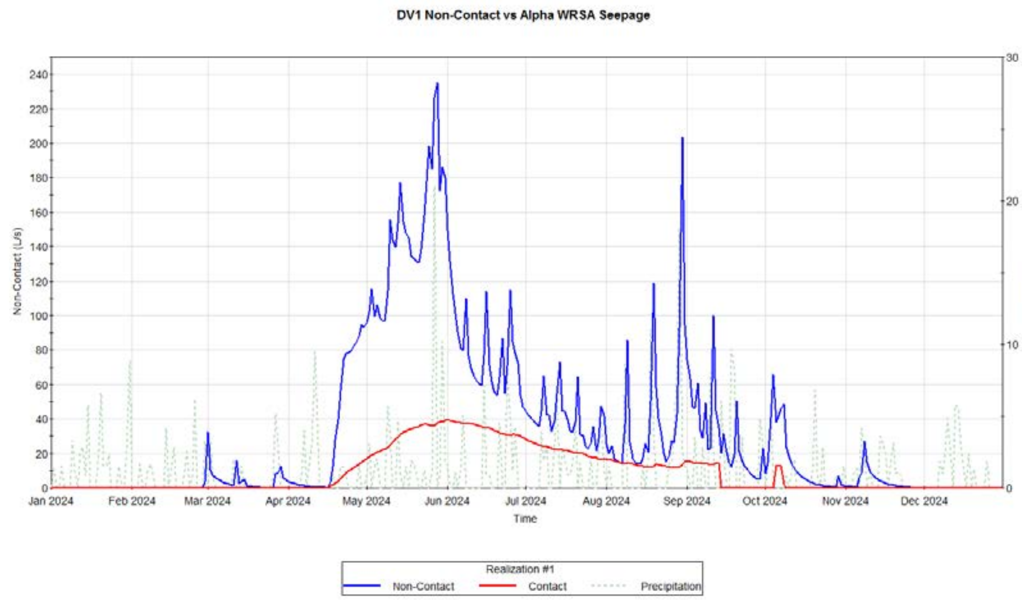


Figure 3-41: Precipitation and runoff relationship for the Alpha WRSF from a representative year (2024) – output from the WBM.

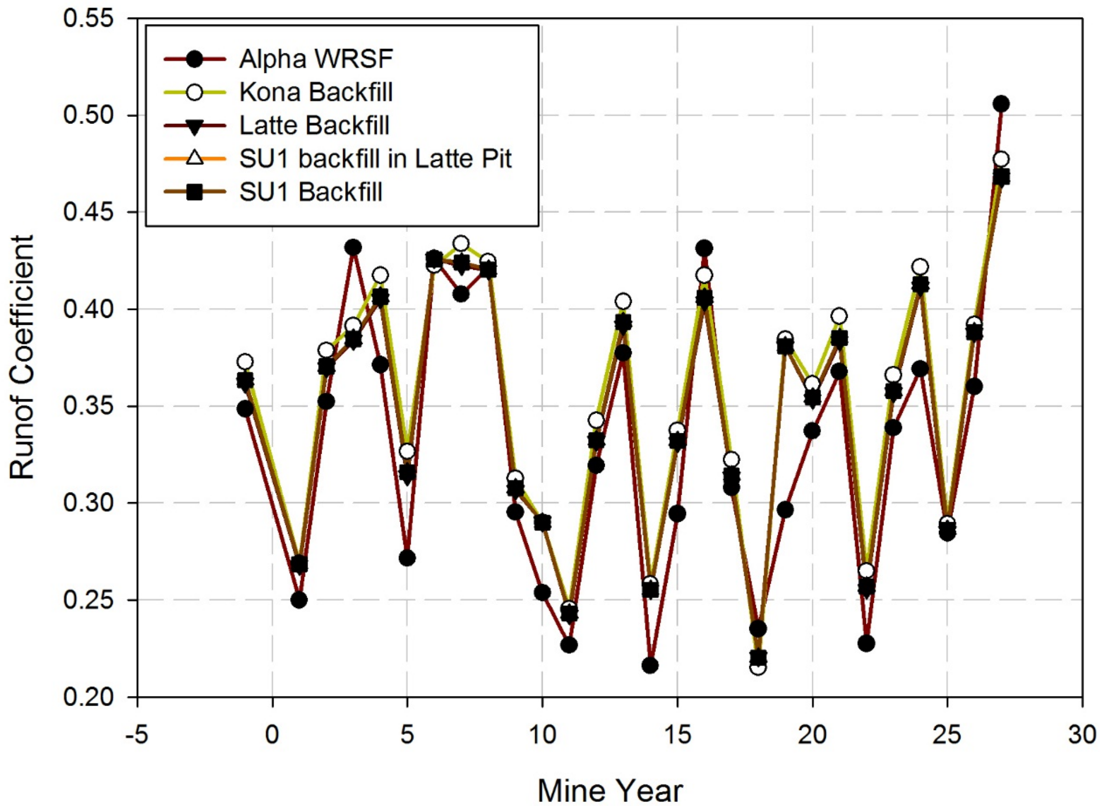


Figure 3-42: Annual variation in the modeled percentage of annual precipitation that infiltrates the Alpha WRSF.

3.5.2 HC-2.5

The HC-2.5 WBM node represents the first receiving environment point below mine infrastructure in Halfway Creek (Figure 3-1), and represents a watershed with area 15 km^2. All flows emanating from the Kona Pit, the Alpha Pond and the natural drainage areas located downgradient of these ponds report to the HC-2.5 water balance node. Table 3-20 provides a summary of the mine affected areas located within the Halfway Creek drainage.

Table 3-20:
End of Mine (EOM) areas by mine footprint type for each watershed of interest

Footprint	Halfway
Exposed Pitwall Area	42.5
WRSF Area	146.4
Backfilled Waste Rock	11.4
Frozen Soil	16.1
Camp/Plant Site	3.8
Soil Stockpile	16
ROM Stockpile	-
Heap Leach Facility	70.8
Total Mine Area (km^2)	3.1

Note: All values are in hectares except where noted.

The information presented in Table 3-21 indicates that the total area occupied by mine infrastructure in each watershed is approximately 3.1 km^2. This results in percent reductions of the un-impacted watershed area of roughly -21% for the HC-2.5 node, and -11% for the HC-5.0 node.

Table 3-19:
Existing and mined (Year 12) watershed areas and median elevations

Station	Pre-mine area	Max mine area (Yr 12)	Yr 12 natural watershed area	Change in natural watershed area	Median elevation	Median elevation – mine infrastructure
	(km^2)	(km^2)	(km^2)	%	(m asl)	(m asl)
HC-2.5	14.76	3.07	11.69	-21%	1,057	1,148
HC-5.0	27.04	3.07	23.97	-11%	896	1,148

Table 3-22 summarizes the parameters used in the watershed model to represent the various mine components and natural drainage areas within the Halfway Creek catchment and may be cross-referenced to the conceptual diagram and GoldSim model architecture (Figure 3-3) in Section 3.2 and the parameter descriptions for the WBM in Table 3-5.

Table 3-22:
Watershed model parameters for the Halfway Creek watershed

Catchment	Kf	Ks	Kb	%Fast	%Slow	%Fast ToDeep	%Slow ToDeep	Deep Retained (mm)	%PE Deep	%Aufeis frozen	Aufeis melt rate/ Snow melt rate
Pitwalls	0.2	0.2	0.200	60%	40%	20%	20%	0	25%	100%	0.1
Backfill*	0.2	0.92	0.960	60%	40%	70%	70%	0	40%	100%	0.1
HLF Closure*	0.4	0.97	0.990	40%	60%	90%	90%	0.5	50%	100%	0.1
Alpha WRSF*	0.2	0.92	0.985	60%	40%	100%	100%	10	35%	100%	0.1
HC-2.5	0.2	0.92	0.985	20%	80%	60%	10%	20	40%	50%	0.1
HC-5.0	0.2	0.92	0.985	20%	80%	60%	10%	20	40%	50%	0.1

*Runoff is masked to zero.

3.5.2.1 *Contribution from Alpha Pond*

The WBM assumes that the Alpha Pond passively fills and is pumped to the HC-2.5 node at a rate of 300 L/s (while water is present within the pond) for the months of May through September throughout operations. This pond is removed in 2043 (Mine Year 23), and all contact drainage that previously reported to this pond is assumed to report passively to the HC-2.5 node.

3.5.2.2 *Contact Groundwater (Pit Leakage)*

Leakage from the upgradient pit lakes that are predicted to leak towards Halfway Creek are assumed to report directly along with surface flows to the HC-2.5 node. The maximum groundwater seepage rate that is predicted to report to HC-2.5 is approximately 1.2 L/s at EOM, and 3.0 L/s during post-closure, which occurs once all pit lakes are at their spill elevations. Specifics on the pit lake leakage rates are provided in Appendix 7-B-1.

3.5.2.3 *Non-contact Runoff*

The WBM assumptions applied to the non-contact areas in the HC-2.5 watershed are the same as those described in Section 3.3.2.4 for the N3 sub-catchment. The non-contact watershed captured by the Alpha WRSF diversion ditch (located to the north-west of the WRSF) is routed to the HC-2.5 node as well. This diversion reduces the volume of water reporting to the Alpha WRSF rock drain, and is assumed to be maintained in perpetuity.

3.5.3 Calibration of the Natural Watershed Model to Baseline Conditions for HC-2.5 and HC-5.0 Nodes

3.5.3.1 *HC-2.5*

In Figure 3-43, Figure 3-44 and Figure 3-45, calibration plots are shown for the HC-2.5 WBM node. Daily flow duration curves for the HC-2.5 node and open water season (*i.e.*, April to October) are shown in Figure 3-43 and compares WBM output to results to the synthetically generated discharge records assembled for this location.

Percent bias results (*i.e.*, PBIAS metric; WBM output *vs*. Synthetic time series) are plotted against probabilities of exceedance for the HC-2.5 assessment node in Figure 3-44. Overall, data in this figure show that for exceedance probabilities greater than 0.08, computed PBIASs are within the +/-25% threshold adopted as being acceptable for a watershed model (Moriarsi *et al.*, 2007). For exceedance probabilities less than 0.08, Figure 3-44 indicates model under-estimation of highest flows at this location (*i.e.*, PBIAS results are in the range -25 to -110%). At monthly time step, all available flow outputs (*i.e.*, measure, synthetic, modelled) are shown in Figure 3-45 for HC-2.5.

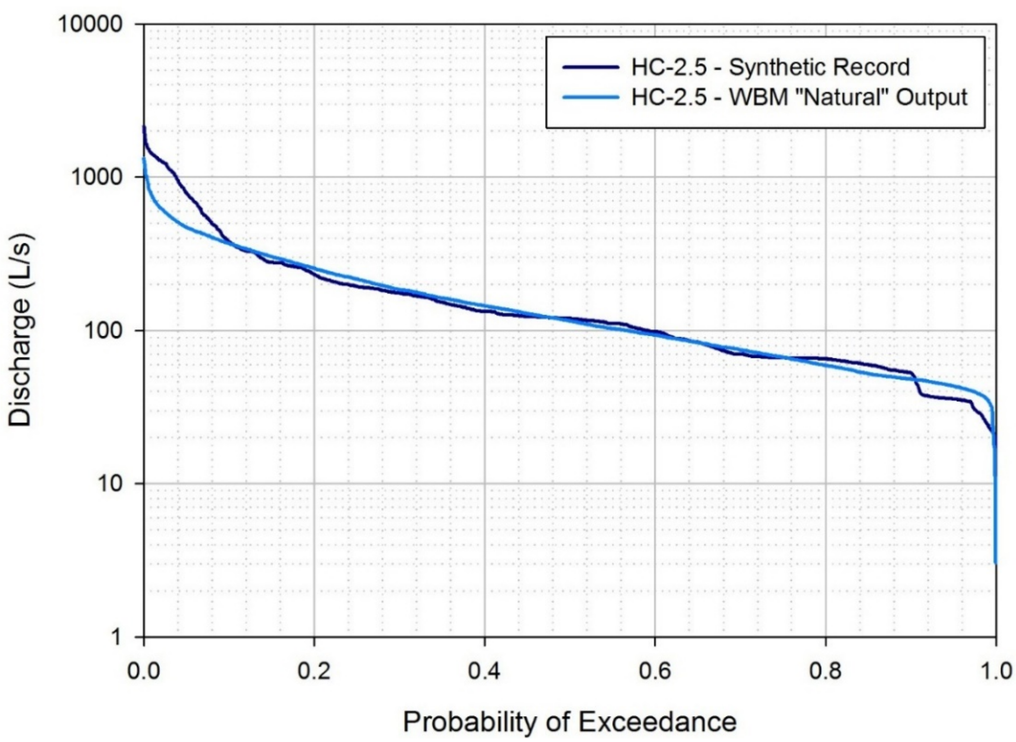


Figure 3-43: Flow duration curves for the HC-2.5 node showing the daily reconstructed discharge series and the WBM Natural run output, for the open water season (April to October).

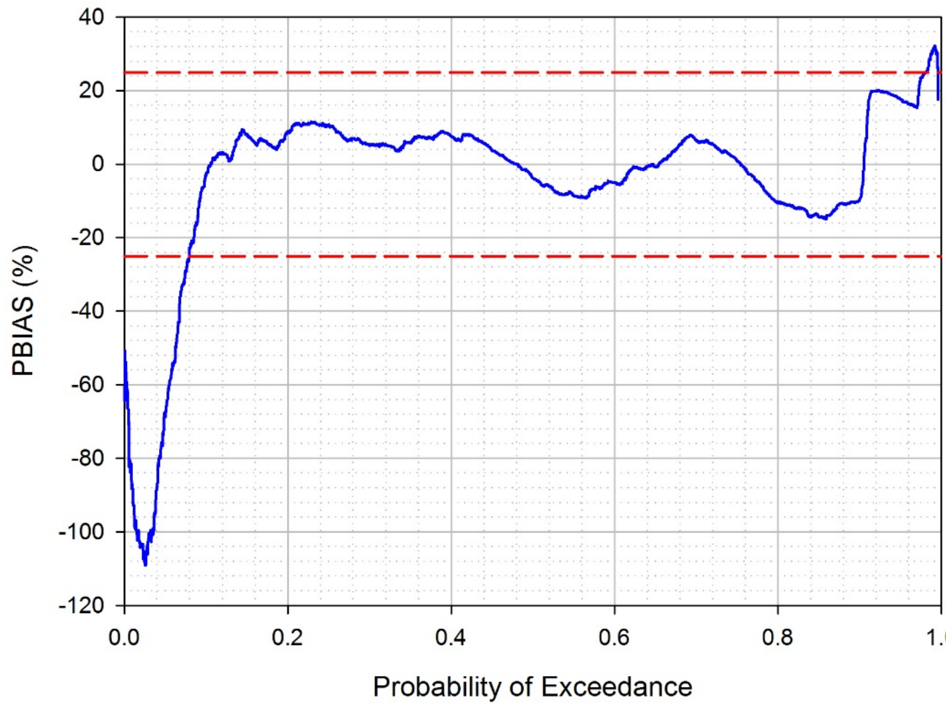


Figure 3-44: Percent bias plotted against the probability of exceedance for the HC-2.5 node, for the open water season (April to October). The red lines represent the +25% and -25% percent bias.

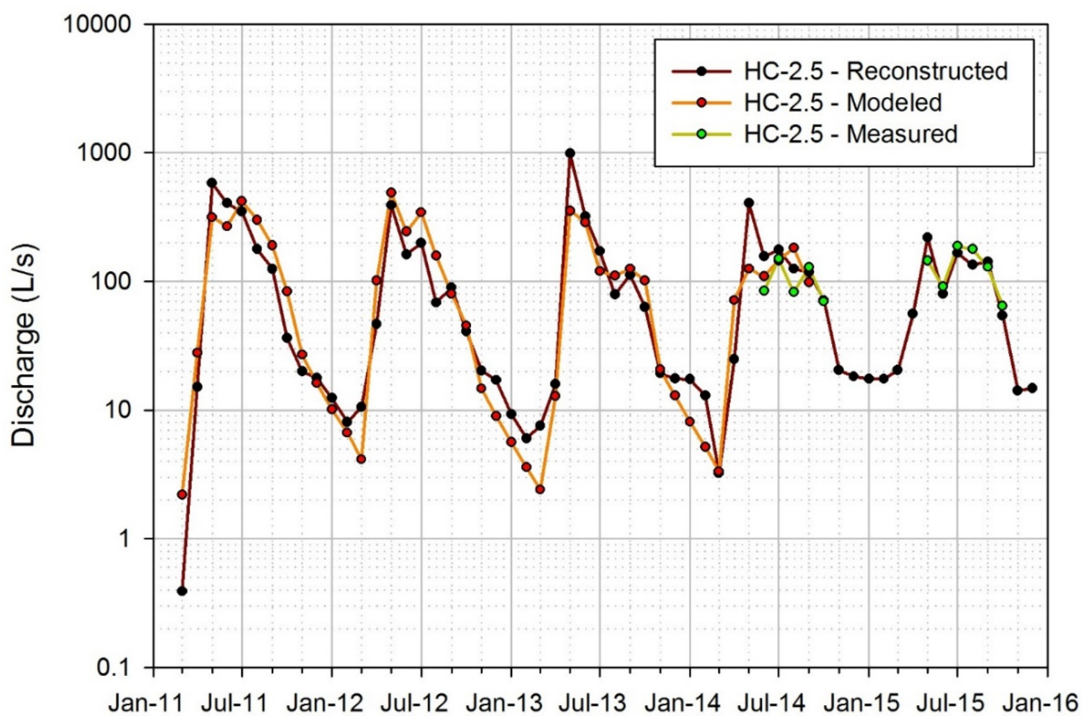


Figure 3-45: Time-series plot for the HC-2.5 showing the reconstructed, modeled (Natural Case) and baseline streamflows. Y-axis is log scale to highlight low-flow calibration.

3.5.3.2 *HC-5.0*

In Figure 3-46, Figure 3-47 and Figure 3-48, calibration plots are shown for the HC-5.0 WBM node. Figure 3-51 shows daily-, flow duration curves for the HC-5.0 node for the open water season (*i.e.,* April to October) and compares WBM output to results to the synthetically generated discharge records assembled for this location.

Percent bias results (*i.e*., PBIAS metric; WBM output vs. Synthetic time series) are plotted against probabilities of exceedance for the HC-5.0 assessment node in Figure 3-47. These data show that this figure show that for exceedance probabilities that range from 0.03 to 0.75, computed PBIASs are within the +/-25% threshold adopted as being acceptable for a watershed model (Moriarsi *et al.,* 2007). For exceedance probabilities greater than 0.75, Figure 3-47 indicates model overestimation of lowest flows predicted at this station (*i.e.,* PBIAS results are in the range 25 to 100%). At monthly time step, all available flow outputs (*i.e.,* measure, synthetic, modelled) are shown in Figure 3-48 for HC-5.0.

As noted in the hydrometeorology baseline report (Appendix 8-A), there is a reduction in streamflow between the HC-2.5 and HC-5.0 stations on Halfway Creek, for certain flow conditions. These “losing” reaches are thought to exist due to flow abstractions through the structural lineament that cross cuts both Halfway and Coffee Creeks (refer to Appendix 7A). These flow abstractions are most noticeable in the baseline record during periods of low streamflow, both during the open water season and the winter. In addition, these losing reaches appear to influence the concentrations of certain PCOCs (*e.g.,* U and As).

The quality of the baseline data set allows these relationships to be ascertained with a high level of confidence, and to be robustly represented in the WBM. The model handles this losing reaches as follows. For Halfway Creek, the surface flow at HC-2.5 is routed to a splitter, which diverts the 15 L/s from surface flow at HC-2.5 to the groundwater system and then directly to the Yukon River – bypassing HC-5.0. The incremental catchment area downstream of HC-2.5 does not have flow diverted using the same method, which allows representative PCOC concentrations to be set for the downstream nodes that reflect baseline conditions. This is done year-round, and as stated above, the effect is most noticeable for the winter flows because the abstracted flow is a relatively larger proportion of the total surface flow.

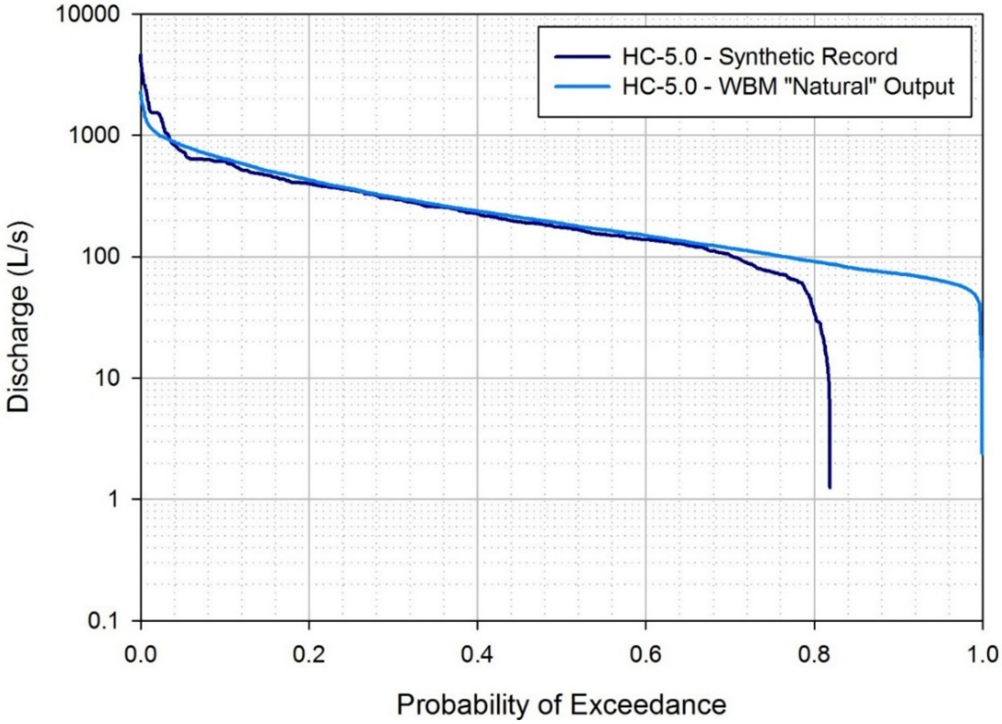


Figure 3-46: Flow duration curves for the HC-5.0 node showing the daily reconstructed discharge series and the WBM Natural run output, for the open water season (April to October).

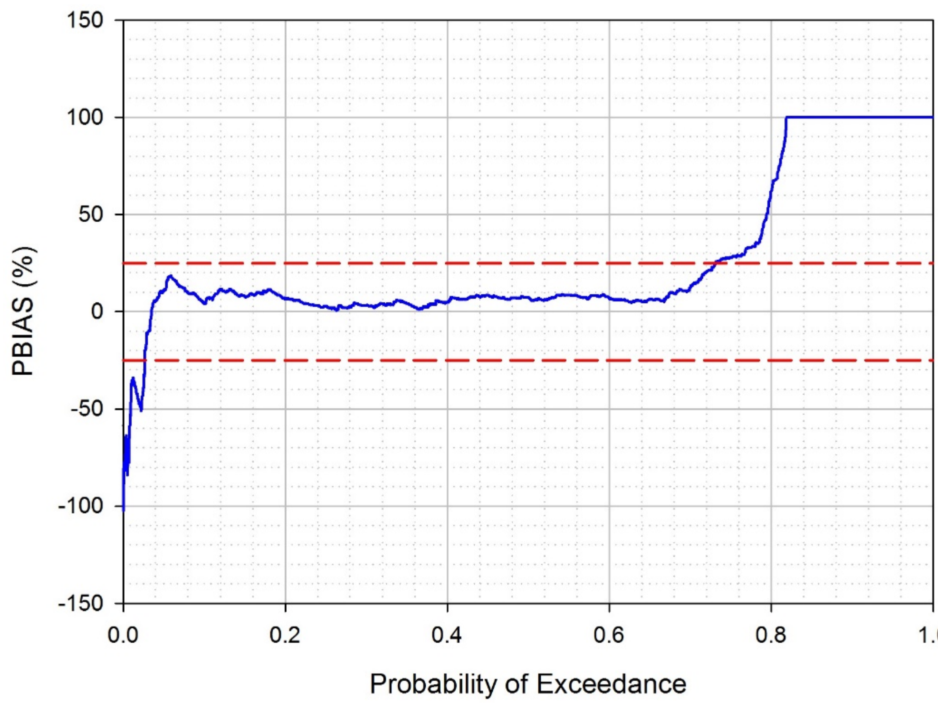


Figure 3-47: Percent bias plotted against the probability of exceedance for the HC-5.0 node, for the open water season (April to October). The red lines represent the +25% and -25% percent bias.

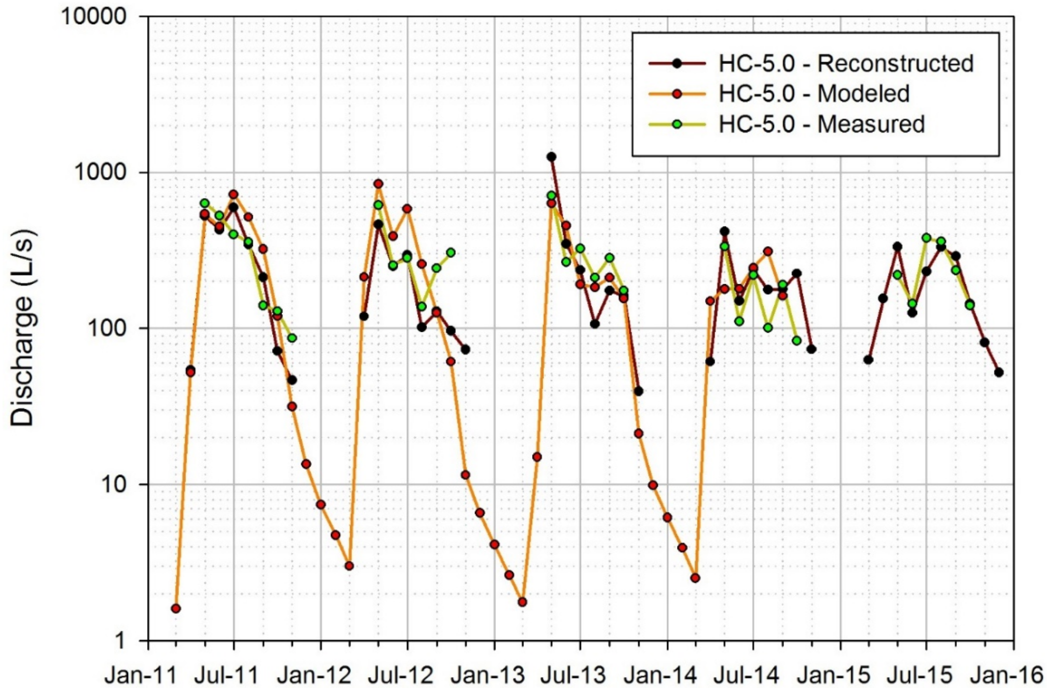


Figure 3-48: Time-series plot for the HC-5.0 showing the reconstructed, modeled (Natural Case) and baseline streamflows. Y-axis is log scale to highlight low-flow calibration.

3.6 *Results*

The degree to which the natural streamflow regimes may be altered must be quantified, as this information is an integral component of the environmental assessment process that is mandated by YESAA. A quantification of the potential residual changes to the existing streamflow regime is also required as an input to site-wide water quality modeling efforts, fish and fish habitat impact assessments, site-wide water management planning and groundwater modeling exercises. The streamflow alterations predicted by the WBM are considered to represent the most plausible impacts of the proposed Project on streamflows in the Project area. The WBM predictions presented in this section of the report compare Baseline (Natural Flow) to Base Case (Mine Altered) flow outputs for several modelling locations, and serve as inputs to the relevant IC and VC assessments included as part of the Project Proposal.

As presented in Section 3.3, 3.4 and 3.5, the year by year progression of open pits, waste rock storage facilities, the HLF and stockpiles *(i.e.*, soil, ROM ore, crushed ore) are all represented in the WBM, as are proposed water management structures (*e.g.*, sediment control ponds, diversion ditches) and water management activities (*e.g.*, pit dewatering, conveyance through toe drains, consumptive uses of water) per phase of the Project. The Construction, Operation, Closure and Post-closure phases of the Project will, to a minor degree, alter the extent of local watershed boundaries as water from various mine components will be routed to central management locations (*e.g.,* open pits, sediment control ponds). Over the Project timeline, ground surface characteristics will change as pits are developed, ore is stockpiled and placed on the heap leach facility, waste rock is deposited in WRSFs and water management infrastructure is constructed and operated.

Open pits will store water and likely will reduce runoff while the pits are filling, whereas surface water diversions have the potential to remove flow from one drainage and increase flow in an adjacent watershed. The Heap Leach Facility (HLF) will operate as a closed loop for most of the Construction and Operation phase, and will therefore remove a portion of the runoff from the headwaters of both Latte and Halfway Creeks – as the HLF is located in the headwaters of both these watersheds. Sediment ponds located downgradient of Project infrastructure (*i.e.,* Facility Pond and Alpha Pond) will collect contact and non-contact runoff and may attenuate peak flows (*i.e.,* delay runoff response and moderate peak flows). Finally, the proposed WRSFs are anticipated to store and release water differently from the natural areas they once were (*e.g.,* attenuate the snowmelt freshet signature and enhance summer low flows). Considered in aggregate, these alterations within the Project drainages have the potential to change flow conditions in local creeks and streams from their baseline condition.

3.6.1 Overview of Appendix 3 - Data Tables and Summary Figures

A comprehensive summary of WBM results is presented for the Coffee Project in Appendix 3 of this report. A short synthesis of Appendix 3 output is presented for Latte/Coffee Creeks (Section 3.6.2), YT-24 Tributary (Section 3.6.3) and Halfway Creek (Section 3.6.4) in the sections below, noting that Appendix 8-B (Surface Hydrology IC Analysis Report) provides a discussion of predicted flow changes for local tributaries and the Yukon River using an Indicator Approach.

Prior to presenting a watershed-by-watershed synthesis of the WBM results, an overview of the results for WBM node CC-1.5 (refer to Appendix 3, 3.1 CC-1.5 Upper Latte Creek) follows to give the reader a sense of the data tables and summary plots that outputs of the WBM. Firstly, in each sub-section of Appendix 3 (*e.g.,* 3.1 is the CC-1.5 assessment node), three summary statistical tables are presented:

e.g., Table 3.1-1: This table summarizes discharge data for the Baseline (Natural Flow) run of the WBM. Data are shown for CC-1.5 and organized by Project Phase (Construction, Operation, Closure and Post-closure). In this table, discharge data are summarized monthly and annually for eight discharge metric (*i.e.*, Minimum, 10^{th} Percentile, Lower Quartile, Median, Mean, Upper Quartile, 90^{th} Percentile, Maximum) with data summarized in units m^3/s.

e.g., Table 3.1-2: Like Table 3.1-1, this table summarizes discharge data for the Base Case (Project Altered) run of the WBM. Data are shown for CC-1.5 and organized by Project Phase (Construction, Operation, Closure and Post-closure). In this table, discharge data are summarized monthly and annually for eight discharge metric (*i.e.*, Minimum, 10^{th} Percentile, Lower Quartile, Median, Mean, Upper Quartile, 90^{th} Percentile, Maximum) with data summarized in units m^3/s.

e.g., Table 3.1-3: This table summarizes Percent Change data for the CC-1.5 WBM node. On a month-by-month basis, Percent Changes were computed using life of mine Baseline and Base Case discharge data using the following equation:

$$\%\Delta Flow = \left(\frac{Base\ Case\ Flow - Baseline\ Flow}{Baseline\ Flow}\right) x\ 100$$

Like the discharge data presented in Tables 3.1-1 and 3.1-2, Percent Change data are summarized monthly and annually for each Project phases, with output for eight statistics (Min, 10^{th} Percentile, Lower Quartile, Median, Mean, Upper Quartile, 90^{th} Percentile, Max) presented in the table.

It is important to note that the three tables and related graphs presented in Appendix 3 that the flow outputs (*i.e.,* monthly discharge data for Baseline (Natural) and Base Case) from the WBM and Percent Change summaries that are presented for each station and Project phase, consider 28 WBM realizations whereby climate input data were time-shifted to give a large output dataset. In this regard, any statistics presented in data tables were computed using all available output per Project phase. For example, the Operation Phase spans twelve years, with 28 iterations for each year. Therefore, the monthly sample size that Percent Change statistics were based on is n = 336 (per month) for the Operation Phase – all of which are incorporated into final tallies in data tables and also shown on summary figures per assessment node.

Four types of plots feature prominently in the WBM output presented in Appendix 3:

e.g., Figure 3.1-3 (reproduced as Figure 3-49 below): For the Construction phase at CC-1.5, this plot shows monthly time series data for the Baseline (Natural) and Base Case WBM runs. Monthly discharge data for three metrics (minimum, average and maximum) are shown in the plot. This time series plot gives an indication of the magnitude (difference between the Baseline and Base Case output) and timing (which months and seasons are different) of streamflow alterations predicted at CC-1.5 for this phase of the Project.

e.g., Figure 3.1-4 (reproduced as Figure 3-50 below): This plot shows the relationship between Discharge (Y-axis, Base Case WBM output) and Percent Change calculations (X-axis) for the Construction phase at CC-1.5. For reference, +/-10 Percent Change thresholds are shown in the figure with dashed grey line.

e.g., Figure 3.1-5 (reproduced as Figure 3-51 below): Baseline (Natural) and Base Case monthly discharge data for CC-1.5 are shown for the Construction phase of the Project in flow duration curve format. Data shown are for the open water period (*i.e.,* April to end of October) with 30% MAD for Construction shown by dashed blue line. Similarities and differences in the flow duration curves for the two cases are indicative of flow conditions (*i.e*., high flow, low flow) and magnitude of predicted streamflow change associated with the Project.

e.g., Figure 3.1-6 (reproduced as Figure 3-52 below): This plot shows a box and whisker summary of Percent Change output for the Construction phase at CC-1.5. Median and upper/lower quartile data are shown by shaded box, 5^{th} and 95^{th} percentile data shown with tails and outliers by shaded circles.

Like the plots presented for Construction phase, four plots are presented in Appendix 3 for each additional phase of the Project *(i.e.,* Operations, Closure, Post-closure), totalling 16 plots as the means to summarize flow changes across the Project timeline. Additionally, two plots (*e.g.,* Figure 3.1-1 and Figure 3.1-2 for CC-1.5) that summarize Life of Mine output from the WBM (*i.e.,* no grouping by Project phase) in Discharge-Percent Change and flow duration curve format are also provided in Appendix 3 for review.

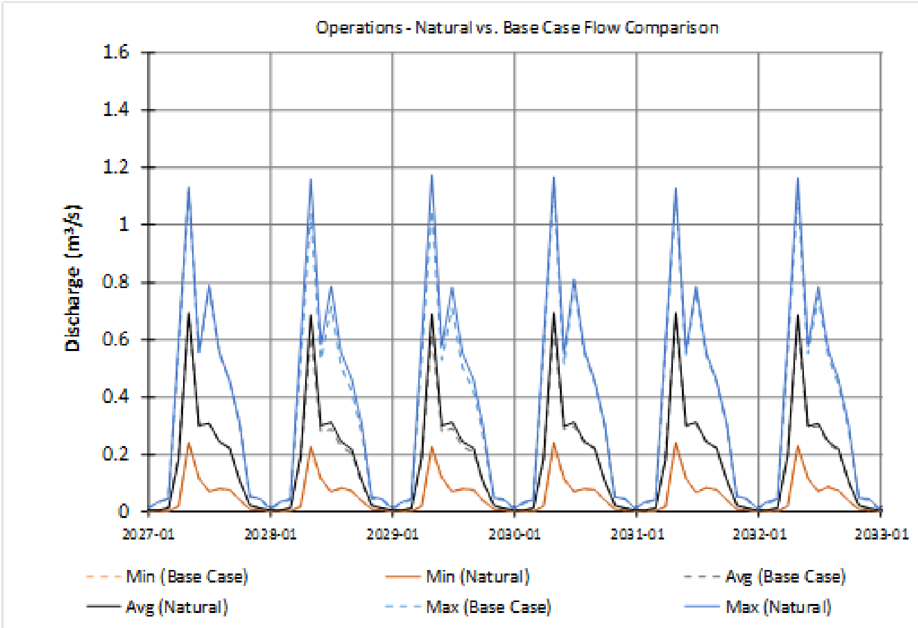


Figure 3-49: Time series plot showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the End of Operations phase of the Project and were computed from 28 WBM realizations.

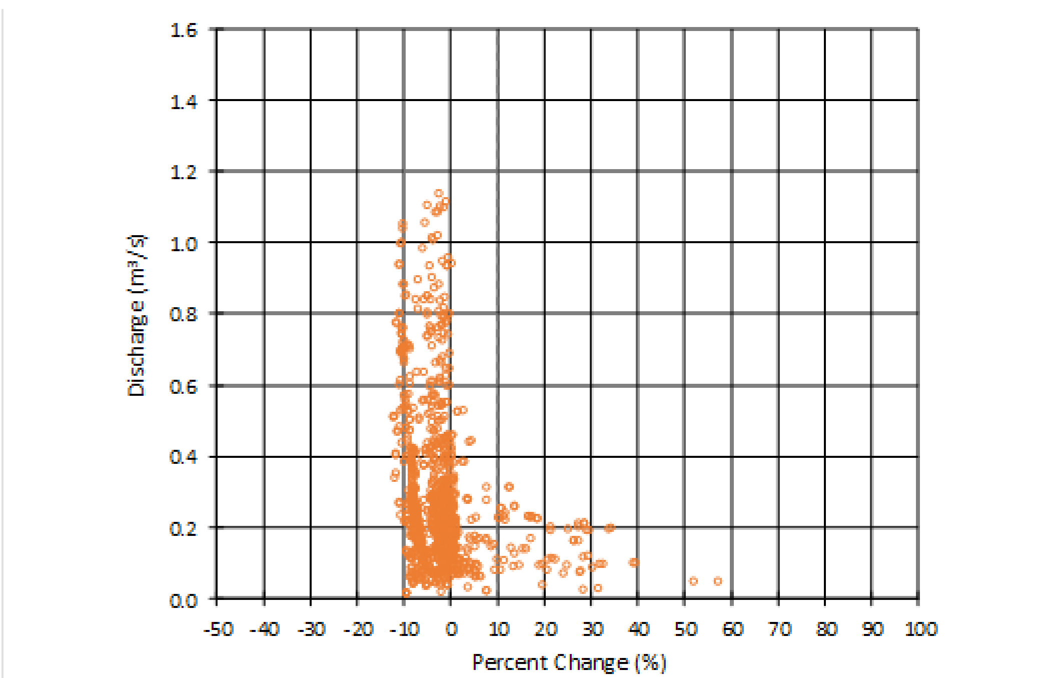


Figure 3-50: End of Operations phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at CC-1.5, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.

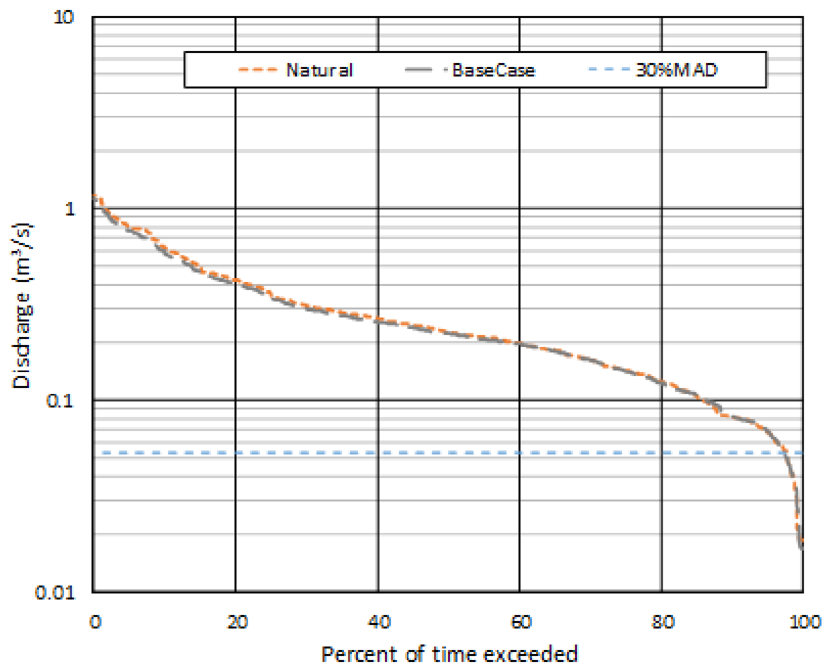


Figure 3-51: Natural and Base Case monthly discharge data for CC-1.5. Data shown are for the End of Operations phase and are presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Operations shown by dashed blue line.

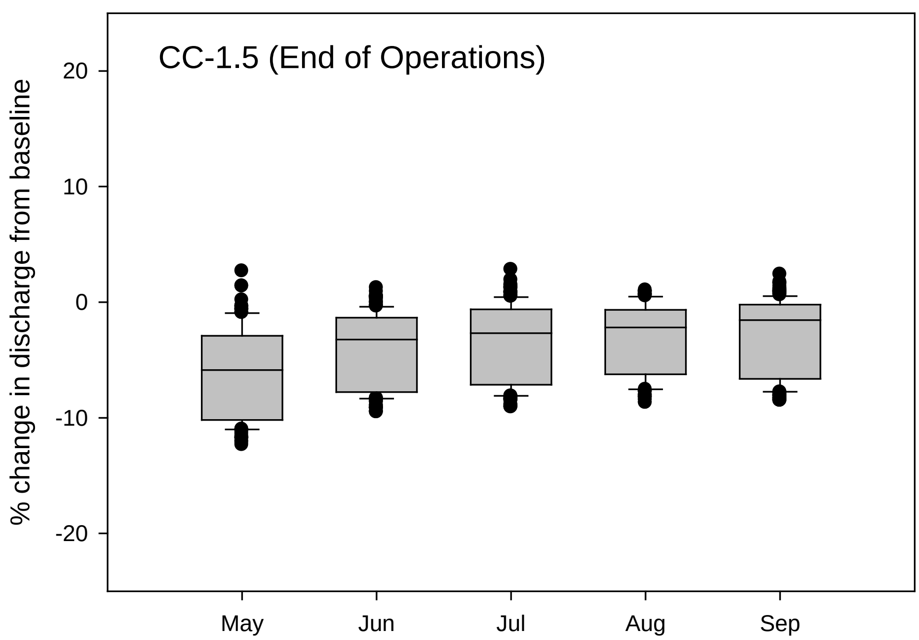


Figure 3-52: Box and Whisker Plot percent change summary for the End of Operations phase at CC-1.5. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

3.6.2 Latte Creek and Coffee Creek

Water balance results for Latte and Coffee Creek modelling locations are presented in Appendix 3.1 through 3.4). Appendix 3 includes output for the following locations in the Latte and Coffee Creek drainages: Appendix 3.1, CC-1.5 (Latte Creek below the N3 sub-catchment); Appendix 3.2, CC-3.5 (Latte Creek upstream of Coffee Creek); Appendix 3.3, CC-0.5 (Coffee Creek upstream of Latte Creek; and Appendix 3.4, CC-4.5 (Coffee Creek downstream of Latte Creek (near Yukon River)). The position of these nodes in the Latte/Coffee Creek watershed has been shown previously (refer to Figure 3-1).

For WBM outputs corresponding to 10th Percentile, Mean and 90th Percentile results, Table 3-21 presents a Percent Change Summary for Latte and Coffee Creek WBM nodes and for each phase of the Project. While outputs for additional metrics, including monthly minimum and maximum Percent Changes are provided as part of the WBM output presented in Appendix 3, 10th/90th percentile and average Percent Changes results are viewed as useful indicators to compare and contrast predicted flows changes by Project phase and frame results.

Percent Change data are reported for months April to end-October (inclusive) in Table 3-21, thus corresponding to months that comprise the open water period. In Table 3-21 and similar tables presented later in this section for YT-24 and Halfway Creek, blue shaded cells represent predicted negatives changes (*i.e.*, flow reductions associated with the Project) greater than a 5% threshold, and beige shaded cells represent predicted positive changes (*i.e*., flow increases associated with the Project) greater than a 5% threshold. The selection of the +/-5% change threshold is viewed as being conservative given that a 10% change from natural condition is associated with having a low probability of detectable impacts to ecosystems that support commercial, recreational or Aboriginal fisheries (DFO, 2013).

Generally speaking, larger percent changes are predicted for winter months (refer to Table 3.1-3 for CC-1.5) compared to open water months, but these larger changes are considered to be less relevant for three reasons:

- Firstly, winter flows are so low at the Project site (see Appendix 8-A; annual low flows range from 0 – 0.7 L/s/km^2) that even a small absolute change in discharge translates into a relatively large relative change from the baseline condition;
- Second, any flow that is present in the winter is very difficult to measure accurately, often flowing between ice layers, or at the edge of the stream channel. Therefore, the error bound of the winter flow measurements is much higher than for the open water season, and;

- Lastly and in the context of impacts for ICs and VCs for the Coffee Gold Project, streamflow reductions are assumed to have strongest interaction with the fish habitat and aquatic resources disciplines. Appendix 8-A confirms that Project streams experience extensive glaciation (aufeis) during the winter, diminishing opportunities for aquatic biota utilization in winter months.

In this regard, the results presented below focus on the open water season (April to end of October) for the key Project area streams.

3.6.2.1 *CC-1.5*

For the CC-1.5 WBM node, the Project is anticipated to influence roughly 2.0 km^2 of the 23.1 km^2 drainage (Table 3-14). Therefore, ~9% of the watershed will generate contact and non-contact runoff signatures potentially different from those expected under a Baseline condition. An inspection of Percent Change output (refer to Table 3-21, *e.g.*, Mean) and the various discharge plots presented in Appendix 3.1 for CC-1.5, confirm that predicted alterations to the streamflow regime at this node are relatively modest.

At CC-1.5, and nodes closest to mines area (*e.g.*, HC-2.5, YT-24), the largest magnitude changes in predicted streamflow are projected to occur within the Operation phase, as the mine area is at its greatest extent, and reclamation activities have not yet commenced. During the Operation phase, active pits are also being dewatered, small volumes may be abstracted from the storage ponds as necessary for process water make-up at the HLF, and the WRSFs (including pit backfills) serve to alter the local flow regimes. For the Operation Phase, Figure 3-53 summarizes 10^{th} percentile, mean and 90^{th} percentile discharge data at CC-1.5 for the Natural/baseline and Base Case model runs. Taken in aggregate with Table 3-21, these discharge data are indicative that future flow changes attributable to the Project are predicted to be relatively minor for Latte Creek at the CC-1.5 water balance node.

For CC-1.5, greatest changes to streamflow (*i.e.*, increase in flow for Base Case compared to Baseline, Natural Case) are predicted to occur in the month of April (Table 3-21), as the mine operations are predicted to result in a slightly earlier snowmelt, and pit walls are expected to translate melt and rainfall more efficiently into runoff. In addition, peak freshet flows are attenuated to a minor degree by the pit sumps and pit backfill. As reported in Table 3-21 the 10^{th} percentile streamflow changes fall below the -5% threshold in all months by a small degree (-7% to -11% below the baseline condition), and the mean and 90^{th} percentile streamflow changes exceed the +5% screening threshold for Operation for April. Streamflows in May are expected to drop slightly as a result of a greater proportion of annual runoff occurring in April. During the Closure and Post-closure phases, the predominant changes are predicted to occur in April, with the predicted flow changes decreasing in magnitude over time (Table 3-21).

During the Closure and Post-closure phases, the magnitude of the predicted flow changes at CC-1.5 decrease, as the Supremo (SU1) Pit spills into upper Latte Creek. Several of the pit lakes are also predicted to leak to upper Latte Creek via the groundwater system at an approximate rate of 2 L/s (total). This leakage has a much larger potential to alter the winter low flows due to the relative magnitude of the leakage compared to the existing streamflows, which are very low during the winter months. However, it is expected that this leakage will contribute to aufeis formation during the winter, and will not report to the surface in liquid form.

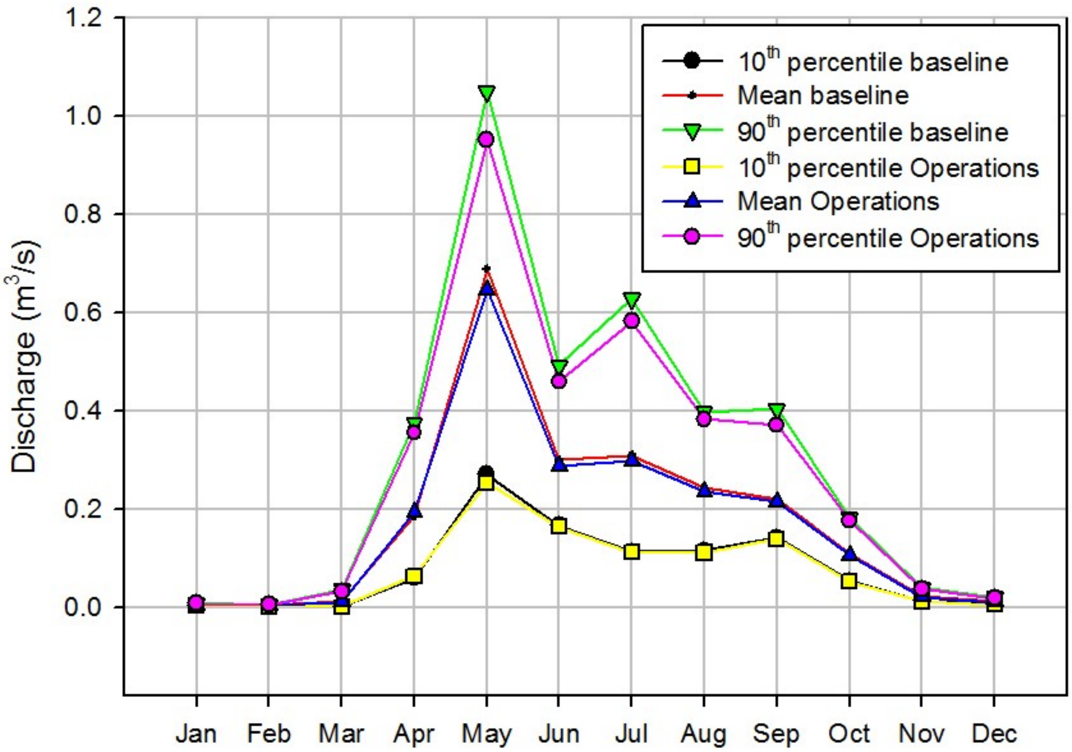


Figure 3-53: Predicted monthly discharges at station CC-1.5 for the Operation phase

It is note-worthy that the largest range in the predicted changes at CC-1.5 (and other WBM nodes as well) occurs at the edges of the open-water season in the months of April and October. These months are most sensitive to inter-annual variability in snowpack magnitude, and the timing of initiation of melt in the spring, and freeze-up in the fall. The potential for measurement and modeling error is also likely higher during these months as a result of the challenging streamflow measurement conditions, as discussed at the start of this sub-section. Finally, the relative magnitude of streamflow is much lower during these months, and thus small changes in discharge from the baseline reference result in relatively greater percent change metrics.

Table 3-23:
Latte Creek and Coffee Creek – Percent Change Summary for Project Phases

			Percent Change from Reference Condition (%)						
Location	**Phase**	**Metric**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
CC-1.5 (23.1 km²)	End Operations	10th Percentile	-7.3	-11.0	-8.3	-8.1	-7.5	-7.7	-8.3
		Mean	8.1	-6.4	-4.2	-3.5	-3.2	-2.9	-3.4
		90th Percentile	27.8	-1.0	-0.4	0.4	0.4	0.4	0.2
	Reclamation and Closure	10th Percentile	-1.2	-6.7	-4.0	-4.2	-3.6	-3.6	-5.0
		Mean	13.0	-4.6	-2.7	-2.8	-2.5	-2.0	-2.4
		90th Percentile	25.7	-2.6	-1.3	-1.0	-1.5	0.3	0.8
	Post-closure	10th Percentile	-2.0	-4.4	-2.1	-2.1	-1.7	-1.7	-2.3
		Mean	5.9	-1.1	-1.0	-0.8	-0.6	-0.1	-0.6
		90th Percentile	20.2	1.9	0.0	0.2	0.4	1.2	1.1
CC-3.5 (69.8 km²)	End of Operations	10th Percentile	-3.0	-5.8	-3.7	-3.6	-3.4	-3.6	-4.3
		Mean	4.1	-3.0	-1.5	-1.1	-1.0	-0.9	-1.2
		90th Percentile	11.9	0.2	0.5	0.9	1.0	1.0	1.3
	Reclamation and Closure	10th Percentile	0.0	-3.4	-1.4	-1.5	-1.1	-1.2	-2.4
		Mean	6.3	-1.9	-0.7	-0.7	-0.7	-0.3	-0.5
		90th Percentile	12.1	-0.8	0.1	0.2	-0.1	0.9	1.8
	Post-closure	10th Percentile	-0.6	-2.1	-0.4	-0.4	-0.2	-0.2	-0.5
		Mean	3.3	0.1	0.2	0.4	0.4	0.7	0.6
		90th Percentile	9.7	2.0	0.8	0.9	1.0	1.5	1.7
CC-4.5 (484 km²)	End of Operations	10th Percentile	-0.2	-0.8	-0.6	-0.4	-0.4	-0.4	-0.6
		Mean	0.3	-0.4	-0.2	-0.1	-0.1	-0.1	-0.1
		90th Percentile	0.9	0.0	0.1	0.1	0.1	0.1	0.2
	Reclamation and Closure	10th Percentile	0.0	-0.4	-0.2	-0.2	-0.1	-0.1	-0.3
		Mean	0.5	-0.2	-0.1	-0.1	-0.1	0.0	-0.1
		90th Percentile	1.0	-0.1	0.0	0.0	0.0	0.1	0.3
	Post-closure	10th Percentile	0.0	-0.3	-0.1	0.0	0.0	0.0	-0.1
		Mean	0.3	0.0	0.0	0.0	0.0	0.1	0.1
		90th Percentile	0.7	0.4	0.1	0.1	0.1	0.2	0.2

* Drainage area reported alongside site location is the pre-development (baseline) estimate
Values in table are the percent change in monthly average streamflow from the baseline condition (Without Project). Blue shaded cells represent predicted negatives changes (i.e., flow reductions) greater than the 5% threshold, and beige shaded cells represent predicted positive changes (i.e., flow increases) greater than the 5% threshold.

3.6.2.2 *CC-3.5 and CC4.5*

CC-3.5 is the next node downstream of CC-1.5, with a drainage area slightly more than double that of the CC-1.5 node (Figure 3-1). During the Operation phase, only the 10th percentile of the May predictions shows streamflow reductions slightly greater than -5%, and the 90th percentile predictions for April show increases above the +5% threshold (Figure 3-54). During the Closure, and into the Post-closure phase, the same activities that serve to increase streamflows from the Operation phase at CC-1.5 have a similar effect at CC-3.5, though they are muted by the larger watershed. As a result, only April shows streamflow change statistics exceeding the 5% screening threshold.

At the CC-4.5 node (which represents a watershed area 21 times larger than the CC-1.5 node), none of the Project phase predict a measurable change in the existing streamflow regime. This is confirmed by inspection of WBM output presented in Table 3-21 and Appendix 3.4 for this modelling location. Overall, alterations to streamflow are predicted to be less than 1% at CC-4.5, which is well below the assessment threshold selected for this exercise, and much lower than the highest hydrometric measurement standards. The muting of predicted flow changes with distance downstream is clearly summarized in box and whisker plots (*e.g.*, Figure 3-55 for Operation phase; Figure 3-56 for Closure phase), Discharge-Percent Change charts (Figure 3-57 for Operation phase) and flow duration curve comparisons (Figure 3-58 for Operation phase) for Latte Creek and Coffee Creek WBM nodes. The muting is most pronounced between CC-3.5 and CC-4.5 owing to flow volumes reporting through CC-0.5 WBM node, which is unaffected by the Project (*i.e.*, Baseline (Natural) and Base Case WBM outputs are the same for this node).

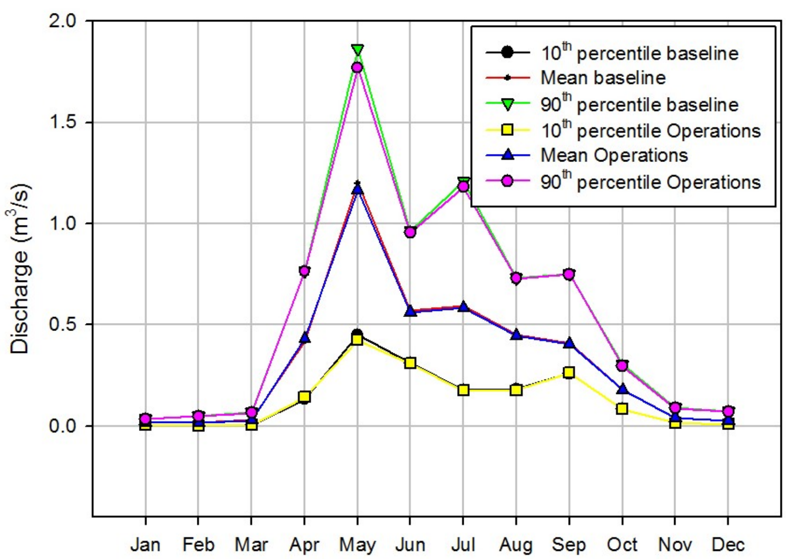


Figure 3-54: Predicted monthly discharges at station CC-3.5 for the Operation phase

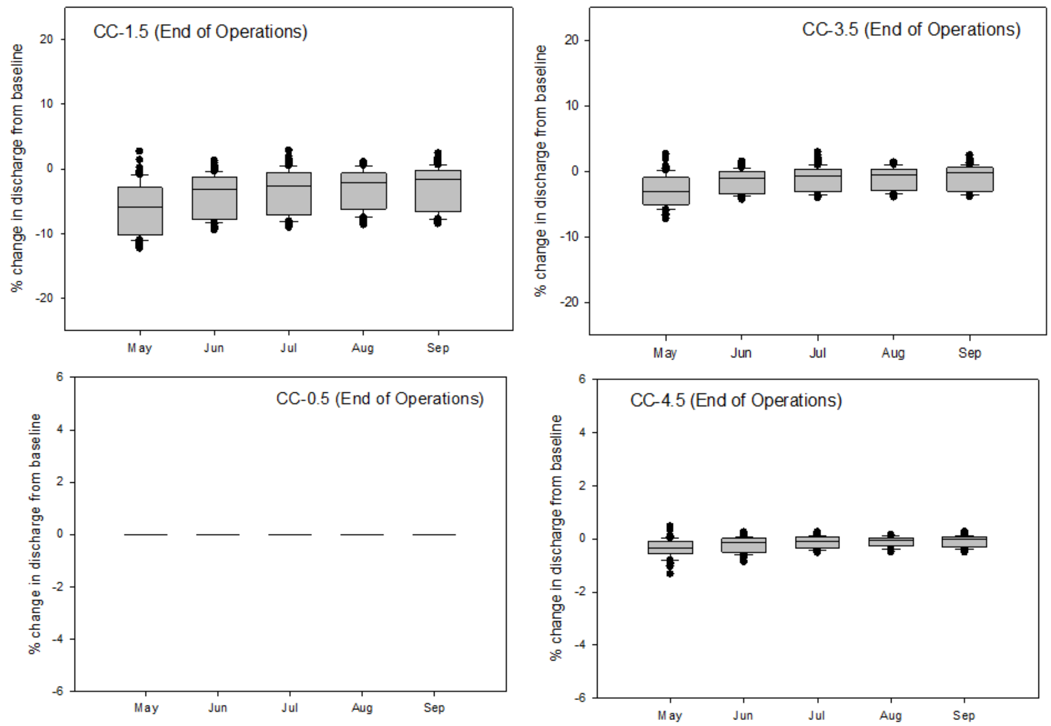


Figure 3-55: Box and whisker summaries of Percent Change metrics for Latte and Coffee Creek WBM nodes for Operation phase

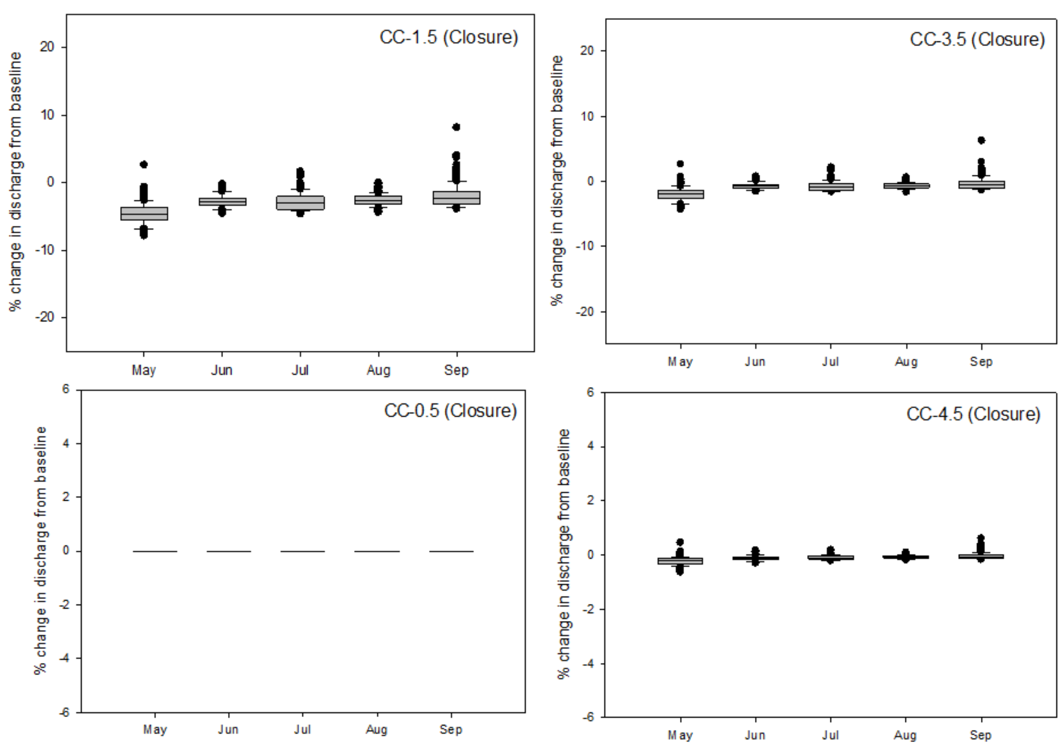


Figure 3-56: Box and whisker summaries of Percent Change metrics for Latte and Coffee Creek WBM nodes for Closure phase.

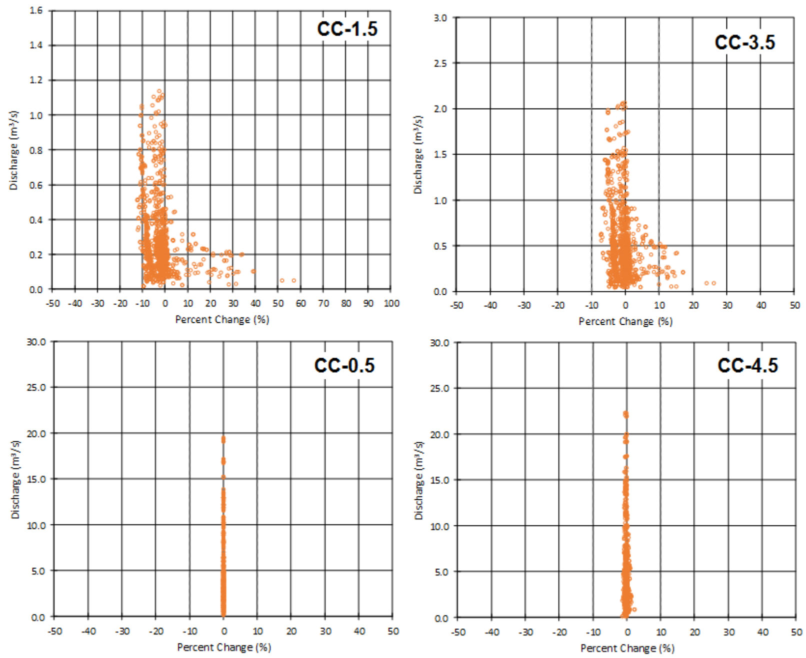


Figure 3-57: Discharge versus Percent Change plots for the End of Operations phase at Latte Creek and Coffee Creek WBM nodes. Thresholds indicating +/-10 Percent Change are shown in the plot with dashed grey vertical lines.

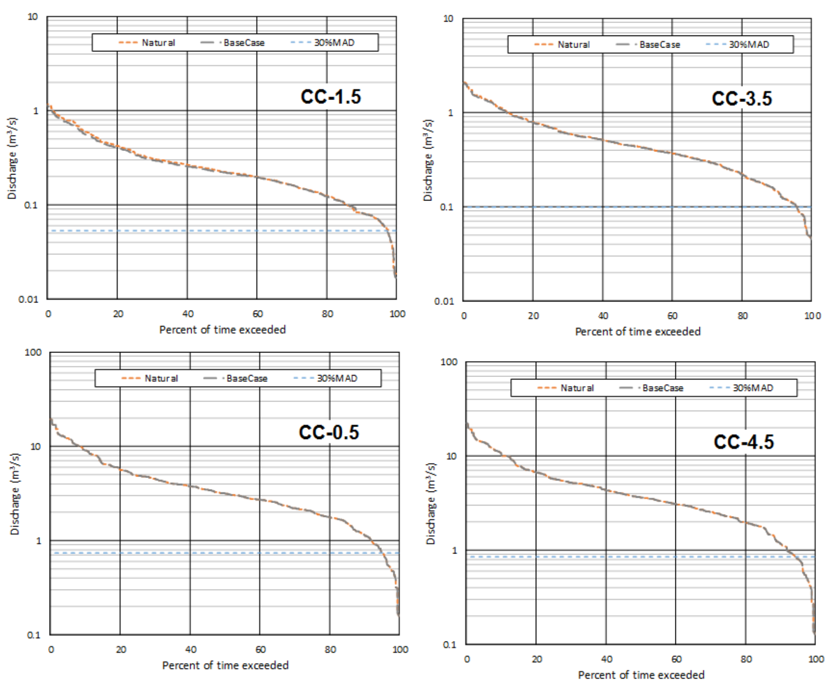


Figure 3-58: Baseline (Natural) and Base Case monthly discharge data for Latte Creek and Coffee Creek WBM nodes. Data shown are for the End of Operations phase of the Project and are presented in flow duration curve format. Data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Operation shown by dashed blue line.

3.6.3 YT-24 Tributary

The YT-24 basin is the smallest of the Project area drainages assessed with the GoldSim WBM. Approximately 0.4 km^2 of the 11.8 km^2 drainage will contain mine infrastructure, or in other terms, 3% of the natural watershed area, all situated at high elevation, will generate contact water (Table 3-18). Also notable for this WBM node is that the post-development drainage reporting to YT-24 is larger than the pre-mine (baseline) watershed area by ~5% (*i.e.*, 12.3 km^2 versus 11.8 km^2). As a result of these modifications, flow increases are expected to results in this watershed as a result of Project development.

A synopses of monthly percent change statistics are presented for YT-24 in Table 3-22. Representative Operation phase plots of predicted streamflow changes at this node are shown in Appendix 3.5 (refer to Figure 3.5-7 through 3.5-10). For months with appreciable discharge (April through October, streamflow predictions generally indicate that enhancements of flows are anticipated at YT-24, throughout the phases of mine life assessed. Using mean percent change results to summarize main patterns and trends (Table 3-22) the following is noted for YT-24: percent change values for the Operation Phase range from 2.6% (April) to 34% (October); mean percent change predictions for months June through September are intermediate to April and October predictions, and range from 9 to 23%; and mean monthly percent change predictions are slightly worst case for the Operation Phase as compared to predictions returned for Closure and Post-Closure Phases. Consistent with the predictions for the other WBM nodes, the largest magnitude changes at YT-24 are predicted to occur during the Operation phase.

Table 3-24:
YT-24 Percent Change Summary for Project Phases

			Percent Change from Reference Condition (%)						
Location	**Phase**	**Metric**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
YT-24 (11.8 km^2)	End of Operations	10th Percentile	-7.6	4.1	0.2	-2.2	-0.7	-0.8	11.1
		Mean	2.6	23.3	9.9	11.0	10.0	9.1	34.1
		90th Percentile	14.2	47.9	17.7	18.5	18.2	16.7	62.3
	Reclamation and Closure	10th Percentile	-5.7	5.5	2.3	2.3	1.4	0.5	8.5
		Mean	-2.0	14.3	4.1	3.5	2.9	3.8	26.4
		90th Percentile	3.9	30.2	5.9	4.7	3.9	7.4	39.2
	Post-closure	10th Percentile	-3.2	3.5	2.7	2.2	2.3	2.5	6.8
		Mean	6.7	14.6	5.7	6.3	5.4	6.6	20.2
		90th Percentile	15.1	31.5	10.2	11.3	10.6	11.4	38.7

* Drainage area reported alongside site location is the pre-development (baseline) estimate. *Values in table are the percent change in monthly average streamflow from the baseline condition (Without Project). Blue shaded cells represent predicted negatives changes (i.e., flow reductions) greater than the 5% threshold, and beige shaded cells represent predicted positive changes (i.e., flow increases) greater than the 5% threshold.*

For the Operation Phase, Figure 3-59 provides an indication of predicted flow changes at YT-24 in time-series format, a result which is attributable to several factors. The widespread predicted increases in streamflows at YT-24 are attributable to several factors. First, as outlined in Appendix 8-A, the YT-24 basin has the lowest median elevation of all Project area gauged basins, and therefore receives relatively lower precipitation amounts overall. The natural runoff coefficient for this station is also quite low, and averages 0.17 for the two years of gauged record, compared to the Project area average of 0.34. Secondly, the relationship between precipitation and elevation is well established for the Project site, with higher elevations receiving proportionately more precipitation than lower elevations. Project infrastructure in the YT-24 drainage is located at, or near, the height of land in the basin, which proportionately receives more precipitation. Thirdly, development of the mine is predicted to result in more of the meteoric water being transformed into runoff. Specifically for YT-24, stripping of overburden and development of open pits will result in lower rates of infiltration and evapotranspiration and more runoff. And lastly, the post-development drainage area for YT-24 slightly exceeds that for the pre-mine condition since a portion of the Supremo sitting in the Latte Creek watershed is predicted to drain northward following Project development. Although this additional contributing area is small (<5% of the pre-mine drainage area), the change occurs at high elevation, where the potential for additional precipitation and runoff potential is realized.

Detailed WBM output is provided in Appendix 3.5 in table and plot format, for each phase of the Project, for reader review and discussion.

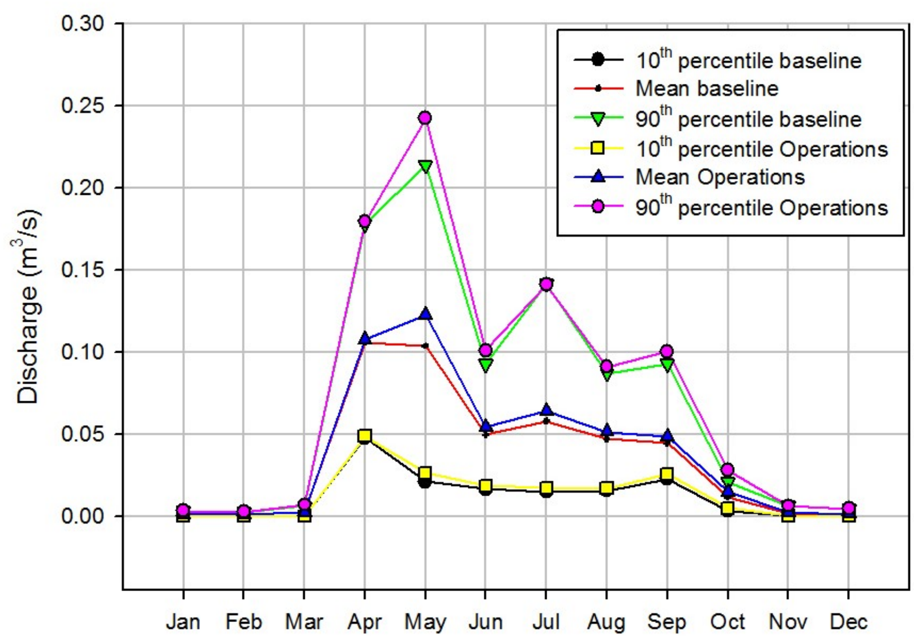


Figure 3-59: Predicted monthly discharges at station YT-24 for the Operation phase

3.6.4 Halfway Creek Drainage

Approximately 3.1 km^2 of the 14.8 km^2 Upper Halfway Creek drainage will contain mine infrastructure, and therefore 21% of the natural watershed area will generate contact water at HC-2.5. An example showing the predicted changes for this location is provided in Figure 3-60 and a synopsis of Percent Change results (10^{th} percentile, mean, 90^{th} percentile) is provided in Table 3-23 for both HC-2.5 and HC-5.0.

At the End of Operations Phase, flows are predicted to increase from the baseline condition beyond the 5% threshold for May through September at HC-2.5. The 10^{th} percentile changes range from 6% to 12% for these months, the mean predicted changes range from 19% to 26% and the 90^{th} percentile predicted increases range from 36% to 47% above the baseline monthly streamflows. The months of April and October show greater variability in the range of predicted alterations, ranging from -27% (10^{th} percentile) to 0% (90^{th} percentile) for April, and -16% (10^{th} percentile) to 20% (90^{th} percentile) for October. Similar to the other basins, data for April and October is subject to larger measurement error due to ice effects, and therefore the model results likely have a larger range of variability. Additionally, the relative streamflow rates are much lower in April and October, and therefore relatively small absolute changes in predicted flows result in larger relative changes.

Exposed pit walls are assumed to generate runoff more efficiently than natural drainage area and additional runoff from these areas has the potential to enhance future low flow regimes compared to the baseline condition. Any change at HC-2.5 associated with pit wall runoff will be greatest during the Operation Phase when actively mined pits are efficiently being dewatered. By comparison, in Closure and Post-Closure open pits passively fill and eventually spill and thus the proportion of exposed pit wall is reduced in these later Project Phases. Piled waste rock in the Halfway Creek drainage also has the potential to enhance low flow signatures given that WRSFs are assumed to attenuate (reduce freshet peak, enhance summer and autumn flows) the natural hydrograph. Finally, the commissioning and operation of the Alpha Pond has the potential to alter the distribution of streamflow timing. All contact water emanating from the upgradient mined areas eventually reports to this pond, which is dewatered at a rate of 300 L/s during the open water season. Depending on the magnitude of a freshet or large rainfall event, some water may leave this pond later than it would have under the baseline condition. Once this pond is removed in the Post-closure phase, this potential attenuation effect is removed, however the alterations due to the presence of the WRSF will are expected to still be present.

A similar pattern (*i.e.*, flow enhancements at HC-2.5) is evident in the Closure Phase predictions, with mean predicted changes for the months of May through September ranging from 22% to 29%. Slightly larger alterations are realized during this phase as a direct result of treated discharge from the HLF drain-down being directed to Halfway Creek over a period of several years during this phase. (Table 3-23). A similar range of predicted flow alterations (-22% to 59% exists for April and October. This variability about the mean, and inconsistent direction (increase or decrease) of flow alteration suggests that the predicted changes are driven by climate as much as by mine operations, and are also a result of small changes due to Project operations being superimposed on the existing low flows. Thus, a small absolute change in flow will result in relatively larger flow alterations when expressed as a percent change.

Table 3-25:
Halfway Creek Drainage Percent Change Summary for Project Phases

			Percent Change from Reference Condition (%)						
Location	**Phase**	**Metric**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
HC-2.5 (14.8 km^2)	End of Operations	10th Percentile	-27.0	9.1	8.5	9.1	11.8	5.6	-15.7
		Mean	-15.1	22.2	24.4	26.3	24.6	19.1	2.0
		90th Percentile	-0.2	47.3	39.1	46.9	40.6	35.7	19.6
	Reclamation and Closure	10th Percentile	-22.4	4.2	9.7	10.2	14.1	7.6	-18.1
		Mean	3.2	21.5	27.6	29.3	29.2	23.2	2.4
		90th Percentile	59.1	49.8	43.4	51.7	46.0	40.6	20.5
	Post-closure	10th Percentile	6.5	-3.3	18.6	12.5	16.0	9.1	-1.0
		Mean	37.8	11.9	31.9	28.9	26.8	22.9	14.5
		90th Percentile	80.5	37.7	45.9	50.4	40.4	38.1	30.1
HC-5.0 (27 km^2)	End of Operations	10th Percentile	-12.4	5.4	5.2	5.4	6.9	3.6	-7.3
		Mean	-6.3	14.1	15.3	16.3	15.1	11.8	4.6
		90th Percentile	1.3	31.1	25.0	29.6	25.7	21.9	17.1
	Reclamation and Closure	10th Percentile	-10.8	2.5	6.2	6.0	8.3	4.4	-9.3
		Mean	2.7	13.6	17.3	18.1	18.0	14.3	4.7
		90th Percentile	29.1	34.0	27.5	32.4	29.2	25.3	19.7
	Post-closure	10th Percentile	3.8	-2.1	11.4	7.4	9.4	5.3	-0.4
		Mean	19.4	7.6	19.9	17.8	16.4	14.0	10.3
		90th Percentile	41.1	24.1	29.2	32.0	25.7	23.9	21.8

* Drainage area reported alongside site location is the pre-development (baseline) estimate.
Values in table are the percent change in monthly average streamflow from the baseline condition (Without Project). Blue shaded cells represent predicted negatives changes (i.e., flow reductions) greater than the 5% threshold, and beige shaded cells represent predicted positive changes (i.e., flow increases) greater than the 5% threshold.

During the Post-Closure Phase, the predicted alterations are weighted toward the positive side of the distribution, and range from 12% to 32% for the months of May to September. No predicted changes below the -5% screening threshold are predicted to occur in this phase. The slight increase in predicted flow changes (relative to the End of Operations and Closure periods) is largely due to the passive spill of the SU3W pit to Halfway Creek, and the routing of passively treated water from the HLF to the Latte pit, which subsequently spills to the Alpha WRSF rock drain.

The HC-5.0 node represents the entirety of the Halfway Creek watershed at its confluence with the Yukon River. The drainage area reporting to this node is 27 km^2, and similar to the downstream stations on Latte Creek (from CC-1.5), all additional runoff from the intervening basin is non-contact. Therefore, the mine affected area comprises only 11% of the total basin area at HC-5.0. The flow alterations signal at HC-5.0 is similar to that for HC-2.5, but muted by the additional non-contact runoff (Table 3-23, see also Figure 3-61, Figure 3-62 and Figure 3-63). These plots and other presented for HC-5.0 in Appendix 3 (refer to 3.7) illustrate that essentially the same patterns of flow change evident at HC-2.5 are returned by the WBM at HC-5.0 per Project phase.

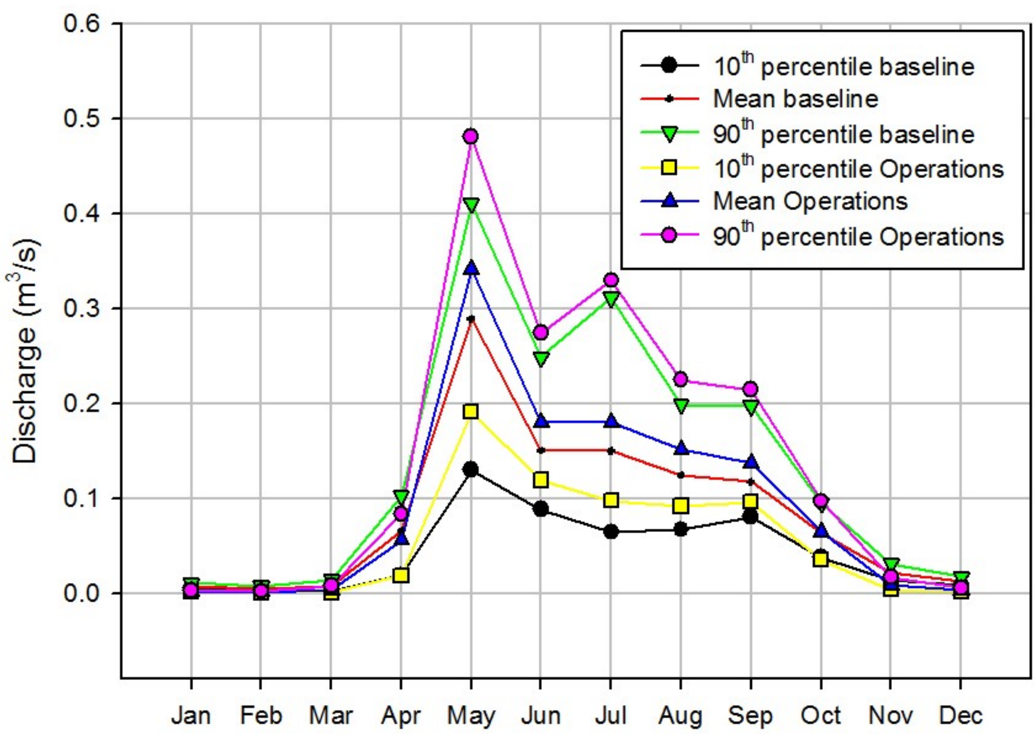


Figure 3-60: Predicted monthly discharges at station HC-2.5 for the Operation phase.

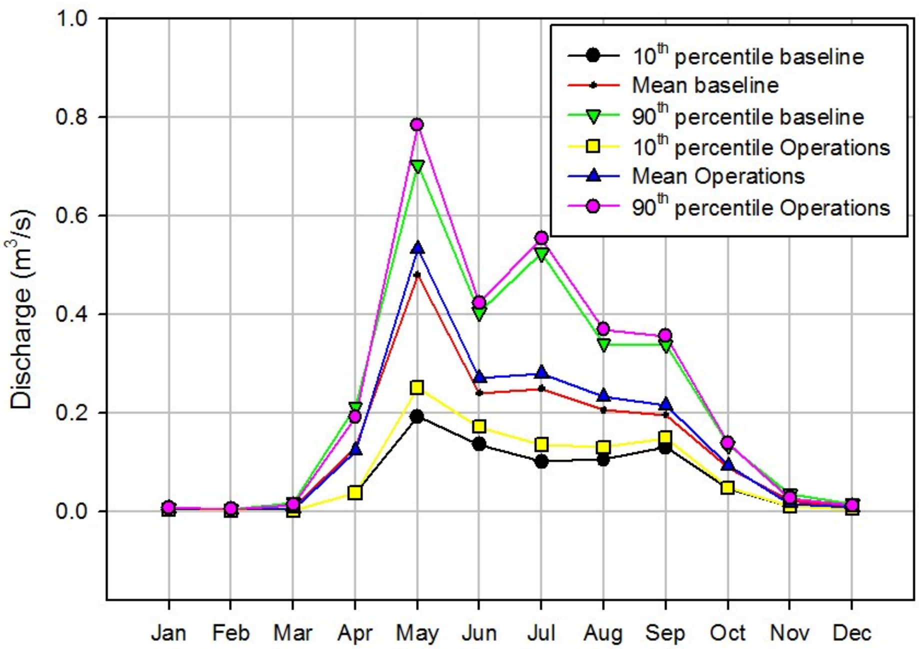


Figure 3-61: Predicted monthly discharges at station HC-5.0 for the Operation phase.

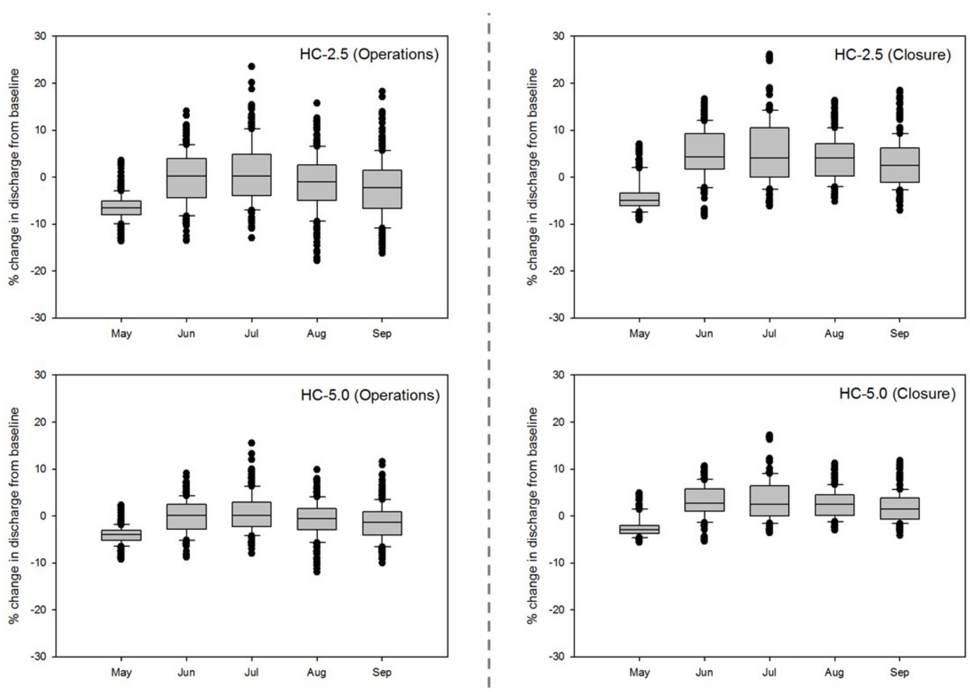


Figure 3-62: Box and whisker plots summarizing percent change statistics at HC-2.5 and HC-5.0 for Operation and Closure Phases. As per box and whisker plots presented in Appendix 3, mean and quartile results are shown by grey shaded box, 5th and 95th percentiles shown by tails and outliers with black shaded dots.

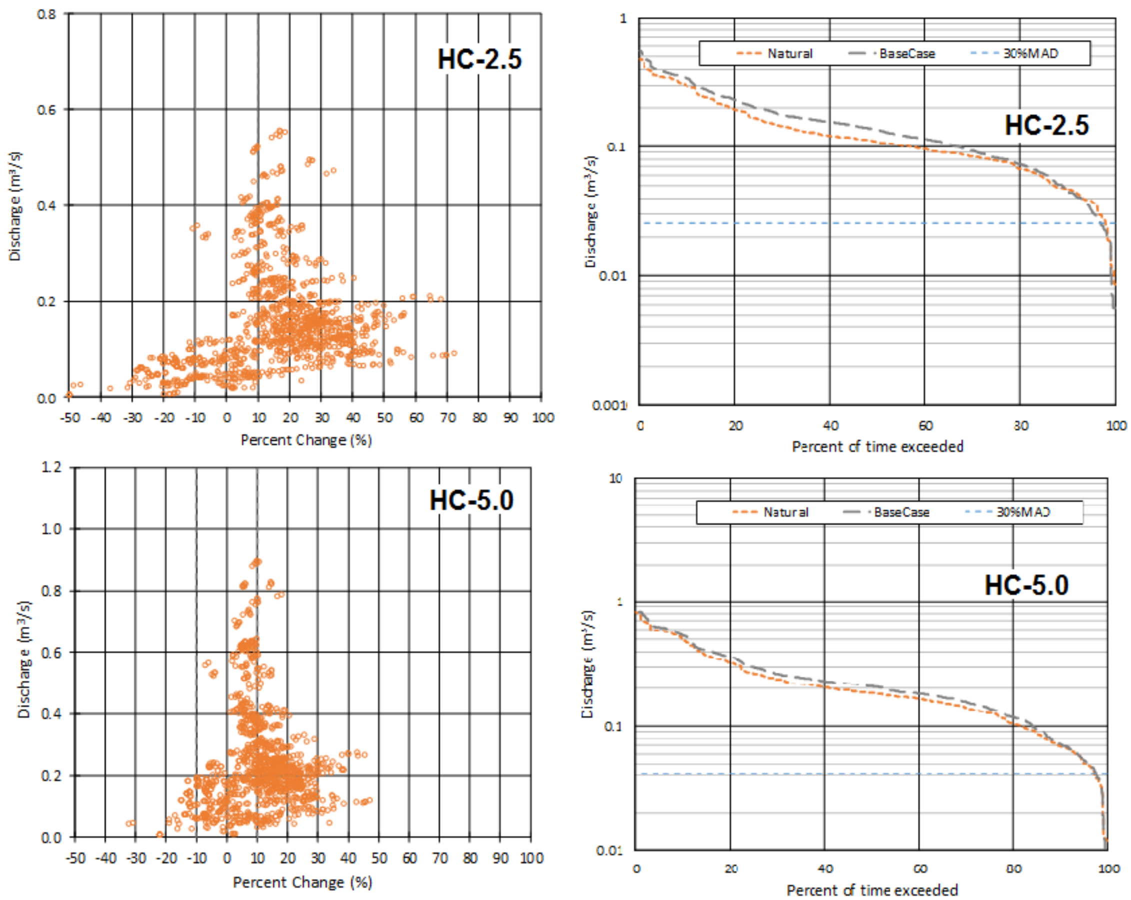


Figure 3-63: Discharge versus Percent Change (left panel, +/-10% thresholds shown with grey dashed lines) and Baseline versus Base Case discharge comparison (right panel, in flow duration curve format; 30% MAD shown by dashed blue horizontal line) for HC-2.5 and HC-5.0 for the end of Operations.

3.6.5 Yukon River

The estimated drainage of the Yukon River above Coffee Creek is 147,317 km^2, while the combined drainage area of all Project area watersheds (Coffee/Latte, Halfway and YT-24 Creeks) is approximately 530 km^2, or 0.4% of the Yukon River drainage.

In order for flow alterations to be detectable in the Yukon River at the +/- 5% change threshold, the predicted streamflow alterations for the Project area watersheds would need to be several orders of magnitude higher than what is presented in this exercise. Therefore, the Project is assumed to cause no discernible change to the streamflow regime of the Yukon River.

4. Water Quality Model

4. Water Quality Model

4.1 *Model Overview*

The water quality model (WQM) developed for the Project builds upon the framework of the water balance model and assigns water quality terms for background (non-contact) and mine-related (contact) sources to each flow term in the model. Baseline hydro-meteorology information incorporated into the water balance model is presented in Section 2.3.1, Section 2.3.2 and Appendix 8A. Specifics relating to the overall layout, parameterization, calibration and validation of the site-wide water balance model have been presented in detail previously (refer to Section 3.1 and Section 3.2).

Water quality inputs to the WQM, or source terms, are based on either a set of assumptions that reflect empirical observations from the Coffee Gold mine site, data collected at analogue sites, or the results of various geochemical and metallurgical tests that have been undertaken to provide a basis for assigning likely future water quality associated with specific mine components. Conceptually, modelled flows and associated source terms are combined in the GoldSim platform to derive predicted water quality estimates at key locations across the mine site (*e.g.*, sumps/ponds, pit lakes) and local receiving streams across the main phases of the Project.

This chapter provides an overview of the water quality model architecture (Section 4.1), a description of the geochemical source terms input to the model (Section 4.2), a summary of the modelled cases (Section 4.3), as well as a synopsis of the major limitations and assumptions incorporated into the water quality model (Section 4.4). The final section (Section 4.5) of the report presents the water quality model results for pit lakes, settling ponds and receiving environment nodes by catchment.

4.1.1 Model Architecture

The WQM employs a mass balance approach and provides a detailed accounting of chemical loadings associated with background flows and mine-impacted flows at the Coffee Gold Project, for a series of unique climate realizations (Section 3.2.1). The WQM was developed using GoldSim simulation software and has been configured to account for natural/background flows and chemical loading, runoff and chemical loads reporting from undisturbed portions of watersheds and regional groundwater, as well as chemical loads emanating from mine-related facilities (*e.g.,* pits, WRSFs, backfilled pits) and associated water infrastructure (*e.g.*, contact water ponds and ditches) that are envisaged for the Project (Appendix 31-E).

For pit lakes, settling ponds and ten specific locations in the receiving environment (*i.e.*, model nodes), the WQM predicts concentrations for 25 parameters (Table 4-1) at monthly time steps for an 84-year time-period (i.e., 1,008 months; 2018 through 2100). For contact water sources, the WQM assumes that dissolved concentrations are equal to total concentrations; whereas total concentrations are incorporated into background source terms for all parameters except Al, where dissolved values are modeled (the BC WQG is based on a dissolved value). Predictions for radium-226, a decay product of uranium, are also generated by the WQM for pit lakes and settling ponds. The spatial extent of the WQM covers four major catchment areas (Figure 3-1) and is described further in Section 4.1.2.

Table 4-1:
Water Quality Parameters included in the Coffee Gold Water Quality Model

Parameters	Formula
Ammonia-N	NH_3-N
Nitrate-N	NO_3-N
Nitrite-N	NO_2-N
Sulfate	SO_4
Phosphorus	P
Weak Acid Dissociable Cyanide	WADCN
Dissolved Aluminum	D-Al
Silver	Ag
Arsenic	As
Calcium	Ca
Cadmium	Cd
Chromium	Cr
Copper	Cu
Iron	Fe
Mercury	Hg
Magnesium	Mg
Manganese	Mn
Molybdenum	Mo
Nickel	Ni
Lead	Pb
Antimony	Sb
Selenium	Se
Thallium	Tl
Uranium	U
Zinc	Zn
Radium-226	Ra-226

4.1.2 Model Phases

As outlined previously in Section 2.1.1, the Project comprises four distinct time-frames: Construction, Operation, Reclamation and Closure and Post-closure Phases (Figure 2-2). Table 2-1 also describes primary activities associated with each Project phase and is indicative of the level of detail incorporated into the WBM/WQM for the Coffee Gold Mine. This version of the WQM considers the full footprint of the current mine plan, and includes consideration of mitigation measures and activities (*e.g.,* pit dewatering) described in the Project Description and Water Management Plan. For reference purposes, Figure 2-3 shows the Project layout at the point of maximum mine infrastructure buildout.

4.1.2.1 *Mine Phases Selected for Assessment*

As outlined in Section 2.1.1.1, the Project phases selected for assessment include the late Operation phase (i.e., starting in Mine Year 7 or 2027); post-mining closure; active closure and post-closure (Figure 2-2). The Post-Closure Phase has been modelled out to the year 2100, although monitoring activities are not expected to continue for the duration of this Project phase. This end-point was selected because the climate change projections that were incorporated into the WBM terminate in this year.

4.1.3 Model Nodes

The receiving environment model nodes for surface water quality are essentially the same as those presented in Section 3.2.5 for the WBM. These locations are intended to represent surface water quality monitoring points downstream of mine footprints within the Coffee/Latte Creeks, YT-24 and Halfway Creek drainages. The model nodes (Figure 3-1) are described as follows:

- CC-1.5 – Latte Creek, immediately downstream of the principle point of discharge from open and backfilled pits in the south mine area.
- CC-3.5 – Latte Creek, immediately upstream of the Latte Creek-Coffee Creek confluence. Project-affected discharges reporting to CC-1.5 will become more dilute as they approach CC-3.5.
- CC-0.5 – Coffee Creek, immediately upstream of the Latte Creek-Coffee Creek confluence. The Project will not influence water quality at, or above, this node. Therefore, the predicted water quality at this node reflects expected ‘background’ conditions.
- CC-4.5 – Coffee Creek, upstream of the confluence with the Yukon River. Water quality at this station reflects combined surface flows from upper Coffee Creek (natural, background) and Latte Creek (influenced by Project footprints in the south mine area).

- YRdsCC45 – Yukon River, immediately downstream of the Coffee Creek confluence.
- YT-24 – YT-24 Tributary, immediately upstream of the confluence with the Yukon River. Water quality changes attributable to mine development in the north mine drainage (i.e., open pits, water management infrastructure) influence this model model. Note that this model node location is the same as water quality monitoring location ML-01.
- YRdsYT24 – Yukon River, immediately downstream of the YT-24 confluence.
- HC-2.5 – Halfway Creek, roughly mid-drainage. This water quality node is situated downstream of the principle points of discharge from the Alpha WRSF and Kona Pit sub-watershed.
- HC-5.0 – Halfway Creek immediately upstream of the Halfway Creek-Yukon River confluence. Project-affected discharges reporting to HC-2.5 will become more dilute as they approach HC-5.0.
- YRdsHC50 – Yukon River, immediately downstream of the Halfway Creek confluence.

4.2 *Inputs*

The source terms included in the surface water quality model incorporate site-specific baseline surface and groundwater water quality data sets, static and kinetic geochemical data sets, and mine-specific outputs. The approach taken for developing inputs to the surface water quality model is summarized in the following sections.

4.2.1 Background Water Quality

Background surface water quality source terms were developed based on a coupled calibration of base flow, interflow and surface flow components, noting that these flow terms are described conceptually in Section 3.2. For all model nodes except those in the Yukon River, modelled background flows and water quality were calibrated against the baseline monitoring dataset to generate a Natural Case (i.e., no Project influence) water quality time series. The Natural Case model water quality results, using hydrological forcing for years 2010-2015, were then compared to observed water quality data for validation purposes.

The WQM incorporates the strong flow-concentration relationships observed in baseline data by assigning unique water quality signatures to the three water balance flow components. For example, in Halfway Creek at HC-2.5, observed total uranium (T-U) values show a maximum of just under 100 µg/L coinciding with low winter flow conditions, but values are much lower (2-3 µg/L) during freshet when surface runoff dilution of the baseflow approaches 100:1 (refer to Section 2.3.3, Baseline Surface Water Quality). As illustrated in Figure 4-1, a simple model which assigns individual static concentrations to the three model flow components reproduces the observed flow-concentration relationships well.

By varying these parameter concentrations and matching the least-squares power law fits to modelled and observed values, the individual concentrations that best fit baseline observations can be established. In the case of Halfway Creek at station HC-2.5, the best-fit baseflow, interflow and surface flow values for T-U were determined to be 100 µg/L, 12 µg/L and 1 µg/L, respectively as shown in Figure 4-1. The time-series of observed baseline (2010-2015) and modeled monthly Natural Case T-U concentrations are presented for HC-2.5 in Figure 4-2 (upper panel). Modelled and observed time series are also shown in Figure 4-2 for total arsenic and total copper concentration (µg/L) and the CC-1.5 model node (refer to the lower panel in the figure).

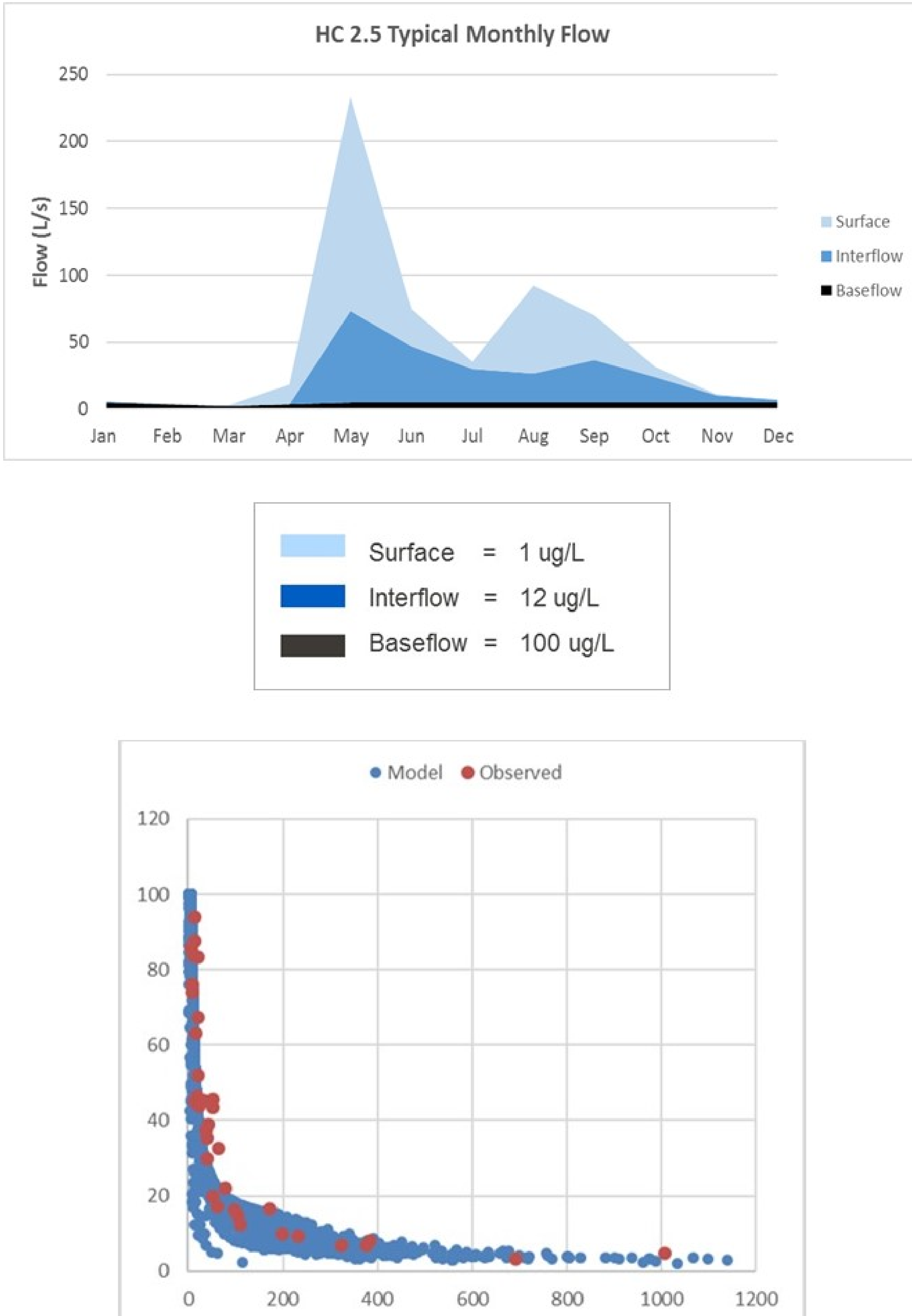


Figure 4-1: Modelled and observed relationship between flow (L/s) and total uranium concentrations (µg/L) at HC-2.5 in Halfway Creek

Figure 4-2: Modelled and observed total uranium, total arsenic and total copper concentration (µg/L) over the calibration time period. The upper panel presents calibration results for HC-2.5, whereas the lower panel presents calibration results for the CC-1.5 model node.

All model parameters (n = 25) were calibrated against baseline water quality data to generate a Natural Case, intended to represent the flow-dependent background water quality at each of the model nodes. This detailed calibration step was undertaken for all three flow components for catchments representing the background loading to each of the model nodes (i.e., HC-2.5, HC-5.0, CC-1.5, CC-3.5, CC-0.5, CC-4.5 and YT-24). A complete list of all assigned background concentrations is presented in Table 4-2 by parameter, site and flow type (i.e., baseflow, interflow, surface).

The background water quality assumed for model nodes within the Yukon River is based on monthly mean background terms calculated directly from the YUK-2.0 baseline monitoring dataset (Appendix 12A; summarized in Section 2.3.3), combined with Natural Case water quality from the tributaries flowing into the Yukon River. For the purpose of modeling water quality, it is assumed that water discharging into the Yukon River initially mixes with only 2% of the Yukon River flow at the modelled downstream locations, with full mixing assumed to occur in the Yukon River between stations YRdsCC and YRdsYT-24 and partial mixing (25%) inferred between stations YRdsYT-24 and YRdsHC. It should be noted that the background term for Yukon River stations does not take inter-annual climate variability within the Yukon River into account.

Table 4-2:
Geochemical Parameter Concentrations assigned for background baseflow, interflow and surface runoff derived from calibration to baseline water quality data

Catchment	Parameter	NH_3-N	NO_3-N	NO_2-N	SO_4	P	WADCN	D-Al	Ag	As	Ca	Cd	Co	Cr	Cu	Fe	Hg	Mg	Mn	Mo	Ni	Pb	Sb	Se	Tl	U	Zn
	Units	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
CC-0.5	Baseflow	0.02	0.4	0.005	150	0.002	0.00001	0.001	0.000015	0.0004	80	0.000010	0.0001	0.0002	0.0005	0.05	0.000008	25	0.005	0.0006	0.0008	0.00015	0.00018	0.00025	0.000003	0.02	0.001
	Interflow	0.03	0.4	0.005	35	0.004	0.00001	0.08	0.000010	0.0006	20	0.000030	0.0002	0.0006	0.001	0.1	0.000010	6	0.02	0.0008	0.0012	0.00020	0.00020	0.00015	0.000006	0.01	0.004
	Surface	0.04	0.15	0.005	5	0.022	0.00001	0.4	0.000010	0.0007	10	0.000045	0.0004	0.0008	0.004	0.5	0.000012	2	0.03	0.0009	0.0016	0.00030	0.00025	0.00010	0.000008	0.001	0.005
CC-1.5	Baseflow	0.02	0.35	0.005	250	0.002	0.00001	0.001	0.000012	0.0018	140	0.000001	0.0001	0.0005	0.001	0.05	0.000008	44	0.005	0.0006	0.0005	0.00015	0.00020	0.00040	0.000008	0.032	0.001
	Interflow	0.03	0.35	0.005	50	0.004	0.00001	0.15	0.000005	0.0007	30	0.000025	0.0002	0.0007	0.002	0.2	0.000010	6	0.01	0.0002	0.0015	0.00020	0.00014	0.00010	0.000005	0.006	0.003
	Surface	0.04	0.15	0.005	5	0.022	0.00001	0.4	0.000005	0.0005	8	0.000060	0.0005	0.0008	0.0032	0.4	0.000012	4	0.08	0.0002	0.0018	0.00040	0.00010	0.00005	0.000005	0.0005	0.006
CC-3.5	Baseflow	0.02	0.7	0.005	40	0.002	0.00001	0.001	0.000012	0.0001	8	0.000001	0.0001	0.0005	0.001	0.05	0.000008	4	0.005	0.0006	0.0005	0.00015	0.00005	0.00005	0.000004	0.0005	0.001
	Interflow	0.03	0.7	0.005	20	0.004	0.00001	0.15	0.000005	0.0001	8	0.000025	0.0002	0.0007	0.002	0.2	0.000010	4	0.01	0.0002	0.0015	0.00020	0.00005	0.00005	0.000004	0.0005	0.003
	Surface	0.04	0.15	0.005	5	0.022	0.00001	0.4	0.000005	0.0001	8	0.000060	0.0005	0.0008	0.0032	0.4	0.000012	4	0.08	0.0002	0.0018	0.00040	0.00010	0.00005	0.000004	0.0005	0.006
CC-4.5	Baseflow	0.02	0.8	0.005	90	0.002	0.00001	0.03	0.000015	0.0004	40	0.000010	0.0001	0.0002	0.002	0.05	0.000008	14	0.005	0.0006	0.0008	0.00015	0.00018	0.00008	0.000003	0.002	0.001
	Interflow	0.03	0.5	0.005	35	0.004	0.00001	0.08	0.000010	0.0006	15	0.000030	0.0002	0.0006	0.002	0.1	0.000010	8	0.02	0.0008	0.0012	0.00020	0.00020	0.00010	0.000006	0.001	0.004
	Surface	0.04	0.15	0.005	5	0.022	0.00001	0.4	0.000010	0.0007	10	0.000045	0.0004	0.0008	0.004	0.5	0.000012	2	0.03	0.0009	0.0016	0.00030	0.00025	0.00010	0.000008	0.001	0.005
HC-2.5	Baseflow	0.02	0.7	0.005	100	0.002	0.00001	0.001	0.000012	0.0004	60	0.000001	0.0001	0.0005	0.0005	0.2	0.000008	25	0.005	0.0025	0.0005	0.00015	0.00120	0.00016	0.000005	0.1	0.001
	Interflow	0.05	0.5	0.005	10	0.004	0.00001	0.08	0.000005	0.001	12	0.000005	0.0002	0.001	0.001	0.5	0.000010	6	0.01	0.0005	0.001	0.00020	0.00030	0.00008	0.000007	0.012	0.003
	Surface	0.02	0.15	0.005	1	0.022	0.00001	0.4	0.000005	0.002	8	0.000040	0.0008	0.0014	0.004	1	0.000012	2	0.08	0.0002	0.0017	0.00040	0.00020	0.00006	0.000010	0.001	0.005
HC-5.0	Baseflow	0.02	0.7	0.005	20	0.002	0.00001	0.001	0.000005	0.0004	4	0.000001	0.0001	0.0005	0.0005	0.2	0.000002	2	0.005	0.0002	0.0005	0.00015	0.00030	0.00001	0.000003	0.001	0.001
	Interflow	0.05	0.5	0.005	15	0.004	0.00001	0.08	0.000005	0.001	30	0.000005	0.0002	0.001	0.001	0.5	0.000010	10	0.01	0.0002	0.001	0.00020	0.00030	0.00008	0.000003	0.005	0.003
	Surface	0.02	0.15	0.005	4	0.022	0.00001	0.4	0.000005	0.002	70	0.000040	0.0008	0.0014	0.004	1	0.000012	10	0.08	0.0002	0.0017	0.00040	0.00020	0.00008	0.000010	0.01	0.005
YT-24	Baseflow	0.03	0.7	0.005	40	0.002	0.00001	0.05	0.000012	0.0004	30	0.000006	0.00015	0.0005	0.0017	0.14	0.000008	10	0.005	0.0005	0.0015	0.00006	0.00040	0.00012	0.000006	0.0006	0.001
	Interflow	0.02	0.7	0.005	15	0.004	0.00001	0.06	0.000005	0.0006	20	0.000008	0.0001	0.0005	0.0025	0.04	0.000005	6	0.004	0.0006	0.001	0.00004	0.00020	0.00009	0.000003	0.0009	0.002
	Surface	0.02	0.3	0.005	8	0.022	0.00001	0.05	0.000005	0.0008	15	0.000010	0.0001	0.0005	0.0032	0.04	0.000005	2	0.003	0.0004	0.0008	0.00003	0.00020	0.00006	0.000003	0.0012	0.0005

4.2.2 Geochemical Source Terms

Geochemical source terms are water quality predictions for water in contact with geologic material disturbed by mining activities. Individual source terms are developed for each mine component at end of mine life and considering the full mine footprint. These source terms therefore include: one out of pit waste rock storage facility (Alpa WRSF) and associated rock drain, four in-pit backfill WRSFs, pit wall rock exposures, the heap leach facility (HLF) and the mine facilities area. Geochemical source terms are not developed for facilities which only exist during mine life, such as run-of mine (ROM) stockpile, frozen materials stockpile, HLF pore water during operations, and Beta WRSF which is backfilled into the Kona Pit before mine closure in Yr 10. The organics stockpile is not assigned a geochemical source term as this facility will contain organic topsoil that will be used for reclamation at the end of mine life. The runoff chemistry from this stockpile is expected to be similar to background water quality.

For each mine component, an upper case and a base case source term has been calculated. The base case source term is meant to reflect a best estimate, while the upper case is meant to reflect a reasonably conservative upper estimate. These predictions become inputs to the site wide water quality model used to assess potential effects of the Project on the receiving environment at the end of mine life and throughout all closure phases.

The approach and assumptions used to develop the geochemical source terms are discussed in detail in Appendix 12-D. A summary of the approach applied to the different mine components is outlined below:

- *Waste Rock Storage Facilities (WRSFs)*: Source terms for WRSFs are calculated by upscaling geochemical loading rates observed in field bin experiments and applying empirical scaling factors from an analogue mine site. Empirical scaling factors are developed based on a comparison between field bin data to a full-scale waste rock seepage data. The scaled loading rates are then applied to the mass, footprint, hydrology and rock types stored in the various WRSFs. Solubility controls are then derived for those parameters that are not expected to behave conservatively. These solubility controls are based on a combination of first principles (thermodynamic equilibria and aqueous speciation), experimental data and field monitoring data.
- *Alpha Rock Drain*: A rock drain will be constructed beneath the Alpha WRSF to convey upgradient runoff under the WRSF. The rock drain will be constructed of waste rock, and will impart a geochemical load on water moving through the drain. Assumptions on particle size and density produce an estimated mass of rock per

linear meter (m) of rock drain. To calculate rock drain loading rates, field bin loading rates are scaled based on particle surface area.

- *Pits*: Source terms have been developed for loads associated with the pitwalls and the backfilled waste rock placed in the pits. Geochemical loading from the pit wall is influenced by the fracture intensity of the walls induced by blasting. Estimates of the tonnage of pit wall rock influenced by blasting are used along with estimates of surface area. The pitwall loading rates are determined by scaling lithology-specific humidity cell loading rates, taking site-specific conditions into account. The backfilled waste rock terms are developed following the same approach outlined for waste rock piles.
- *Heap Leach Facility (HLF)*: The chemistry of HLF pore water and drainage will vary widely depending on the stage of mine life. To reflect this, separate geochemical source terms have been developed for three different types of HLF water; process water, treated drainage, and passive discharge in post closure. Process water estimates are based on leachate collected from metallurgical test columns. The treated effluent concentrations are based on bench-scale treatability testwork using site-specific ore and metallurgical process water solutions. The passive discharge source term is based on published literature on effluent quality from permeable reactive barriers with an emphasis on mining examples and solutions containing elevated parameters predicted for Coffee Gold (e.g., nitrate, arsenic, uranium)
- *Stockpiles*: A source term has been developed to account for loads associated with overburden placed in the plant site area and is based on the results of shake flask extraction data from site specific materials. The model does not account for any additional loads associated with soil salvage stockpiles since these loads are expected to be insignificant. An ROM stockpile source term has been developed based on humidity cell results, but because the drainage will be captured by the HLF drainage collection system, these terms are not reflected in the water quality model output.
- *Blasting residues*: source terms have been developed to quantify nitrogen (N) loads resulting from the use of nitrogen-based explosives. The residues associated with blasted waste rock are calculated as a function of annual project schedules for waste rock deposition and explosives consumption, as per an Environment Canada study (Ferguson and Leask, 1988). Concentrations of N in waste rock leachate were calculated as a function of mean annual precipitation and normalized to leachate data from analogue mine sites in northern environments. Nitrogen loadings at the Project site were assumed to decline based on observations from large-scale instrumented waste rock lysimeters at the Diavik Mine (Bailey et al, 2013) and were normalized to local mean annual precipitation. The loads are assumed to decrease

at a constant decay rate of 14% through to the end of the modelled Post-Closure phase and until they reach background levels. A detailed description of the methods used to derive the N source terms for different Project components is provided in Appendix E-1 of Appendix 12-D, the Geochemical Characterization Report, and includes the equations as well as the complete set of calculated N source terms.

4.3 *Model Cases*

Water quality predictions throughout Operation, Closure and Post-closure mine phases were generated for a Base Case and an Upper Geochemistry Case. All of the model cases are based upon data generated from 28 different climate realizations such that variable flow conditions have been applied to each mine year. The details of the different model cases are presented below. The effects of climate change on temperature and precipitation are incorporated into all modelled scenarios.

4.3.1 Base Case

The Base Case model scenario incorporates base case geochemical source terms for mine-related inputs (Appendix 12-D; summarized in Section 4.2.2), expected flow conditions and conservative assumptions regarding climate change. Base case water quality predictions are calculated from the mean of the model output generated from 28 different climate realizations applied to each mine year (Section 3.2.1). The Base Case is considered to represent a robust expected case and, as such, forms the basis for the surface water quality effects assessment (Appendix 12-B).

4.3.2 Upper Geochemistry Case

The Upper Geochemistry Case incorporates upper case geochemical source terms for all mine-related inputs, expected case flow conditions and conservative assumptions regarding climate change. Similar to the Base Case, Upper Geochemistry Case water quality predictions are calculated from the mean of the model output generated from 28 different climate realizations. Details of the approach for developing Upper Geochemistry Case source terms are provided in Appendix 12-D.

4.4 *Limitations and Assumptions*

The water quality predictions developed for the Project are subject to certain limitations and assumptions related to the design of the Project and the site-specific data sets available. The main water quality model limitations and assumptions are highlighted below:

- Water will be managed at the mine site in accordance with the Water Management Plan (Appendix 31-E);
- Non-contact water is diverted around pits and WRSF where possible do so. In circumstances where non-contact water flows into the WRSF, the WQM assigns a contact load to the flow term. Specifically, the model applies an additional load to the flow term that is 20% the magnitude assigned to an equivalent WRSF infiltration flow;
- It is assumed that there is no leakage from collection ditches and storage ponds;
- The settling ponds will receive both contact flow and non-contact water and will function as designed; they will be effective in eliminating total suspended solids (TSS) prior to discharge;
- Sedimentation ponds are allowed to fill according to the water balance flows and pond volumes and discharge accordingly (e.g., no managed flow), with the exception of the Alpha Pond which is pumped during open water season to a maximum of 300 L/s;
- Precipitation runoff associated with pit walls for all pits collects within the pit and is discharged directly to the receiving environment (unless otherwise stated in the Water Management Plan);
- It is assumed that contact water is not used for dust suppression at the mine site
- Mine facilities will be developed according to the development schedules and timelines set out in the mine plan, as described in Section 2.0 (the Project Description). For this version of the GoldSim WBM/WQM, facility footprints are assumed to be at maximum for all of the Operation and Closure phase;
- The WTP will treat contact water from the heap leach facility as specified below:
    - Discharge of treated water will begin in Operation YR9, at a rate of 4L/s for eight years, followed by four additional years of discharge at a higher treatment rate (11 L/s) as dictated by the operation and drain-down heap leach water balance model (see Appendix 12-C-1 and Appendix 12-C-2);
    - Effluent quality from the water treatment plant are based on bench scale test results of metallurgical heap leach solutions;
    - Treatment and discharge are assumed to only occur during the 6-month open-water period;

  - It is assumed that active treatment will no longer be required by YR 20, at which point discharge from the detoxified HLF will be directed to Latte pit via passive treatment at flow rates dictated by variable meteoric inputs;

- A portion of water collected in certain pits (*e.g.*, Latte, SU2, SU4N and SU4S) will leak via groundwater pathways
  - Leakage is determined based on elevation-dependent flows (Appendix 7-B1) and the predicted water quality in the respective pits;
  - It is assumed that leakage reports instantaneously to the receiving environment;

- The GoldSim water quality model employs a mass balance approach and does not explicitly account for geochemical or microbially-mediated reactions that are likely to occur in the surface receiving environment; however, it is assumed that a seventy-five percent load reduction is applied to species subject to reductive attenuation in anaerobic groundwater environments (*e.g.*, NO_2, NO_3, WADCN) and species where natural attenuation in the groundwater environment has been observed (Sb and As). All other parameters are treated conservatively.

4.5 *Results*

4.5.1 Overview

The full set of water quality model (WQM) results are presented for the Base Case and Upper Case in Appendix 12-C-5 and Appendix 12-C-6. The results include monthly water quality predictions for all modelled parameters in Pit lakes, Sedimentation Ponds and the receiving environment. For the receiving environment plots, the Natural Case results, reflecting baseline mean monthly concentrations in the receiving Creeks and Yukon River, are also provided for comparison.

Water quality results for pit lakes, sedimentation ponds and receiving environment locations are summarized in the following sections with relevant guidelines provided for reference. The discussion is focused on parameters showing mine-related signatures, highlighting the time periods where the impact is most pronounced.

4.5.2 Pit Lakes

The proposed Project includes plans to develop eleven pits over the course of the Construction and Operation phases. Some of the pits will be backfilled with waste rock, whereas others will be flooded and eventually spill to the receiving environment via settling ponds. This section presents a summary of the WQM results for pit lakes throughout all mine phases for Base Case, Upper Case, and Upper Geochemistry Case scenarios. The full Pit Lake data set is included in Appendix B.1.

The proposed timeline for pit development and management is shown in Figure 4-3, by pit. The main activities that relate to pit development and management include:

- Dewatering during pit development;
- Water accumulation in the absence of water management (filling);
- Back-filling with waste-rock where relevant (backfilled); and
- Discharge of accumulated water to the receiving environment (spill-over).

The water balance model (WBM) assumes pits are dewatered while they are under construction. Once each pit is fully developed, management of pit water is assumed to cease and pits are allowed to fill via groundwater infiltration and surface runoff. Depending on the leakage rate assigned to each pit, surface water from pits is assumed to spill over into receiving creeks at a certain point during mine life, representing a direct surface discharge that continues beyond the Closure phase. The model predicts the SU2 pit may or may not spill depending on climate and hydrological conditions.

For the purpose of evaluating pit lake water quality, maximum predicted values of parameters listed as Deleterious Substances under Schedule 4 of Metal Mining Effluent Regulation (MMER) are compared to their corresponding MMER Maximum Authorized Monthly Mean (Table 4-3; except TSS which was not modelled).

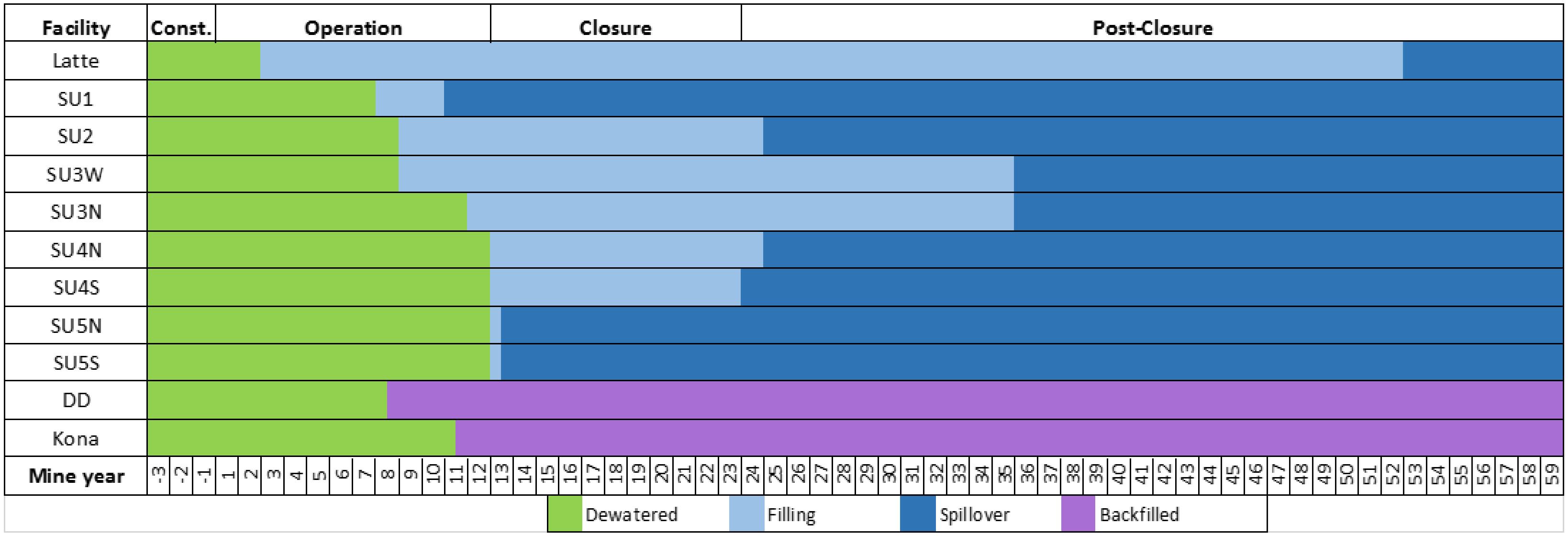


Figure 4-3: Proposed Timeline for Development and Management of Coffee Gold Pits

Although water in pit lakes will not be subject to regulatory limits, including MMER, this water may report to the receiving environment via surface discharge or groundwater without treatment, making MMER limits appropriate for screening purposes. Maximum monthly values across all Project phases are shown (as opposed to the mean or another statistic by mine phase) to identify parameters that have potential to exceed their MMER limit at any point during mine life.

The pit lake results indicate that all monthly predictions fall well below corresponding MMER Maximum Authorized Monthly Mean (Table 4-3) values. In general, the model predicts that SU1 Pit will have the highest concentrations of Cu, Pb, Zn and Ra-226 whereas, Latte Pit will have the highest concentrations of WADCN, SO_4 As, Sb, Ni and Zn as a result of discharge of HLF seepage at closure. However, the predicted maximum concentrations in Latte Pit, even under the Upper Case assumptions are well below MMER limits. Most parameters of interest for all pits are predicted to be at low concentrations throughout all mine phases.

Table 4-3:
Maximum modelled water quality predictions through life of mine at Coffee Gold Pit Lakes for Base Case and Upper Case Scenarios for Key Parameters

Modelled parameter			WADCN	SO_4	NO_3	As	Sb	Cd	Cu	Pb	Ni	Se	U	Zn	Ra-226
Units			mg/L	mg/L	mg/L	mg/L	mg/L	Mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Bq/L
Receiver	Pit	MMER Guideline	1**			0.5			0.3		0.5		0.2	0.5	0.37
Catchment	Base Case														
Latte	SU1		0.0003	197	6.2	0.013	0.011	0.000028	0.0013	0.00017	0.0013	0.00058	0.103	0.013	0.024
	SU2		0.00001	35	0.5	0.02	0.011	0.000033	0.001	0.0001	0.0012	0.0006	0.06	0.009	0.019
	SU4S		0.00001	38	0.4	0.018	0.008	0.000043	0.0017	0.0002	0.0015	0.0006	0.046	0.011	0.039
YT-24	SU5N		0.00001	33	0.51	0.023	0.011	0.000034	0.001	0.0001	0.0012	0.0006	0.064	0.010	0.022
	SU5S		0.00001	33	0.51	0.023	0.011	0.000034	0.001	0.0001	0.0012	0.0006	0.064	0.010	0.022
	SU3N		0.00001	33	0.5	0.026	0.011	0.00003	0.001	0.0001	0.0012	0.0006	0.064	0.010	0.023
	SU3W		0.00001	33	0.51	0.027	0.011	0.00003	0.001	0.0001	0.0012	0.0006	0.064	0.010	0.023
Halfway	Latte		0.031	199	3.6	0.033	0.028	0.000065	0.0021	0.0003	0.0056	0.0044	0.042	0.014	0.022
Catchment	Upper Case														
Latte	SU1		0.006	283	9.3	0.025	0.011	0.00003	0.0015	0.00026	0.0016	0.0009	0.241	0.018	0.045
	SU2		0.00001	37	0.5	0.035	0.015	0.000037	0.001	0.0002	0.0013	0.0008	0.156	0.010	0.058
	SU4S		0.00001	39	0.42	0.028	0.011	0.000045	0.0018	0.00028	0.0015	0.00058	0.114	0.011	0.064
YT-24	SU5N		0.00001	34	0.5	0.039	0.013	0.000038	0.0011	0.00022	0.0013	0.0008	0.160	0.011	0.064
	SU5S		0.00001	34	0.5	0.039	0.013	0.000038	0.0011	0.00022	0.0013	0.0008	0.160	0.011	0.064
	SU3N		0.00001	34	0.5	0.044	0.013	0.000037	0.0011	0.00022	0.0013	0.00076	0.155	0.010	0.064
	SU3W		0.00001	34	0.5	0.045	0.013	0.000037	0.0011	0.00022	0.0013	0.00076	0.156	0.010	0.065
Halfway	Latte		0.06	371	9.8	0.066	0.054	0.00018	0.0046	0.0011	0.011	0.011	0.106	0.024	0.028

Notes: *Maximum authorized monthly mean concentration under Schedule 4 (Authorized Limits of Deleterious Substances) of Metal Mining Effluent Regulation (MMER).
**MMER maximum authorized monthly mean concentration for total cyanide shown for comparison to model prediction for weak acid dissociable (WAD) CN.

4.5.3 Alpha WRSF Seepage and Alpha Pond Overflow Chemistry

There are two sedimentation ponds as part of the water management plan for the Coffee Mine: Alpha Pond and Facility Pond. Only the Alpha Pond discharges to the receiving environment of Halfway Creek; water in the Facility Pond is used within the HLF process. Discharge from the Alpha Pond will include contributions from infiltration seepage from the Alpha WRSF, runoff from the Beta WRSF that reports to the rock drain and undisturbed catchment runoff also reporting to the rock drain. As such, water quality for the Alpha WRSF is provided in addition to water quality from the Alpha Pond; the latter receives non-contact runoff and therefore moderate reductions in concentrations are observed within the Alpha Pond relative to Alpha WRSF seepage.

In Table 4-4, the Base Case and Upper Case water quality exiting the toe of the Alpha WRSF is presented along with the Alpha Pond water quality which is the final point prior to discharge to Halfway Creek. Results for the maximum modelled values of parameters are compared to their corresponding MMER Maximum Authorized Monthly Mean.

As illustrated, predicted maximum values for the Alpha Pond discharge, under both Base Case and Upper Case assumptions, fall well below the corresponding MMER Maximum Authorized Monthly Mean (Table 4-4).

Table 4-4:
Maximum modelled water quality predictions through life of mine for Alpha WRSF Seepage and Alpha Pond Discharge for Base Case and Upper Case Scenarios for Key Parameters

Modelled parameter			WADCN	SO_4	NO_3	As	Sb	Cd	Cu	Pb	Ni	Se	U	Zn	Ra-226
Units			mg/L	mg/L	mg/L	mg/L	mg/L	Mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Bq/L
Receiver	**Model Case**	**MMER Guideline**	**1****			**0.5**			**0.3**		**0.5**		**0.2**	**0.5**	**0.37**
Catchment	**Base Case**														
Alpha Pond	*Alpha WRSF Seepage*		0.0046	461	9.3	0.0095	0.01	0.000033	0.0033	0.0004	0.003	0.0012	0.125	0.03	0.06
Halfway Creek	*Alpha Pond Discharge*		0.0023	362	7.5	0.005	0.0076	0.00002	0.002	0.0003	0.002	0.0008	0.087	0.024	0.047
Catchment	**Upper Case**														
Alpha Pond	*Alpha WRSF Seepage*		0.009	672	13.7	0.025	0.017	0.00005	0.0037	0.00061	0.005	0.0024	0.255	0.044	0.06
Halfway Creek	*Alpha Pond Discharge*		0.0047	533	11	0.02	0.012	0.000028	0.0024	0.00041	0.003	0.0015	0.195	0.035	0.049

Notes: *Maximum authorized monthly mean concentration under Schedule 4 (Authorized Limits of Deleterious Substances) of Metal Mining Effluent Regulation (MMER).
**MMER maximum authorized monthly mean concentration for total cyanide shown for comparison to model prediction for weak acid dissociable (WAD) CN.

4.5.4 Receiving Environment

The receiving environment for the Project covers four major catchments (Latte Creek, Coffee Creek, YT-24, and Halfway Creek; Figure 3-1). In support of the Project Proposal for the Coffee Gold Project, water quality predictions were generated for 10 locations (model nodes) within these catchments.

Base Case and Upper Geochemistry Case results are compared to Natural Case. Natural Case represents the predevelopment base for each corresponding catchment, while Base Case model scenario incorporates base case geochemical source terms for mine-related inputs. The Upper Geochemistry Case incorporates upper case geochemical source terms for all mine-related inputs, and expected case flow conditions.

The full set of Base Case and Upper Geochemistry Case modelling results for each model node are presented in full in Appendix 12-C-5 and Appendix 12-C-6, respectively. The discussion of results presented in the following sections focuses on select parameters at nine model nodes:

- Latte Creek: CC-1.5, mid-catchment, CC-3.5, lower-catchment;
- Coffee Creek: CC-4.5, downstream of confluence with Latte Creek;
- YT-24: YT-24, lower-catchment near outlet to the Yukon River;
- Halfway Creek: HC-2.5, mid-catchment, HC-5.0, lower catchment; and
- Yukon River: YRdsCC , downstream of Coffee Creek, YRdsYT-24, downstreatm of YT-24, and YRdsHC, downstreatm of Halfway Creek.

Model results for the tenth model node, CC-0.5, are not presented here as this station is located upstream of all mine discharges and was included in the water quality model largely for the purpose of model calibration.

Water quality results for each catchment are summarized in the following sections, including monthly maximum values for all 25 modelled parameters compared to (generic) water quality guidelines (GWQG), and preliminary site-specific water quality objectives (SSWQO) as relevant. Water quality results for key parameters are highlighted and discussed in the context of contributing sources through mine life and seasonal variations. The predicted concentrations are plotted from the beginning of late Operation phase (YR 7) through to Post-closure (YR 33), at which point, mine-related changes to parameter concentration are predicted to have generally stabilized with proposed Project footprints near, or at, their maxima.

4.5.4.1 *Latte Creek*

The Water Management Plan for the Project (Appendix 31-E) assumes that the Latte Creek catchment will receive water from various mine-related sources, most notably the Double Double Pit, individual pits associated with the Supremo Pit (SU1, SU2, SU4N and SU4S), and limited passive discharge from the reclaimed HLF via Latte Pit in Post-Closure. Water quality predictions for all modelled parameters at Latte Creek model nodes CC-1.5 and CC-3.5 are summarized in Table 4-5 and Table 4-6, respectively. Maximum modelled values through life of mine are also presented for all model scenarios and compared to GWQG and SSWQO.

Table 4-5:
Maximum modelled water quality predictions through life of mine at CC-1.5 for Natural Case, Base Case and Upper Geochemistry Case scenarios

Parameters	Units	PSSWQO*	GWQG**	Natural Case	Base Case	Upper Geochem Case
NH3-N	mg/L	-	1.63	0.0344	0.0350	0.0419
NO3-N	mg/L	-	3	0.349	1.05	1.45
NO2-N	mg/L	-	0.02	0.005	0.007	0.013
SO4	mg/L	-	309	249	249	249
P	mg/L	-	0.1	0.0139	0.0155	0.0213
WADCN	mg/L	-	0.005	0.00001	0.00011	0.00021
D-Al	mg/L	0.351	0.05	0.265	0.261	0.261
Ag	mg/L	-	0.00025	0.000012	0.000012	0.000015
As	mg/L	-	0.005	0.00180	0.00298	0.00420
Ca	mg/L	-	-	140	140	140
Cd	mg/L	-	0.00013	0.000041	0.000040	0.000040
Cr	mg/L	-	0.001	0.00074	0.00075	0.00079
Cu	mg/L	0.003	0.002	0.00254	0.00252	0.00252
Fe	mg/L	-	1	0.290	0.287	0.287
Hg	mg/L	-	0.000026	0.000011	0.000011	0.000014
Mg	mg/L	-	-	43.9	43.9	43.9
Mn	mg/L	-	0.966	0.0492	0.0489	0.0501
Mo	mg/L	-	0.073	0.00060	0.00519	0.01071
Ni	mg/L	-	0.082	0.00160	0.00159	0.00166
Pb	mg/L	-	0.0025	0.00030	0.00029	0.00030
Sb	mg/L	-	0.009	0.00020	0.00116	0.00144
Se	mg/L	-	0.002	0.00040	0.00040	0.00040
Tl	mg/L	-	0.0008	0.000008	0.000033	0.000061
U	mg/L	0.031	0.015	***0.0319***	***0.0326***	***0.0414***
Zn	mg/L	-	0.015	0.00437	0.00543	0.00605

Notes: *Proposed site specific water quality objective. Refer to Appendix 12-C-4 of Project Proposal for further detail.
**Generic British Columbia Ministry of Environment (BCMOE) or Canadian Council of Ministers of the Environment (CCME) water quality guideline for protection of aquatic life. Hardness- and pH-dependent guidelines calculated from 25th percentile of baseline dataset. Refer to Appendix 12-C-4 of Project Proposal for further detail. Note that the CCME P trigger range varies seasonally and only applies during open-water time periods (April-September) with upper trigger range value and 0.1 mg/L.
Shaded values exceed their BC or CCME WQG. ***Bold-italic*** values exceed their proposed SSWQO.

Table 4-6:
Maximum modelled water quality predictions through life of mine at CC-3.5 for Natural Case, Base Caseand Upper Geochemistry Case scenarios

Parameters	Units	PSSWQO*	GWQG**	Natural Case	Base Case	Upper Geochem Case
NH3-N	mg/L	-	1.63	0.0343	0.0343	0.0385
NO3-N	mg/L	-	3	0.566	0.817	1.07
NO2-N	mg/L	-	0.02	0.0050	0.0065	0.0098
SO4	mg/L	-	309	174	171	171
P	mg/L	-	0.1	0.0144	0.0151	0.0182
WADCN	mg/L	-	0.005	0.00001	0.00008	0.00016
D-Al	mg/L	0.351	0.05	0.270	0.256	0.256
Ag	mg/L	-	0.00025	0.000011	0.000011	0.000011
As	mg/L	-	0.005	0.00124	0.00148	0.00230
Ca	mg/L	-	-	94.8	92.9	92.9
Cd	mg/L	-	0.00013	0.000041	0.000040	0.000041
Cr	mg/L	-	0.001	0.00074	0.00074	0.00076
Cu	mg/L	0.003	0.002	0.00253	0.00248	0.00248
Fe	mg/L	-	1	0.291	0.282	0.282
Hg	mg/L	-	0.000026	0.000011	0.000011	0.000013
Mg	mg/L	-	-	30.1	29.5	29.5
Mn	mg/L	-	0.966	0.0513	0.0500	0.0507
Mo	mg/L	-	0.073	0.000567	0.00312	0.00622
Ni	mg/L	-	0.082	0.00160	0.00158	0.00162
Pb	mg/L	-	0.0025	0.000310	0.000296	0.000307
Sb	mg/L	-	0.009	0.000153	0.000654	0.000806
Se	mg/L	-	0.002	0.000280	0.000275	0.000275
Tl	mg/L	-	0.0008	0.000007	0.000020	0.000036
U	mg/L	0.031	0.015	0.0212	0.0208	0.0230
Zn	mg/L	-	0.015	0.00441	0.00497	0.00531

Notes: *Proposed site specific water quality objective. Refer to Appendix 12-C-4 of Project Proposal for further detail.
**Generic British Columbia Ministry of Environment (BCMOE) or Canadian Council of Ministers of the Environment (CCME) water quality guideline for protection of aquatic life. Hardness- and pH-dependent guidelines calculated from 25th percentile of baseline dataset. Refer to Appendix 12-C-4 of Project Proposal for further detail. Note that the CCME P trigger range varies seasonally and only applies during open-water time periods (April-September) with upper trigger range value and 0.1 mg/L.
Shaded values exceed their BC or CCME GWQG.

In general, the CC-1.5 results (Table 4-5) predict GWQG exceedances of three parameters (D-Al, Cu, and U) for both the Base Case and Upper Geochemistry Case scenarios. Water quality guideline exceedances for these parameters are driven by naturally-elevated background levels, with predicted values being only marginally higher than the Natural Case. Uranium is also predicted to exceed its proposed SSWQO by a small amount due to mine-related discharge, most notably in the Upper Geochemistry Case.

Water quality predictions at CC-3.5, located ~10 km downstream of CC-1.5, show considerably lower maximum values compared to CC-1.5 (Table 4-6). The Latte Creek discussion presented below focuses on nitrate and U predictions at CC-1.5 (where mine influence will be most pronounced), to illustrate the effect of different mine-related sources to water quality predictions. It is noted that predicted exceedances of the D-Al GWQG are driven exclusively by the Natural Case (i.e., background) rather than by mining-related sources; as such, results for D-Al are not presented in further detail.

Nitrate

Concentrations of nitrogen species, including nitrate (NO_3), are predicted to increase by a small degree at Latte Creek stations CC-1.5 and CC-3.5 commensurate with Project development due to nitrogen-based explosives use.

Base Case NO_3 is predicted to exceed Natural Case levels during open-water months through the Construction and Operation phases due pit development (Figure 4-4). As the Double Double Pit and the southern portions of Supremo Pit are developed, contact waters from pit walls and back-fill materials carrying blasting residues are expected to increase NO_3 levels reporting to CC-1.5 during open-water months, up to a maximum of 0.93 mg-N/L (YR 3) (Figure 4-4). Peak monthly concentrations gradually decline on an annual basis through Closure as mine development (and thus explosives use) ceases and the inventory of leachable nitrogen species diminishes. Following Closure, Base Case NO_3 concentrations return to Natural Case levels once nitrogen sources from pits and backfill are reduced. Nitrate loadings over time to CC-1.5 from mine related components is presented in Figure 4-5.

The Upper Geochemistry Case predicts somewhat higher NO_3 levels relative to Base Case (up to 1.26 mg-N/L; YR 3). Similar to Base Case, predicted increases above Natural Case occur during open-water periods in association with dewatering of the Double Double and Supremo Pits to Latte Creek (Figure 4-6). Peak concentrations gradually decline through Closure. Nitrogen loads are considered a finite mine source and concentrations of all nitrogen species in Latte Creek are predicted to return to Natural Case levels following Closure once this source is exhausted.

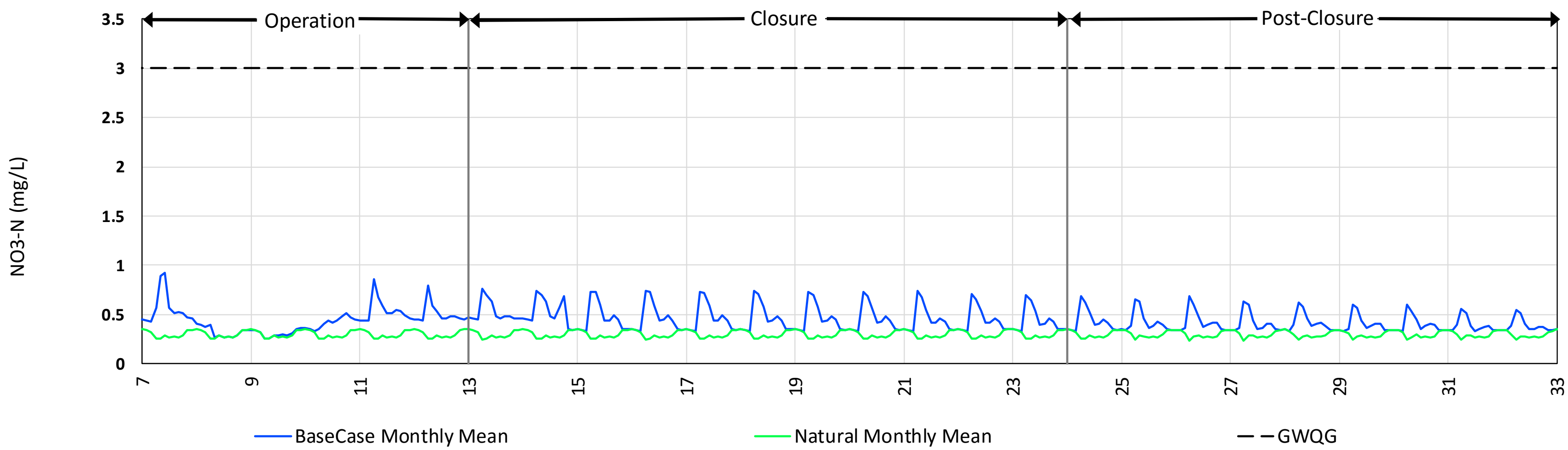


Figure 4-4: Nitrate Base Case compared to Natural case at CC-1.5 through Operation, Closure, and Post-Closure Mine Phases. GWQG = Generic BC long-term water quality guideline for the protection of freshwater aquatic life.

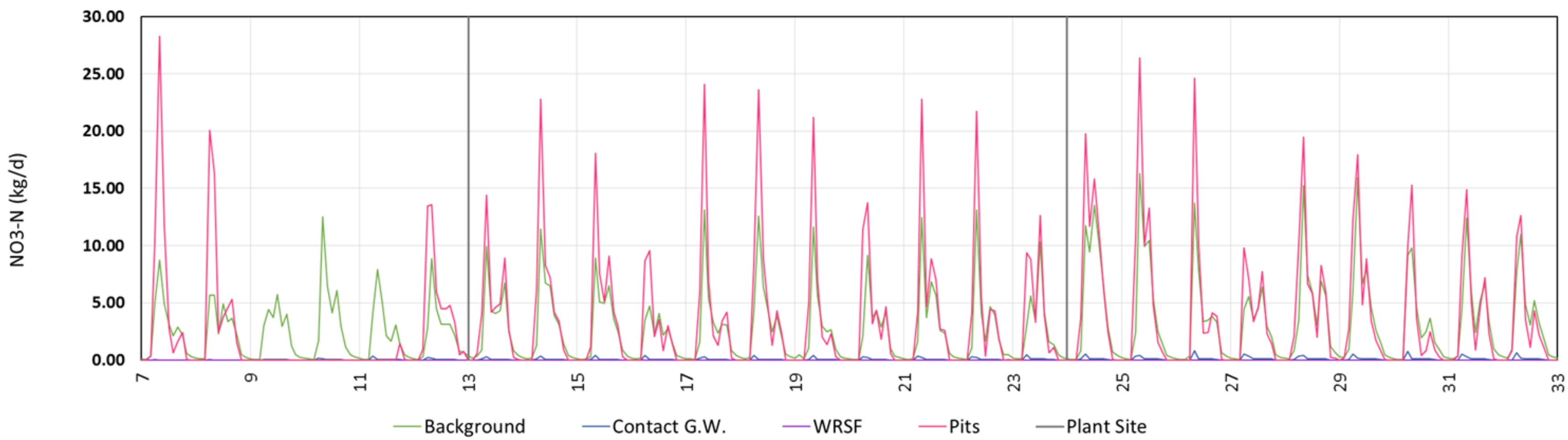


Figure 4-5: Base Case nitrate loadings in kg/day at CC-1.5 from major mine-related sources through Operation, Closure, and Post-Closure Mine Phases.

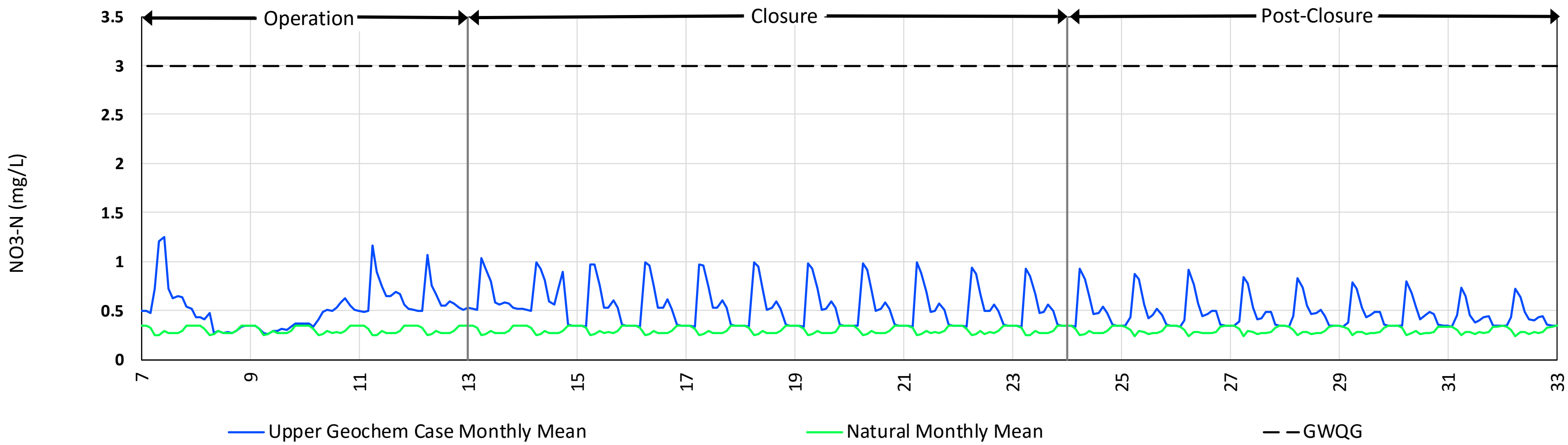


Figure 4-6: Nitrate Upper Geochemistry Case compared to Natural case at CC-1.5 through Operation, Closure, and Post-Closure Mine Phases. GWQG = Generic BC long-term water quality guideline for the protection of freshwater aquatic life.

Uranium

Natural Case U concentrations in Latte Creek are predicted to exceed the GWQG (0.015 mg/L) during winter months, reflecting natural enrichment within this catchment (Figure 4-7). Indeed, U is enriched in gneiss and schist waste rock (and ore) at the Project site (Appendix 12-D). The predicted mine-related U loadings to Latte Creek will be controlled by the pH of mine site drainage and the presence of complexing ions which can promote U leaching from exposed rock surfaces.

Uranium concentrations in Latte Creek are therefore predicted to increase with Project development. During months of open water in the Base Case, small relative increases above the Natural Case are predicted to occur beginning during operations phase and continuing beyond Closure (Figure 4-7). These increases are attributed to pit wall contact run-off and backfill from the Double Double Pit and portions of the Supremo Pit (SU1, SU2, SU4N, and SU4S), most notably during Operations (as the pit walls are progressively exposed, followed by pit backfilling) and during Post-Closure (when water management has ceased and water accumulating in the pits spill-over into the receiving environment) (Figure 4-7 and Figure 4-8).

Marginal increases above Natural Case are also predicted to occur in winter months of certain years of the Base Case (e.g., YR 10 to YR 13), resulting in small increases above the SSWQO at CC-1.5. However, naturally-elevated background concentrations of ~0.03 mg/L during the low-flow months dominates the U signature in Latte Creek, such that the predicted exceedances above the SSWQO represent a very minor Project-related change.

As expected, the Upper Geochemistry Case predictions show a larger increase in U concentrations to Latte Creek, compared to Base Case, with winter low-flow values increasing to levels above the GWQG year-round for most of mine life. Increases are attributed to upper case geochemical source terms for the Double Double and Supremo Pit contact areas (most notably pit walls and backfill). The Upper Geochemistry Case further indicates small relative exceedances of the proposed SSWQO may occur under certain water management conditions, as illustrated by short-lived U peaks occurring in the month of April from YR 11 onwards (Figure 4-9).

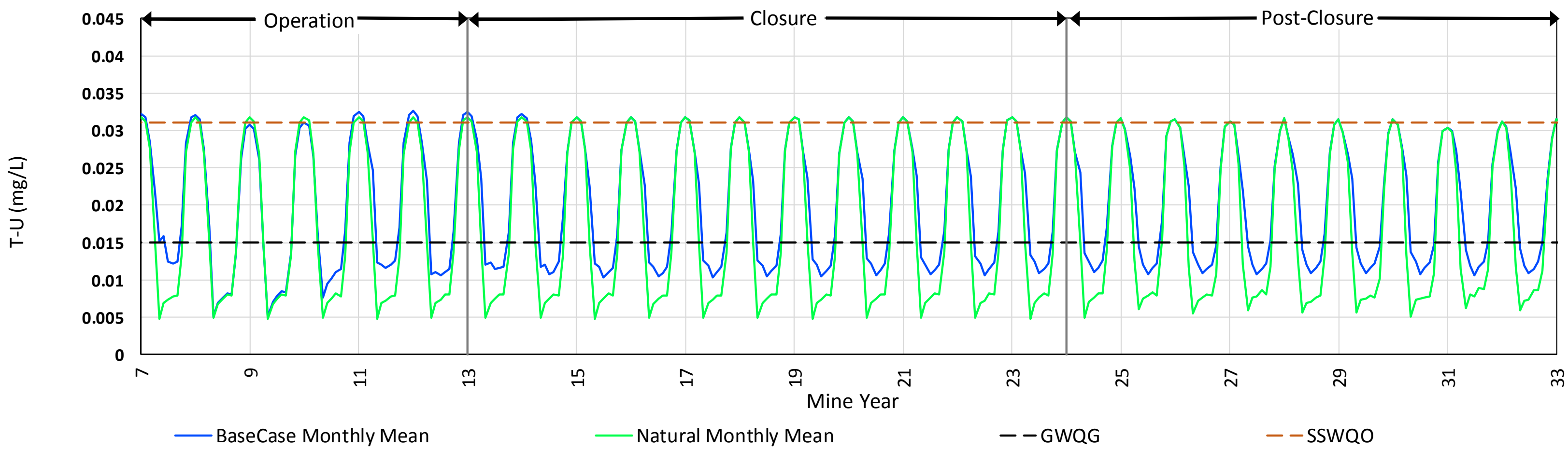


Figure 4-7: Total Uranium Base Case compared to Natural case at CC-1.5 through Operations, Closure, and Post-Closure Mine Phases. GWQG = Generic CCME long-term water quality guideline for the protection of freshwater aquatic life. SSWQO = Proposed Site Specific Water Quality Objective.

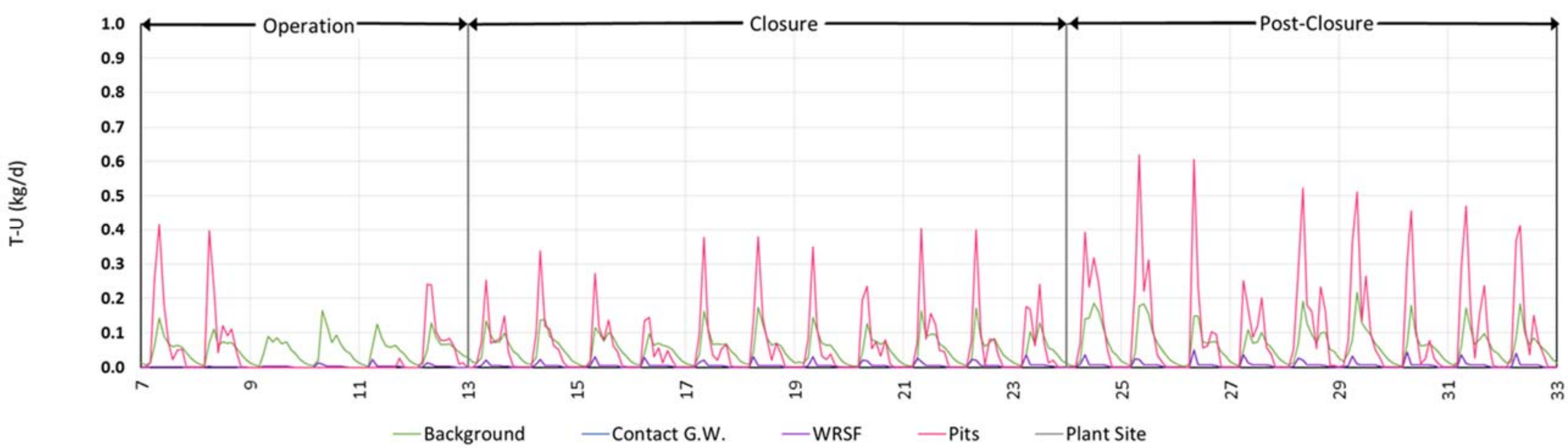


Figure 4-8: Base Case total uranium loadings in kg/day at CC-1.5 from mine-related sources through Operation, Closure, and Post-Closure Mine Phases.

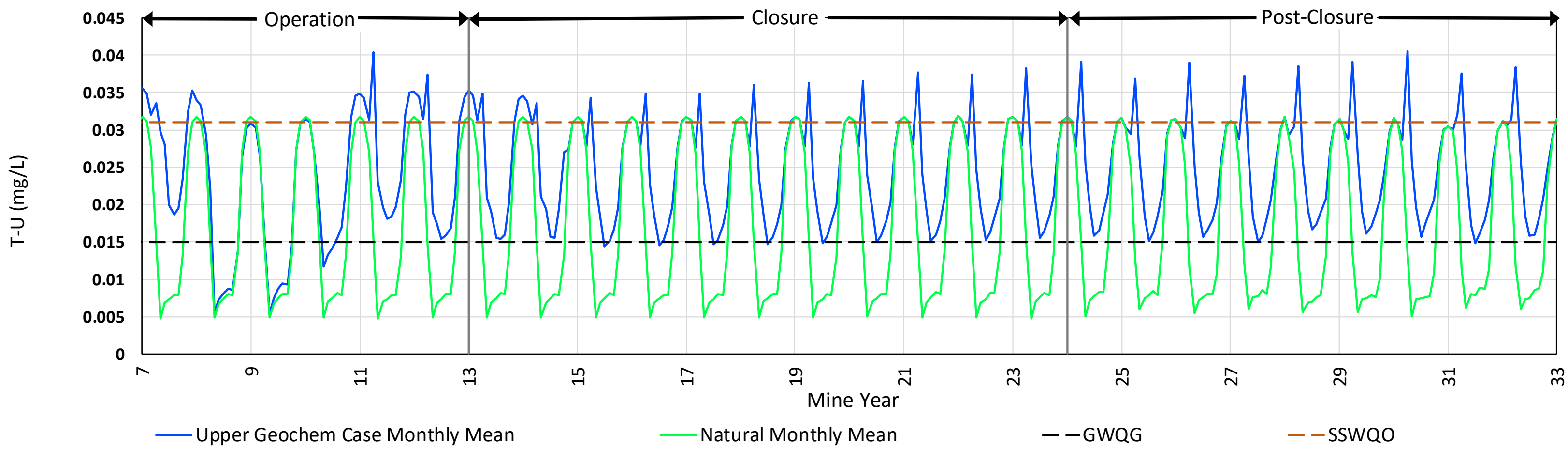


Figure 4-9: Total Uranium Upper Geochemistry Case compared to Natural case at CC-1.5 through Operations, Closure, and Post-Closure Mine Phases. GWQG = Generic CCME long-term water quality guideline for the protection of freshwater aquatic life. SSWQO = Proposed Site Specific Water Quality Objective.

4.5.4.2 *Coffee Creek*

Coffee Creek receives flows from Latte Creek, but the overall Coffee Creek catchment area is much larger than the Latte Creek catchment and thus affords significant dilution. Comparison of the maximum predicted values for Natural Case, Base Case and Upper Geochemistry Case (Table 4-7) show a negligible to very low mine-related effect at CC-4.5. Note CC-4.5 predictions presented below are not compared to GWQGs or SSWQOs as measured values will be screened against site-specific, non-degradation benchmark objectives that are considered more appropriate for monitoring effects to Coffee Creek (non-degradation objectives are presented in Appendix 12-C-4 for reference). Overall, the water quality model results for Cu and U are highlighted below and discussed in the context of seasonal variability and mine-related activities.

Table 4-7:
Maximum modelled water quality predictions through life of mine at CC-4.5 for Natural Case, Base Case and Upper Geochemistry Case scenarios

Parameters	Units	Natural Case	Base Case	Upper Geochemistry Case
NH3-N	mg/L	0.0365	0.0364	0.0368
NO3-N	mg/L	0.792	0.792	0.792
NO2-N	mg/L	0.0050	0.0052	0.0057
SO4	mg/L	88.9	88.9	88.9
P	mg/L	0.0173	0.0173	0.0176
WADCN	mg/L	0.000010	0.000018	0.000026
D-Al	mg/L	0.315	0.313	0.313
Ag	mg/L	0.000015	0.000015	0.000015
As	mg/L	0.00064	0.00072	0.00084
Ca	mg/L	39.6	39.6	39.6
Cd	mg/L	0.000040	0.000040	0.000040
Cr	mg/L	0.00072	0.00072	0.00072
Cu	mg/L	0.00333	0.00331	0.00331
Fe	mg/L	0.392	0.389	0.389
Hg	mg/L	0.000011	0.000011	0.000011
Mg	mg/L	13.9	13.9	13.9
Mn	mg/L	0.0283	0.0284	0.0284
Mo	mg/L	0.00081	0.00114	0.00160
Ni	mg/L	0.00148	0.00147	0.00148
Pb	mg/L	0.000275	0.000274	0.000275
Sb	mg/L	0.000226	0.000281	0.000306
Se	mg/L	0.000129	0.000133	0.000138
Tl	mg/L	0.000007	0.000009	0.000011
U	mg/L	0.00638	0.00668	0.00816
Zn	mg/L	0.00450	0.00457	0.00461

Similar to Latte Creek, D-Al, Cu, and Fe are naturally-elevated in Coffee Creek, as reflected in the Natural Case for CC-4.5. The predicted trends in seasonal and inter-annual concentrations are also comparable for these parameters in all modelled scenarios. Model results for total copper at CC-4.5 are described here, but would similarly apply to predictions for D-Al and Fe.

Overall, Project development is predicted to result in a negligible change to both mean monthly total Cu and U values in the Base Case from Natural Case (Figure 4-10 and Figure 4-12. Given Cu levels are driven almost exclusively by background, no change from Natural Case or Base Case is predicted in the Upper Geochemistry Case for Cu (Figure 4-11).

In the Upper Geochemistry Case for total U, however, a minor increase (1 to 2 µg/L) from Natural Case is predicted during months of open water (Figure 4-13). This increase is attributed to contributions from the southern lobes of Supremo Pit backfill and Double Double Pit to Latte Creek during open-water months when active dewatering (during Operation) or passive pit overflow occurs (during Closure and afterwards).

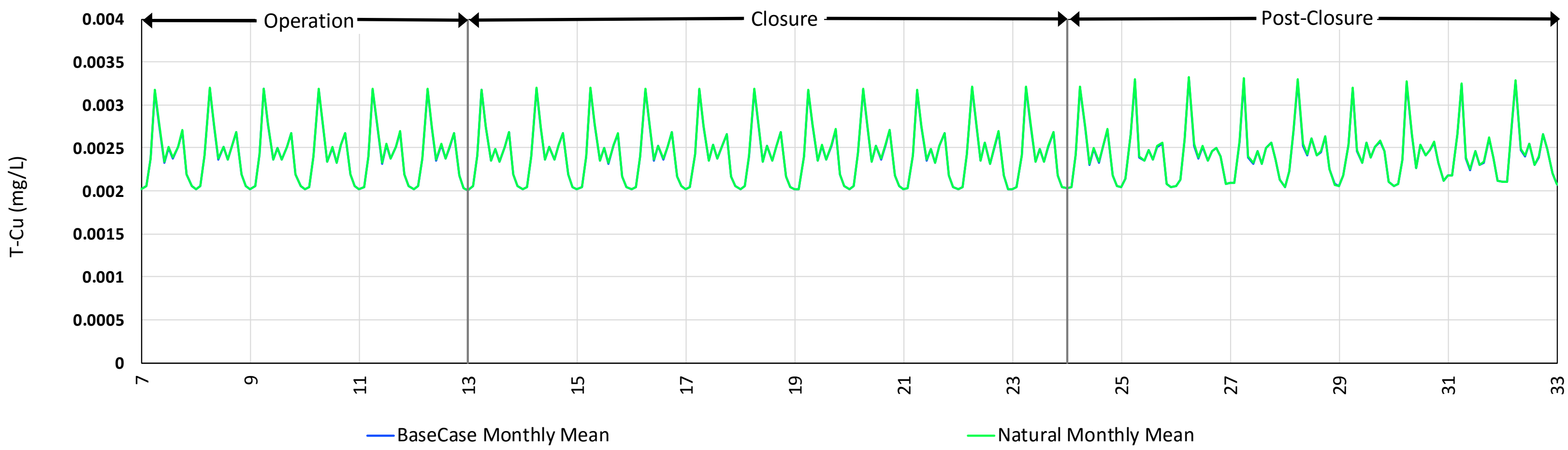


Figure 4-10: Total Copper Base Case compared to Natural case at CC-4.5 through Operations, Closure, and Post-Closure Mine Phases.

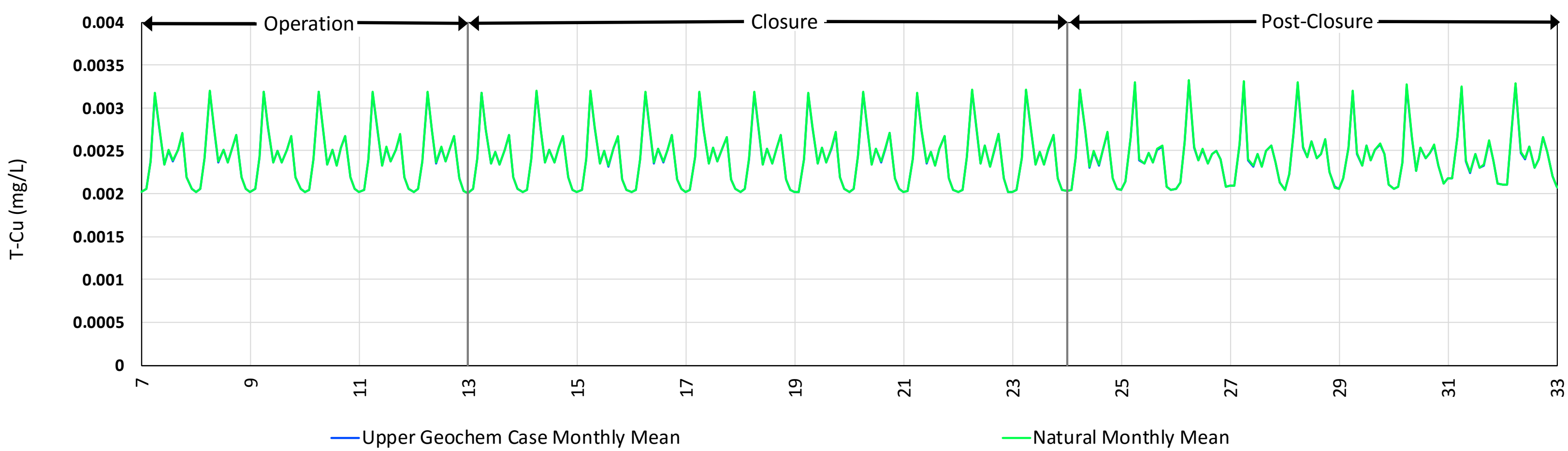


Figure 4-11: Total Copper Upper Geochemistry Case compared to Natural case at CC-4.5 through Operation, Closure, and Post-Closure Mine Phases.

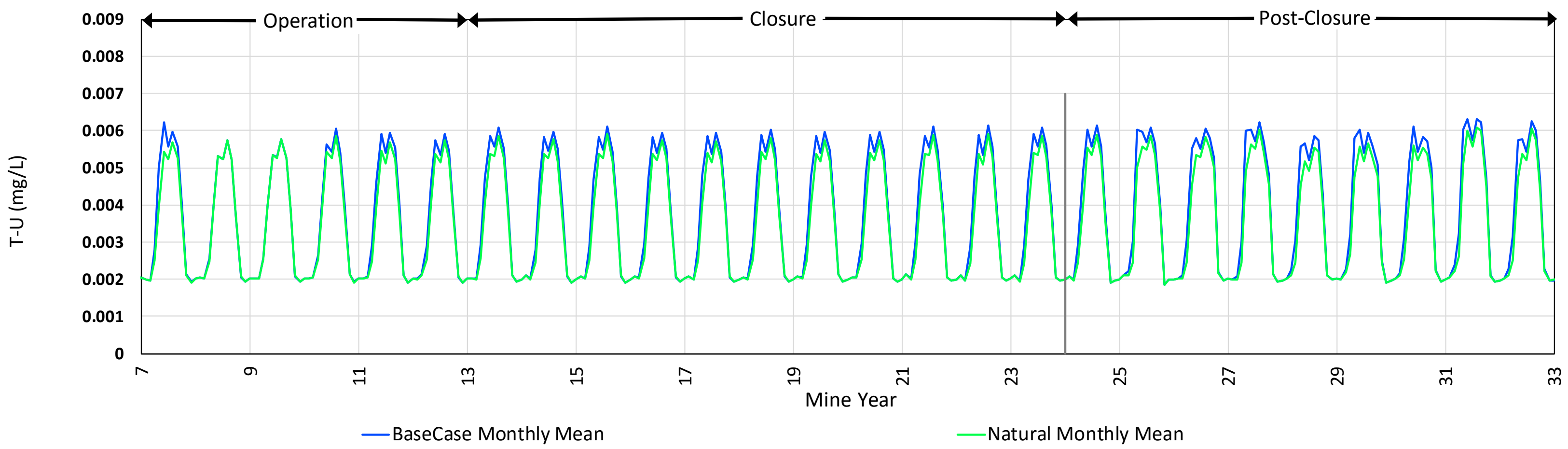


Figure 4-12: Total Uranium Base Case compared to Natural case at CC-4.5 through Operation, Closure, and Post-Closure Mine Phases.

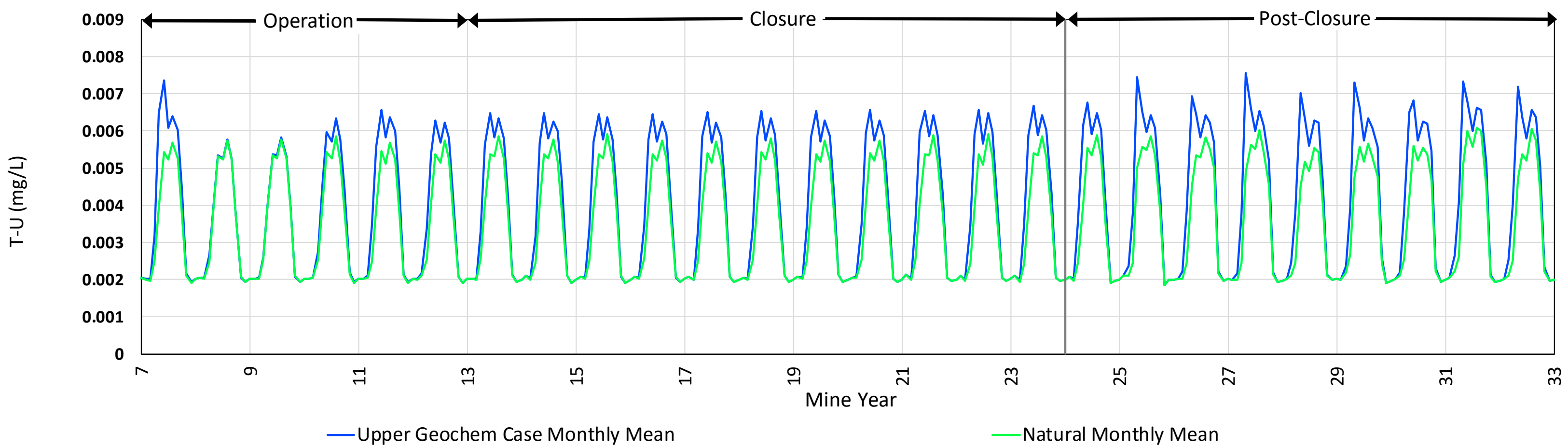


Figure 4-13: Total Uranium Upper Geochemistry Case compared to Natural case at CC-4.5 through Operation, Closure, and Post-Closure Mine Phases.

4.5.4.3 *YT-24 Tributary*

YT-24 Tributary receives drainage (during mine operation) and contact groundwater (during mine closure and in post-closure) from the northern portion of the Supremo Pit. Source areas include SU3W (end of mine only), SU3N, SU5N and SU5S.

Water quality predictions for all modelled parameters at model node YT-24 are summarized in Table 4-8, where the maximum modelled values for any given month through life of mine are presented for all model scenarios as compared to GWQG and SSWQO.

Table 4-8:
Maximum modelled water quality predictions through life of mine at YT-24 for Natural Case, Base Case and Upper Geochemistry Case scenarios

Parameters	Units	PSSWQO*	GWQG**	Natural Case	Base Case	Upper Geochemistry Case
NH_3-N	mg/L	-	1.91	0.0300	0.0322	0.0322
NO_3-N	mg/L	-	3	0.700	0.699	0.699
NO_2-N	mg/L	-	0.02	0.0050	0.0052	0.0052
SO4	mg/L	-	218	40.0	39.9	39.9
P	mg/L	-	0.1	0.0146	0.0166	0.0185
WADCN	mg/L	-	0.005	0.000010	0.000010	0.000010
D-Al	mg/L	0.205	0.05	0.0554	0.0533	0.0533
Ag	mg/L	-	0.00025	0.000012	0.000013	0.000013
As	mg/L	-	0.005	0.0007	0.0064	0.0105
Ca	mg/L	-	-	30.0	40.5	42.7
Cd	mg/L	-	0.0001	0.000009	0.000015	0.000015
Cr	mg/L	-	0.00100	0.00050	0.00050	0.00050
Cu	mg/L	0.0034	0.002	0.00270	0.00261	0.00261
Fe	mg/L	-	1	0.140	0.140	0.140
Hg	mg/L	-	0.000026	0.000008	0.000008	0.000008
Mg	mg/L	-	-	10.0	13.0	13.7
Mn	mg/L	-	0.856	0.0050	0.0219	0.0243
Mo	mg/L	-	0.073	0.00053	0.00588	0.00675
Ni	mg/L	-	0.061	0.00150	0.00150	0.00150
Pb	mg/L	-	0.0015	0.000060	0.000065	0.000085
Sb	mg/L	-	0.009	0.00040	0.00261	0.00315
Se	mg/L	-	0.002	0.00012	0.00021	0.00024
Tl	mg/L	-	0.0008	0.000006	0.000041	0.000049
U	mg/L	-	0.015	0.00100	0.0146	0.0355
Zn	mg/L	-	0.011	0.00144	0.00316	0.00319

Notes: *Proposed site specific water quality objective for HC-2.5. Refer to Appendix 14-C-4 of the Project Proposal for further detail.
**Generic British Columbia Ministry of Environment (BCMOE) or Canadian Council of Ministers of the Environment (CCME) water quality guideline for protection of aquatic life. Hardness- and pH-dependent guidelines calculated from 25th percentile of baseline dataset. Refer to Appendix 12-C-4 of the Project Proposal for further detail. Note that the CCME P trigger range varies seasonally and only applies during open-water time periods (April-September) with upper trigger range value and 0.1 mg/L.
Shaded values exceed their BC or CCME GWQG.

YT-24 results (Table 4-8) predict GWQG exceedances of four parameters (D-Al, As, Cu, and U) across the different modelled scenarios. Base case GWQG exceedances of D-Al, Cu and U are driven by naturally-elevated background levels; maximum Natural Case values are only slightly lower than Base Case levels (or higher, in the case of Cu). The Upper Geochemistry Case predicts the highest concentrations of mine-related parameters, particularly in the case of As and U, which are both predicted to occur at levels up to twice their corresponding GWQGs. Results for As are summarized below while noting that trends shown by As are similar to those returned by U.

Arsenic

Natural Case As is typically low in the YT-24 system, with mean annual values of approximately <0.001 mg/L (Figure 4-14).

Base Case water quality predictions for As at YT-24 indicate year-round increases above Natural Case levels from Construction through Operations, with minor exceedances of the GWQG (up to 0.0064 mg/L) predicted in the months of May and October (Figure 4-14). Run-off from exposed pit walls of the northern portions of the Supremo Pit (SU3W, SU3N, SU5N and SU5S) and pit dewatering represents the dominant source of As to YT-24 (Figure 4-15). During Closure, the SU5S and SU5N pits fill relatively quickly and begin to passively spill in the direction of YT-24 (Figure 4-3). In contrast, the SU3N and SU3W pits are not predicted to fill and spill passively in the Post-closure Phase. It should be noted that SU3W will spillover toward Halfway Creek during this phase.

The Upper Geochemistry Case follows a similar general trend as the Base Case, although predicted As levels are relatively higher. Arsenic is predicted to exceed the GWQG from during the later period of operation up to a maximum of 0.0105 mg/L during Yr 9 (Figure 4-16). As described for Base Case, this trend is attributed to contact water associated with development of southern lobes of the Supremo pit, and pit dewatering discharging to YT-24.

Trends shown by arsenic are mirrored by other mine-related parameters predicted to increase in YT-24 with Project development (e.g., U).

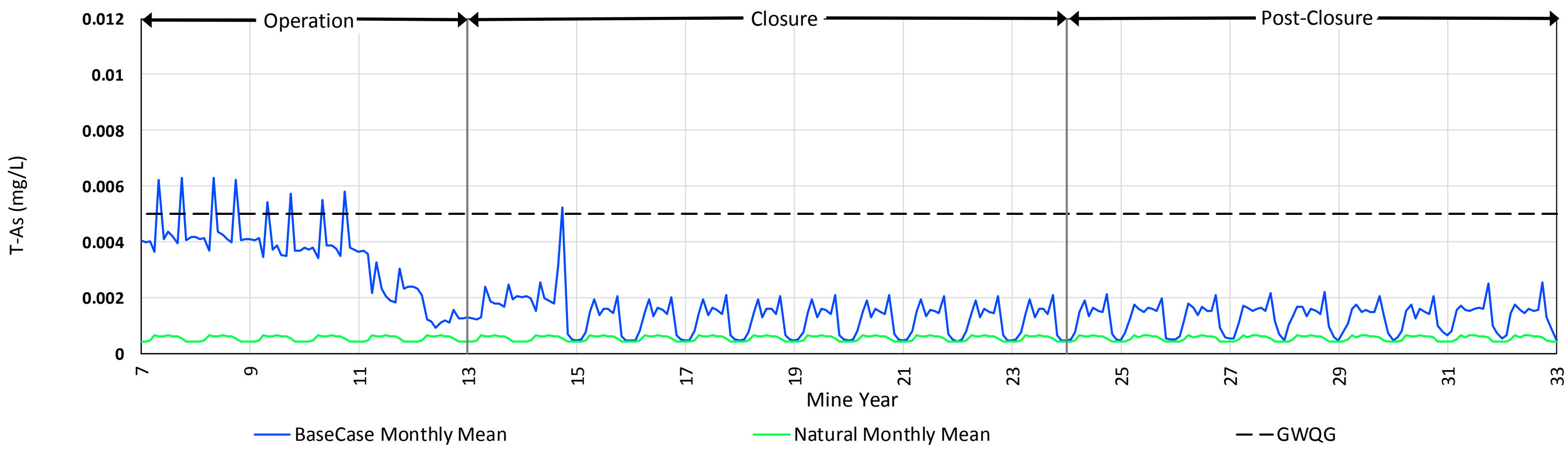


Figure 4-14: Total As Base Case compared to Natural case at YT-24 through Operation, Closure, and Post-Closure Mine Phases. GWQG = Generic CCME long-term water quality guideline for the protection of freshwater aquatic life.

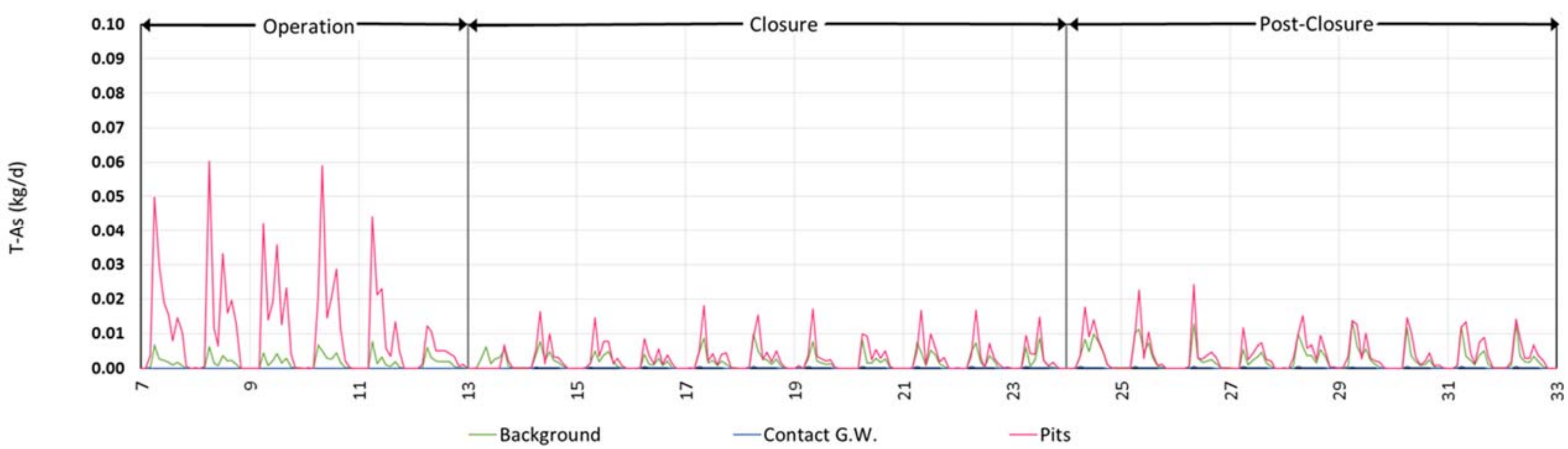


Figure 4-15: Base Case arsenic loadings in kg/day at YT-24 from mine-related sources through Operation, Closure, and Post-Closure Mine Phases.

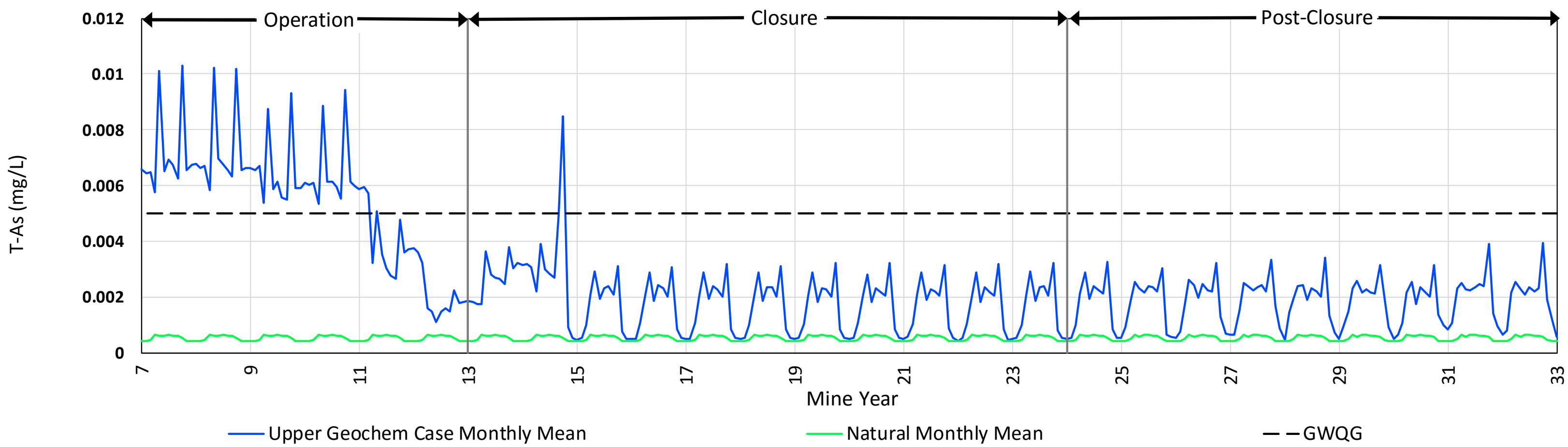


Figure 4-16: Total As Upper Geochemistry Case compared to Natural case at YT-24 through Operation, Closure, and Post-Closure Mine Phases. GWQG = Generic CCME long-term water quality guideline for the protection of freshwater aquatic life.

4.5.4.4 *Halfway Creek*

The Halfway Creek catchment will be the primary receiver of mine-related contact water associated with the Coffee Gold Project. Halfway Creek will receive surface flows from the Alpha Pond, which included contact water from the Alpha WRSF, Beta WRSF and water treatment plant effluent from the HLF. Following Closure, Halfway Creek will receive passive drainage from the back-filled Kona Pit, the HLF (post-treatment and after the facility has been decommissioned) via Latte Pit, and Supremo Pit area SU3W, as well as continued seepage from the Alpha WRSF.

Water quality predictions for two Halfway Creek model nodes are presented: HC-2.5 and HC-5.0. Results are summarized in Table 4-9 and Table 4-10, where maximum modelled values through life of mine are presented for all model scenarios as compared to GWQG and SSWQO. In general, the HC-2.5 results (Table 4-9) predict GWQG exceedances of four parameters (D-Al, Cr, Cu, and U) for the Base Case scenario; and 10 parameters (NO_3-N, NO_2-N, SO_4, D-Al, As, Cr, Cu, Hg, U and Zn) for the Upper Geochemistry Case scenario. Except for U, most of the elevated parameters in Base Case predictions can be attributed to naturally-elevated background levels. The Upper Geochemistry Case results show concentration ranges similar to the Base Case, but with notably higher predictions for NO_3-N, NO_2-N, As, Hg, U and Zn.

HC-5.0 results predict measurably lower maximum values (Table 4-10) as compared to HC-2.5 results, as expected due to the additional background flows available for dilution. The Halfway Creek discussion presented below focuses on NO_3-N, SO4, Cu and U predictions at HC-2.5 to illustrate various model conditions and pathways for this catchment.

Table 4-9:
Maximum modelled water quality predictions through life of mine at HC-2.5 for Natural Case, Base Case and Upper Geochemistry Case scenarios

Parameters	Units	PSSWQO*	GWQG**	Natural Case	Base Case	Upper Geochemistry Case
NH3-N	mg/L	-	1.91	0.0384	0.0369	0.0888
NO3-N	mg/L	-	3	0.698	2.75	4.00
NO2-N	mg/L	-	0.02	0.005	0.0151	0.0280
SO4	mg/L	-	218	99.6	200	293
P	mg/L	-	0.1	0.0158	0.0256	0.0571
WADCN	mg/L	-	0.005	0.00001	0.00158	0.00316
D-Al	mg/L	0.403	0.05	0.282	0.268	0.268
Ag	mg/L	-	0.00025	0.000012	0.000018	0.000052
As	mg/L	-	0.005	0.00157	0.00274	0.0105
Ca	mg/L	-	-	59.8	59.8	82.6
Cd	mg/L	-	0.00011	0.000028	0.000027	0.000033
Cr	mg/L	-	0.00100	0.00120	0.00134	0.00168
Cu	mg/L	0.003	0.002	0.00294	0.00282	0.00282
Fe	mg/L	-	1	0.785	0.726	0.726
Hg	mg/L	-	0.000026	0.000011	0.000010	0.000032
Mg	mg/L	-	-	24.9	27.4	40.4
Mn	mg/L	-	0.891	0.0563	0.0950	0.125
Mo	mg/L	-	0.073	0.00249	0.0270	0.0635
Ni	mg/L	-	0.069	0.00139	0.00176	0.00278
Pb	mg/L	-	0.0018	0.000326	0.00031	0.00038
Sb	mg/L	-	0.009	0.00120	0.00432	0.00683
Se	mg/L	-	0.002	0.000160	0.000667	0.00134
Tl	mg/L	-	0.0008	0.00001	0.00015	0.00032
U	mg/L	0.086	0.015	***0.0996***	***0.0996***	***0.112***
Zn	mg/L	-	0.013	0.0040	0.0142	0.0203

Notes: *Proposed site specific water quality objective. Refer to Appendix 12-C-4 of the Project Proposal for further detail.
**Generic British Columbia Ministry of Environment (BCMOE) or Canadian Council of Ministers of the Environment (CCME) water quality guideline for protection of aquatic life. Hardness- and pH-dependent guidelines calculated from 25th percentile of baseline dataset. Refer to Appendix 12-C-4 of the Project Proposal for further detail. Note that the CCME P trigger range varies seasonally and only applies during open-water time periods (April-September) with upper trigger range value and 0.1 mg/L. As such, the maximum P concentrations presented are the maximum values predicted during open-water months.
Shaded values exceed their BC or CCME GWQG. ***Bold-italic*** values exceed their proposed SSWQO.

Table 4-10:
Maximum modelled water quality predictions through life of mine at HC-5.0 for Natural Case, Base Case, Upper Case and Upper Geochemistry Case scenarios

Parameters	Units	PSSWQO*	GWQG**	Natural Case	Base Case	Upper Geochemistry Case
NH_3-N	mg/L	-	1.91	0.0399	0.0382	0.0719
NO_3-N	mg/L	-	3	0.694	1.87	2.64
NO_2-N	mg/L	-	0.02	0.005	0.0115	0.0196
SO_4	mg/L	-	218	29.1	131	189
P	mg/L	-	0.1	0.0163	0.0199	0.0406
WADCN	mg/L	-	0.005	0.00001	0.00102	0.00204
D-Al	mg/L	0.403	0.05	0.291	0.281	0.281
Ag	mg/L	-	0.00025	0.000006	0.000013	0.000036
As	mg/L	-	0.005	0.00162	0.00231	0.00706
Ca	mg/L	-	-	41.9	48.5	67.7
Cd	mg/L	-	0.00011	0.000029	0.000028	0.000029
Cr	mg/L	-	0.00100	0.00121	0.00127	0.00148
Cu	mg/L	0.003	0.002	***0.00302***	0.00293	0.00293
Fe	mg/L	-	1	0.808	0.758	0.758
Hg	mg/L	-	0.000026	0.000011	0.000010	0.000025
Mg	mg/L	-	-	10.0	20.8	29.0
Mn	mg/L	-	0.891	0.0583	0.0750	0.0927
Mo	mg/L	-	0.073	0.00066	0.01740	0.04119
Ni	mg/L	-	0.069	0.00142	0.00158	0.00221
Pb	mg/L	-	0.0018	0.00033	0.00032	0.00035
Sb	mg/L	-	0.009	0.000451	0.002832	0.004459
Se	mg/L	-	0.002	0.00008	0.00046	0.00089
Tl	mg/L	-	0.0008	0.00001	0.00010	0.00021
U	mg/L	0.086	0.015	0.0225	0.0374	0.0725
Zn	mg/L	-	0.013	0.00413	0.0102	0.0140

Notes: *Proposed site specific water quality objective for HC-2.5. Refer to Appendix A of Project Proposal Appendix 12-B for further detail.

**Generic British Columbia Ministry of Environment (BCMOE) or Canadian Council of Ministers of the Environment (CCME) water quality guideline for protection of aquatic life. Hardness- and pH-dependent guidelines calculated from 25th percentile of baseline dataset. Refer to Appendix A of Project Proposal Appendix 12-B for further detail. Note that the CCME P trigger range varies seasonally and only applies during open-water time periods (April-September) with upper trigger range value and 0.1 mg/L. As such, the maximum P concentrations presented are the maximum values predicted during open-water months.

Shaded values exceed their BC or CCME GWQG. ***Bold-italic*** values exceed their proposed SSWQO.

Nitrate

Similar to other catchments, NO_3 levels are predicted to temporarily increase at Halfway Creek station HC-2.5 in association with Project development and nitrogen-based explosives use. Highest mean monthly concentrations are predicted to occur at HC-2.5, relative to HC-5.0, due to less background dilution available for Project-related contact water at this station.

In the Natural Case, NO_3 levels in Halfway Creek are low (typically around 0.5 mg-N/L) reflecting a low-nutrient baseline condition. Base Case concentrations at HC-2.5 are initially elevated through the Operation phase (Figure 4-17), peaking annually in May and June, but remaining <2.5 mg-N/L, largely driven by loading from the Alpha WRSF (Figure 4-18). Nitrate levels begin to decay through the Closure phase, but are predicted to temporarily increase up to 2.75 mg-N/L in YR 21 as the HLF transitions from active to passive treatment. Following this event, monthly NO_3 concentrations are predicted to gradually decline on an annual through to Post-Closure in conjunction with the cessation of explosives use.

Higher NO_3 levels are predicted in the Upper Geochemistry Case relative to Base Case (Figure 4-19) due to increased conservatism in nitrogen source terms associated with blasted rock (Appendix 12-D). In this model scenario, mean monthly concentrations during the open-water period are predicted to exceed the BC GWQG (3 mg-N/L) by a small margin (up to 11%) through Construction and Operation, but gradually decline through Closure. As reported in the Base Case, the transition to passive HLF treatment in YR 21 results in a temporary increase in HC-2.5 annual maxima (up to 4.0 mg-N/L during open-water months), but concentrations gradually decline to Natural Case through Closure and Post-Closure.

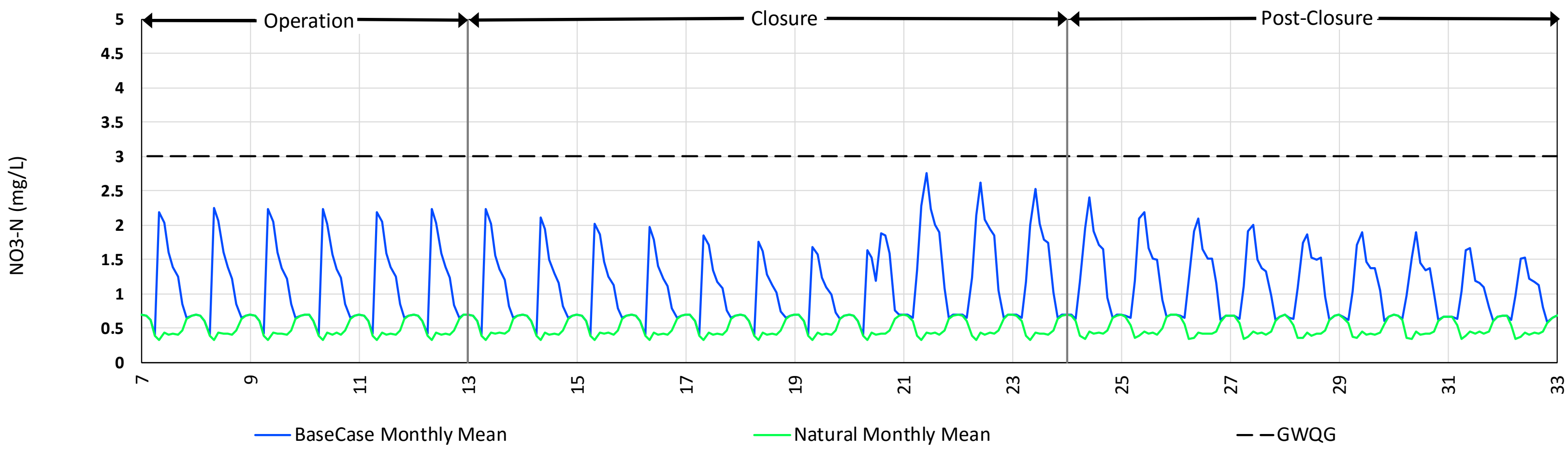


Figure 4-17: Nitrate Base Case compared to Natural case at HC-2.5 through Operation, Closure, and Post-Closure Mine Phases. GWQG = Generic BC long-term water quality guideline for the protection of freshwater aquatic life.

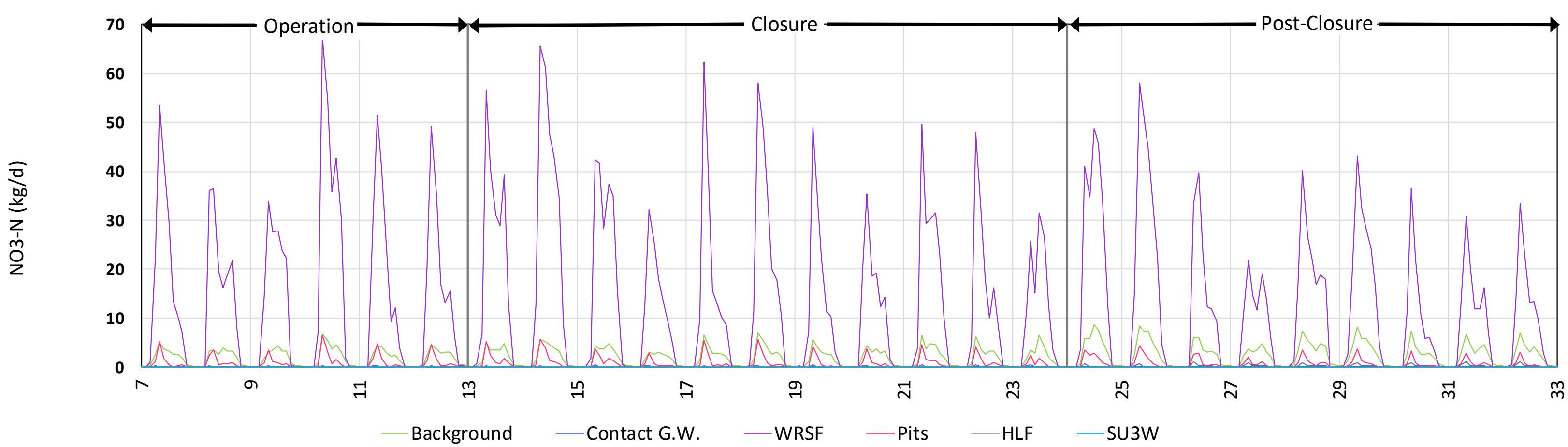


Figure 4-18: Base Case nitrate loadings in kg/day at HC-2.5 from mine-related sources through Operation, Closure, and Post-Closure Mine Phases.

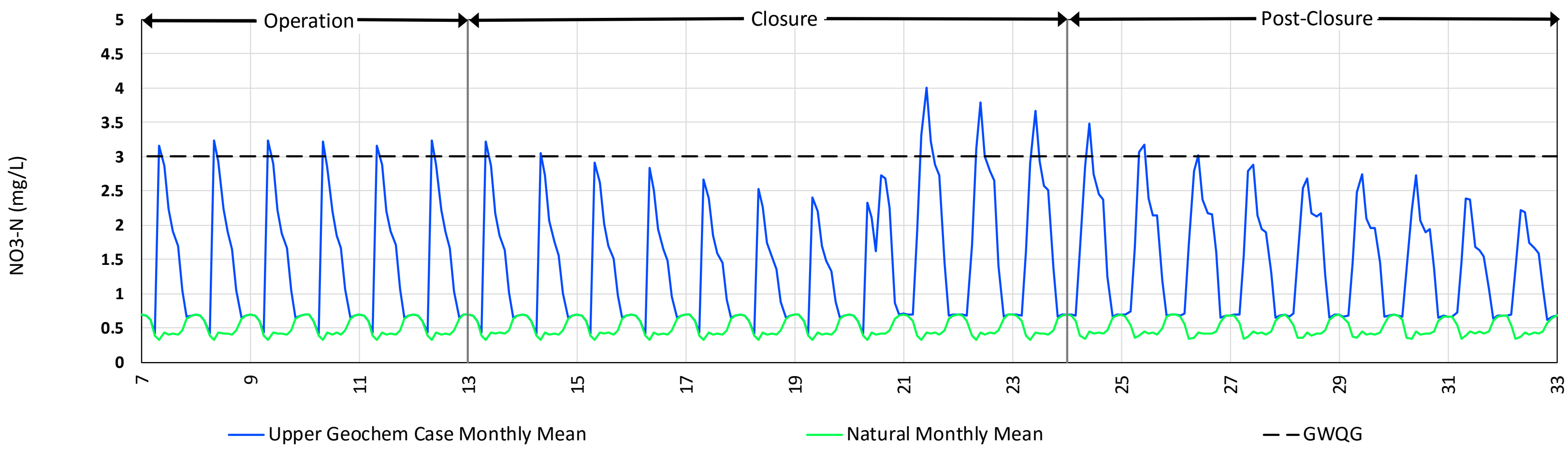


Figure 4-19: Nitrate Upper Geochemistry Case compared to Natural case at HC-2.5 through Operation, Closure, and Post-Closure Mine Phases. GWQG = Generic BC long-term water quality guideline for the protection of freshwater aquatic life.

Sulphate

Sulphate levels in Halfway Creek are predicted to increase from baseline levels during months of open water due to Project development (Figure 4-20 and Figure 4-21). In the Base Case, increases through Operation and early Closure are driven by the Alpha WRSF, with minor contributions from the Kona and Latte Pits, and from the HLF during summer months. During months of ice cover, Base Case SO_4 levels are driven almost exclusively by background as reflected in the Natural Case (Figure 4-22).

Predicted Base Case SO_4 concentrations further increase starting in YR 20 during months of open water, driven by loading associated with the WRSF paired with additional contributions from contact groundwater once active HLF treatment is discontinued. Despite predicted increases to annual Base Case peaks, starting in YR 21 and onwards, all predictions remain below the GWQG.

Higher SO_4 levels are predicted to occur in the Upper Geochemistry Case relative to Base Case (Figure 4-22), most notably following the HLF transition to passive treatment, at the onset of passive contact groundwater losses to Halfway Creek via Latte pit. This phenomenon results in peak summer concentrations for the Upper Geochemistry Case predicted to consistently exceed the BC GWQG from YR 21 onwards, up to a maximum of 293 mg/L.

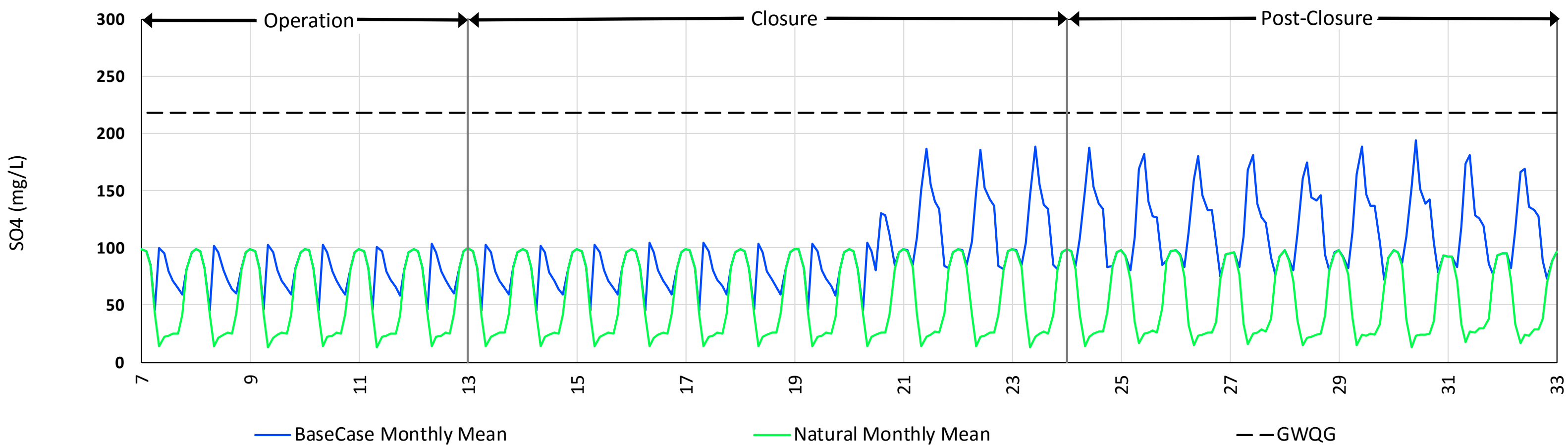


Figure 4-20: Sulphate Base Case compared to Natural case at HC-2.5 through Operation, Closure, and Post-Closure Mine Phases. GWQG = Generic BC long-term water quality guideline for the protection of freshwater aquatic life; calculated using 25th percentile baseline hardness data.

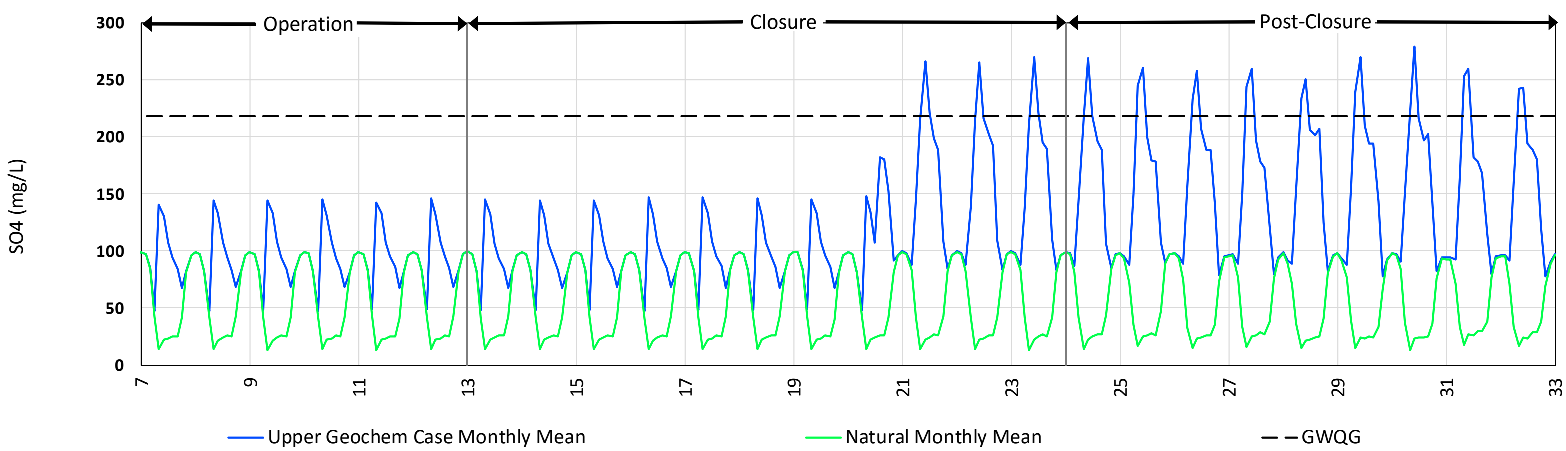


Figure 4-21: Sulphate Upper Geochemistry Case compared to Natural case at HC-2.5 through Operation, Closure, and Post-Closure Mine Phases. GWQG = Generic BC long-term water quality guideline for the protection of freshwater aquatic life; calculated using 25th percentile baseline hardness data.

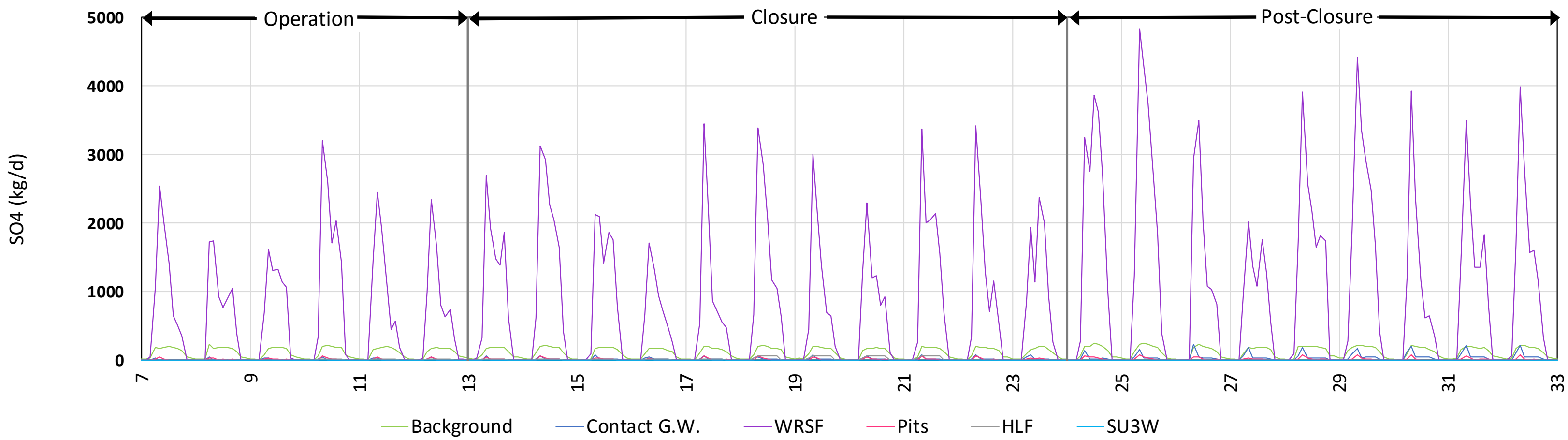


Figure 4-22: Base Case sulphate loadings in kg/day at HC-2.5 from mine-related sources through Operation, Closure, and Post-Closure Mine Phases.

Copper

As shown for other Project area catchments, Cu, D-Al and Fe are naturally-elevated in Halfway Creek. Guidelines for these parameters are exceeded on an annual basis in the Natural Case, and similar seasonal and inter-annual trends are predicted for the Base Case and Upper Geochemistry Case. As such, model results described below for Cu are representative of trends shown by D-Al and Fe as well.

Total Cu concentrations are predominantly driven by background flows, with minor contributions from the Alpha WRSF (Operations and Closure), and passive discharge of contact groundwater and pit spillage through Closure and Post Closure (Figure 4-23 and Figure 4-24). Despite mine-related contributions, Base Case mine discharge to Halfway Creek results in a net dilution effect to Cu levels relative to the Natural Case attributed to low level of Cu in mine contact and diverted water relative to background (Figure 4-23).

Upper Geochemistry Case predictions (Figure 4-25) are similar to Base Case, indicating that increases to Cu in Halfway Creek are more likely to be driven by Project- and climate-related changes to flows rather than geochemical sources.

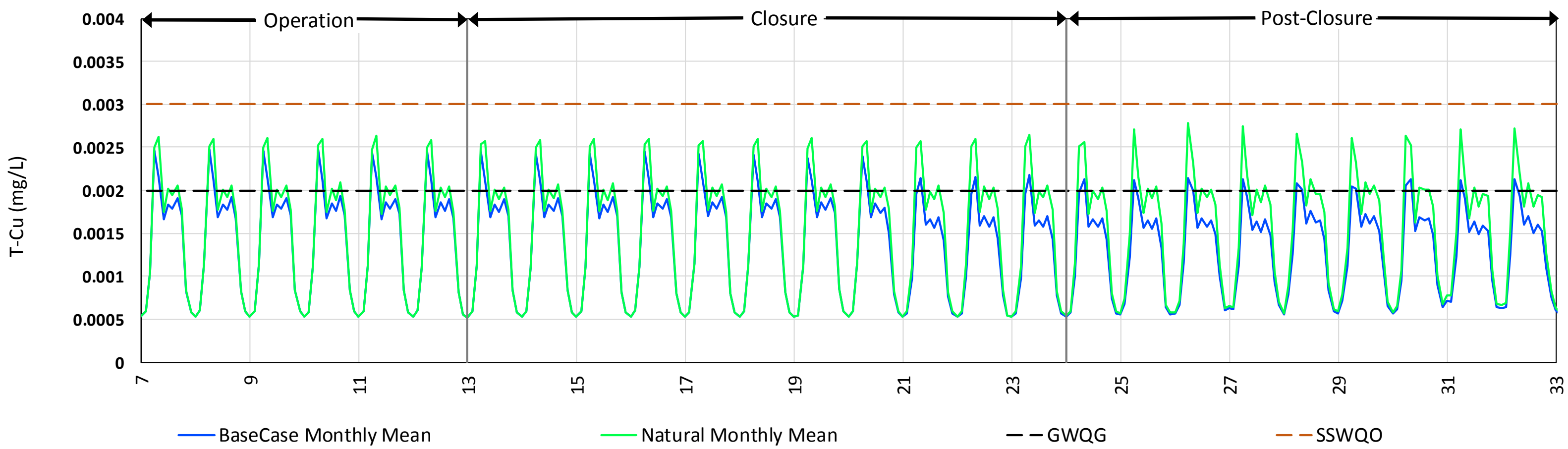


Figure 4-23: Total Copper Base Case compared to Natural case at HC-2.5 through Operation, Closure, and Post-Closure Mine Phases. GWQG = Generic CCME long-term water quality guideline for the protection of freshwater aquatic life; calculated using 25th percentile baseline hardness data. SSWQO = Proposed Site Specific Water Quality Objective.

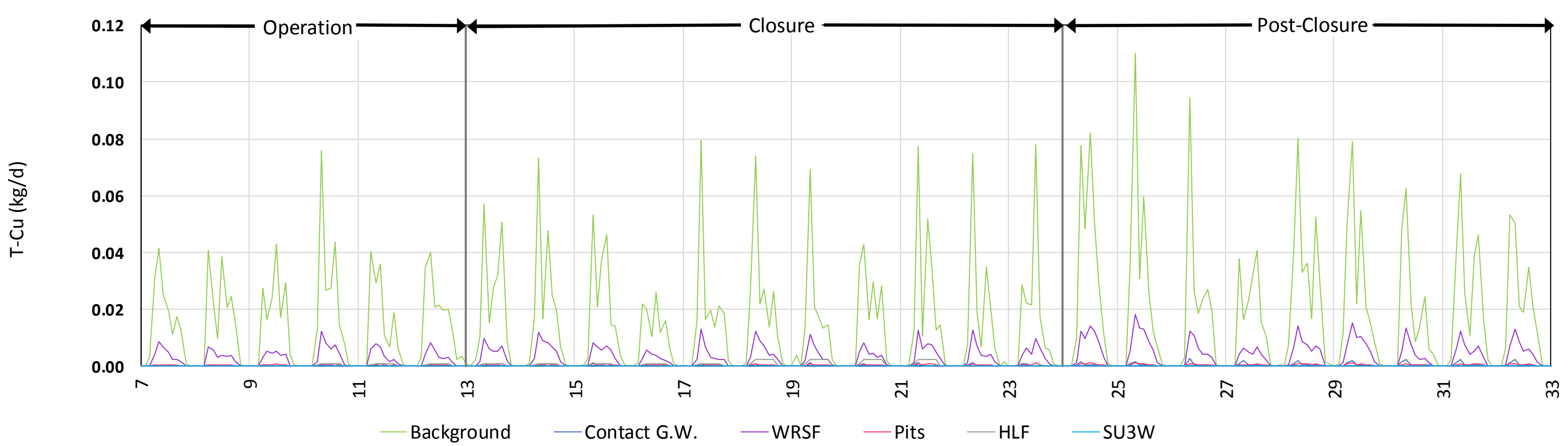


Figure 4-24: Base Case total copper loadings in kg/day at HC-2.5 from mine-related sources through Operations Closure, and Post-Closure Mine Phases.

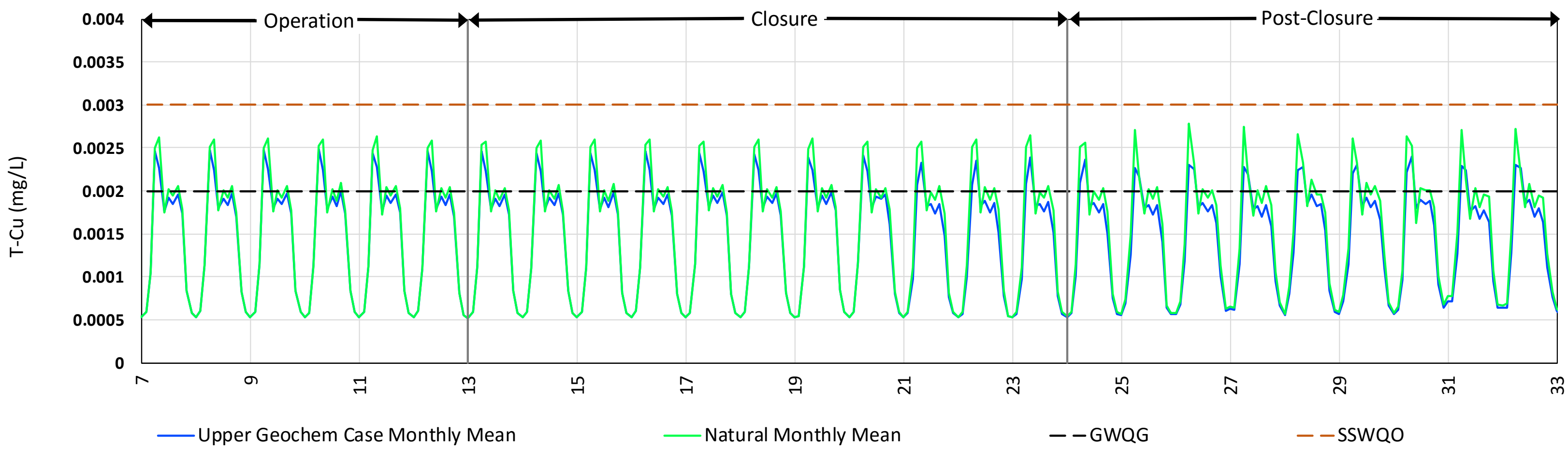


Figure 4-25: Total Copper Upper Geochemistry Case compared to Natural case at HC-2.5 through Operation, Closure, and Post-Closure Mine Phases. GWQG = Generic CCME long-term water quality guideline for the protection of freshwater aquatic life; calculated using 25th percentile baseline hardness data. SSWQO = Proposed Site Specific Water Quality Objective.

Uranium

Natural Case U concentrations in Halfway Creek are predicted to exceed the GWQG (0.015 mg/L) nearly year-round, reflecting the natural U enrichment within this catchment primarily from groundwater discharge (Figure 4-26). The predicted mine-related U loadings to Halfway Creek will be controlled by the alkalinity of mine site drainage.

In the model Base Case, U concentrations are predicted to increase from the Natural Case during months of open water (up to approximately 0.04 mg/L) from late operations onwards (Figure 4-26). Although there are several sources of U from the Project to Halfway Creek, the Alpha WRSF is predicted to represent the dominant source followed by smaller but notable U contributions from discharge from Latte and Kona Pits, and passive contact groundwater discharge from the mine site area (Figure 4-27).

Higher annual U concentrations are predicted in the Upper Geochemistry Case (Figure 4-28). From later operation through mid-Closure, U concentrations are predicted to increase from the Natural Case (up to 0.063 mg/L) during months of open water, similar to the Base Case. Starting in YR 21, annual summer peaks in U are predicted to further increase in association with the onset of higher loading rates from contact groundwater following mine closure. Peak values up to 0.112 mg/L are predicted in YRs 30 and 74. Outside of summer months, U concentrations during months of ice-cover are not predicted to increase above the Natural Case.

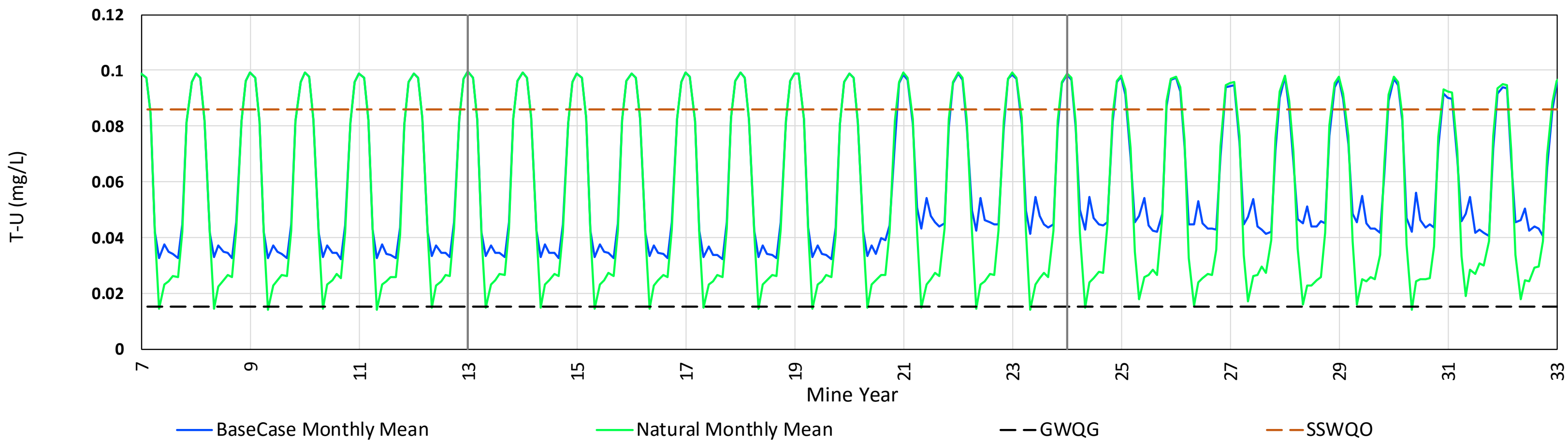


Figure 4-26: Total Uranium Base Case compared to Natural case at HC-2.5 through Operation, Closure, and Post-Closure Mine Phases. GWQG = Generic CCME long-term water quality guideline for the protection of freshwater aquatic life. SSWQO = Proposed Site Specific Water Quality Objective.

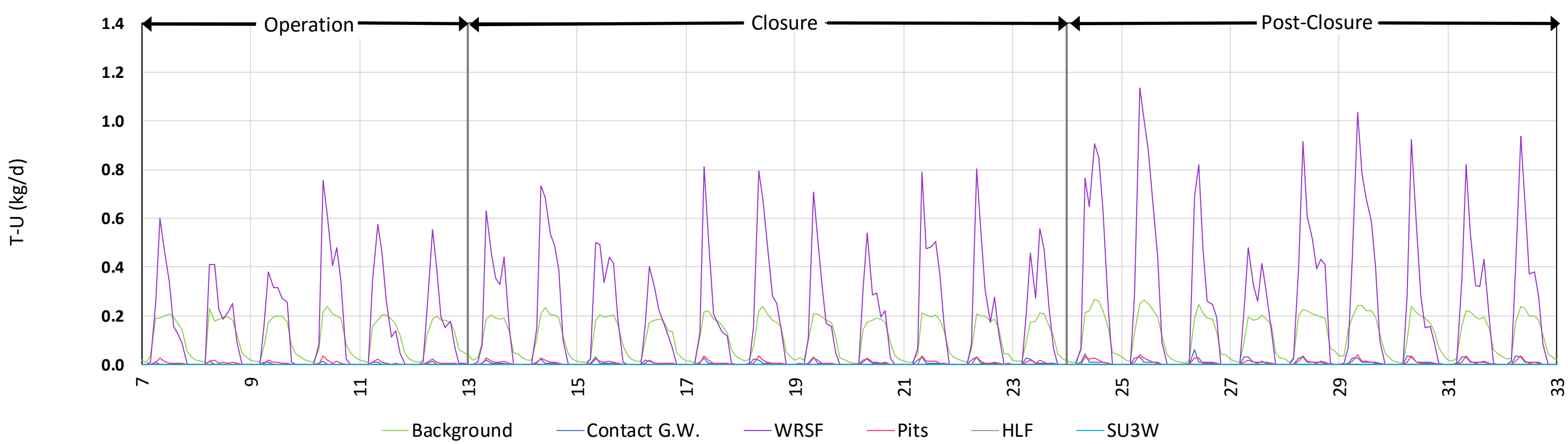


Figure 4-27: Base Case total uranium loadings in kg/day at HC-2.5 from mine-related sources through Operation, Closure, and Post-Closure Mine Phases.

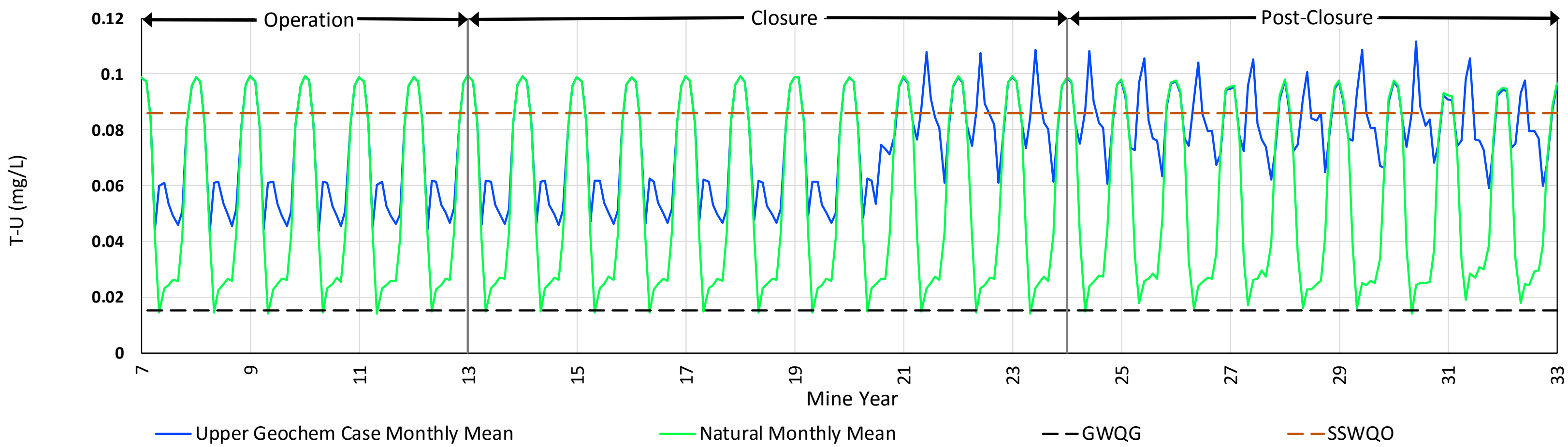


Figure 4-28: Total Uranium Upper Geochemistry Case compared to Natural case at HC-2.5 through Operation, Closure, and Post-Closure Mine Phases. GWQG = Generic CCME long-term water quality guideline for the protection of freshwater aquatic life. SSWQO = Proposed Site Specific Water Quality Objective.

4.5.4.5 *Yukon River*

The Yukon River will receive mine-impacted drainage from Coffee Creek, YT-24 Creek and Halfway Creek through life of mine. Water quality predictions at the downstream model nodes (YRdsCC, YRdsYT24, YRdsHC) are derived based on specified mixing relationships as described in Section 4.2.1.

The water quality results for the Yukon River model nodes are summarized in Table 4-11, (YRdsCC), Table 4-12 (YRdsYT24) and Table 4-13 (YRdsHC). As with summary tables presented in the previous sections, the maximum modelled concentrations are presented for all parameters through mine life for all model cases. In general, mine-related discharges exert a minor to negligible influence on Yukon River chemistry.

Table 4-11:
Maximum modelled water quality predictions through life of mine at YRdsCC for Natural Case, Base Case and Upper Geochemistry Case scenarios

Parameters	Units	Natural Case	Base Case	Upper Geochemistry Case
NH_3-N	mg/L	0.0294	0.0294	0.0294
NO_3-N	mg/L	0.128	0.131	0.131
NO_2-N	mg/L	0.0129	0.0129	0.0129
SO_4	mg/L	27.8	27.7	27.8
P	mg/L	0.215	0.215	0.215
WADCN	mg/L	0.00084	0.00084	0.00084
D-Al	mg/L	0.163	0.163	0.163
Ag	mg/L	0.000039	0.000039	0.000039
As	mg/L	0.00232	0.00232	0.00233
Ca	mg/L	31.9	31.9	31.9
Cd	mg/L	0.00048	0.00048	0.00048
Cr	mg/L	0.00263	0.00263	0.00263
Cu	mg/L	0.00776	0.00776	0.00776
Fe	mg/L	3.01	3.01	3.01
Hg	mg/L	0.000009	0.000009	0.000009
Mg	mg/L	8.80	8.79	8.80
Mn	mg/L	0.169	0.169	0.169
Mo	mg/L	0.00139	0.00139	0.00139
Ni	mg/L	0.00934	0.00934	0.00934
Pb	mg/L	0.00226	0.00226	0.00226
Sb	mg/L	0.00154	0.00155	0.00155
Se	mg/L	0.00048	0.00048	0.00048
Tl	mg/L	0.000030	0.000030	0.000030
U	mg/L	0.00159	0.00188	0.00228
Zn	mg/L	0.0351	0.0351	0.0351

Table 4-12:
Maximum modelled water quality predictions through life of mine at YRdsYT24 for Natural Case, Base Case and Upper Geochemistry Case scenarios

Parameters	Units	Natural Case	Base Case	Upper Geochemistry Case
NH_3-N	mg/L	0.0260	0.0260	0.0260
NO_3-N	mg/L	0.100	0.101	0.101
NO_2-N	mg/L	0.0135	0.0135	0.0135
SO_4	mg/L	26.9	26.9	26.9
P	mg/L	0.230	0.230	0.230
WADCN	mg/L	0.00090	0.00090	0.00090
D-Al	mg/L	0.0508	0.0508	0.0508
Ag	mg/L	0.000041	0.000041	0.000041
As	mg/L	0.00245	0.00246	0.00249
Ca	mg/L	31.7	31.7	31.7
Cd	mg/L	0.00052	0.00052	0.00052
Cr	mg/L	0.00278	0.00278	0.00278
Cu	mg/L	0.00813	0.00813	0.00813
Fe	mg/L	3.21	3.21	3.21
Hg	mg/L	0.000007	0.000007	0.000007
Mg	mg/L	8.71	8.71	8.71
Mn	mg/L	0.180	0.180	0.180
Mo	mg/L	0.00139	0.00139	0.00139
Ni	mg/L	0.00995	0.00995	0.00995
Pb	mg/L	0.00241	0.00241	0.00241
Sb	mg/L	0.00185	0.00186	0.00187
Se	mg/L	0.00049	0.00049	0.00049
Tl	mg/L	0.000032	0.000032	0.000032
U	mg/L	0.00125	0.00133	0.00168
Zn	mg/L	0.0374	0.0374	0.0374

Table 4-13:
Maximum modelled water quality predictions through life of mine at YRdsHC for Natural Case, Base Case and Upper Geochemistry Case scenarios

Parameters	Units	Natural Case	Base Case	Upper Geochemistry Case
NH_3-N	mg/L	0.0261	0.0261	0.0269
NO_3-N	mg/L	0.101	0.113	0.137
NO_2-N	mg/L	0.0135	0.0135	0.0137
SO_4	mg/L	27.0	27.0	28.6
P	mg/L	0.229	0.229	0.229
WADCN	mg/L	0.00090	0.00090	0.00092
D-Al	mg/L	0.0584	0.0569	0.0570
Ag	mg/L	0.000041	0.000041	0.000041
As	mg/L	0.00245	0.00246	0.00258
Ca	mg/L	31.7	31.7	31.7
Cd	mg/L	0.00052	0.00052	0.00052
Cr	mg/L	0.00277	0.00277	0.00277
Cu	mg/L	0.00809	0.00809	0.00809
Fe	mg/L	3.20	3.20	3.20
Hg	mg/L	0.000007	0.000007	0.000008
Mg	mg/L	8.73	8.73	8.73
Mn	mg/L	0.179	0.180	0.180
Mo	mg/L	0.00139	0.00155	0.00219
Ni	mg/L	0.00990	0.00990	0.00991
Pb	mg/L	0.00240	0.00240	0.00240
Sb	mg/L	0.00185	0.00185	0.00186
Se	mg/L	0.00049	0.00049	0.00050
Tl	mg/L	0.000032	0.000033	0.000036
U	mg/L	0.00159	0.00250	0.00380
Zn	mg/L	0.0373	0.0373	0.0373

For most parameters, modelled monthly predictions for Base Case and Upper Geochemistry Case at Yukon River model nodes are indistinguishable from Natural Case. Any model results that are distinguishable from Natural Case are typically observed at the Yukon River station downstream of Halfway Creek (YRdsHC), which receives the bulk of the mine-related loading. As such, the discussion below highlights NO_3-N and U predictions at YRdsHC where mine-related contributions can be discerned (*e.g*, Table 4-13).

In the Natural Case, most parameters modelled for Yukon River stations exhibit seasonal signatures reflective of the annual hydrograph. Annual concentration maxima for predicted parameters typically coincide with spring freshet during which elevated levels of suspended particles and surface run-off increase total metals and nutrients. Concentrations gradually decline through the summer and autumn period, yielding annual minima during months of ice-cover.

The Yukon River has high flow (typically ranging from 400 to 3,000 m^3/s on an annual basis) relative to Project-area creeks and is expected to provide significant dilution of mine-influenced waters year-round. This is reflected in Base Case concentrations for all model parameters at Yukon River nodes, which show negligible change from Natural Case (Table 4-11 to Table 4-13 and Figure 4-29 and Figure 4-31).

Upper Geochemistry Case predictions are similar to Base Case predictions and show negligible changes in most parameter concentrations as compared to Natural Case predictions through all Project phases. Upper Geochemistry NO_3 and U predictions (Figure 4-30 and Figure 4-32) show slightly elevated concentrations in late winter months during Operation and Closure. During these months, the water balance model assumes spring freshet in Project area creeks occurs approximately one month earlier than Yukon River freshet, resulting in a slightly higher Project loading rate to Yukon River stations for a short period of time. In subsequent months, the onset of spring freshet in Yukon River affords complete dilution of this mine signature. For all other modelled parameters, a mine-related change to predicted water quality is virtually indistinguishable from the Natural Case.

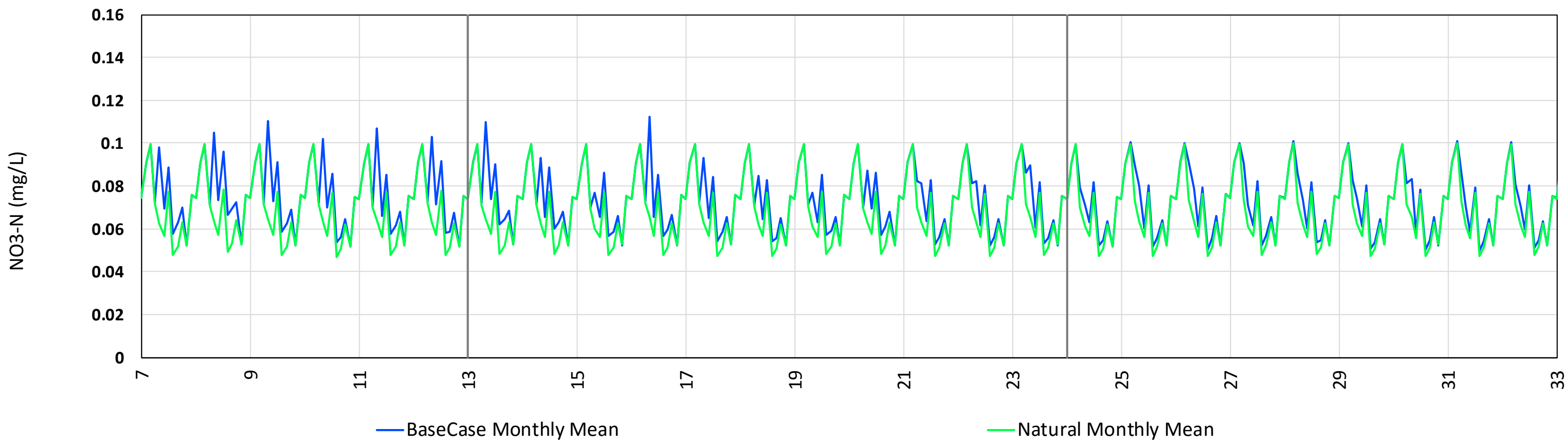


Figure 4-29: Nitrate Base Case compared to Natural case at YRdsHC through Operation, Closure, and Post-Closure Mine Phases.

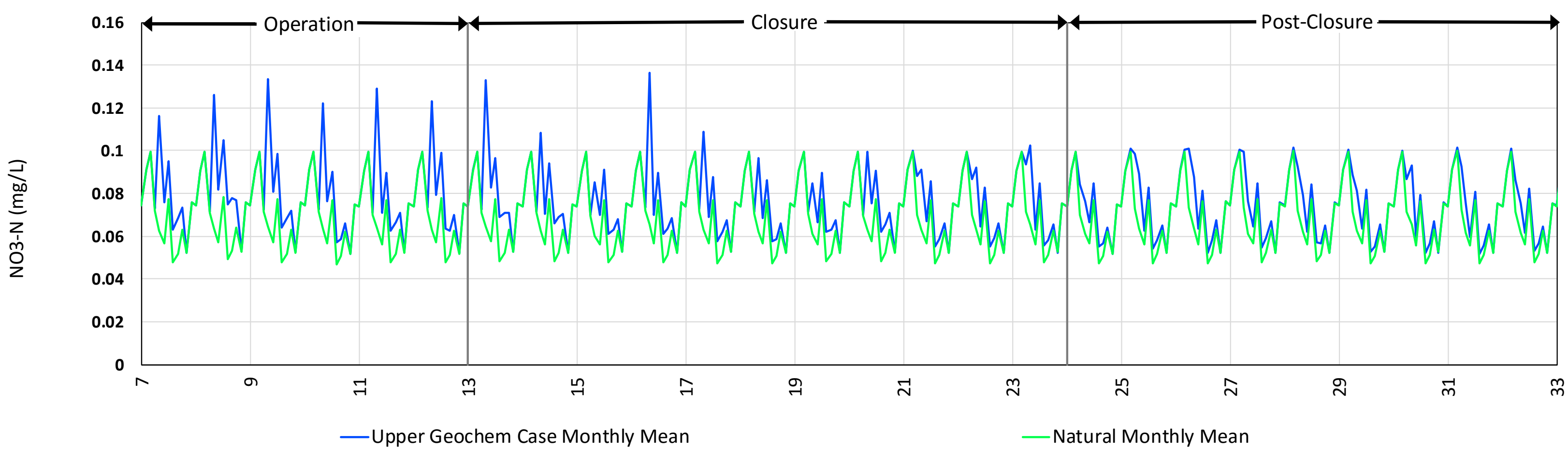


Figure 4-30: Nitrate Upper Geochemistry Case compared to Natural case at YRdsHC through Operation, Closure, and Post-Closure Mine Phases.

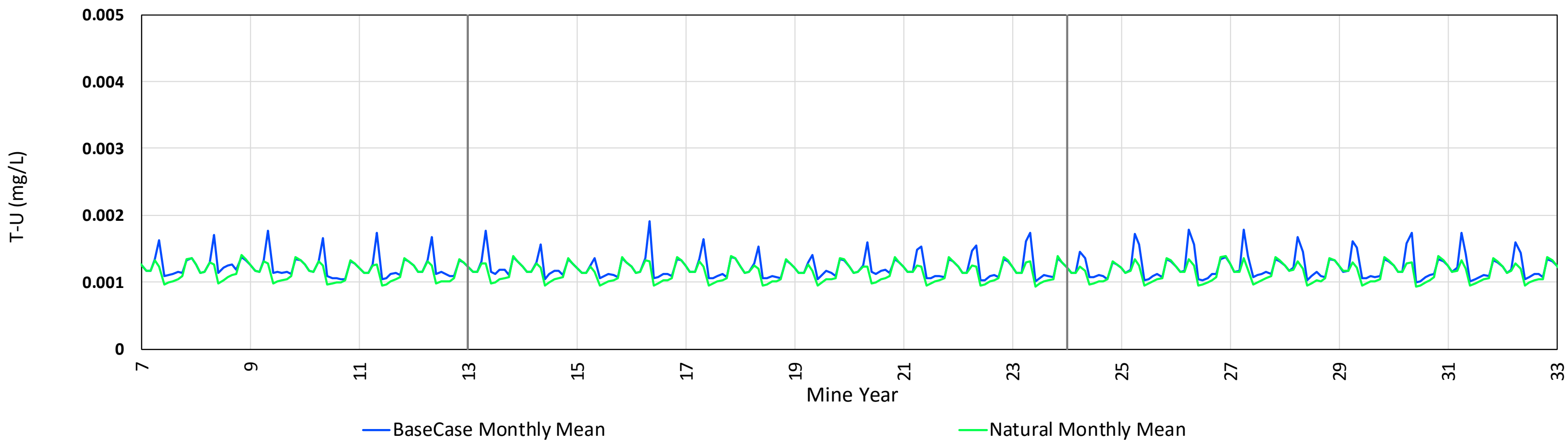


Figure 4-31: Total Uranium Base Case compared to Natural case at YRdsHC through Operation, Closure, and Post-Closure Mine Phases.

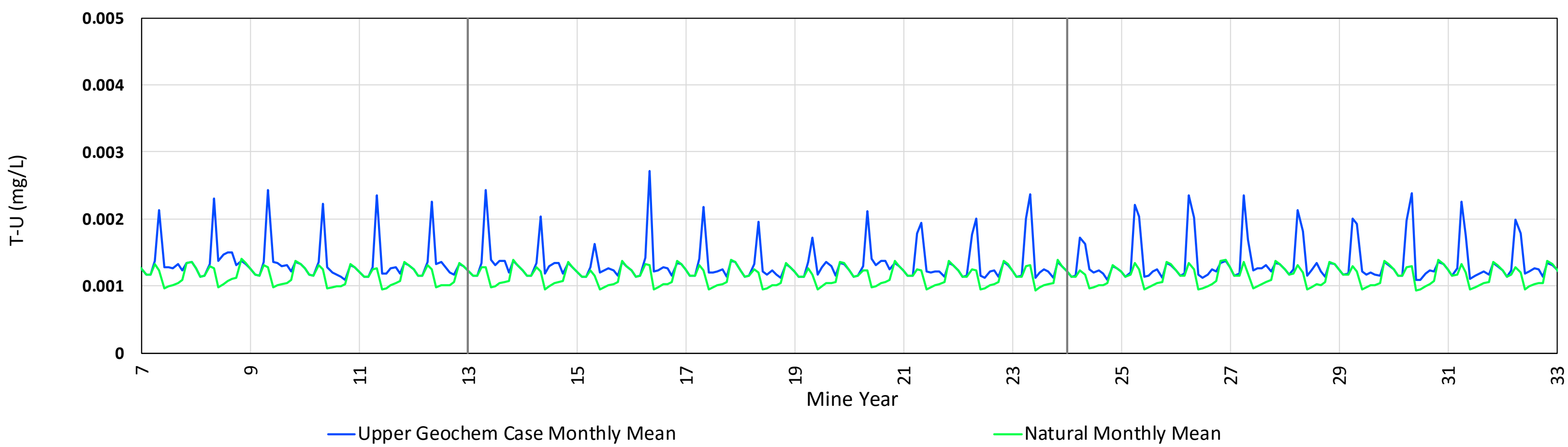


Figure 4-32: Total Uranium Upper Geochemistry Case compared to Natural case at YRdsHC through Operation, Closure, and Post-Closure Mine Phases.

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Appendix 12-C-1: Heap Leach Operation Water Balance Model

GOLDCORP

Memorandum

To: James Scott

From: Kenneth Myers

Date: March 21, 2017

Re.: Comparison of water balance performance for heap capacities ranging from 47.3 to 60.4 million tonnes

---

This memorandum will compare and contrast differences in the performance of the proposed Heap Leach Facility (HLF) for the Coffee Project in Yukon Territory, Canada at two different maximum ore capacities (47.3 million tonnes (MT) and 60.4 MT).

Design criteria that are common to both scenarios:

- Ore production rate remains the same for each scenario at 18,265 tonnes per day for 9 months out of each year (5 MT per year).
- Application rate is 10 liters/s/m^2 for both scenarios with a pumping rate of 455,000 liters per hour producing an area under leach of 45,500 m^2.
- Rinsing is assumed to begin in June of year 4 at an application rate of 10 liters/s/m^2 for both scenarios with a pumping rate of 118,000 liters per hour.
- Pumping to treatment begins in March of year 9 at a maximum rate of 4 liters/s (10,513 m^3 per month).
- Ore characteristics include an estimated delivered gravimetric water content of 4.5%, a specific retention of 6.5%, and an operating water content of 10.6% on an estimated stacked ore density of 1.6 tonnes per m^3.

The 47.3 MT scenario continues ore stacking into November of year 9. Given that the ore production rate, solution application rate, and solution pumping rate are the same in both scenarios, performance is virtually identical up through October of year 9. Ore stacking continues in the 60.4 MT scenario into July of year 12, and in order to accommodate the additional volume, additional lined footprint is required. In October of year 9, the lined footprint is increased from 819,050 m2 to 1,090,407 m2 (see Figure 1 and Figure 2). The leaching of the additional volume of ore extends ore wetting losses and makeup water demand into July of year 12 (See Figure 3 and Figure 4). However, makeup water demand continues to be satisfied using fresh water runoff from raincoat areas and concurrent reclamation areas (see Figure 5 through Figure 8).

Reno Office:
1325 Airmotive Way
Reno, NV 89502
Phone: 775-322-7622
Fax: 775-322-2660
E-Mail: MINESGrp@aol.com

West Reno Office:
1835 Daniel Webster Drive
Reno, NV 89509
Phone: 775-329-3383
Fax: 775-329-2923
E-Mail: Email REDACTED

Figure 1 – 47.3 MT Scenario

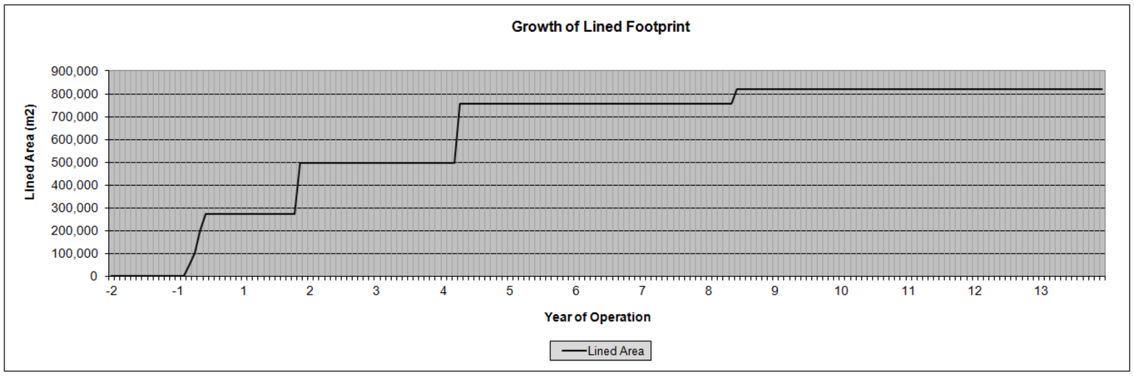


Figure 2 – 60.4 MT Scenario

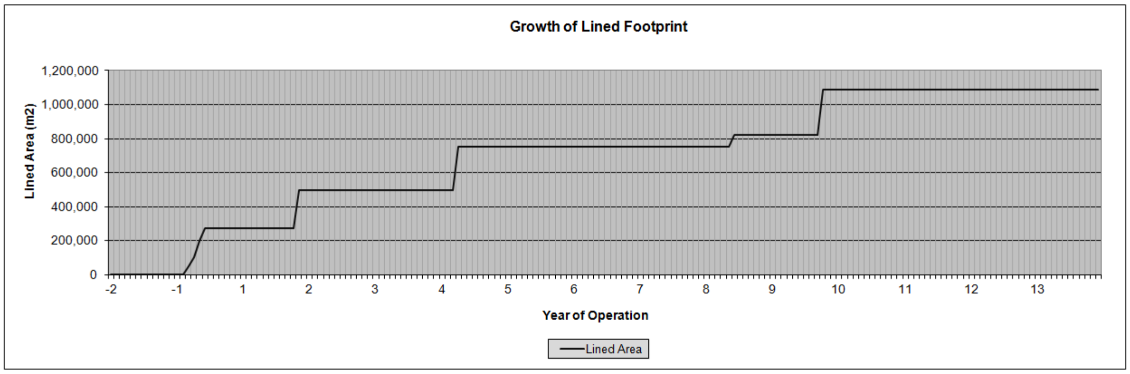


Figure 3 – 47.3 MT Scenario

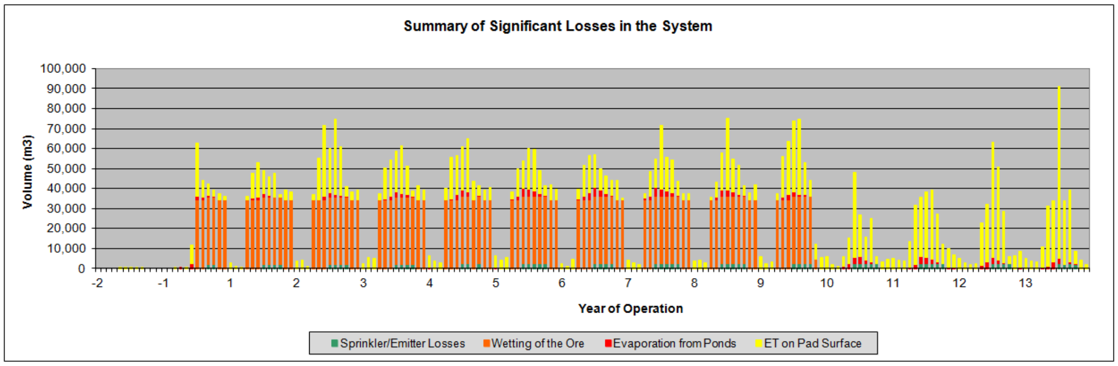


Figure 4 – 60.4 MT Scenario

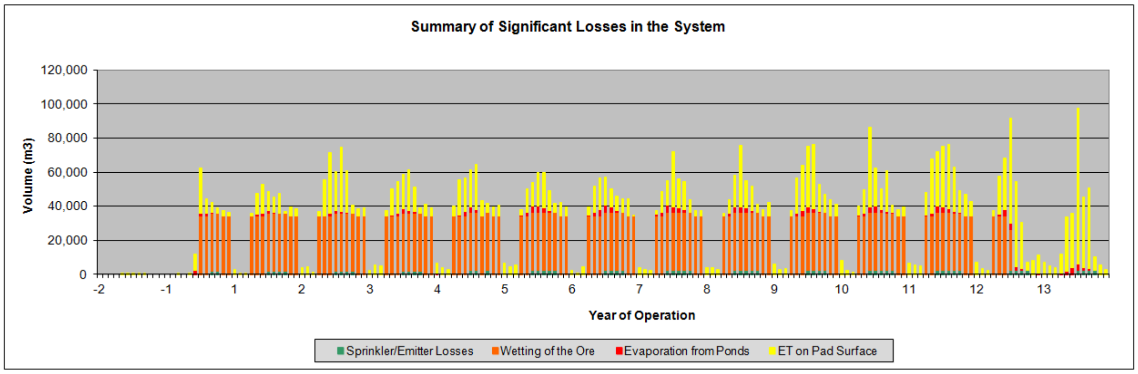


Figure 5 – 47.3 MT Scenario

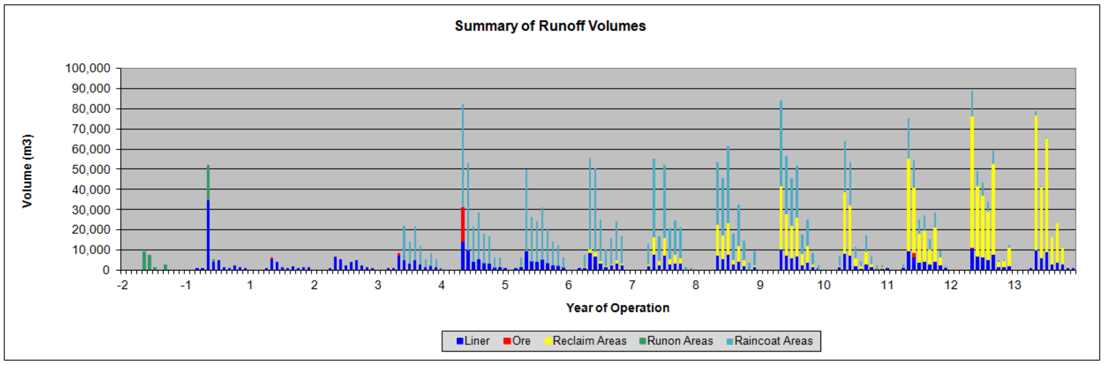


Figure 6 – 60.4 MT Scenario

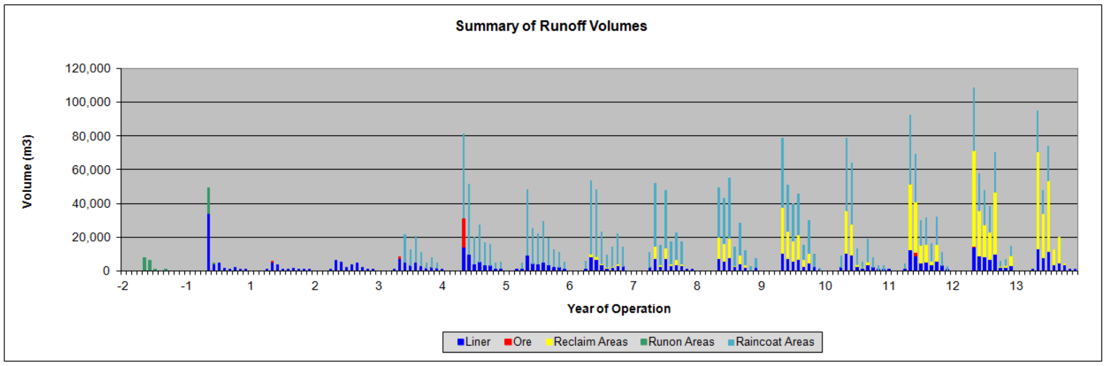


Figure 7 – 47.3 MT Scenario

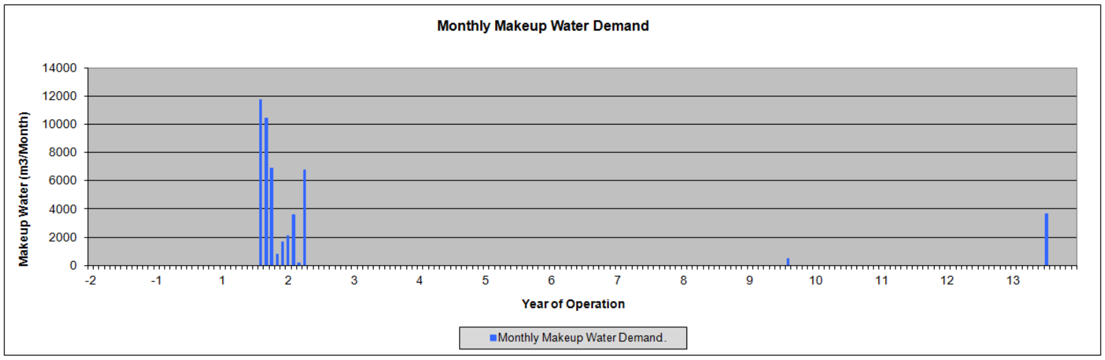
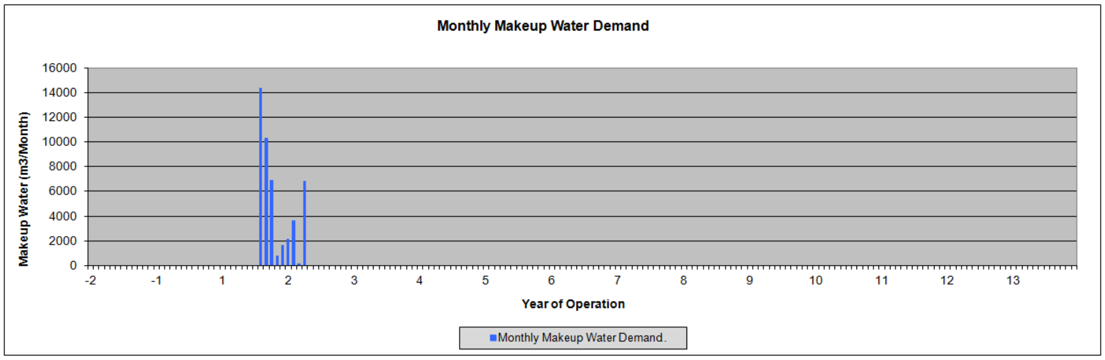


Figure 8 – 60.4 MT Scenario



Given the increase in lined footprint for the 60.4 MT scenario, the HLF system does accumulate more meteoric water. However, continuation of the pumping to treatment during operations at a rate of 4 liters/s prevents excessive buildup of solution within the pond system. The maximum volume of seasonally accumulated water in the pond system is essentially the same at 194,091 m^3 for the 47.3 MT scenario and 212,209 m^3 for the 60.4 MT scenario (see Figure 9 and Figure 10). However, the increase in lined footprint with no increase in pumping to treatment rate results in a change in the peak seasonal pond volume accumulation (after initiation of treatment) from +/- 100,000 m^3 for the 47.3 MT scenario to +/- 150,000 m^3 for the 60.4 MT scenario.

Figure 9 – 47.3 MT Scenario

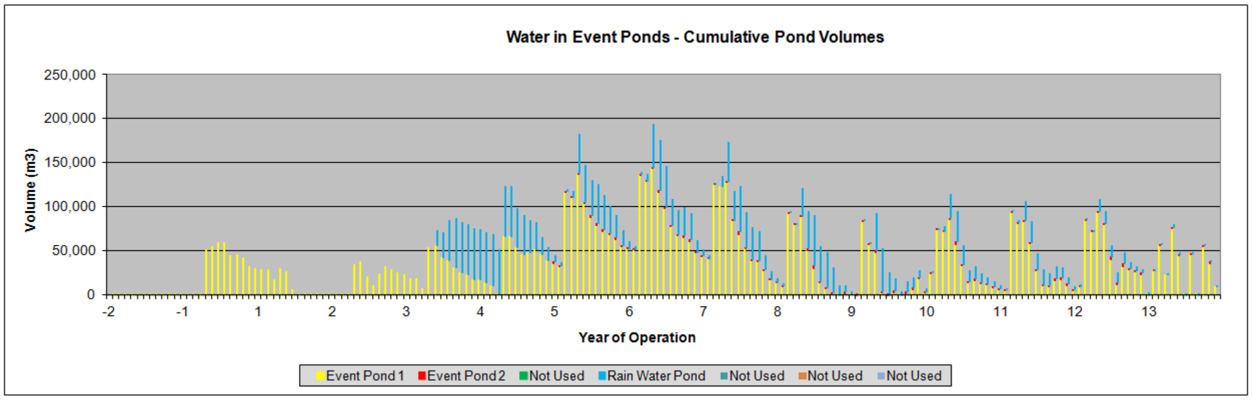
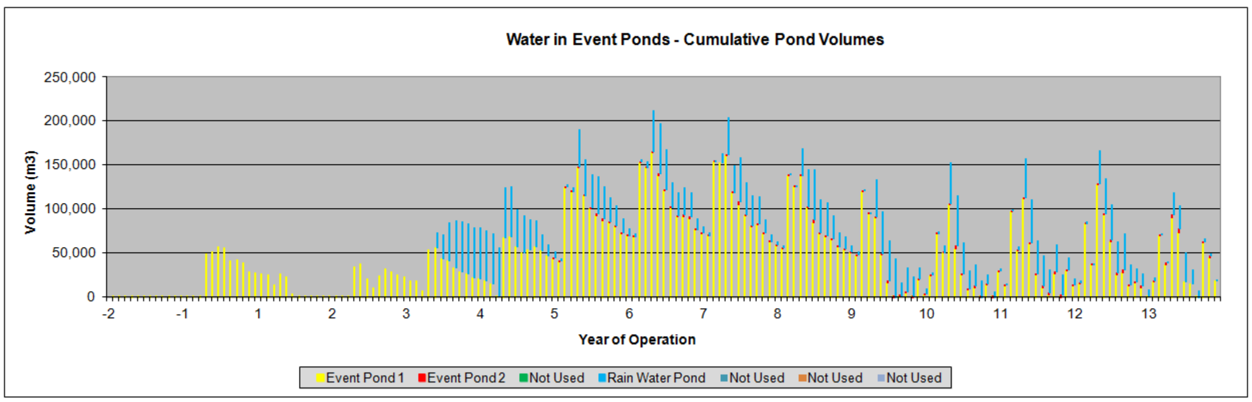


Figure 10 – 60.4 MT Scenario



During the final month of ore stacking for the 47.3 MT scenario (November of year 9), the total volume of water stored within the ore stack prior to draindown is 3,225,248 m^3. During the final month of ore stacking for the 60.4 MT scenario (July of year 12), the total volume of water stored within the ore stack prior to draindown is 4,070,765 m^3.

Please call if you need additional information or have any questions.

Regards,
The MINES Group, Inc.

Kenneth L. Myers

Appendix 12-C-2: Heap Leach Draindown Water Balance Model

GOLDCORP

Memorandum

To: James Scott

From: Kenneth Myers

Date: March 22, 2017

Re.: Comparison of draindown performance for heap capacities ranging from 47.3 to 60.4 million tonnes

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This memorandum will compare and contrast differences in the draindown performance of the proposed Heap Leach Facility (HLF) for the Coffee Project in Yukon Territory, Canada at two different maximum ore capacities (47.3 million tonnes (MT) and 60.4 MT).

Design criteria that are common to both scenarios:

- Ore production rate remains the same for each scenario at 18,265 tonnes per day for 9 months out of each year (5 MT per year).
- Application rate is 10 liters/s/m^2 for both scenarios with a pumping rate of 455,000 liters per hour producing an area under leach of 45,500 m^2.
- Rinsing is assumed to begin in June of year 4 at an application rate of 10 liters/s/m^2 for both scenarios with a pumping rate of 118,000 liters per hour.
- Pumping to treatment begins in March of year 9 at a rate of 2 liters/s (5184 m^3 per month) for April and 4 liters/s (about 10,513 m^3 per month) for the months of May through September.
- Ore characteristics include an estimated delivered gravimetric water content of 4.5%, a specific retention of 6.5%, and an operating water content of 10.6% on an estimated stacked ore density of 1.6 tonnes per m^3.

The timeline for draindown modeling begins (elapsed time (ET) = 0) in April of operational year five (5) shortly before concurrent reclamation and use of raincoat covers is expected to begin. The constant relocation of the active area under leach over the entire area of the ore stack is assumed to maintain the water content in the unirrigated portion of the ore at or near the specific retention level. Once ore stacking stops and the main leach pumping rate is no longer being supported by outside makeup water, the active leach column also begins to dewater to water contents below the specific retention, starting from the higher operating water content. This is assumed to occur after all gold production has ceased and the rinsing operation has completed which for the 47.3 MT scenario is assumed to happen about December of year 13 (ET = 104 months or 8.67 years) and for the 60.4 MT scenario about March of year 15 (ET = 121 months or 10.08 yrs). Flow rates for water diverted to treatment are assumed to be at levels associated with the management of pond levels and system water volumes during operations. This is assumed to be 2 liters per second (l/s) in April and 4 l/s for May through September during operations for both scenarios. For the 60.4 MT scenario, the post operations pumping to treatment rate is 5 l/s during April and 11 l/s for May through September (this increased slightly from the earlier 10 l/s for the 47.3 MT scenario due to the larger lined footprint). The schedule for progressive

Reno Office:
1325 Airmotive Way
Reno, NV 89502
Phone: 775-322-7622
Fax: 775-322-2660
E-Mail: MINESGrp@aol.com

West Reno Office:
1835 Daniel Webster Drive
Reno, NV 89509
Phone: 775-329-3383
Fax: 775-329-2923
E-Mail: Email REDACTED

reclamation and raincoat cover application were imported into the draindown model from the operational model.

Before dewatering of the leach column can end it must catch up to the water content of the unirrigated ore. The leach column is assumed to be dewatered when the mean water content in the leach column equals the mean water content in the unirrigated ore. All dewatering is assumed to end when the mean water content of the ore reaches some arbitrary low value (in our case the estimated permanent wilting point). From then on, water moving through the pad cycles in response to whatever meteoric water it receives.

Figure 1 through Figure 6 show expected mean monthly draindown rates in various units (m^3/month, l/s, and m^3/hr) over the elapsed time in months. The timing of the initiation of the draindown of the leach column varies as a result of the extended duration of operations for the 60.4 MT scenario. However, the increase in the post operations pumping to treatment rate results in an acceleration of the time required to dewater the leach column (Figure 9 and Figure 10).

Figure 1 – 47.3 MT Scenario

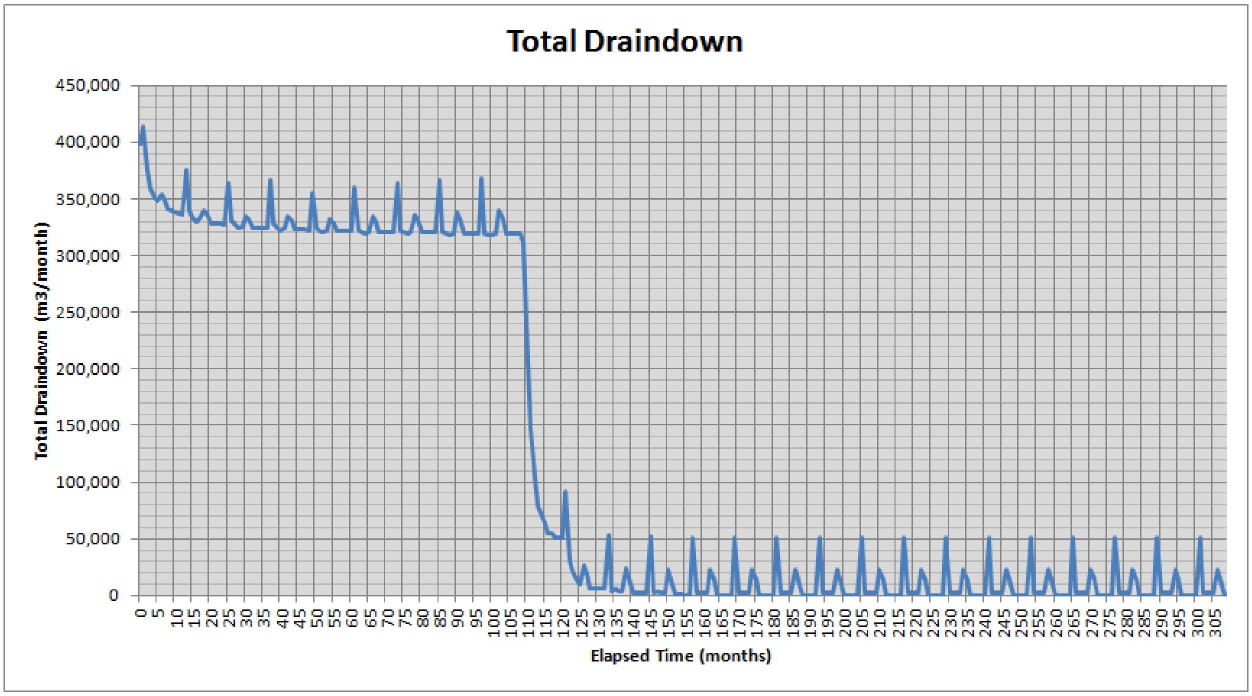


Figure 2 – 60.4 MT Scenario

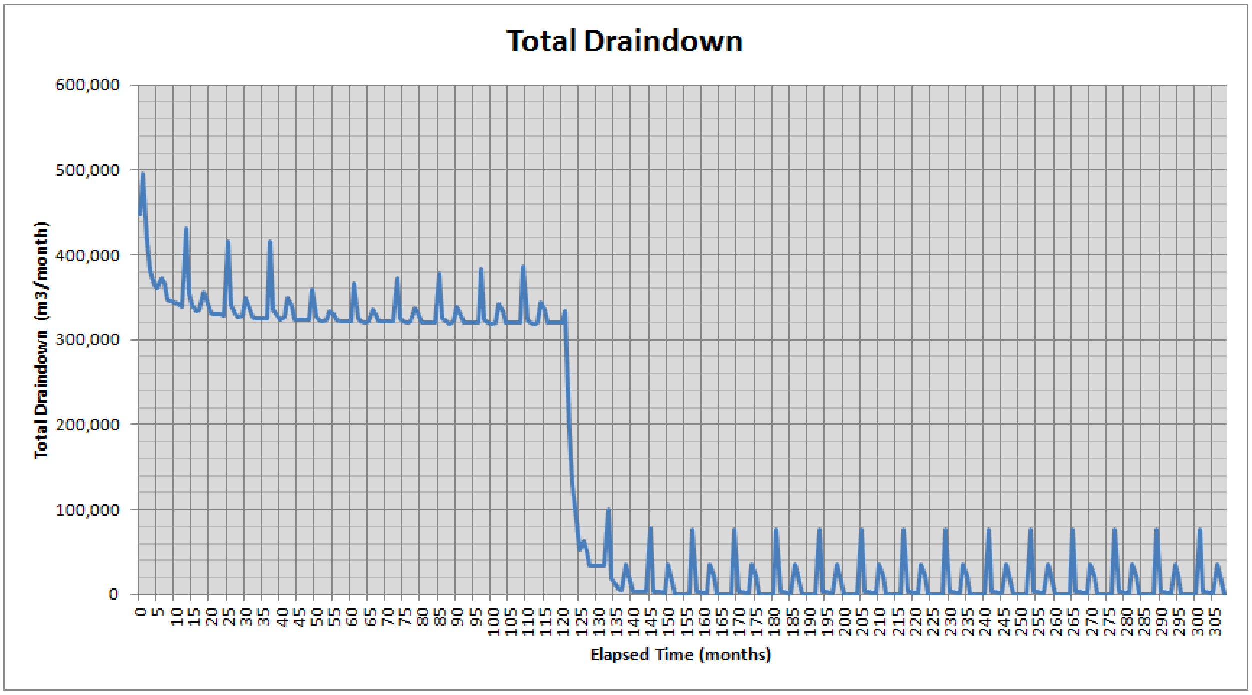


Figure 3 – 47.3 MT Scenario

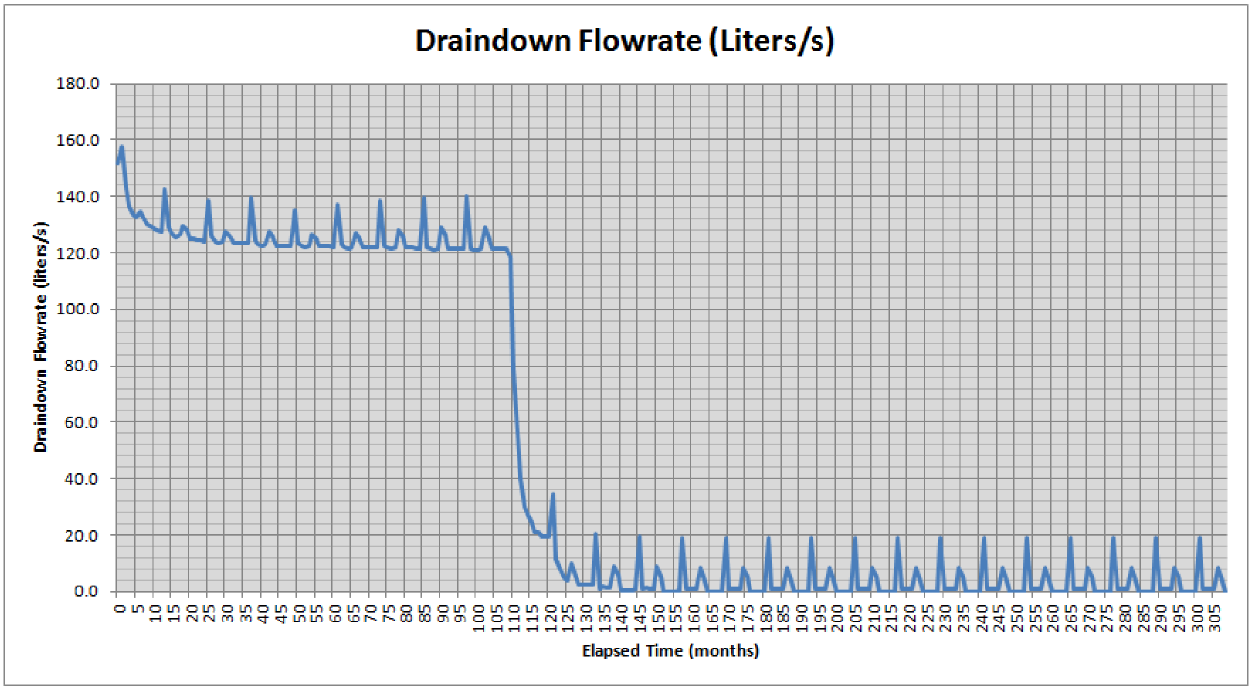


Figure 4 – 60.4 MT Scenario

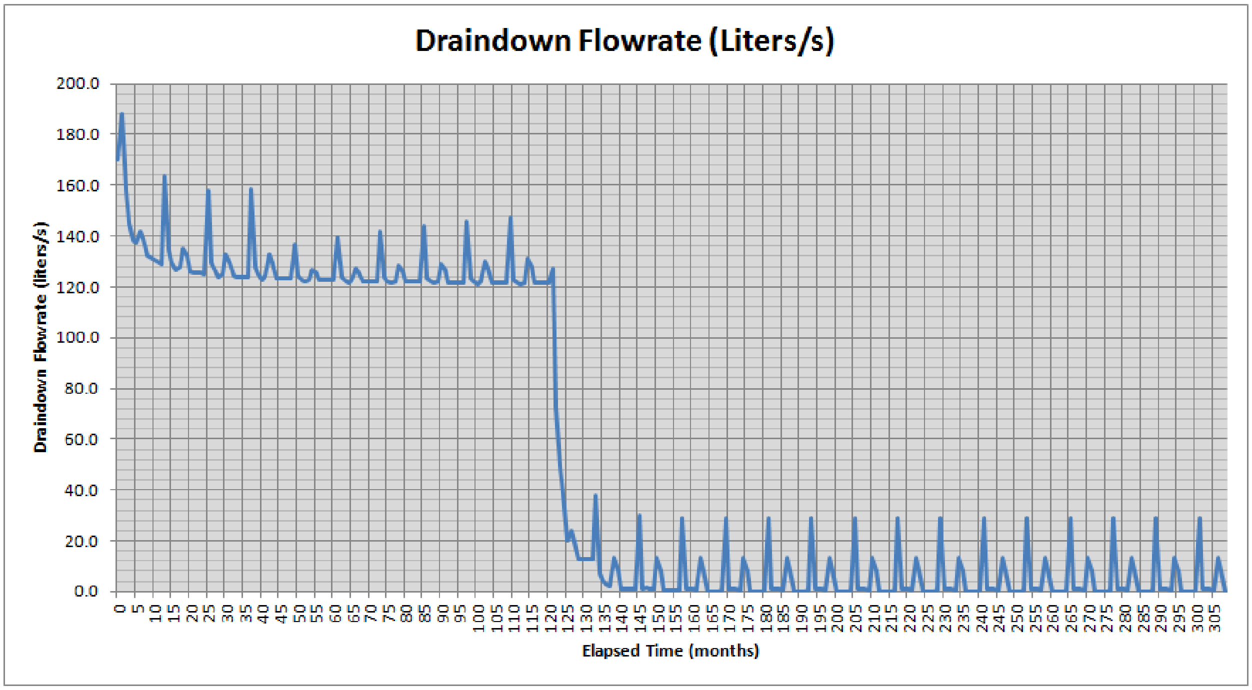


Figure 5 – 47.3 MT Scenario

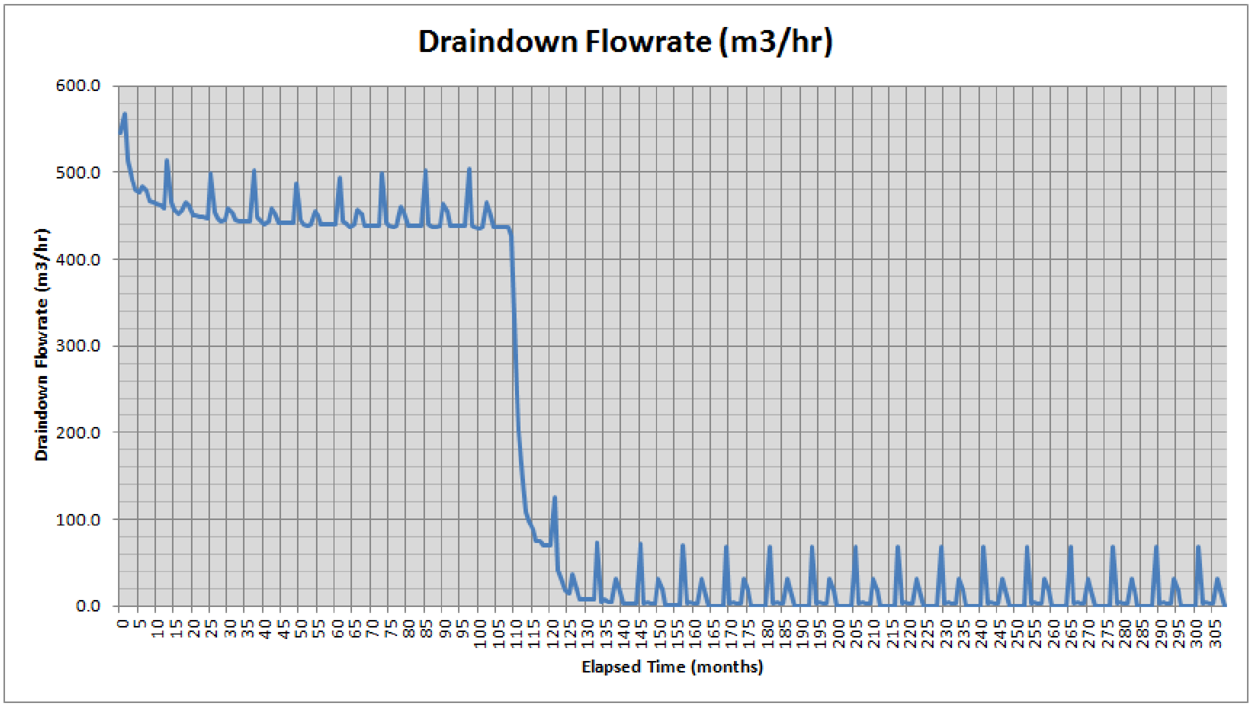


Figure 6 – 60.4 MT Scenario

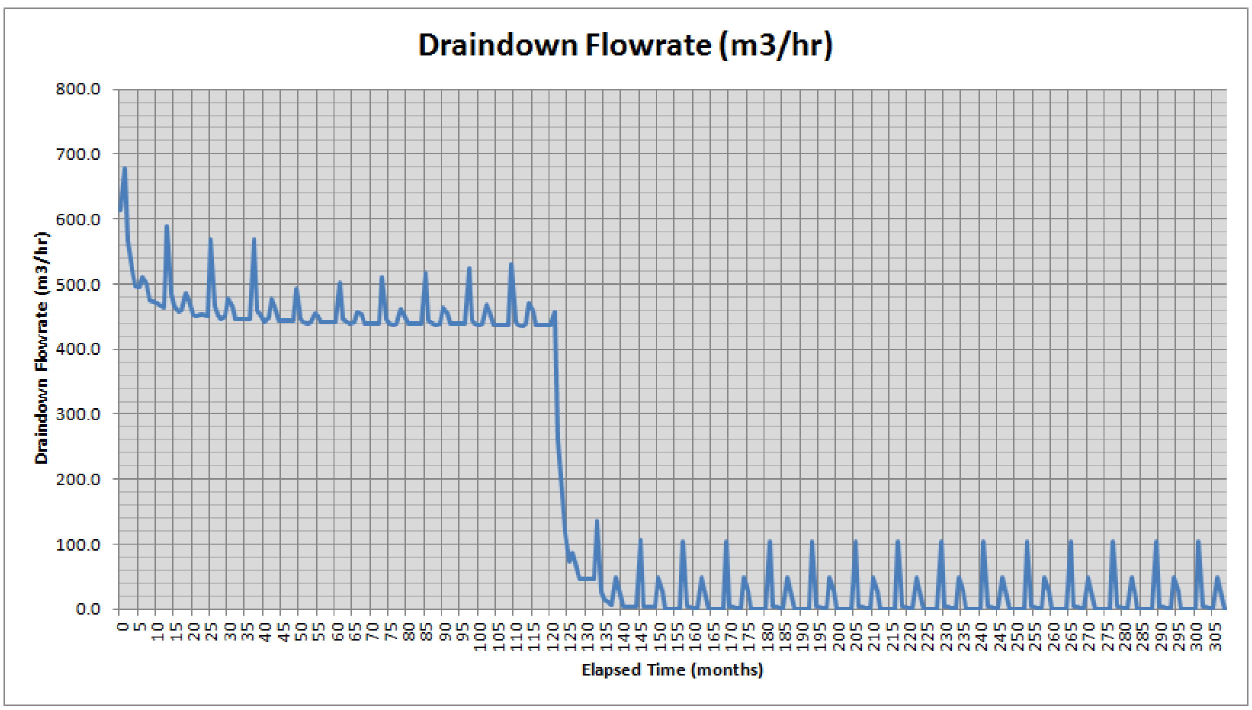


Figure 7 shows an undrainable volume on the order of 1.4 million m^3 for the 47.3 MT scenario while Figure 8 shows an undrainable volume on the order of 1.8 million m^3 for the 60.4 MT scenario.

Figure 7 – 47.3 MT Scenario

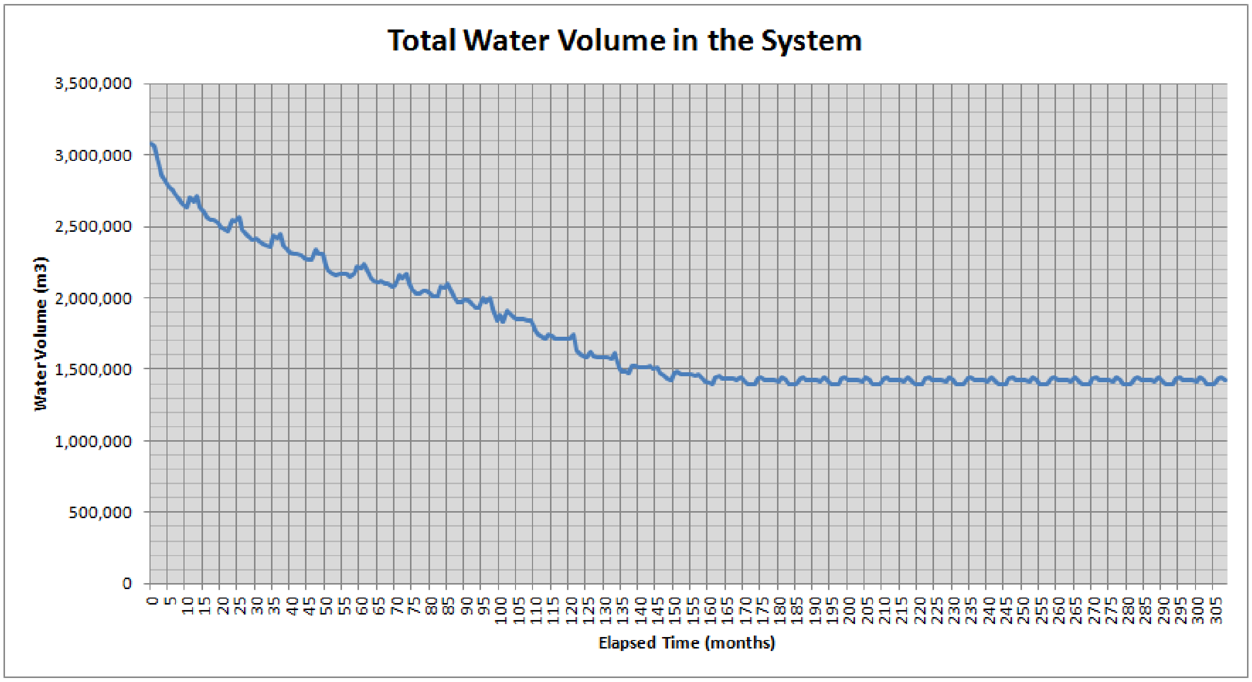


Figure 8 – 60.4 MT Scenario

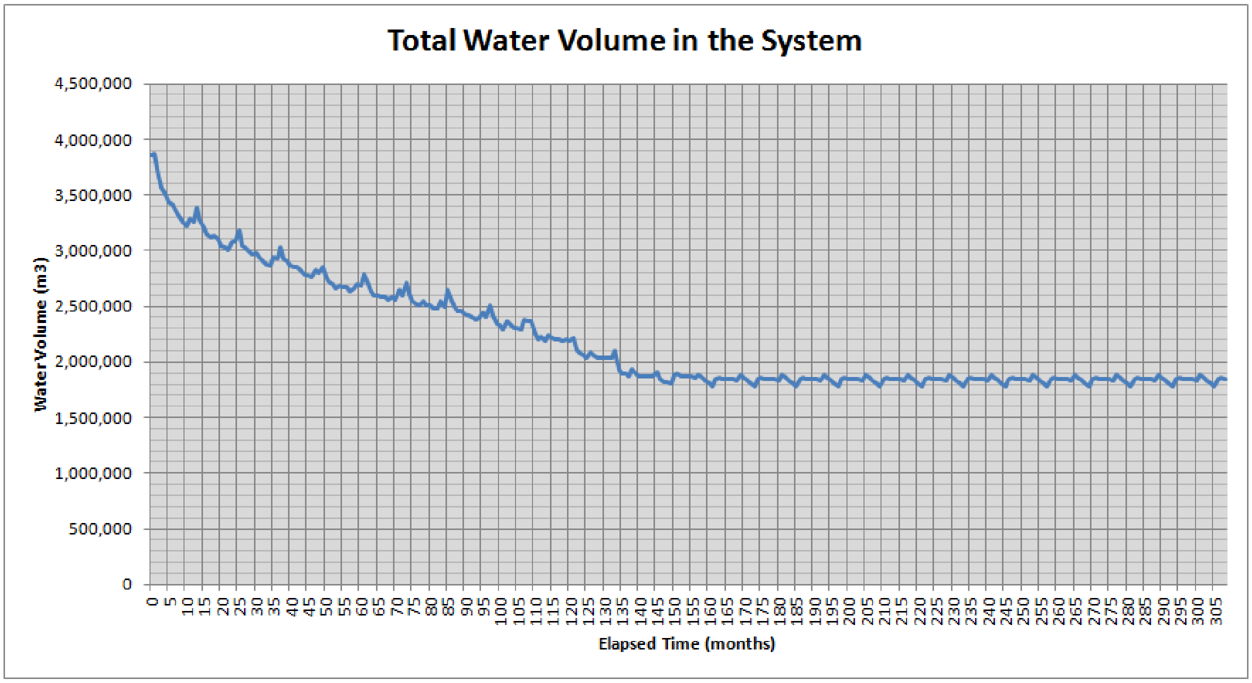


Figure 9 – 47.3 MT Scenario

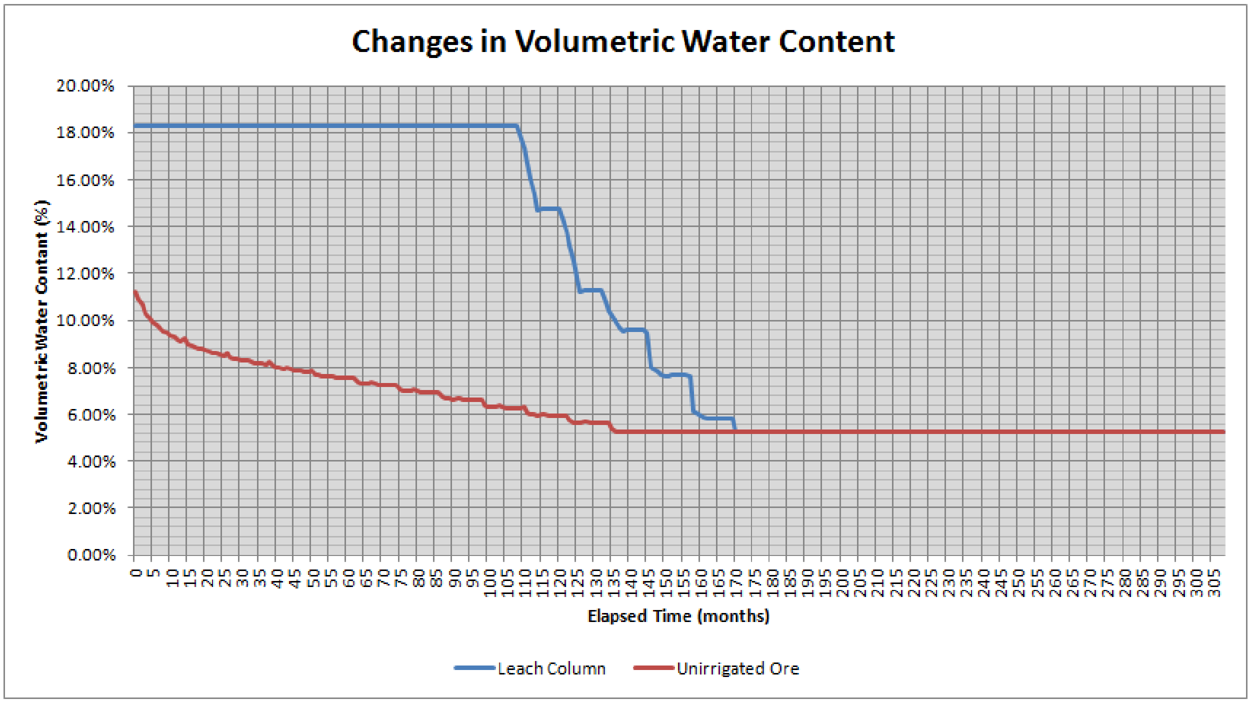
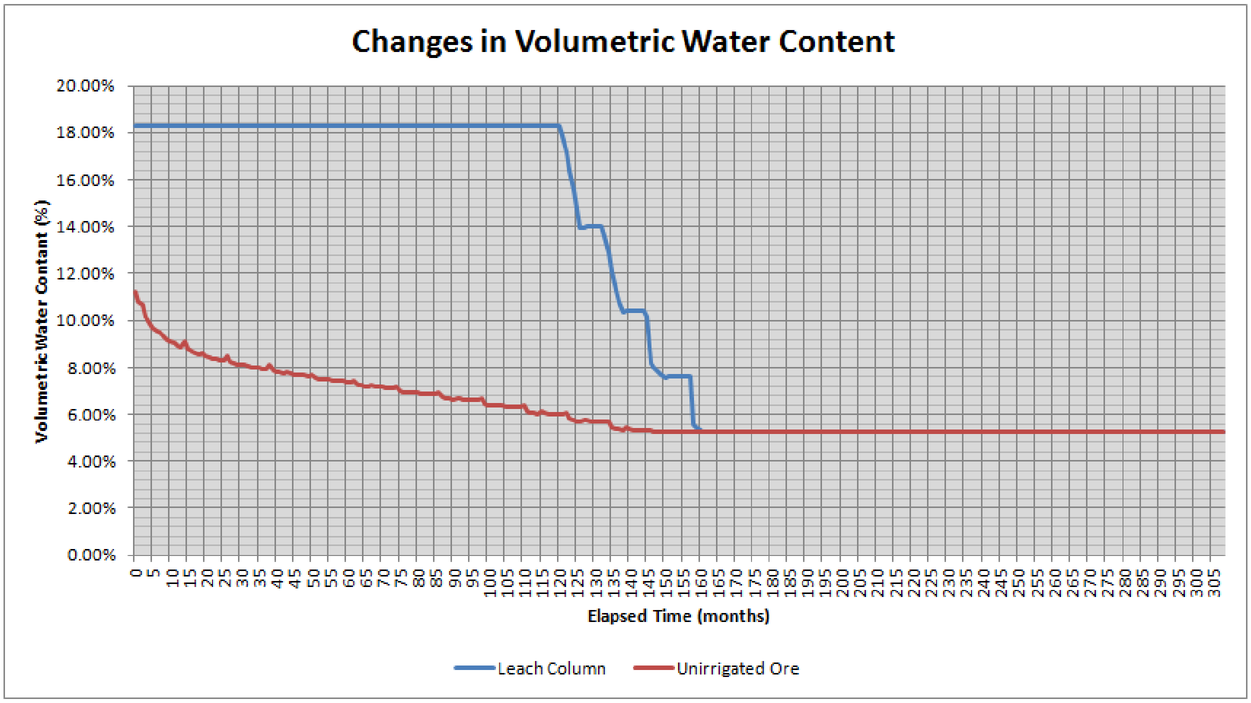


Figure 10 – 60.4 MT Scenario



The larger lined footprint of the 60.4 MT scenario results in an increase in the average maximum annual peak pond storage level from about 75,000 m^3 (Figure 11) to about 120,000 m^3 (Figure 12).

Figure 11 – 47.3 MT Scenario

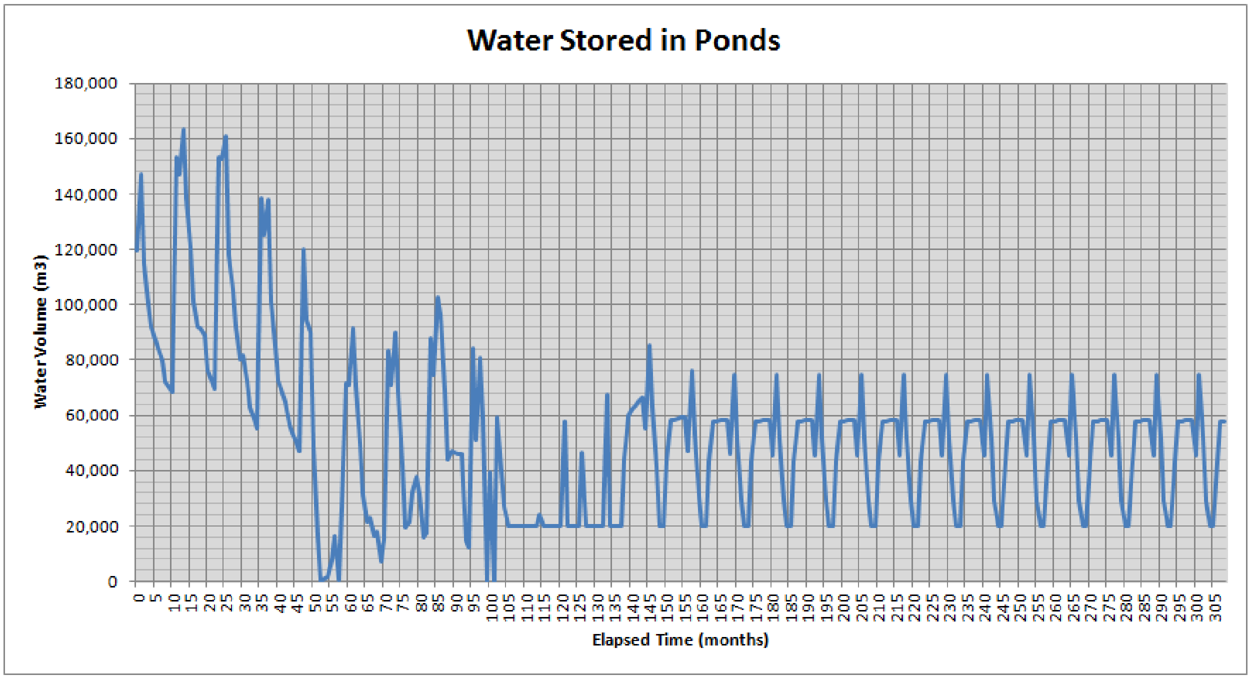
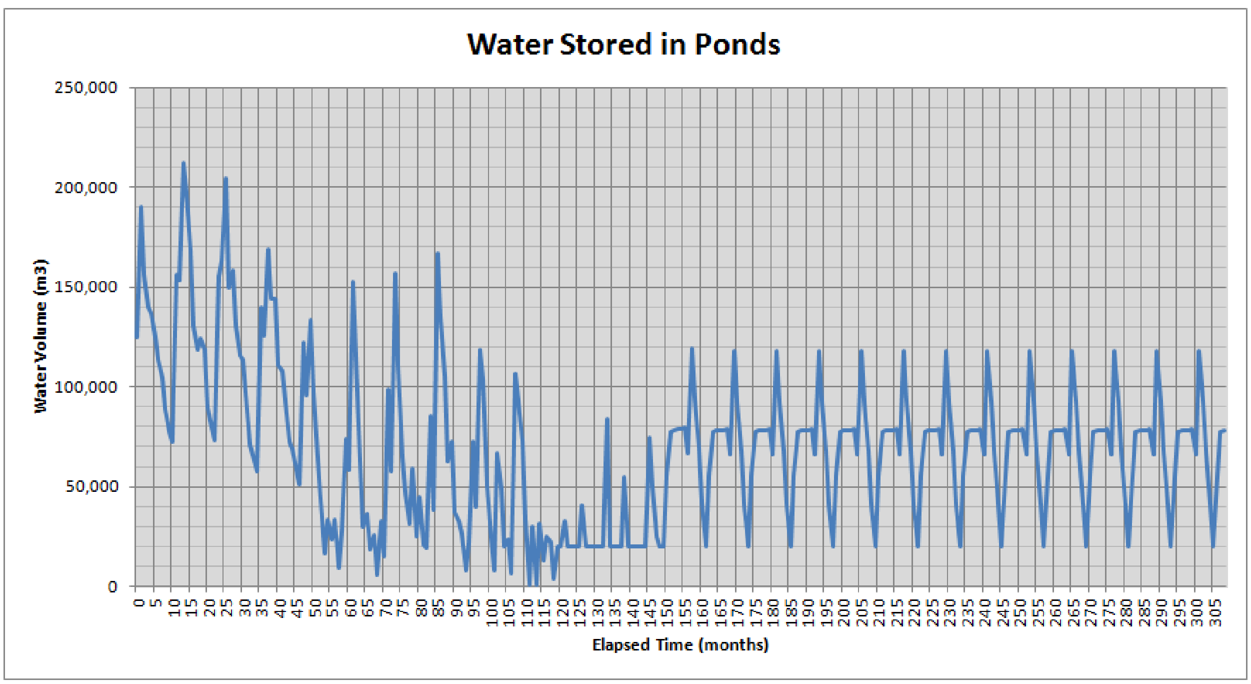


Figure 12 – 60.4 MT Scenario



To prevent accumulation of water in the pond system long term, the peak pumping to treatment rate for the

60.4 MT scenario must be increased from 10 l/s (Figure 13) to 11 l/s (Figure 14). The peak pumping rate can only be applied when there is sufficient water present to sustain it. If there is not sufficient water present, then the mean rate will be that required to empty the pond.

Figure 13 – 47.3 MT Scenario

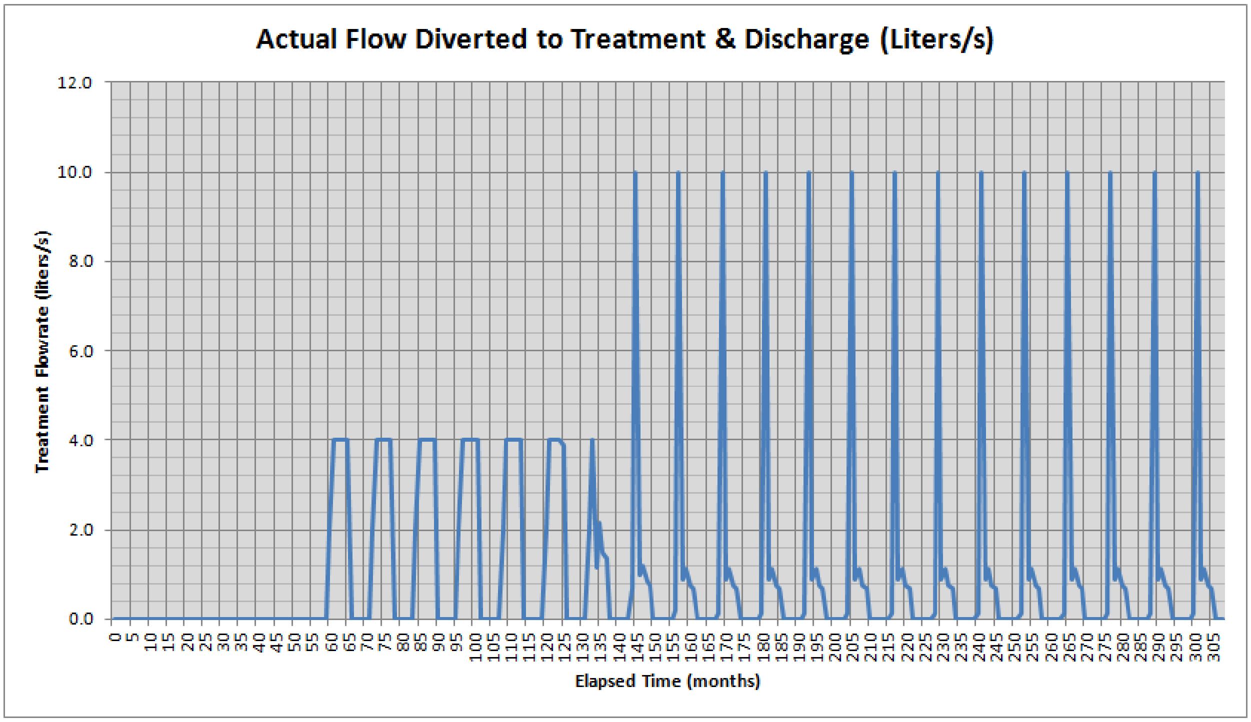
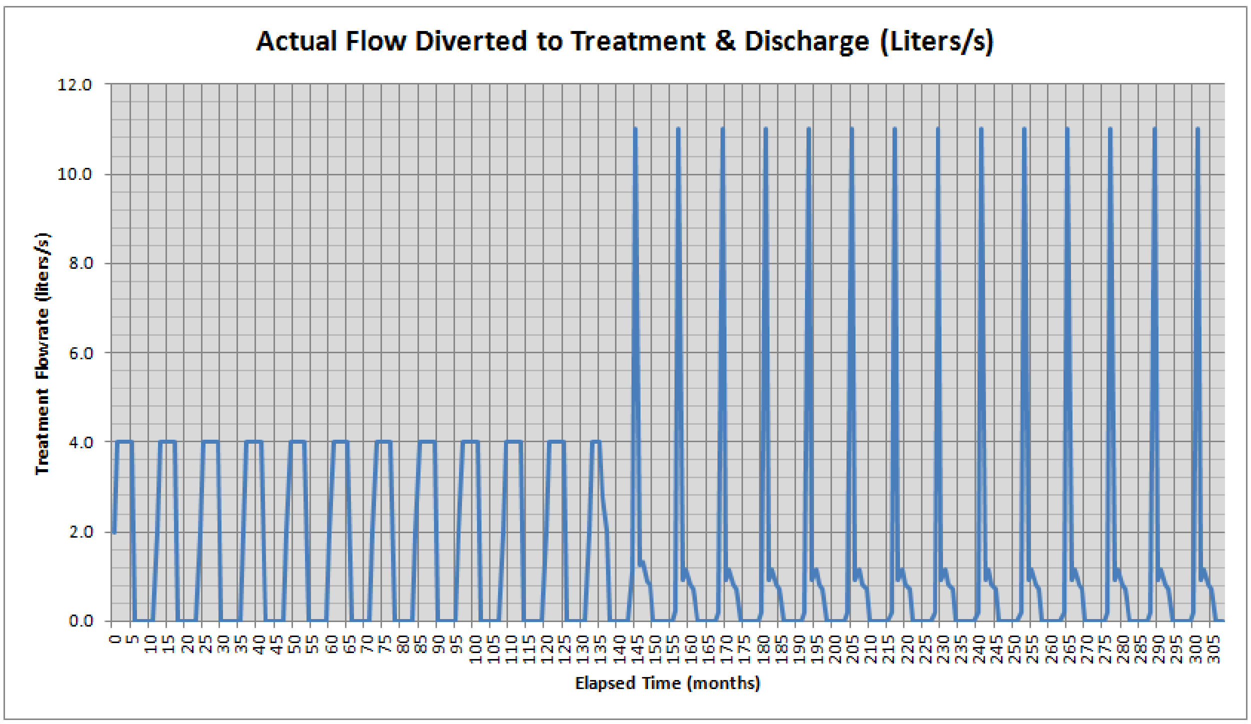


Figure 14 – 60.4 MT Scenario



It should be noted that the model utilizes mean estimates of precipitation, snowmelt, runoff, infiltration, and so on. Spikes in meteoric water and seasonal variability would be managed within the pond system with surges resulting in increases in pond storage that would be reduced over time by the maximum pumping to treatment rates. For the 60.4 MT scenario pumping rate schedule consisting of 5 l/s for April and 11 l/s for May through September, the treatment system would be capable of evacuating up to 155,370 m^3 of water from the system per year.

Please call if you need additional information or have any questions.

Regards,
The MINES Group, Inc.

Kenneth L. Myers

Appendix 12-C-3:
Coffee Gold Water Balance Model Output

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Appendix 12-C-3

Coffee Gold Water Balance Model Output

12-C-3.1. CC-1.5 Water Balance Node (Upper Latte Creek)

12-C-3.2. CC-3.5 Water Balance Node (Latte Creek at Coffee Creek)

12-C-3.3. CC-0.5 Water Balance Node (Coffee Creek upstream of Latte Creek)

12-C-3.4. CC-4.5 Water Balance Node (Coffee Creek downstream of Latte Creek)

12-C-3.5. YT-24 Water Balance Node (YT-24 Tributary at the Mouth)

12-C-3.6. HC-2.5 Water Balance Node (Upper Halfway Creek)

12-C-3.7. HC-5.0 Water Balance Node (Halfway Creek at the Mouth)

Appendix 12-C-3

Coffee Gold Water Balance Model Output

12-C-3.1. CC-1.5 Water Balance Node (Upper Latte Creek)

Table 12-C-3.1-1 End of Operations, Closure and Post-closure discharge data for the CC-1.5 Water Balance Model (WBM) node. Data shown are outputs from the Baseline (Natural Flow) Model.

	Discharge (m^3/s)												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
End of Operations (2027 through 2032)													
Min	0.003	0.002	0.001	0.019	0.227	0.115	0.067	0.081	0.072	0.039	0.010	0.005	0.001
10th Percentile	0.004	0.002	0.001	0.060	0.271	0.167	0.114	0.116	0.143	0.054	0.013	0.007	-
Lower Quartile	0.004	0.002	0.002	0.089	0.511	0.225	0.197	0.166	0.166	0.078	0.016	0.008	-
Median	0.005	0.003	0.005	0.157	0.752	0.282	0.272	0.220	0.196	0.089	0.019	0.009	-
Mean	0.006	0.005	0.012	0.186	0.690	0.300	0.310	0.244	0.222	0.109	0.023	0.012	0.177
Upper Quartile	0.007	0.005	0.019	0.231	0.861	0.343	0.397	0.310	0.251	0.137	0.029	0.014	-
90th Percentile	0.009	0.006	0.036	0.376	1.049	0.493	0.628	0.397	0.404	0.182	0.040	0.021	-
Max	0.012	0.035	0.046	0.594	1.175	0.583	0.812	0.565	0.464	0.309	0.054	0.046	1.175
Closure (2033 through 2042)													
Min	0.003	0.002	0.001	0.019	0.228	0.111	0.067	0.078	0.072	0.038	0.010	0.005	0.001
10th Percentile	0.004	0.002	0.001	0.060	0.272	0.166	0.109	0.110	0.138	0.054	0.013	0.007	-
Lower Quartile	0.004	0.002	0.002	0.083	0.504	0.222	0.200	0.163	0.165	0.075	0.015	0.008	-
Median	0.005	0.003	0.005	0.158	0.751	0.274	0.267	0.217	0.187	0.085	0.019	0.009	-
Mean	0.006	0.005	0.012	0.185	0.688	0.298	0.310	0.242	0.221	0.108	0.023	0.012	0.176
Upper Quartile	0.007	0.005	0.020	0.231	0.869	0.335	0.399	0.308	0.248	0.138	0.029	0.014	-
90th Percentile	0.009	0.006	0.035	0.376	1.039	0.493	0.630	0.390	0.402	0.175	0.040	0.021	-
Max	0.012	0.035	0.046	0.599	1.168	0.584	0.809	0.577	0.467	0.308	0.054	0.046	1.168
Long-term Monitoring (2043 through 2100)													
Min	0.003	0.001	0.001	0.017	0.075	0.091	0.063	0.073	0.072	0.033	0.009	0.005	0.001
10th Percentile	0.005	0.003	0.003	0.119	0.173	0.139	0.117	0.113	0.132	0.079	0.016	0.009	-
Lower Quartile	0.006	0.004	0.006	0.256	0.280	0.191	0.192	0.155	0.163	0.098	0.023	0.012	-
Median	0.009	0.008	0.022	0.441	0.502	0.240	0.256	0.214	0.209	0.134	0.043	0.018	-
Mean	0.013	0.011	0.037	0.454	0.551	0.264	0.301	0.241	0.237	0.156	0.055	0.026	0.195
Upper Quartile	0.015	0.014	0.050	0.638	0.771	0.316	0.376	0.306	0.271	0.192	0.071	0.032	-
90th Percentile	0.025	0.024	0.094	0.792	1.024	0.432	0.533	0.406	0.409	0.265	0.108	0.055	-
Max	0.111	0.064	0.329	1.536	1.469	0.636	1.078	0.758	0.730	0.548	0.351	0.187	1.536

Table 12-C-3.1-2 End of Operations, Closure and Post-closure discharge data for the CC-1.5 WBM node. Data shown are outputs from the Base Case (With Project) Model.

	Discharge (m^3/s)												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
End of Operations (2027 through 2032)													
Min	0.003	0.001	0.001	0.017	0.207	0.109	0.067	0.077	0.071	0.037	0.009	0.005	0.001
10th Percentile	0.004	0.002	0.001	0.064	0.253	0.164	0.112	0.111	0.140	0.053	0.013	0.007	-
Lower Quartile	0.004	0.002	0.002	0.098	0.473	0.217	0.192	0.157	0.162	0.073	0.015	0.007	-
Median	0.005	0.003	0.005	0.175	0.698	0.274	0.258	0.217	0.190	0.088	0.018	0.009	-
Mean	0.006	0.005	0.011	0.194	0.646	0.287	0.298	0.236	0.215	0.105	0.022	0.012	0.170
Upper Quartile	0.007	0.005	0.018	0.252	0.805	0.326	0.383	0.296	0.238	0.131	0.027	0.013	-
90th Percentile	0.008	0.006	0.033	0.356	0.951	0.459	0.583	0.384	0.372	0.177	0.038	0.019	-
Max	0.012	0.034	0.045	0.572	1.138	0.554	0.794	0.552	0.459	0.306	0.052	0.044	1.138
Closure (2033 through 2042)													
Min	0.003	0.001	0.001	0.017	0.224	0.109	0.068	0.077	0.073	0.038	0.009	0.005	0.001
10th Percentile	0.004	0.002	0.001	0.073	0.262	0.165	0.108	0.108	0.137	0.052	0.013	0.006	-
Lower Quartile	0.004	0.002	0.002	0.103	0.494	0.217	0.196	0.160	0.163	0.073	0.014	0.007	-
Median	0.005	0.003	0.005	0.195	0.718	0.267	0.260	0.212	0.185	0.087	0.018	0.009	-
Mean	0.006	0.005	0.011	0.200	0.656	0.289	0.299	0.236	0.216	0.106	0.022	0.012	0.171
Upper Quartile	0.007	0.005	0.018	0.254	0.816	0.326	0.385	0.296	0.242	0.133	0.027	0.013	-
90th Percentile	0.009	0.006	0.032	0.376	0.977	0.472	0.603	0.379	0.388	0.171	0.038	0.020	-
Max	0.011	0.032	0.042	0.579	1.153	0.564	0.776	0.555	0.450	0.304	0.050	0.042	1.153
Long-term Monitoring (2043 through 2100)													
Min	0.003	0.001	0.001	0.015	0.077	0.090	0.064	0.073	0.074	0.032	0.009	0.005	0.001
10th Percentile	0.005	0.003	0.002	0.143	0.175	0.138	0.116	0.112	0.133	0.078	0.015	0.009	-
Lower Quartile	0.006	0.004	0.006	0.287	0.276	0.190	0.190	0.154	0.163	0.098	0.022	0.011	-
Median	0.009	0.007	0.022	0.456	0.496	0.239	0.253	0.212	0.209	0.134	0.040	0.016	-
Mean	0.012	0.010	0.040	0.467	0.542	0.261	0.298	0.239	0.237	0.155	0.053	0.025	0.195
Upper Quartile	0.014	0.013	0.055	0.643	0.751	0.313	0.374	0.304	0.269	0.190	0.068	0.030	-
90th Percentile	0.023	0.023	0.103	0.794	0.993	0.425	0.530	0.406	0.409	0.264	0.108	0.052	-
Max	0.106	0.063	0.363	1.493	1.452	0.630	1.070	0.750	0.727	0.544	0.339	0.182	1.493

Table 12-C-3.1-3 End of Operations, Closure and Post-closure percent change data for the CC-1.5 WBM node. Data shown are computed from Natural and Base Case Model outputs.

	Percent Change (%)												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
End of Operations (2027 through 2032)													
Min	-9.5	-11.0	-10.3	-10.7	-12.4	-9.5	-9.1	-8.7	-8.5	-9.6	-9.6	-10.6	-12.4
10th Percentile	-8.4	-9.3	-9.8	-7.3	-11.0	-8.3	-8.1	-7.5	-7.7	-8.3	-7.5	-7.8	-
Lower Quartile	-7.0	-8.1	-9.1	-2.1	-10.2	-7.8	-7.1	-6.2	-6.6	-6.5	-6.6	-6.9	-
Median	-6.5	-6.8	-6.8	5.1	-5.9	-3.2	-2.7	-2.2	-1.6	-2.6	-5.7	-6.2	-
Mean	-6.2	-6.6	-5.2	8.1	-6.4	-4.2	-3.5	-3.2	-2.9	-3.4	-5.6	-6.0	-3.8
Upper Quartile	-5.5	-5.3	-3.8	16.6	-2.9	-1.4	-0.6	-0.7	-0.2	-1.0	-4.7	-5.3	-
90th Percentile	-3.4	-3.4	0.6	27.8	-1.0	-0.4	0.4	0.4	0.4	0.2	-3.2	-3.5	-
Max	-1.7	-1.7	37.1	57.2	2.7	1.2	2.8	1.0	2.4	6.0	-1.2	-1.4	57.2
Closure (2033 through 2042)													
Min	-8.5	-10.1	-9.1	-8.8	-7.8	-4.5	-4.6	-4.4	-3.9	-6.0	-7.4	-8.5	-10.1
10th Percentile	-7.5	-8.4	-8.8	-1.2	-6.7	-4.0	-4.2	-3.6	-3.6	-5.0	-7.1	-7.3	-
Lower Quartile	-6.3	-7.3	-8.3	5.6	-5.5	-3.3	-3.9	-3.2	-3.1	-4.0	-6.3	-6.5	-
Median	-5.6	-5.8	-6.7	13.4	-4.6	-2.8	-3.0	-2.6	-2.4	-3.2	-5.9	-5.6	-
Mean	-5.8	-6.2	-4.8	13.0	-4.6	-2.7	-2.8	-2.5	-2.0	-2.4	-5.7	-5.7	-2.7
Upper Quartile	-5.0	-5.0	-4.4	22.1	-3.7	-2.3	-2.0	-2.0	-1.3	-1.7	-4.8	-4.8	-
90th Percentile	-4.4	-4.2	0.5	25.7	-2.6	-1.3	-1.0	-1.5	0.3	0.8	-4.2	-4.2	-
Max	-3.9	-3.7	28.3	47.9	2.6	-0.2	1.7	0.0	8.2	12.5	-3.1	-3.1	47.9
Long-term Monitoring (2043 through 2100)													
Min	-10.9	-11.4	-9.9	-9.0	-7.9	-3.8	-4.2	-4.1	-3.1	-5.1	-7.9	-10.1	-11.4
10th Percentile	-8.6	-9.5	-8.7	-2.0	-4.4	-2.1	-2.1	-1.7	-1.7	-2.3	-6.7	-8.0	-
Lower Quartile	-7.8	-8.6	-7.7	-0.1	-2.8	-1.5	-1.2	-1.2	-0.5	-1.5	-6.2	-7.3	-
Median	-6.7	-7.4	-0.4	2.3	-1.1	-0.9	-0.7	-0.6	-0.1	-0.6	-5.1	-6.4	-
Mean	-6.4	-6.4	4.6	5.9	-1.1	-1.0	-0.8	-0.6	-0.1	-0.6	-4.6	-5.9	-1.4
Upper Quartile	-5.4	-5.6	10.7	10.5	0.3	-0.4	-0.3	-0.1	0.5	0.1	-3.9	-5.0	-
90th Percentile	-4.4	-4.0	23.8	20.2	1.9	0.0	0.2	0.4	1.2	1.1	-1.6	-4.0	-
Max	23.2	33.6	122.6	47.1	6.9	1.6	3.5	1.4	3.8	10.4	9.9	16.0	122.6

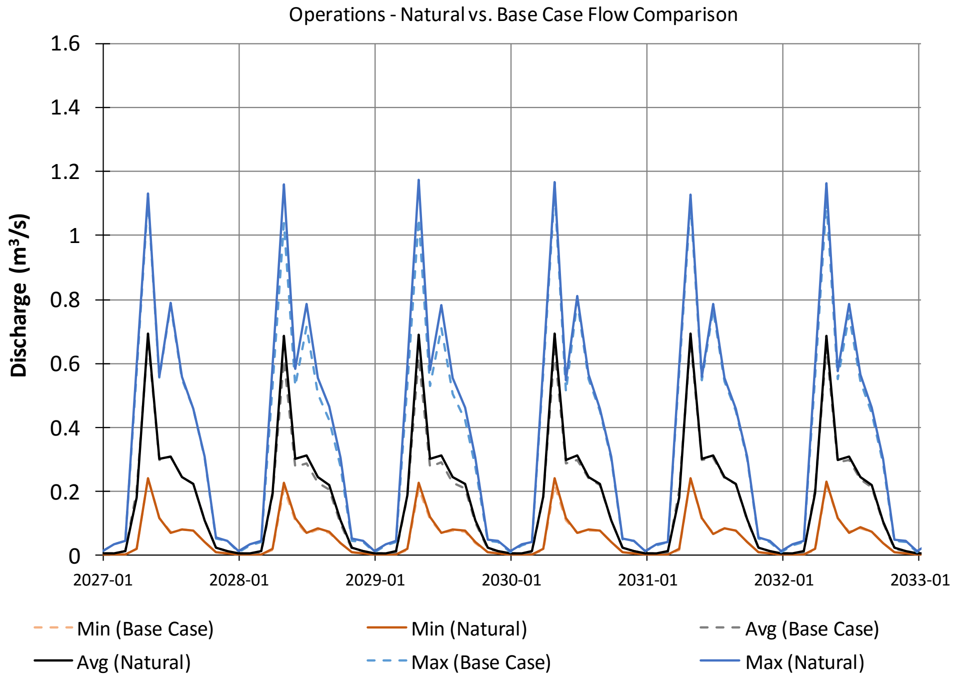

Figure 12-C-3.1-1 Time series plot showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the End of Operations phase of the Project and were computed from 28 WBM realizations.

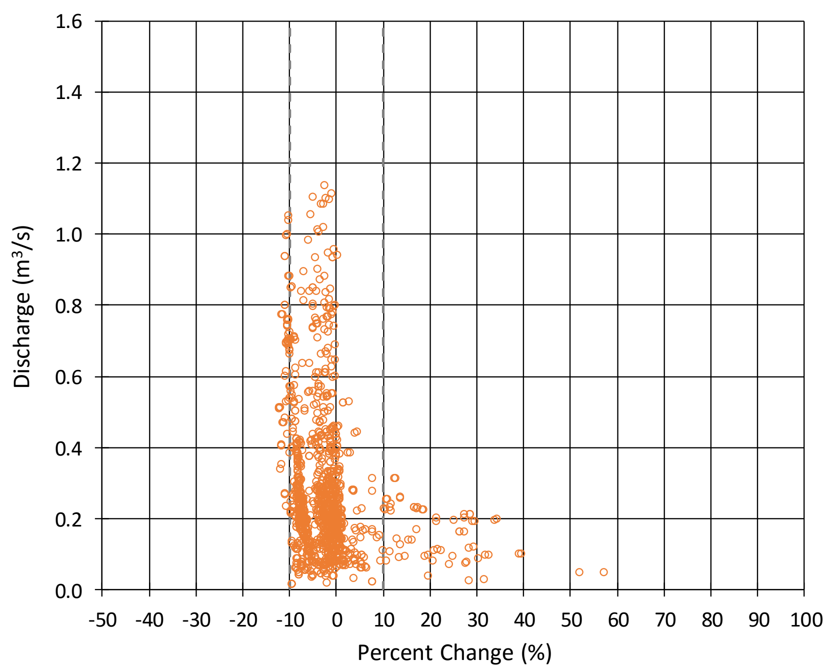

Figure 12-C-3.1-2 End of Operations phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at CC-1.5, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.

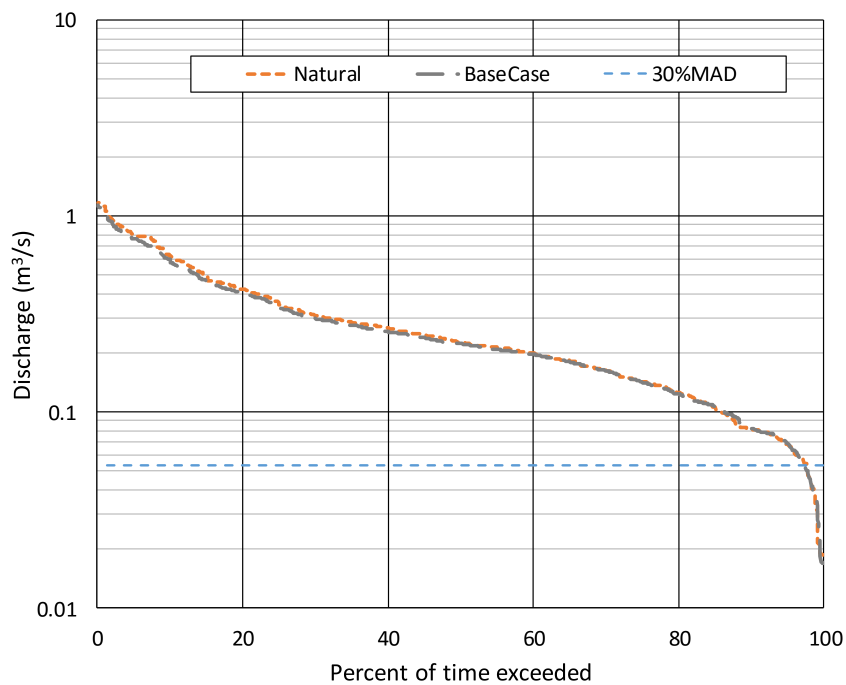

Figure 12-C-3.1-3 Natural and Base Case monthly discharge data for CC-1.5. Data shown are for the End of Operations phase and are presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Operations shown by dashed blue line.

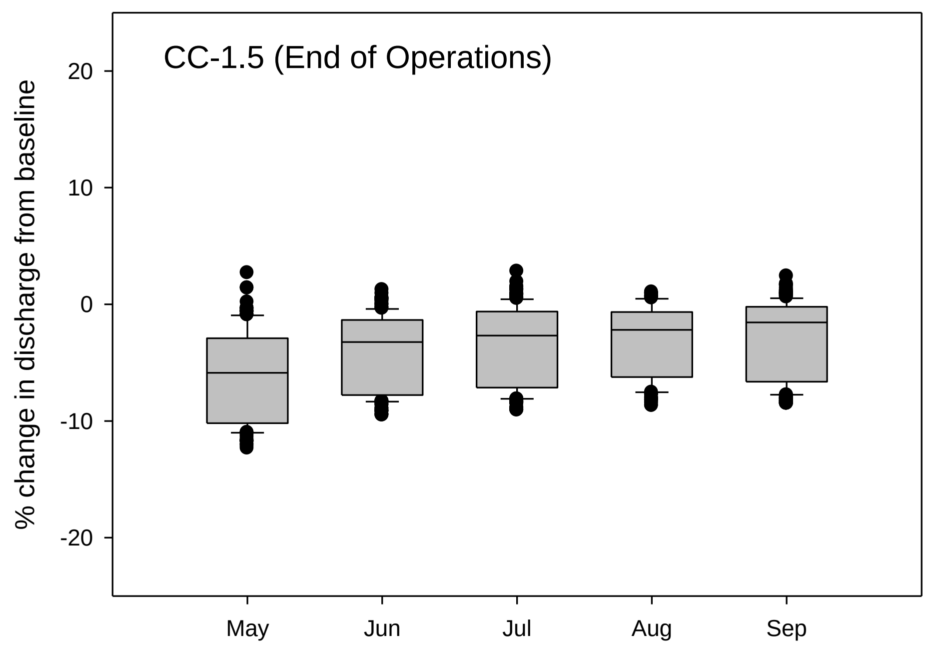

Figure 12-C-3..1-4 Box and Whisker Plot percent change summary for the End of Operations phase at CC-1.5. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

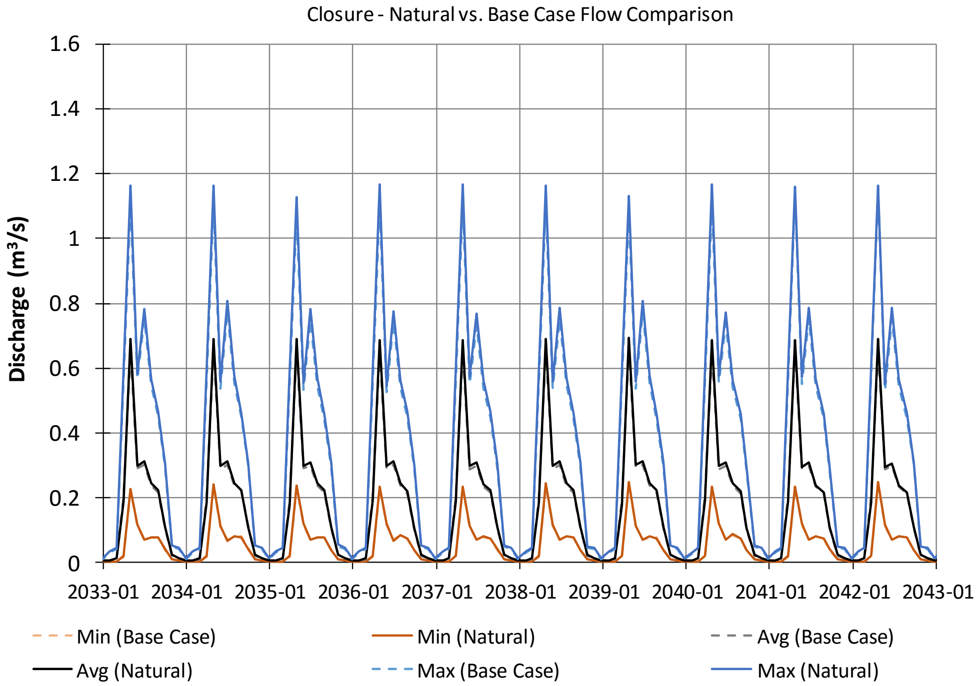

Figure 12-C-3.1-5 Time series plot showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the Closure phase of the Project and were computed from 28 WBM realizations.

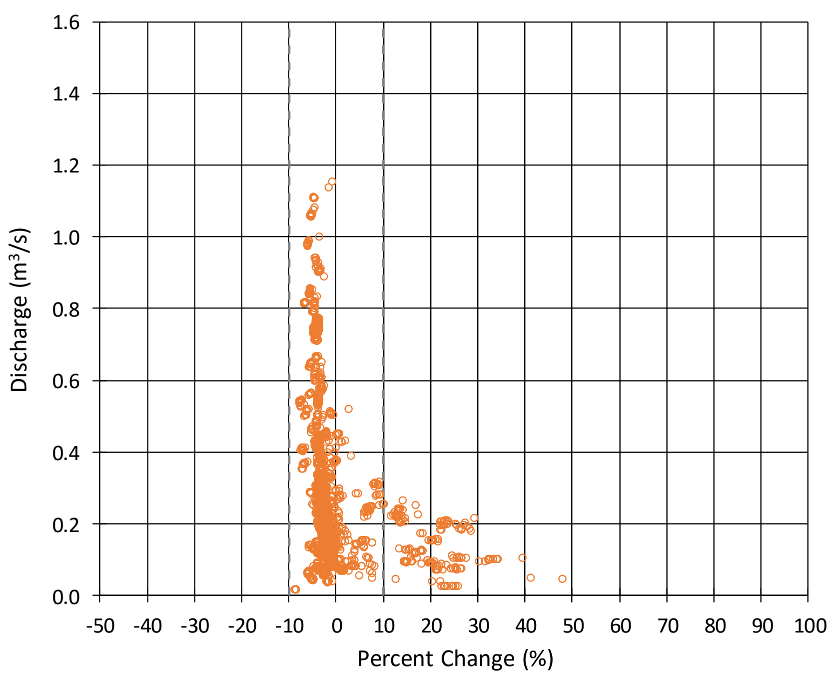

Figure 12-C-3.1-6 Closure phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at CC-1.5, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.

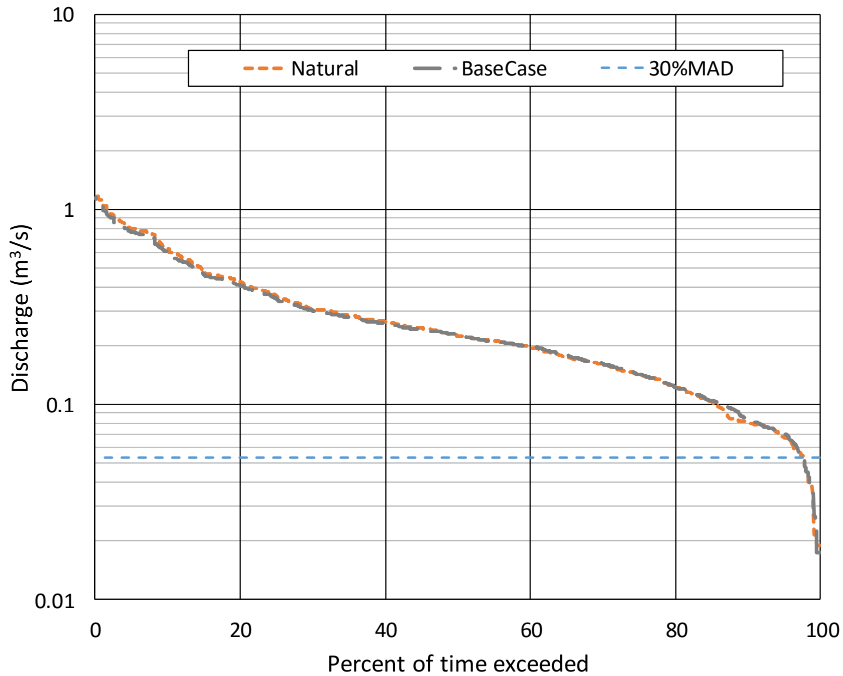

Figure 12-C-3.1-7 Natural and Base Case monthly discharge data for CC-1.5. Data shown are for the Closure phase of the Project and are presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Closure shown by dashed blue line.

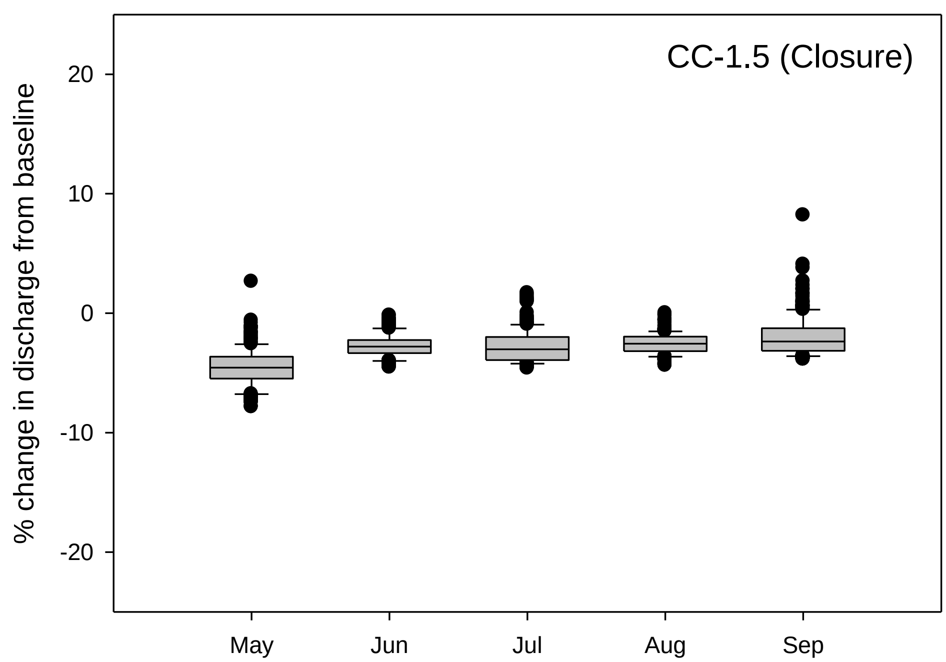

Figure 12-C-3.1-8 Box and Whisker Plot percent change summary for the Closure phase at CC-1.5. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

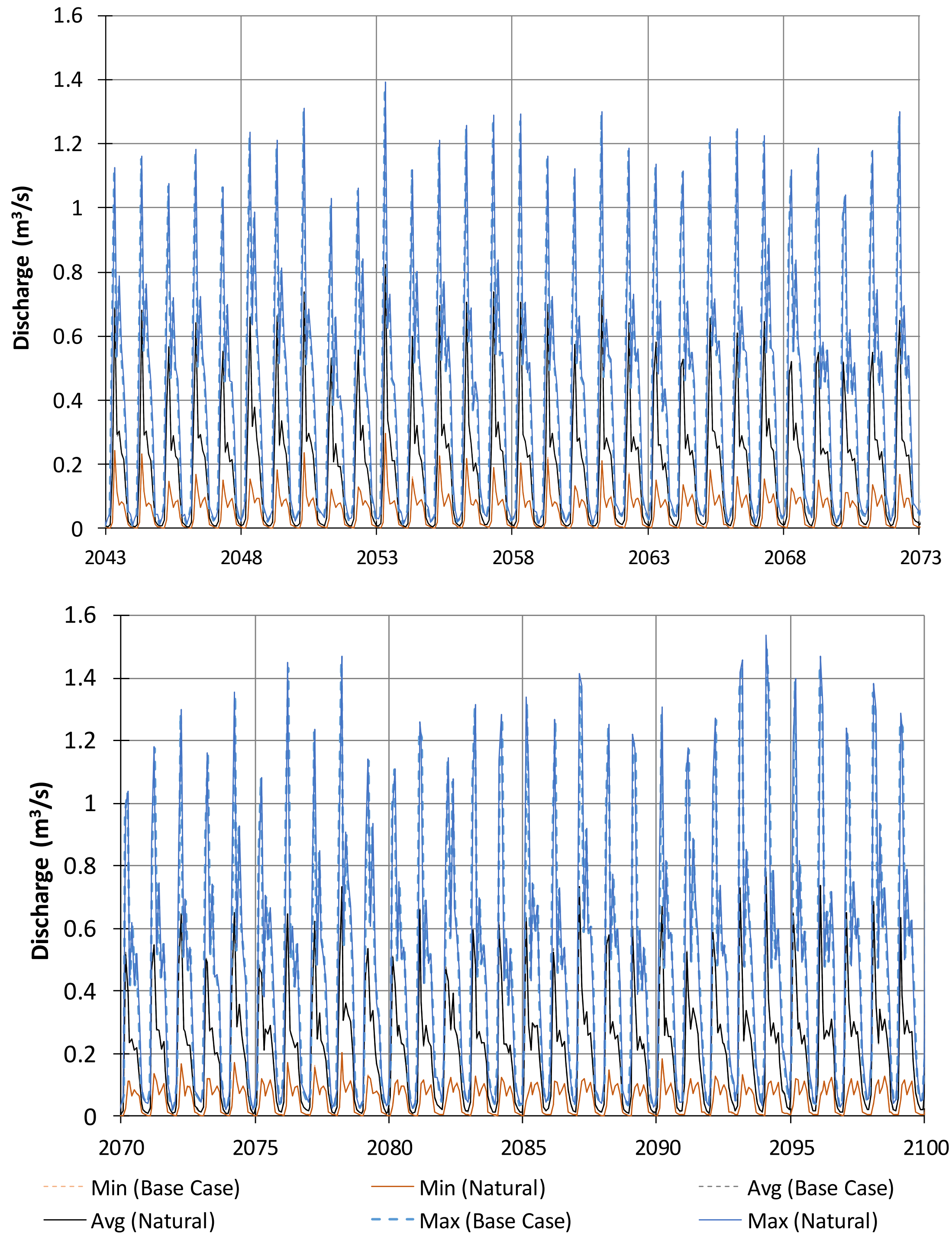

Figure 12-C-3.1-9 **Time series plots showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the Post-closure phase of the Project and were computed from 28 WBM realizations. The upper panel shows output for 2043-2073 and the lower plot shows output from 2070-2100.**

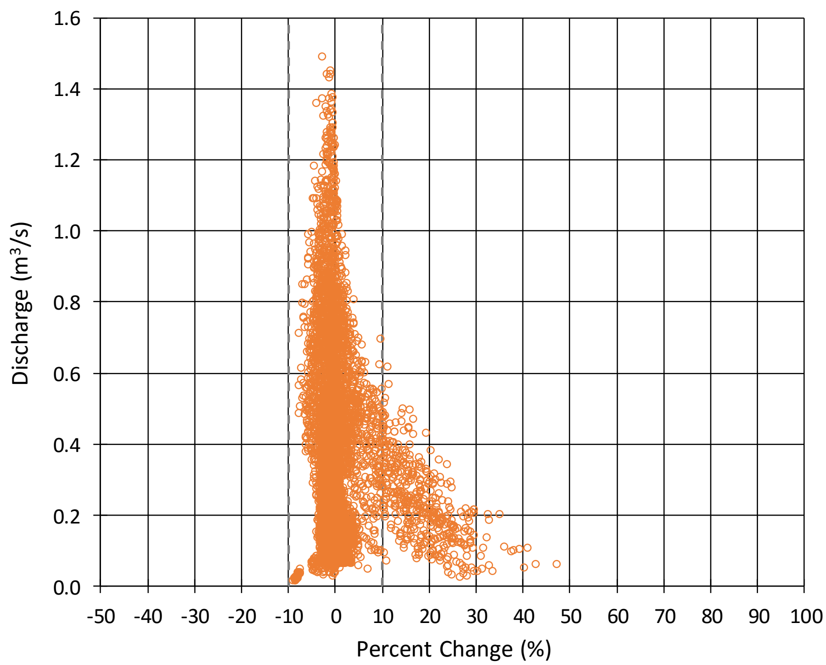

Figure 12-C-3-.1-10 Post-closure phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at CC-1.5, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.

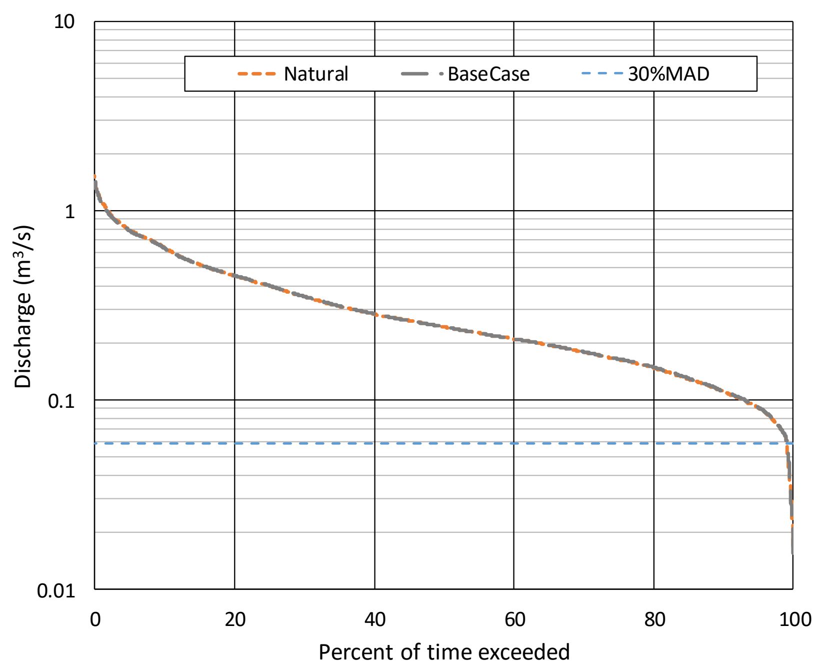

Figure 12-C-3.1-11 Natural and Base Case monthly discharge data for CC-1.5. Data shown are for Post-closure and presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Post-closure shown by dashed blue line.

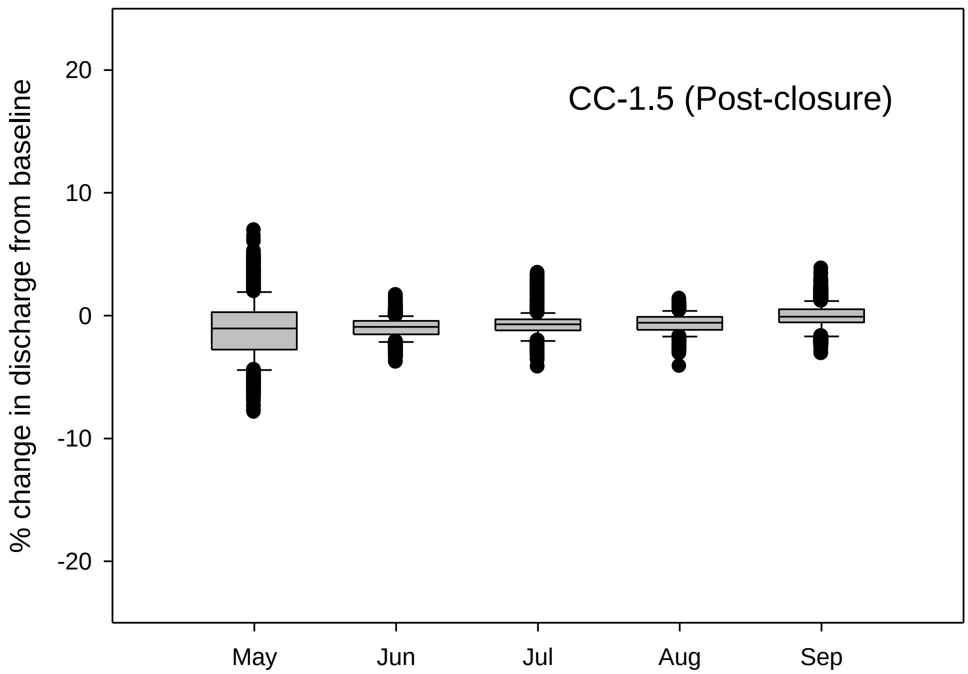

Figure 12-C-3.1-12 Box and Whisker Plot percent change summary for the Post-closure phase at CC-1.5. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

Appendix 12-C-3

Coffee Gold Water Balance Model Output

12-C-3.2. CC-3.5 Water Balance Node (Latte Creek at Coffee Creek)

Table 12-C-3.2-1 End of Operations, Closure and Post-closure discharge data for the CC-3.5 Water Balance Model (WBM) node. Data shown are outputs from the Baseline (Natural Flow) Model.

	Discharge (m^3/s)												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
End of Operations (2027 through 2032)													
Min	0.003	0.002	0.001	0.047	0.368	0.180	0.096	0.116	0.109	0.047	0.010	0.005	0.001
10th Percentile	0.006	0.003	0.005	0.132	0.450	0.310	0.178	0.183	0.260	0.084	0.017	0.008	-
Lower Quartile	0.008	0.007	0.009	0.198	0.863	0.412	0.357	0.275	0.307	0.111	0.022	0.012	-
Median	0.014	0.011	0.018	0.416	1.287	0.541	0.517	0.412	0.361	0.151	0.031	0.020	-
Mean	0.018	0.017	0.029	0.421	1.201	0.571	0.592	0.452	0.410	0.179	0.042	0.027	0.330
Upper Quartile	0.023	0.023	0.044	0.555	1.510	0.686	0.754	0.593	0.444	0.223	0.059	0.037	-
90th Percentile	0.035	0.049	0.067	0.765	1.863	0.963	1.208	0.731	0.751	0.304	0.091	0.073	-
Max	0.063	0.065	0.103	1.115	2.095	1.101	1.579	1.158	0.915	0.599	0.103	0.079	2.095
Closure (2033 through 2042)													
Min	0.003	0.002	0.001	0.048	0.366	0.174	0.097	0.111	0.110	0.045	0.010	0.006	0.001
10th Percentile	0.006	0.003	0.005	0.135	0.451	0.308	0.168	0.167	0.250	0.083	0.016	0.008	-
Lower Quartile	0.008	0.006	0.009	0.199	0.853	0.418	0.362	0.267	0.297	0.112	0.022	0.012	-
Median	0.013	0.010	0.017	0.404	1.322	0.523	0.517	0.398	0.348	0.145	0.030	0.019	-
Mean	0.018	0.016	0.029	0.419	1.197	0.566	0.591	0.447	0.407	0.178	0.042	0.027	0.328
Upper Quartile	0.022	0.022	0.045	0.562	1.512	0.676	0.759	0.595	0.440	0.226	0.059	0.037	-
90th Percentile	0.041	0.048	0.066	0.764	1.839	0.962	1.254	0.734	0.760	0.298	0.089	0.072	-
Max	0.064	0.065	0.102	1.119	2.080	1.102	1.578	1.179	0.916	0.597	0.105	0.080	2.080
Long-term Monitoring (2043 through 2100)													
Min	0.003	0.002	0.001	0.037	0.108	0.133	0.083	0.103	0.110	0.043	0.010	0.005	0.001
10th Percentile	0.008	0.005	0.008	0.277	0.299	0.243	0.182	0.176	0.219	0.117	0.020	0.013	-
Lower Quartile	0.012	0.009	0.015	0.569	0.506	0.343	0.338	0.259	0.279	0.147	0.033	0.018	-
Median	0.019	0.019	0.043	0.860	0.865	0.448	0.469	0.378	0.367	0.212	0.067	0.031	-
Mean	0.026	0.024	0.073	0.897	0.953	0.500	0.559	0.432	0.425	0.257	0.087	0.046	0.357
Upper Quartile	0.037	0.033	0.102	1.229	1.297	0.623	0.706	0.563	0.489	0.326	0.114	0.062	-
90th Percentile	0.054	0.051	0.183	1.500	1.778	0.851	1.057	0.745	0.759	0.457	0.181	0.097	-
Max	0.188	0.118	0.636	2.835	2.588	1.213	2.070	1.533	1.373	1.026	0.614	0.318	2.835

Table 12-C-3.2-2 End of Operations, Closure and Post-closure discharge data for the CC-3.5 WBM node. Data shown are outputs from the Base Case (With Project) Model.

	Discharge (m³/s)												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
End of Operations (2027 through 2032)													
Min	0.003	0.002	0.001	0.049	0.348	0.178	0.099	0.113	0.110	0.045	0.010	0.005	0.001
10th Percentile	0.006	0.003	0.005	0.143	0.424	0.308	0.175	0.178	0.262	0.082	0.017	0.008	-
Lower Quartile	0.008	0.007	0.009	0.216	0.830	0.408	0.355	0.268	0.298	0.108	0.021	0.012	-
Median	0.013	0.011	0.018	0.440	1.263	0.537	0.513	0.414	0.356	0.154	0.031	0.019	-
Mean	0.018	0.016	0.028	0.431	1.166	0.562	0.584	0.447	0.405	0.177	0.041	0.027	0.325
Upper Quartile	0.022	0.022	0.044	0.569	1.470	0.678	0.740	0.585	0.439	0.218	0.057	0.037	-
90th Percentile	0.034	0.048	0.064	0.764	1.769	0.954	1.179	0.728	0.749	0.296	0.088	0.071	-
Max	0.063	0.064	0.102	1.097	2.067	1.071	1.572	1.143	0.912	0.599	0.102	0.078	2.067
Closure (2033 through 2042)													
Min	0.003	0.002	0.001	0.049	0.363	0.173	0.099	0.111	0.111	0.045	0.010	0.005	0.001
10th Percentile	0.006	0.003	0.004	0.152	0.438	0.309	0.168	0.167	0.251	0.082	0.015	0.008	-
Lower Quartile	0.007	0.006	0.009	0.217	0.852	0.419	0.359	0.267	0.298	0.110	0.021	0.012	-
Median	0.013	0.010	0.017	0.442	1.299	0.519	0.511	0.396	0.346	0.148	0.029	0.019	-
Mean	0.018	0.016	0.028	0.437	1.174	0.561	0.584	0.444	0.405	0.176	0.041	0.027	0.326
Upper Quartile	0.022	0.021	0.045	0.578	1.474	0.672	0.749	0.587	0.437	0.223	0.058	0.035	-
90th Percentile	0.040	0.047	0.063	0.775	1.791	0.948	1.234	0.728	0.754	0.295	0.086	0.071	-
Max	0.064	0.063	0.099	1.103	2.061	1.090	1.554	1.164	0.905	0.594	0.103	0.080	2.061
Long-term Monitoring (2043 through 2100)													
Min	0.003	0.002	0.001	0.035	0.110	0.133	0.085	0.104	0.113	0.043	0.009	0.005	0.001
10th Percentile	0.007	0.005	0.008	0.303	0.304	0.246	0.183	0.176	0.221	0.117	0.020	0.012	-
Lower Quartile	0.011	0.009	0.015	0.598	0.508	0.344	0.339	0.260	0.281	0.149	0.032	0.018	-
Median	0.019	0.018	0.044	0.879	0.870	0.449	0.470	0.381	0.369	0.214	0.065	0.030	-
Mean	0.026	0.024	0.077	0.915	0.952	0.501	0.561	0.434	0.428	0.258	0.086	0.045	0.359
Upper Quartile	0.036	0.032	0.106	1.239	1.287	0.623	0.708	0.564	0.491	0.327	0.112	0.061	-
90th Percentile	0.053	0.050	0.194	1.513	1.766	0.854	1.062	0.750	0.764	0.460	0.181	0.095	-
Max	0.189	0.118	0.677	2.807	2.591	1.215	2.076	1.536	1.380	1.029	0.615	0.317	2.807

Table 12-C-3.2-3 End of Operations, Closure and Post-closure percent change data for the CC-3.5 WBM node. Data shown are computed from Natural and Base Case Model outputs.

	Percent Change (%)												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
End of Operations (2027 through 2032)													
Min	-4.8	-7.1	-4.9	-5.3	-7.3	-4.3	-4.0	-3.9	-3.8	-5.2	-5.2	-5.5	-7.3
10th Percentile	-3.8	-3.5	-4.2	-3.0	-5.8	-3.7	-3.6	-3.4	-3.6	-4.3	-4.2	-4.0	-
Lower Quartile	-2.9	-2.3	-3.3	-0.1	-5.1	-3.4	-3.1	-2.9	-3.0	-3.0	-3.4	-3.1	-
Median	-2.0	-1.6	-1.5	3.1	-3.0	-1.0	-0.7	-0.5	-0.1	-0.7	-2.6	-2.4	-
Mean	-2.1	-1.9	-0.9	4.1	-3.0	-1.5	-1.1	-1.0	-0.9	-1.2	-2.5	-2.4	-1.2
Upper Quartile	-1.2	-0.9	-0.4	7.7	-1.0	0.0	0.4	0.4	0.6	0.4	-1.6	-1.5	-
90th Percentile	-0.6	-0.4	1.2	11.9	0.2	0.5	0.9	1.0	1.0	1.3	-0.9	-0.9	-
Max	0.0	0.0	37.6	26.2	2.7	1.5	2.9	1.4	2.5	4.6	0.3	0.0	37.6
Closure (2033 through 2042)													
Min	-3.8	-6.6	-4.3	-2.7	-4.4	-1.5	-1.6	-1.7	-1.3	-2.7	-4.0	-4.7	-6.6
10th Percentile	-3.1	-3.4	-3.7	0.0	-3.4	-1.4	-1.5	-1.1	-1.2	-2.4	-3.9	-3.6	-
Lower Quartile	-2.6	-2.0	-3.4	3.1	-2.6	-1.1	-1.4	-1.0	-1.0	-1.5	-3.3	-2.8	-
Median	-1.8	-1.4	-1.6	6.6	-1.9	-0.7	-0.9	-0.7	-0.6	-1.0	-2.5	-2.1	-
Mean	-1.9	-1.8	-0.6	6.3	-1.9	-0.7	-0.7	-0.7	-0.3	-0.5	-2.6	-2.3	-0.6
Upper Quartile	-1.3	-1.1	-0.6	9.8	-1.3	-0.5	-0.3	-0.4	0.0	-0.1	-2.0	-1.6	-
90th Percentile	-0.9	-0.6	1.3	12.1	-0.8	0.1	0.2	-0.1	0.9	1.8	-1.7	-1.3	-
Max	-0.4	-0.3	28.6	22.4	2.6	0.8	2.2	0.6	6.3	11.7	-0.9	-0.6	28.6
Long-term Monitoring (2043 through 2100)													
Min	-8.5	-6.7	-5.0	-4.0	-4.5	-1.3	-1.5	-1.5	-1.0	-2.4	-5.5	-7.3	-8.5
10th Percentile	-4.5	-5.0	-3.8	-0.6	-2.1	-0.4	-0.4	-0.2	-0.2	-0.5	-3.6	-4.5	-
Lower Quartile	-3.7	-3.8	-2.4	0.6	-0.9	-0.1	0.1	0.1	0.5	0.0	-3.0	-3.6	-
Median	-2.7	-2.4	0.7	1.9	0.2	0.3	0.4	0.4	0.7	0.5	-2.4	-2.7	-
Mean	-2.6	-2.3	3.8	3.3	0.1	0.2	0.4	0.4	0.7	0.6	-2.0	-2.6	0.0
Upper Quartile	-1.6	-1.5	6.8	5.4	1.0	0.5	0.6	0.7	1.1	1.0	-1.5	-1.9	-
90th Percentile	-1.1	-0.6	14.1	9.7	2.0	0.8	0.9	1.0	1.5	1.7	0.1	-1.2	-
Max	17.8	22.8	71.2	20.6	5.4	1.9	3.5	1.5	3.4	8.3	9.2	15.3	71.2

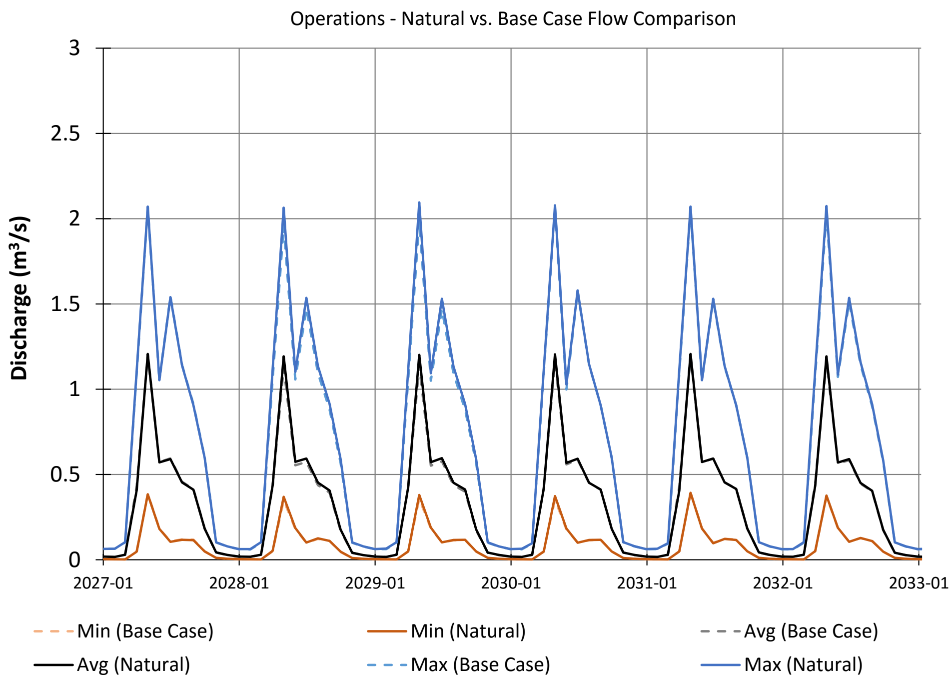

Figure 12-C-3.2-1 Time series plot showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the End of Operations phase of the Project and were computed from 28 WBM realizations.

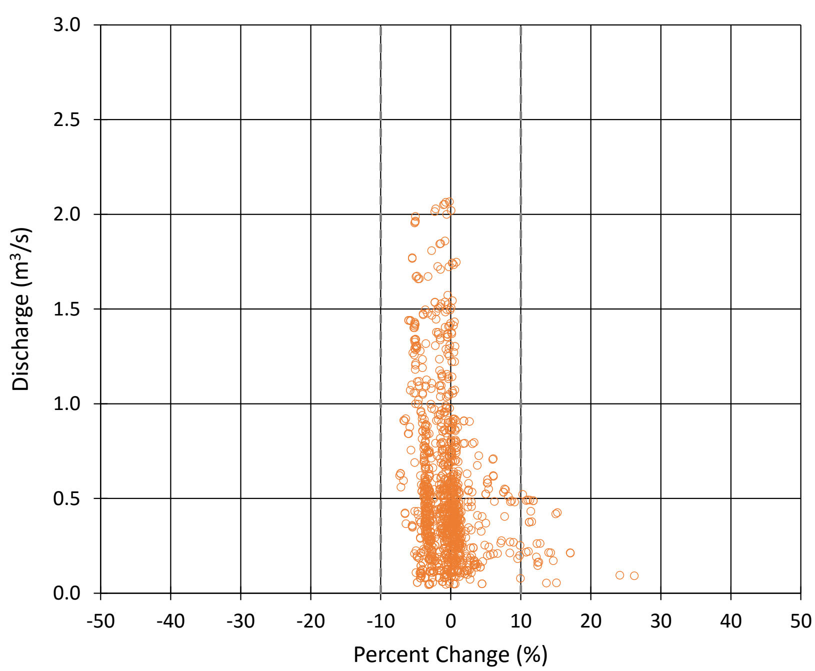

Figure 12-C-3-2 End of Operations phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at CC-3.5, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.

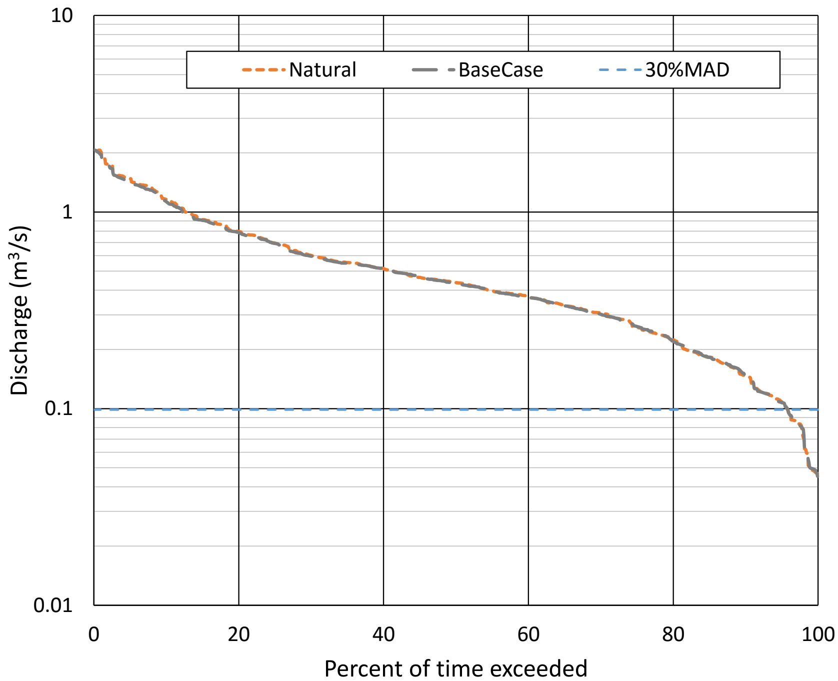

Figure 12-C-3.2-3 Natural and Base Case monthly discharge data for CC-3.5. Data shown are for the End of Operations phase and are presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Operations shown by dashed blue line.

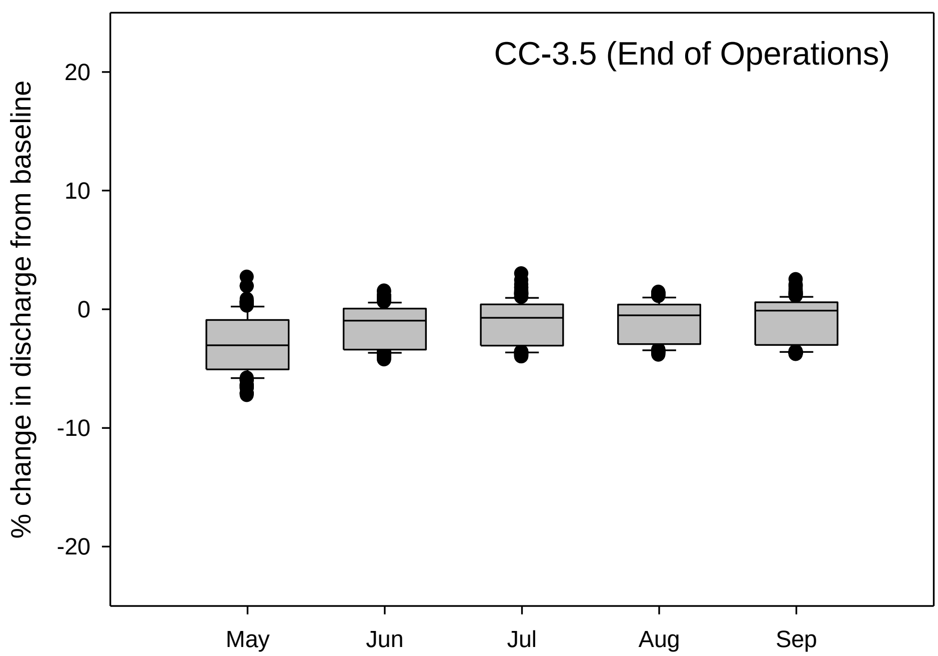

Figure 12-C-3-4 Box and Whisker Plot percent change summary for the End of Operations phase at CC-3.5. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

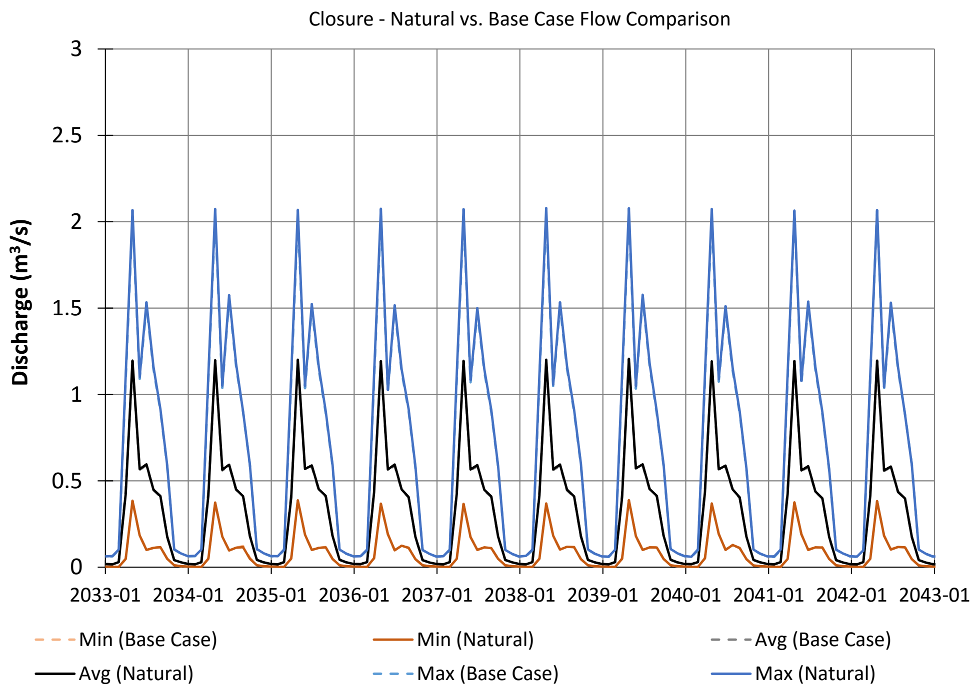

Figure 12-C-3.2-5 Time series plot showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the Closure phase of the Project and were computed from 28 WBM realizations.

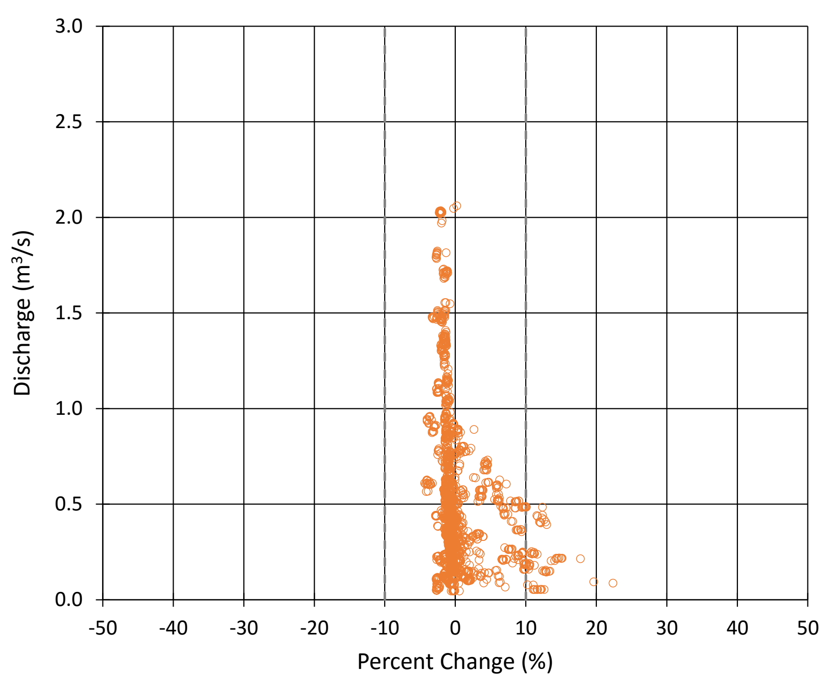

Figure 12-C-3.2-6 Closure phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at CC-3.5, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.

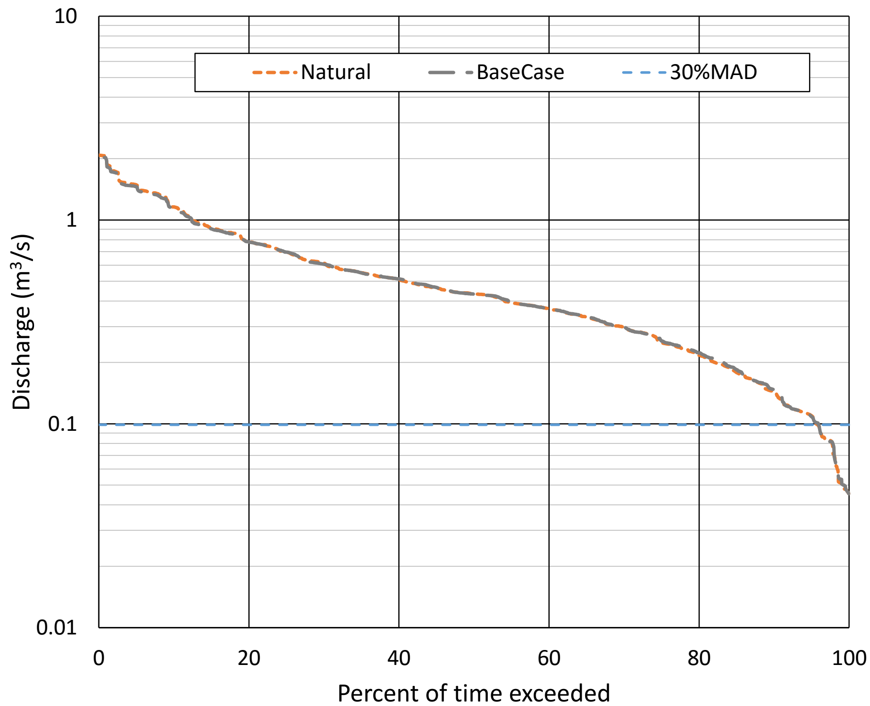

Figure 12-C-3.2-7 Natural and Base Case monthly discharge data for CC-3.5. Data shown are for the Closure phase of the Project and are presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Closure shown by dashed blue line.

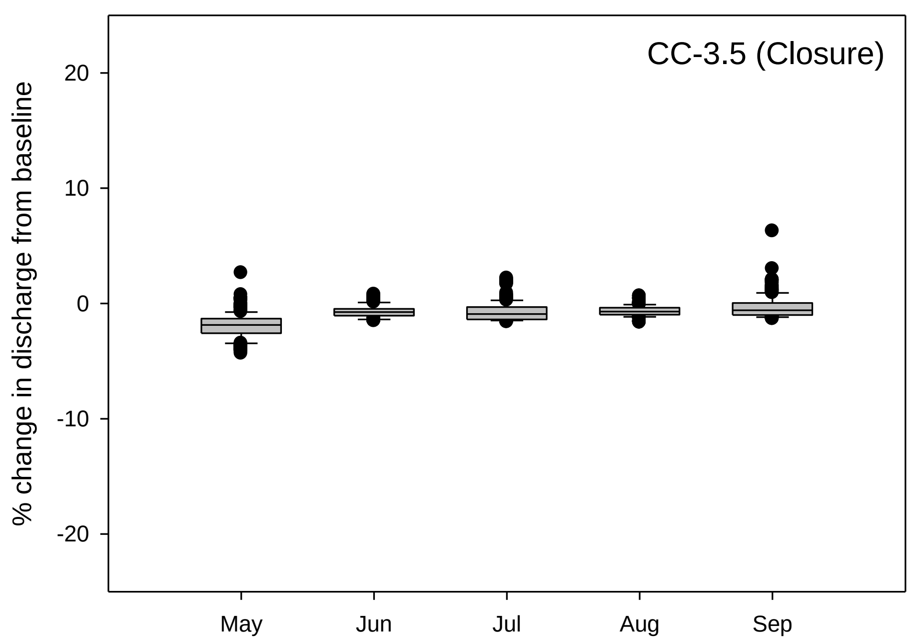

Figure 12-C-3-8 Box and Whisker Plot percent change summary for the Closure phase at CC-3.5. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

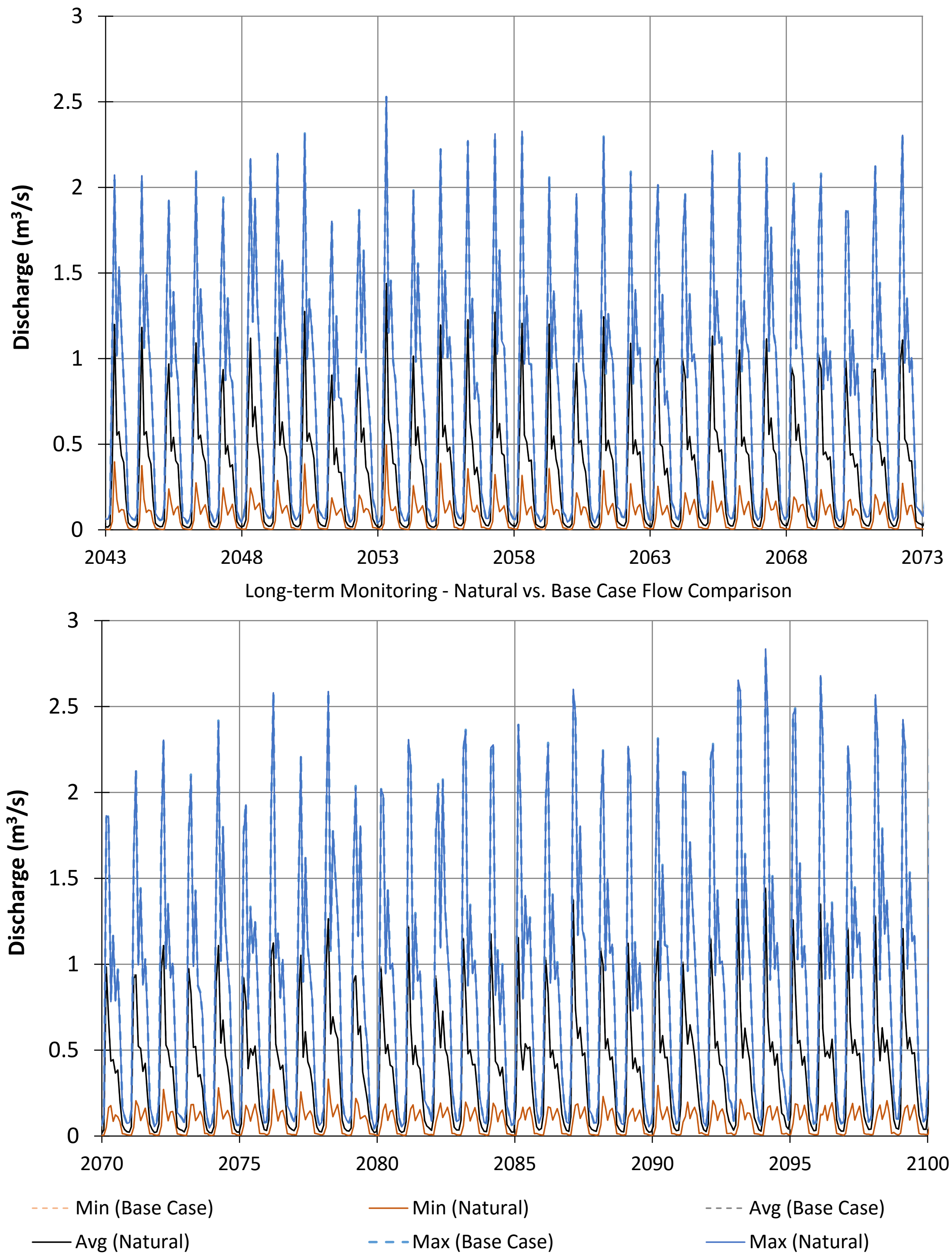

Figure 12-C-3.2-9 Time series plots showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the Post-closure phase of the Project and were computed from 28 WBM realizations. The upper panel shows output for 2043-2073 and the lower plot shows output from 2070-2100.

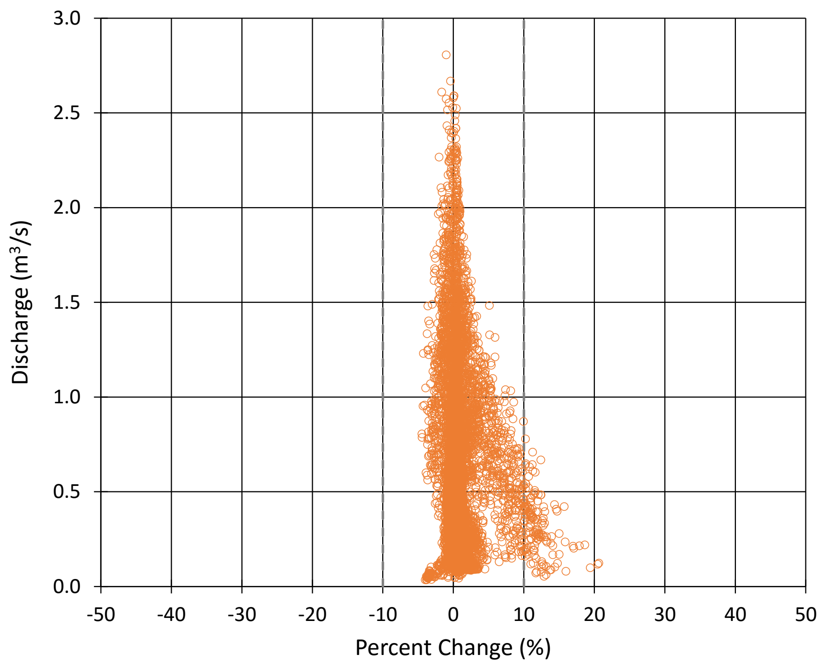

Figure 12-C-3.2-10 Post-closure phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at CC-3.5, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.

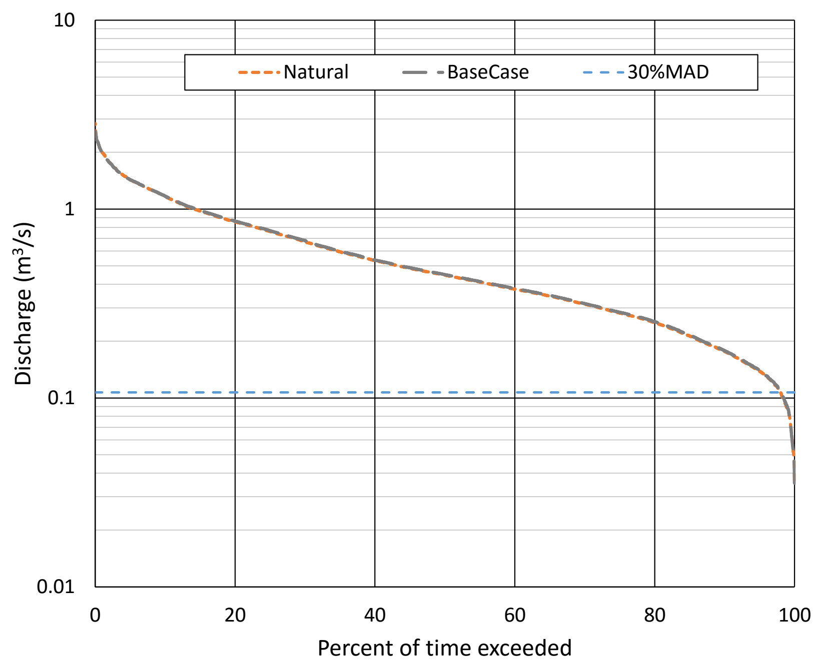

Figure 12-C-3.2-11 Natural and Base Case monthly discharge data for CC-3.5. Data shown are for Post-closure and presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Post-closure shown by dashed blue line.

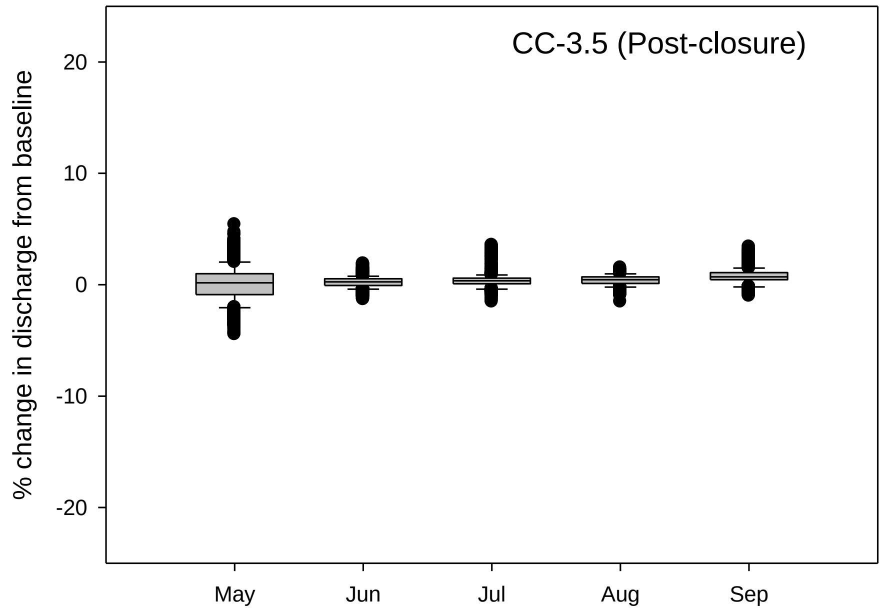

Figure 12-C-3.2-12 Box and Whisker Plot percent change summary for the Post-closure phase at CC-3.5. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

Appendix 12-C-3

Coffee Gold Water Balance Model Output

12.C-3.3. CC-0.5 Water Balance Node (Coffee Creek upstream of Latte Creek)

Table 12-C-3.3-1 End of Operations, Closure and Post-closure discharge data for the CC-0.5 Water Balance Model (WBM) node. Data shown are outputs from the Baseline (Natural Flow) Model.

	Discharge (m³/s)												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
End of Operations (2027 through 2032)													
Min	0.000	0.000	0.000	0.313	1.511	1.100	1.215	1.178	1.073	0.160	0.009	0.001	0.000
10th Percentile	0.001	0.000	0.002	1.269	1.889	1.805	1.879	2.083	1.733	0.471	0.025	0.005	-
Lower Quartile	0.002	0.004	0.032	2.152	4.168	2.300	2.736	2.487	2.298	0.665	0.046	0.016	-
Median	0.031	0.031	0.066	4.692	10.240	2.987	3.463	3.228	2.998	1.009	0.062	0.034	-
Mean	0.032	0.051	0.173	4.882	9.350	3.044	4.221	3.425	3.172	1.179	0.102	0.055	2.474
Upper Quartile	0.045	0.057	0.277	6.538	12.569	3.872	5.443	4.223	3.745	1.653	0.113	0.053	-
90th Percentile	0.082	0.097	0.488	9.058	16.769	4.113	8.117	4.857	5.201	2.061	0.235	0.103	-
Max	0.094	0.498	0.711	12.963	19.490	6.413	9.600	6.521	6.514	3.580	0.425	0.423	19.490
Closure (2033 through 2042)													
Min	0.000	0.000	0.000	0.316	1.571	1.118	1.204	1.121	1.041	0.160	0.008	0.001	0.000
10th Percentile	0.001	0.000	0.002	1.306	1.965	1.787	1.824	1.963	1.694	0.447	0.024	0.005	-
Lower Quartile	0.001	0.004	0.037	2.106	4.095	2.311	2.659	2.426	2.194	0.666	0.044	0.014	-
Median	0.030	0.032	0.069	4.520	10.259	2.951	3.435	3.128	2.872	0.970	0.066	0.034	-
Mean	0.030	0.054	0.173	4.860	9.323	3.016	4.221	3.404	3.130	1.163	0.100	0.056	2.461
Upper Quartile	0.043	0.075	0.283	6.642	12.548	3.807	5.525	4.273	3.732	1.632	0.104	0.057	-
90th Percentile	0.068	0.098	0.502	9.029	16.717	4.018	8.138	4.897	5.356	2.028	0.239	0.102	-
Max	0.106	0.507	0.710	12.982	19.345	6.387	9.540	6.610	6.537	3.569	0.434	0.423	19.345
Long-term Monitoring (2043 through 2100)													
Min	0.000	0.000	0.000	0.278	0.673	1.049	1.030	0.937	0.971	0.141	0.008	0.001	0.000
10th Percentile	0.001	0.001	0.028	3.248	1.130	1.793	1.942	1.876	1.738	0.841	0.039	0.009	-
Lower Quartile	0.009	0.009	0.077	6.230	2.070	2.243	2.710	2.349	2.344	1.201	0.080	0.025	-
Median	0.038	0.042	0.289	9.107	3.747	2.893	3.950	3.203	3.234	1.699	0.256	0.053	-
Mean	0.072	0.088	0.570	9.464	5.966	3.025	4.309	3.414	3.404	1.918	0.428	0.164	2.735
Upper Quartile	0.070	0.112	0.769	12.689	9.081	3.651	5.481	4.394	4.017	2.473	0.609	0.170	-
90th Percentile	0.163	0.223	1.499	15.500	13.601	4.342	7.212	5.177	5.471	3.349	1.078	0.511	-
Max	1.382	0.658	5.905	27.869	23.660	7.649	13.420	8.993	9.817	6.229	3.631	2.723	27.869

Table 12-C-3.3-2 End of Operations, Closure and Post-closure discharge data for the CC-0.5 WBM node. Data shown are outputs from the Base Case (With Project) Model.

	Discharge (m^3/s)												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
End of Operations (2027 through 2032)													
Min	0.000	0.000	0.000	0.313	1.511	1.100	1.215	1.178	1.073	0.160	0.009	0.001	0.000
10th Percentile	0.001	0.000	0.002	1.269	1.889	1.805	1.879	2.083	1.733	0.471	0.025	0.005	-
Lower Quartile	0.002	0.004	0.032	2.152	4.168	2.300	2.736	2.487	2.298	0.665	0.046	0.016	-
Median	0.031	0.031	0.066	4.692	10.240	2.987	3.463	3.228	2.998	1.009	0.062	0.034	-
Mean	0.032	0.051	0.173	4.882	9.350	3.044	4.221	3.425	3.172	1.179	0.102	0.055	2.474
Upper Quartile	0.045	0.057	0.277	6.538	12.569	3.872	5.443	4.223	3.745	1.653	0.113	0.053	-
90th Percentile	0.082	0.097	0.488	9.058	16.769	4.113	8.117	4.857	5.201	2.061	0.235	0.103	-
Max	0.094	0.498	0.711	12.963	19.490	6.413	9.600	6.521	6.514	3.580	0.425	0.423	19.490
Closure (2033 through 2042)													
Min	0.000	0.000	0.000	0.316	1.571	1.118	1.204	1.121	1.041	0.160	0.008	0.001	0.000
10th Percentile	0.001	0.000	0.002	1.306	1.965	1.787	1.824	1.963	1.694	0.447	0.024	0.005	-
Lower Quartile	0.001	0.004	0.037	2.106	4.095	2.311	2.659	2.426	2.194	0.666	0.044	0.014	-
Median	0.030	0.032	0.069	4.520	10.259	2.951	3.435	3.128	2.872	0.970	0.066	0.034	-
Mean	0.030	0.054	0.173	4.860	9.323	3.016	4.221	3.404	3.130	1.163	0.100	0.056	2.461
Upper Quartile	0.043	0.075	0.283	6.642	12.548	3.807	5.525	4.273	3.732	1.632	0.104	0.057	-
90th Percentile	0.068	0.098	0.502	9.029	16.717	4.018	8.138	4.897	5.356	2.028	0.239	0.102	-
Max	0.106	0.507	0.710	12.982	19.345	6.387	9.540	6.610	6.537	3.569	0.434	0.423	19.345
Long-term Monitoring (2043 through 2100)													
Min	0.000	0.000	0.000	0.278	0.673	1.049	1.030	0.937	0.971	0.141	0.008	0.001	0.000
10th Percentile	0.001	0.001	0.028	3.248	1.130	1.793	1.942	1.876	1.738	0.841	0.039	0.009	-
Lower Quartile	0.009	0.009	0.077	6.230	2.070	2.243	2.710	2.349	2.344	1.201	0.080	0.025	-
Median	0.038	0.042	0.289	9.107	3.747	2.893	3.950	3.203	3.234	1.699	0.256	0.053	-
Mean	0.072	0.088	0.570	9.464	5.966	3.025	4.309	3.414	3.404	1.918	0.428	0.164	2.735
Upper Quartile	0.070	0.112	0.769	12.689	9.081	3.651	5.481	4.394	4.017	2.473	0.609	0.170	-
90th Percentile	0.163	0.223	1.499	15.500	13.601	4.342	7.212	5.177	5.471	3.349	1.078	0.511	-
Max	1.382	0.658	5.905	27.869	23.660	7.649	13.420	8.993	9.817	6.229	3.631	2.723	27.869

Table 12-C-3.3-3 End of Operations, Closure and Post-closure percent change data for the CC-0.5 WBM node. Data shown are computed from Natural and Base Case Model outputs.

	Percent Change (%)												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
End of Operations (2027 through 2032)													
Min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10th Percentile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Lower Quartile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Median	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Mean	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Upper Quartile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
90th Percentile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Max	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Closure (2033 through 2042)													
Min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10th Percentile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Lower Quartile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Median	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Mean	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Upper Quartile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
90th Percentile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Max	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Long-term Monitoring (2043 through 2100)													
Min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10th Percentile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Lower Quartile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Median	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Mean	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Upper Quartile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
90th Percentile	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Max	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

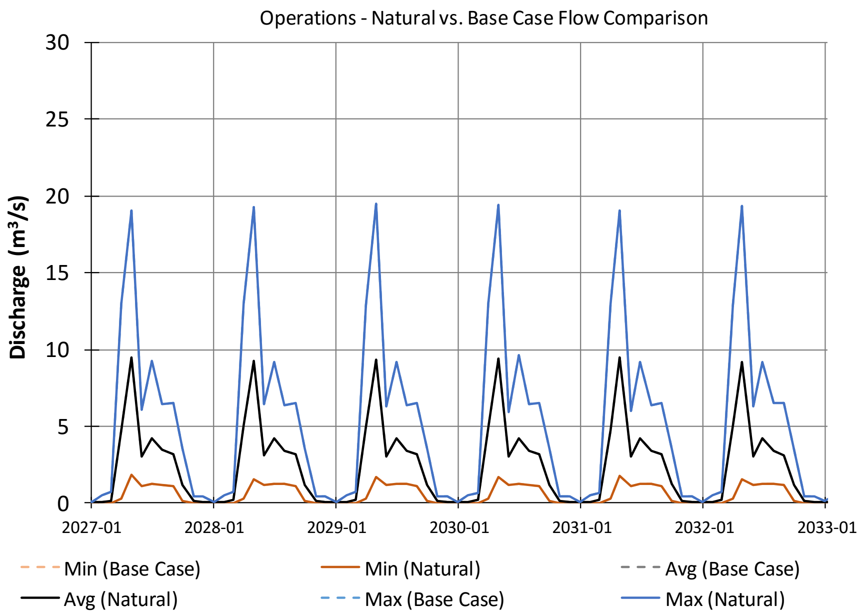

Figure 12-C-3.3-1 Time series plot showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the End of Operations phase of the Project and were computed from 28 WBM realizations.

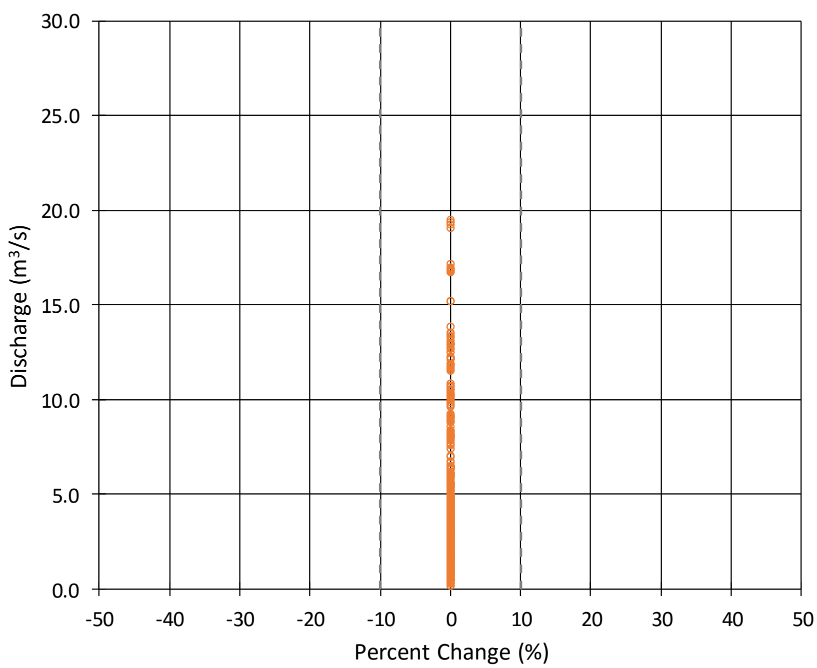

Figure 12-C-3.3-2 End of Operations phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at CC-0.5, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.

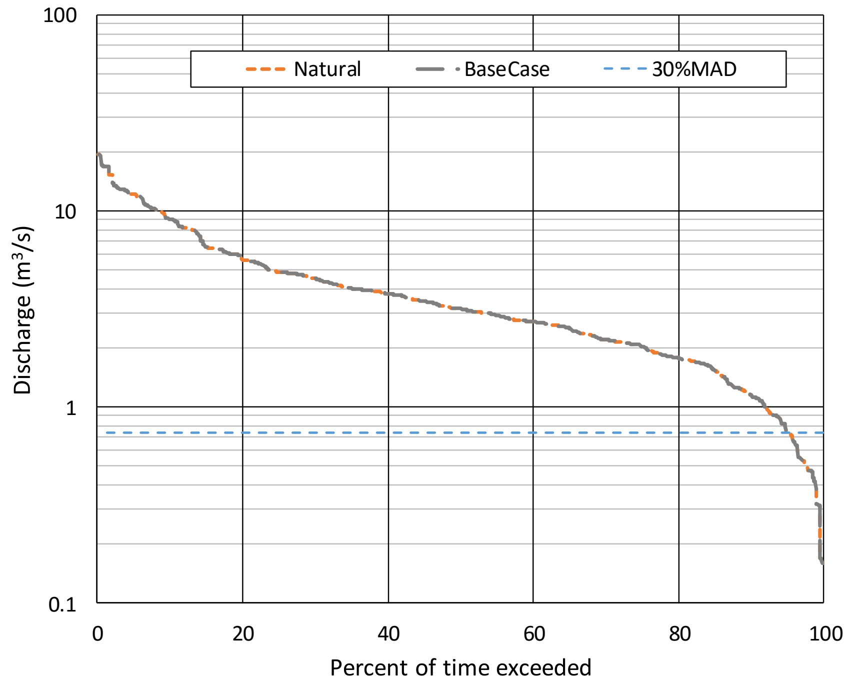

Figure 12-C-3.3-3 Natural and Base Case monthly discharge data for CC-0.5. Data shown are for the End of Operations phase and are presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Operations shown by dashed blue line.

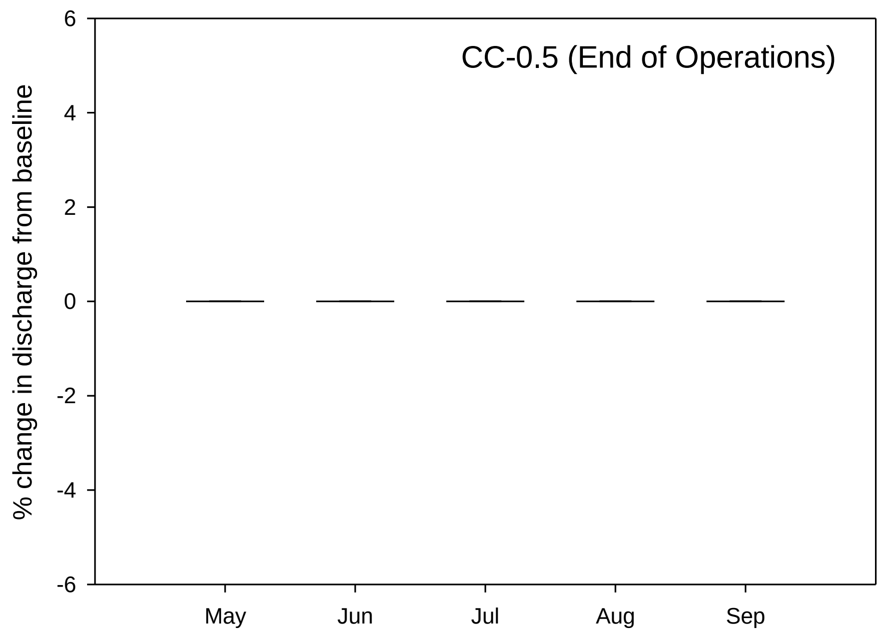

Figure 12-C-3.3-4 Box and Whisker Plot percent change summary for the End of Operations phase at CC-0.5. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

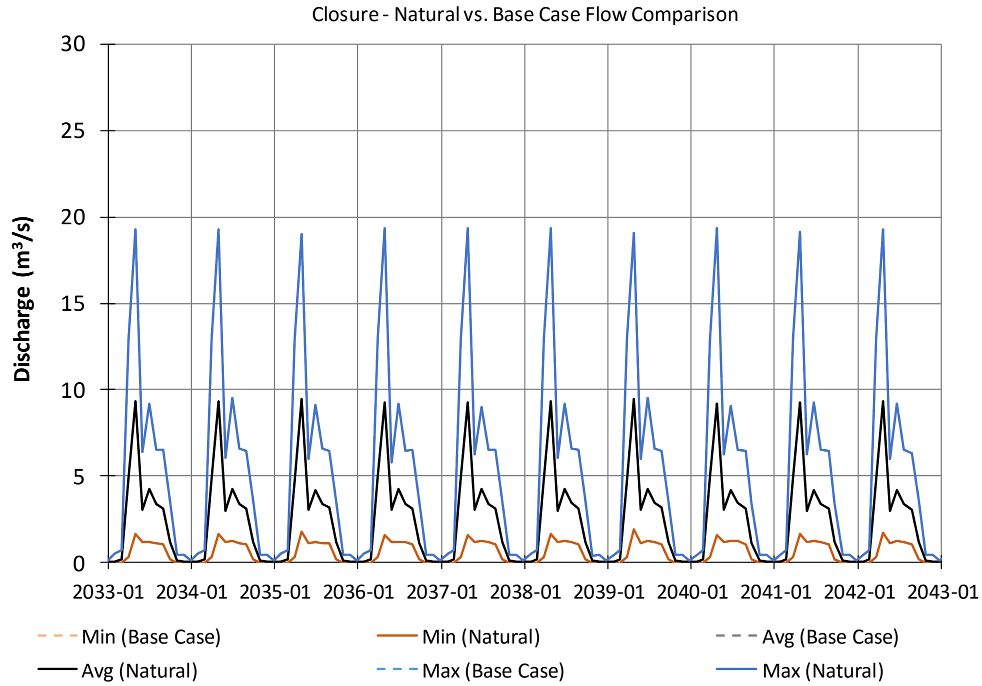

Figure 12-C-3.3-5 Time series plot showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the Closure phase of the Project and were computed from 28 WBM realizations.

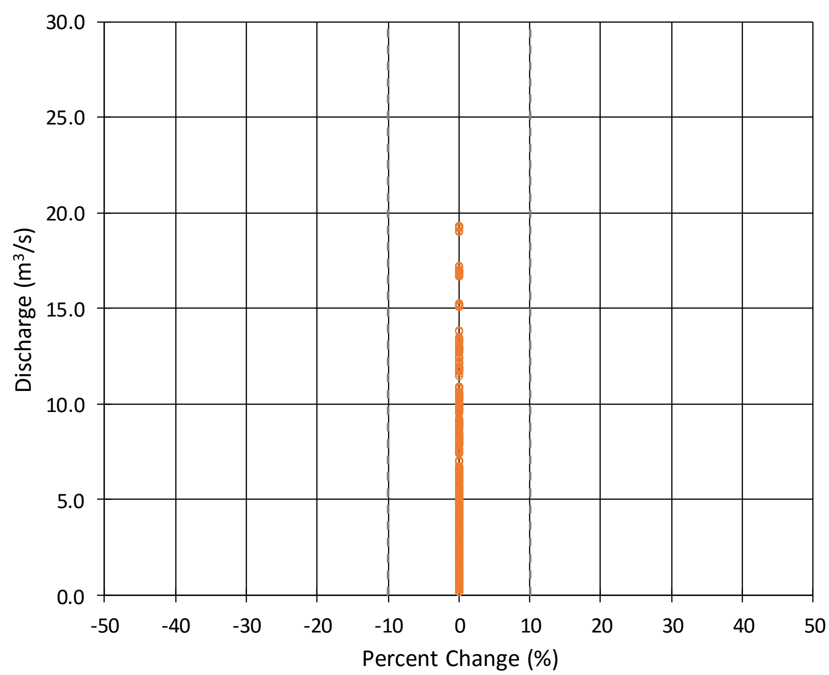

Figure 12-C-3.3-6 Closure phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at CC-0.5, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.

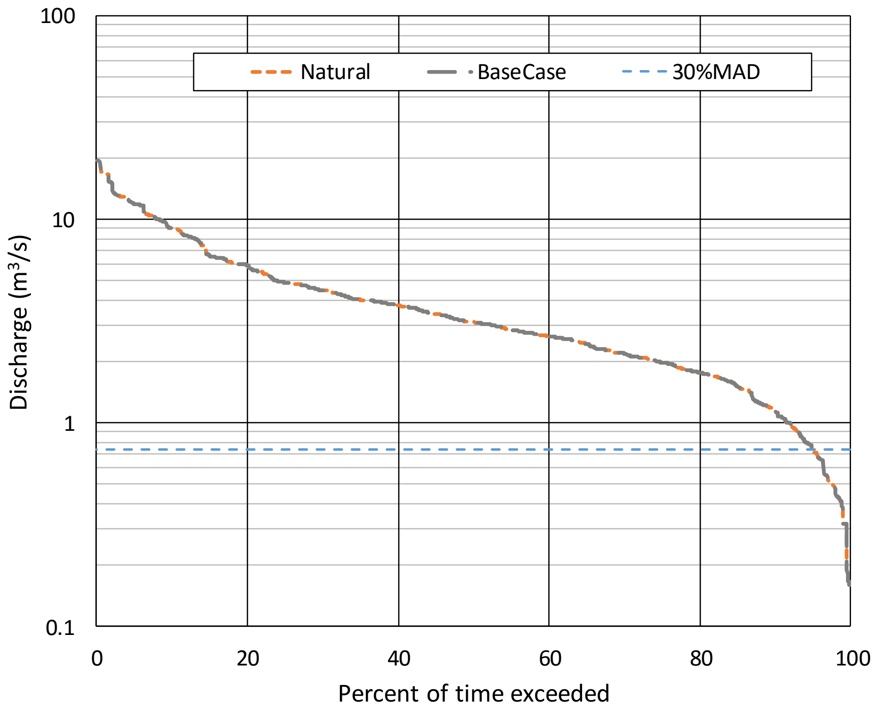

Figure 12-C-3.3-7 Natural and Base Case monthly discharge data for CC-0.5. Data shown are for the Closure phase of the Project and are presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Closure shown by dashed blue line.

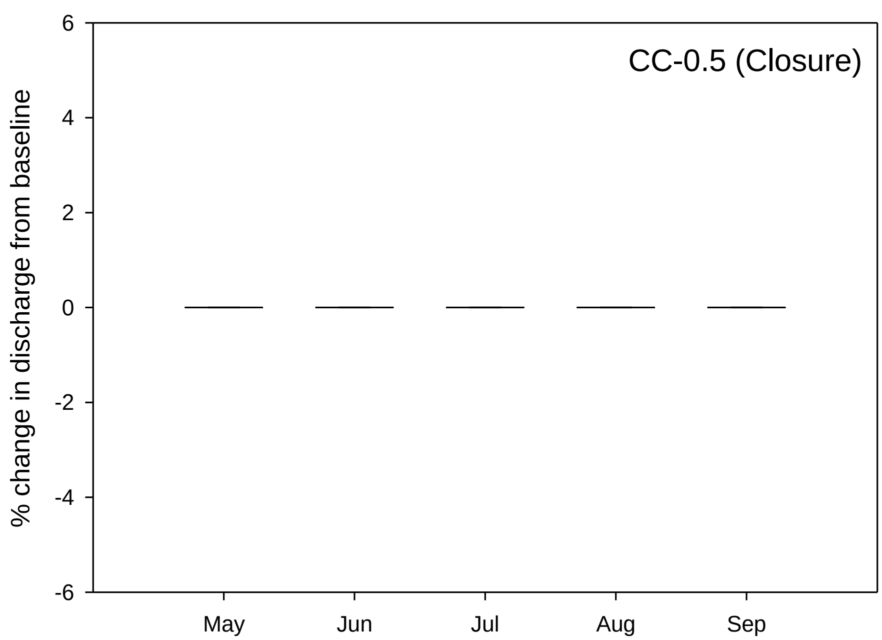

Figure 12-C-3.3-8 Box and Whisker Plot percent change summary for the Closure phase at CC-0.5. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

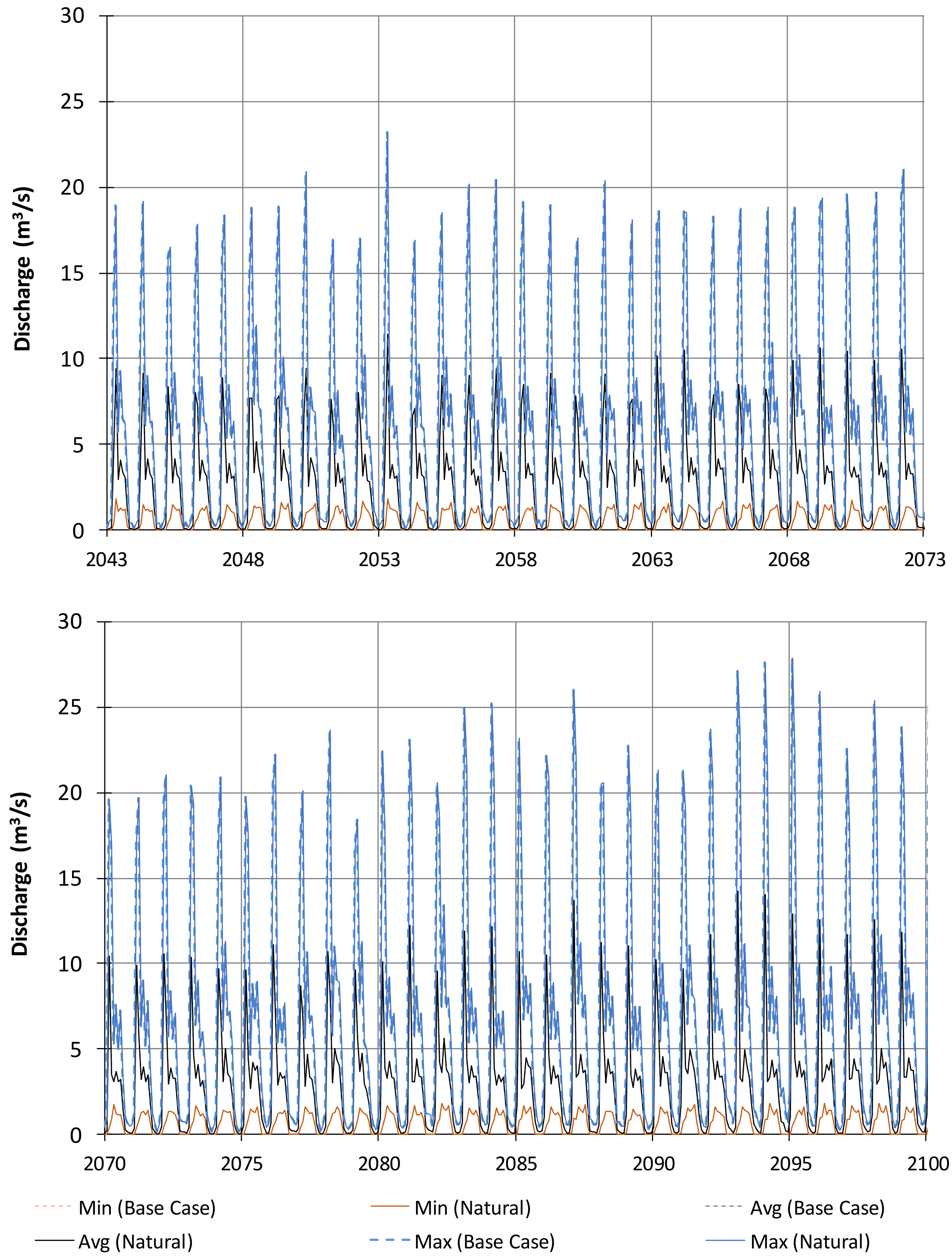

Figure 12-C-3.3-9 Time series plots showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the Post-closure phase of the Project and were computed from 28 WBM realizations. The upper panel shows output for 2043-2073 and the lower plot shows output from 2070-2100.

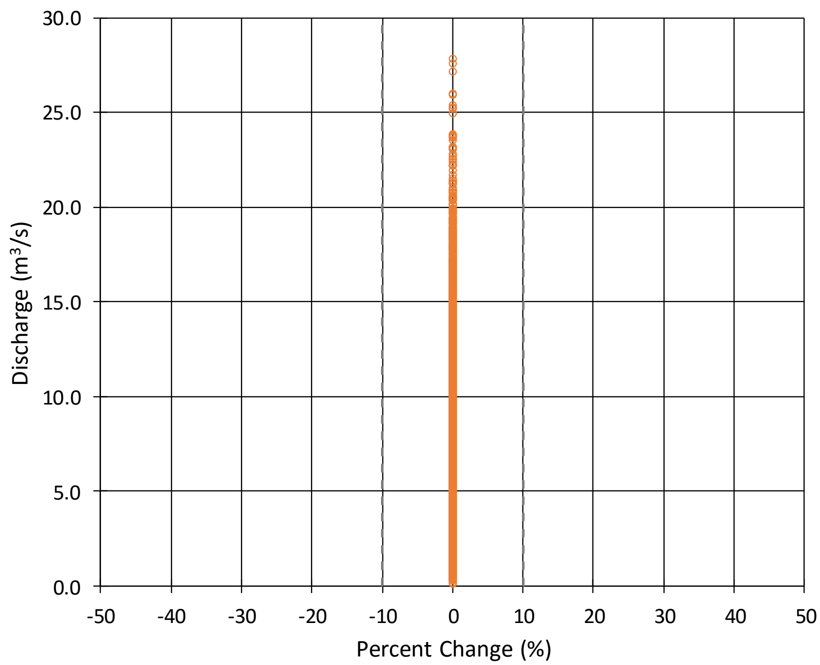

Figure 12-C-3.3-10 Post-closure phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at CC-0.5, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.

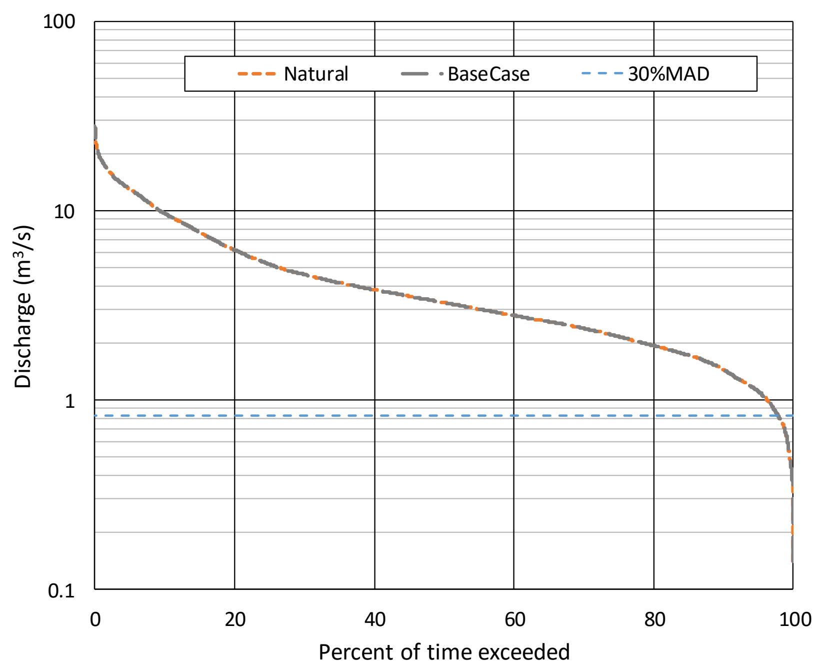

Figure 12-C-3.3-11 Natural and Base Case monthly discharge data for CC-0.5. Data shown are for Post-closure and presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Post-closure shown by dashed blue line.

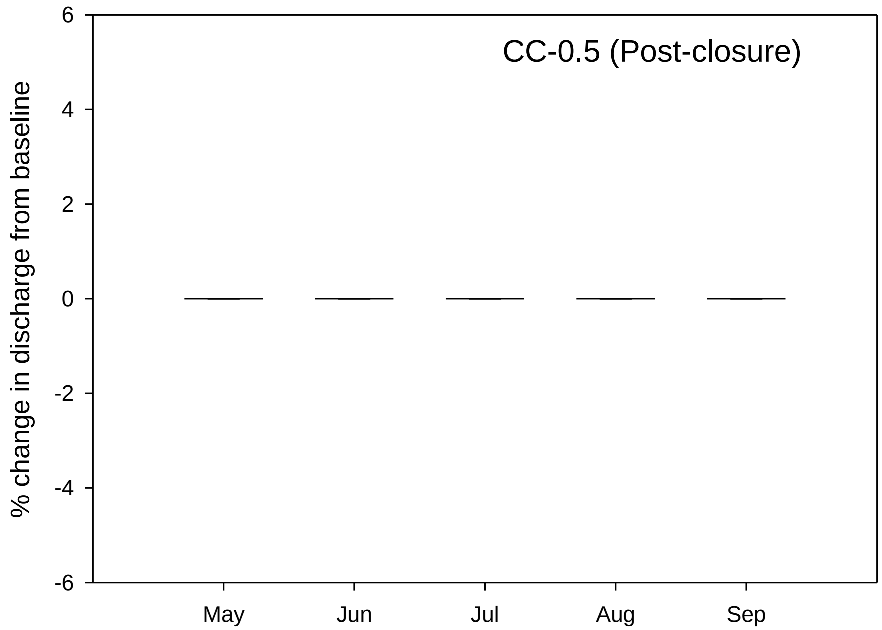

Figure 12-C-3-12 Box and Whisker Plot percent change summary for the Post-closure phase at CC-0.5. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

Appendix 12-C-3

Coffee Gold Water Balance Model Output

12-C-3.4. CC-4.5 Water Balance Node (Coffee Creek downstream of Latte Creek)

Table 12-C-3.4-1 End of Operations, Closure and Post-closure discharge data for the CC-4.5 Water Balance Model (WBM) node. Data shown are outputs from the Baseline (Natural Flow) Model.

	Discharge (m^3/s)												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
End of Operations (2027 through 2032)													
Min	0.003	0.002	0.001	0.273	1.853	1.360	1.184	1.174	1.074	0.130	0.008	0.005	0.001
10th Percentile	0.004	0.002	0.002	1.459	2.343	1.960	1.978	2.226	1.937	0.470	0.010	0.006	-
Lower Quartile	0.004	0.003	0.004	2.451	5.236	2.771	3.206	2.679	2.586	0.759	0.013	0.007	-
Median	0.005	0.004	0.030	5.337	12.050	3.551	4.064	3.547	3.322	1.032	0.016	0.009	-
Mean	0.006	0.026	0.147	5.443	10.884	3.700	4.933	3.929	3.617	1.283	0.065	0.029	2.839
Upper Quartile	0.008	0.006	0.253	7.244	14.482	4.731	6.435	4.987	4.187	1.795	0.059	0.013	-
90th Percentile	0.011	0.032	0.501	9.972	19.141	5.142	9.930	5.787	6.181	2.213	0.199	0.019	-
Max	0.012	0.510	0.739	14.344	22.433	7.886	11.832	8.065	7.734	4.285	0.389	0.457	22.433
Closure (2033 through 2042)													
Min	0.003	0.002	0.001	0.273	1.910	1.379	1.174	1.106	1.041	0.130	0.007	0.005	0.001
10th Percentile	0.004	0.002	0.002	1.499	2.395	1.996	1.938	2.071	1.886	0.468	0.010	0.006	-
Lower Quartile	0.004	0.003	0.004	2.385	5.180	2.820	3.091	2.630	2.499	0.746	0.012	0.006	-
Median	0.005	0.004	0.026	5.220	12.012	3.525	4.064	3.539	3.159	0.999	0.017	0.009	-
Mean	0.006	0.026	0.146	5.419	10.852	3.664	4.931	3.901	3.571	1.265	0.064	0.030	2.823
Upper Quartile	0.008	0.006	0.257	7.362	14.458	4.660	6.465	5.052	4.183	1.758	0.053	0.013	-
90th Percentile	0.011	0.033	0.513	9.942	19.078	5.167	9.959	5.810	6.321	2.179	0.202	0.019	-
Max	0.015	0.518	0.738	14.365	22.263	7.861	11.770	8.186	7.759	4.268	0.398	0.456	22.263
Long-term Monitoring (2043 through 2100)													
Min	0.003	0.002	0.001	0.238	0.830	1.281	1.019	0.914	1.021	0.110	0.007	0.005	0.001
10th Percentile	0.005	0.003	0.004	3.631	1.459	2.002	2.049	1.997	1.883	0.866	0.013	0.008	-
Lower Quartile	0.006	0.004	0.043	6.987	2.621	2.628	3.085	2.590	2.612	1.273	0.033	0.010	-
Median	0.009	0.009	0.269	10.257	4.912	3.422	4.445	3.569	3.605	1.838	0.222	0.017	-
Mean	0.051	0.067	0.609	10.654	7.165	3.588	4.981	3.894	3.879	2.132	0.434	0.151	3.134
Upper Quartile	0.021	0.076	0.828	14.309	10.774	4.390	6.371	5.115	4.577	2.780	0.610	0.132	-
90th Percentile	0.126	0.189	1.676	17.436	16.027	5.261	8.597	6.115	6.447	3.855	1.165	0.530	-
Max	1.537	0.691	6.827	31.462	27.154	9.242	16.444	11.127	11.732	7.611	4.384	3.051	31.462

Table 12-C-3.4-2 End of Operations, Closure and Post-closure discharge data for the CC-4.5 WBM node. Data shown are outputs from the Base Case (With Project) Model.

	Discharge (m³/s)												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
End of Operations (2027 through 2032)													
Min	0.003	0.002	0.001	0.272	1.843	1.364	1.186	1.175	1.077	0.129	0.008	0.005	0.001
10th Percentile	0.004	0.002	0.002	1.464	2.334	1.961	1.978	2.224	1.938	0.468	0.010	0.006	-
Lower Quartile	0.004	0.003	0.004	2.473	5.212	2.761	3.199	2.677	2.586	0.757	0.012	0.007	-
Median	0.005	0.004	0.030	5.369	11.998	3.541	4.058	3.536	3.317	1.030	0.016	0.009	-
Mean	0.006	0.026	0.147	5.453	10.850	3.691	4.926	3.924	3.613	1.281	0.065	0.029	2.834
Upper Quartile	0.008	0.006	0.254	7.274	14.466	4.712	6.433	4.988	4.177	1.788	0.059	0.013	-
90th Percentile	0.011	0.031	0.498	9.974	19.124	5.139	9.910	5.787	6.179	2.208	0.199	0.019	-
Max	0.012	0.507	0.738	14.320	22.327	7.841	11.825	8.050	7.708	4.283	0.386	0.455	22.327
Closure (2033 through 2042)													
Min	0.003	0.002	0.001	0.272	1.906	1.381	1.176	1.106	1.047	0.129	0.007	0.005	0.001
10th Percentile	0.004	0.002	0.002	1.515	2.388	1.994	1.938	2.070	1.888	0.466	0.010	0.006	-
Lower Quartile	0.004	0.003	0.004	2.404	5.170	2.813	3.087	2.629	2.498	0.750	0.012	0.006	-
Median	0.005	0.004	0.026	5.258	11.995	3.524	4.061	3.537	3.157	0.997	0.017	0.009	-
Mean	0.006	0.026	0.145	5.438	10.829	3.660	4.925	3.898	3.569	1.264	0.064	0.030	2.821
Upper Quartile	0.008	0.006	0.255	7.373	14.436	4.656	6.454	5.049	4.179	1.757	0.051	0.013	-
90th Percentile	0.011	0.032	0.511	9.942	19.055	5.156	9.940	5.803	6.312	2.178	0.201	0.019	-
Max	0.015	0.516	0.735	14.338	22.220	7.848	11.746	8.171	7.747	4.266	0.396	0.454	22.220
Long-term Monitoring (2043 through 2100)													
Min	0.003	0.002	0.001	0.237	0.830	1.285	1.022	0.915	1.025	0.109	0.007	0.005	0.001
10th Percentile	0.005	0.003	0.004	3.649	1.465	2.003	2.050	1.997	1.886	0.866	0.013	0.008	-
Lower Quartile	0.006	0.004	0.043	7.010	2.623	2.629	3.086	2.591	2.615	1.274	0.033	0.010	-
Median	0.009	0.009	0.270	10.295	4.912	3.424	4.447	3.571	3.607	1.841	0.221	0.017	-
Mean	0.051	0.067	0.613	10.673	7.163	3.588	4.983	3.896	3.882	2.134	0.433	0.151	3.136
Upper Quartile	0.021	0.075	0.835	14.317	10.770	4.391	6.375	5.121	4.576	2.781	0.609	0.131	-
90th Percentile	0.125	0.189	1.685	17.464	16.011	5.261	8.602	6.120	6.453	3.858	1.166	0.527	-
Max	1.538	0.690	6.868	31.433	27.164	9.247	16.450	11.129	11.740	7.614	4.386	3.050	31.433

Table 12-C-3.4-3 End of Operations, Closure and Post-closure percent change data for the CC-4.5 WBM node. Data shown are computed from Natural and Base Case Model outputs.

	Percent Change (%)												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
End of Operations (2027 through 2032)													
Min	-1.0	-3.1	-1.0	-0.5	-1.3	-0.9	-0.5	-0.5	-0.5	-1.2	-4.2	-1.2	-4.2
10th Percentile	0.0	-0.9	-0.8	-0.2	-0.8	-0.6	-0.4	-0.4	-0.4	-0.6	-1.0	-0.1	-
Lower Quartile	0.0	0.0	-0.6	0.0	-0.5	-0.5	-0.3	-0.3	-0.3	-0.5	-0.5	0.0	-
Median	0.0	0.0	-0.1	0.2	-0.4	-0.1	-0.1	-0.1	0.0	-0.1	-0.1	0.0	-
Mean	0.0	-0.2	-0.2	0.3	-0.4	-0.2	-0.1	-0.1	-0.1	-0.1	-0.4	-0.1	-0.1
Upper Quartile	0.0	0.0	0.0	0.6	-0.1	0.0	0.1	0.0	0.1	0.1	0.0	0.0	-
90th Percentile	0.0	0.0	0.0	0.9	0.0	0.1	0.1	0.1	0.1	0.2	0.0	0.0	-
Max	0.0	0.0	0.9	2.3	0.5	0.2	0.2	0.2	0.3	0.9	0.4	0.0	2.3
Closure (2033 through 2042)													
Min	-2.1	-3.0	-0.9	-0.5	-0.6	-0.3	-0.2	-0.2	-0.2	-0.7	-3.1	-1.0	-3.1
10th Percentile	0.0	-0.8	-0.8	0.0	-0.4	-0.2	-0.2	-0.1	-0.1	-0.3	-1.4	-0.5	-
Lower Quartile	0.0	-0.1	-0.6	0.2	-0.3	-0.2	-0.2	-0.1	-0.1	-0.2	-0.6	0.0	-
Median	0.0	0.0	-0.2	0.5	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1	-0.3	0.0	-
Mean	-0.1	-0.2	-0.3	0.5	-0.2	-0.1	-0.1	-0.1	0.0	-0.1	-0.5	-0.1	-0.1
Upper Quartile	0.0	0.0	0.0	0.8	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	-
90th Percentile	0.0	0.0	0.2	1.0	-0.1	0.0	0.0	0.0	0.1	0.3	0.0	0.0	-
Max	0.0	0.0	1.0	1.9	0.5	0.2	0.2	0.1	0.6	1.0	0.0	0.0	1.9
Long-term Monitoring (2043 through 2100)													
Min	-4.8	-4.7	-0.9	-0.5	-0.9	-0.3	-0.2	-0.2	-0.1	-0.5	-2.6	-5.6	-5.6
10th Percentile	-0.9	-1.0	-0.6	0.0	-0.3	-0.1	0.0	0.0	0.0	-0.1	-0.8	-1.0	-
Lower Quartile	-0.4	-0.6	-0.5	0.1	-0.1	0.0	0.0	0.0	0.0	0.0	-0.5	-0.6	-
Median	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.1	0.1	-0.3	0.0	-
Mean	-0.2	-0.3	0.4	0.3	0.0	0.0	0.0	0.0	0.1	0.1	-0.3	-0.3	0.0
Upper Quartile	0.0	0.0	0.8	0.4	0.2	0.1	0.1	0.1	0.1	0.1	0.0	0.0	-
90th Percentile	0.0	0.0	1.6	0.7	0.4	0.1	0.1	0.1	0.2	0.2	0.0	0.0	-
Max	7.6	8.5	8.8	1.7	1.2	0.4	0.3	0.2	0.4	1.5	1.7	5.5	8.8

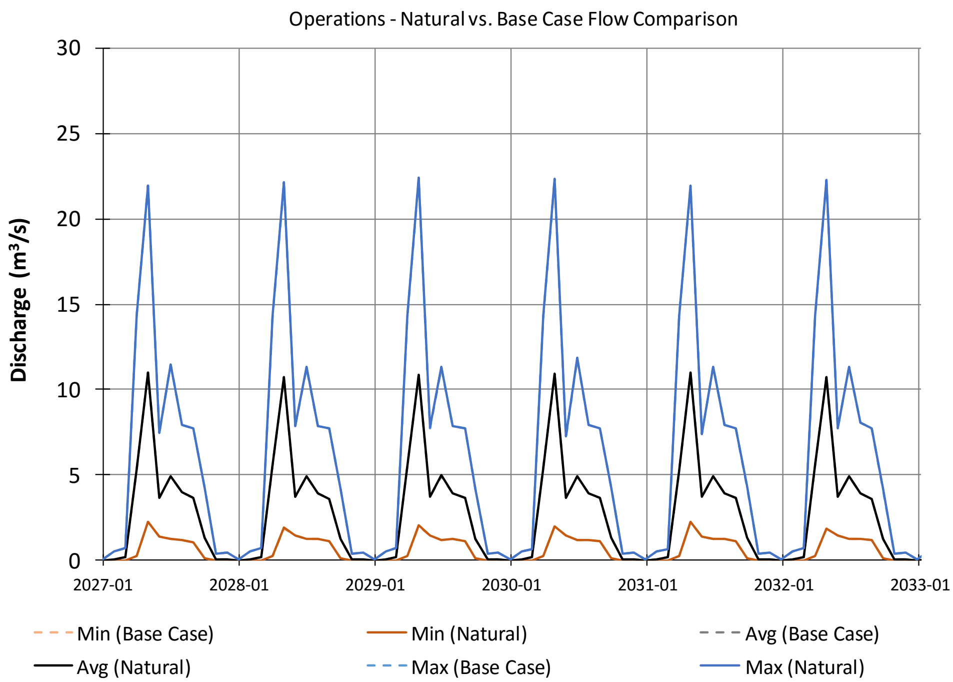

Figure 12-C-3.4-1 Time series plot showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the End of Operations phase of the Project and were computed from 28 WBM realizations.

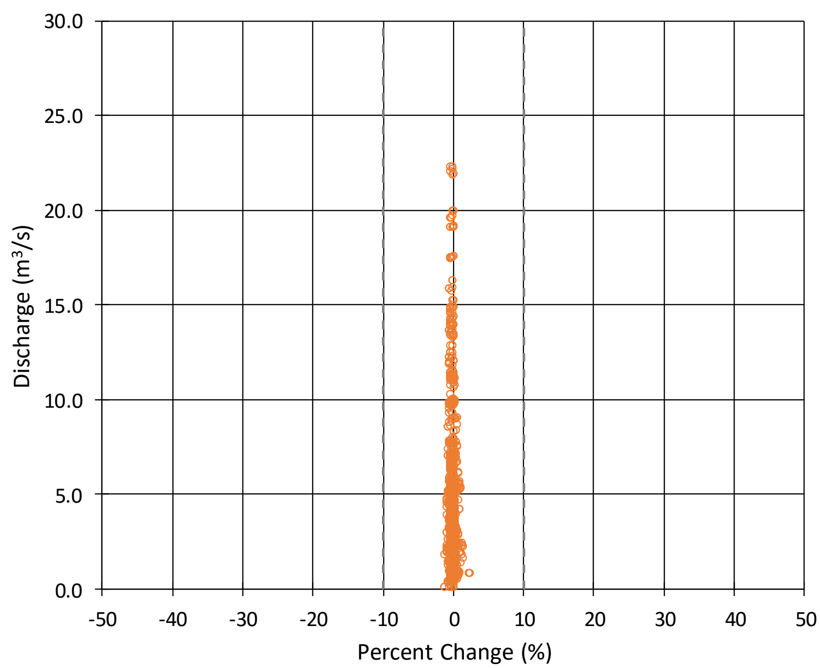

Figure 12-C-3.4-2End of Operations phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at CC-4.5, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.

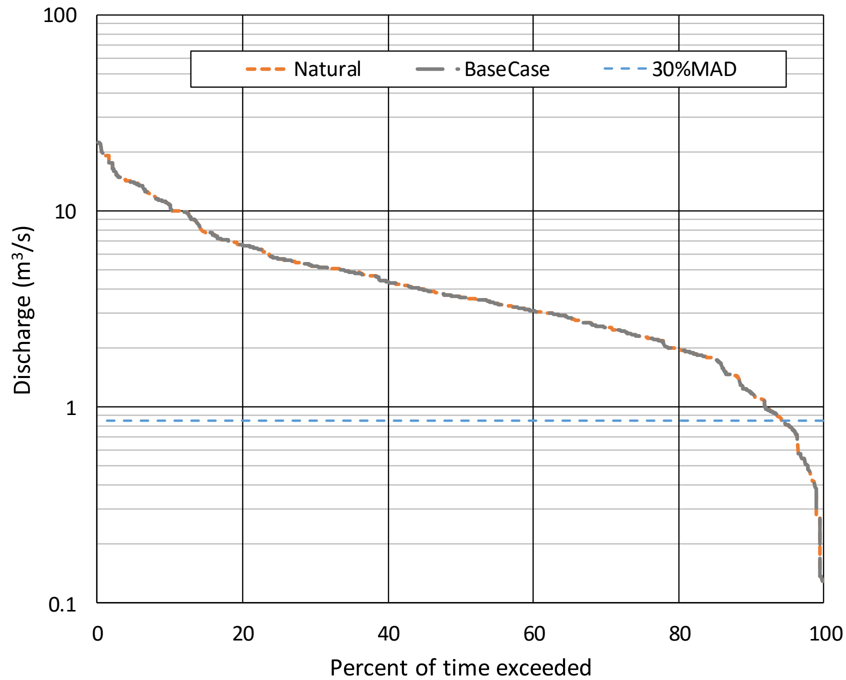

Figure 12-C-3.4-3 Natural and Base Case monthly discharge data for CC-4.5. Data shown are for the End of Operations phase and are presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Operations shown by dashed blue line.

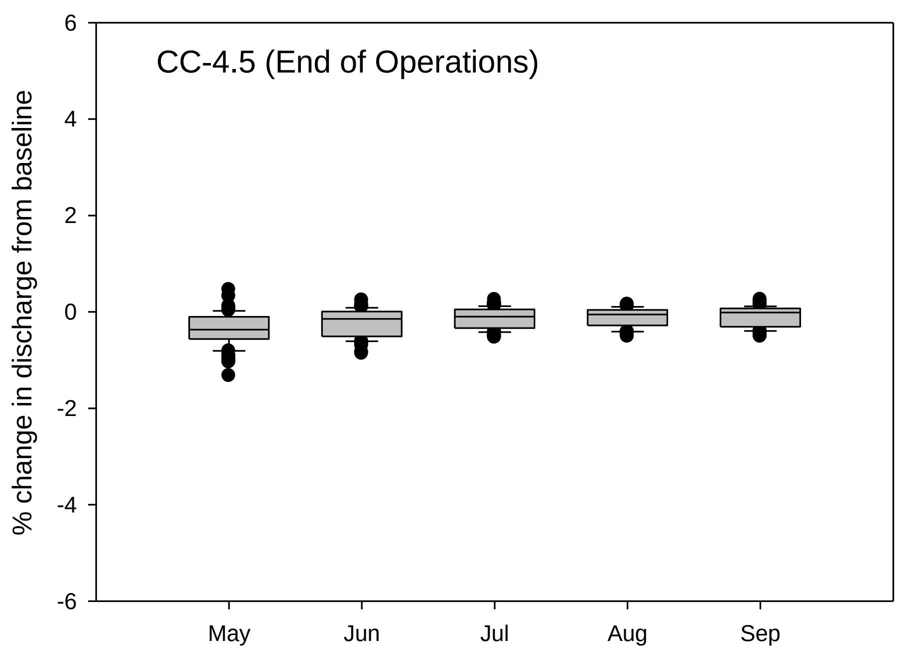

Figure 12-C-3.3-4 Box and Whisker Plot percent change summary for the End of Operations phase at CC-4.5. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

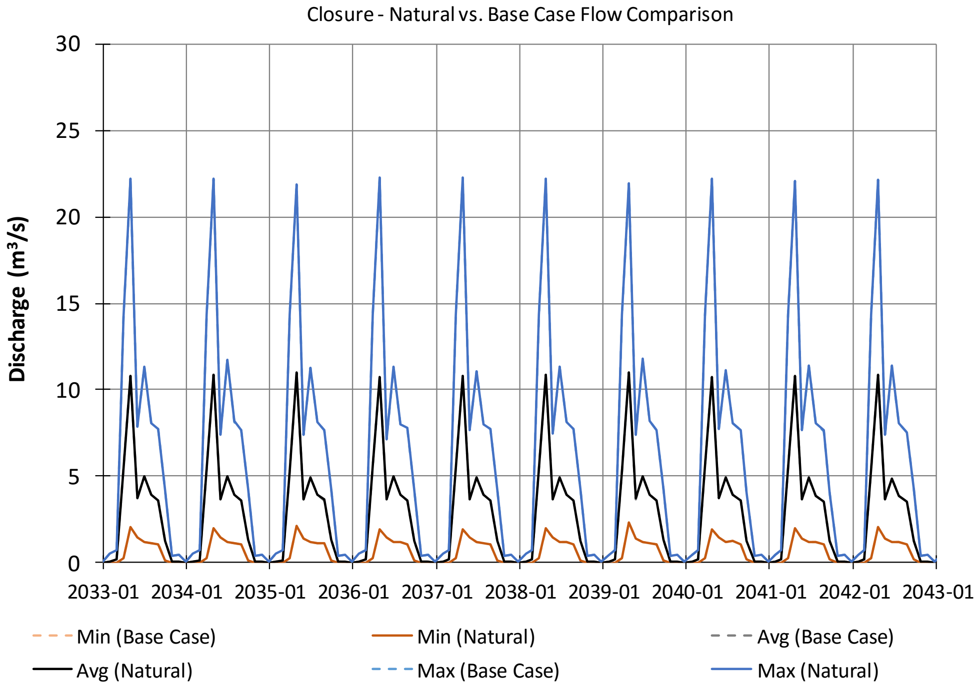

Figure 12-C-3.4-5 Time series plot showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the Closure phase of the Project and were computed from 28 WBM realizations.

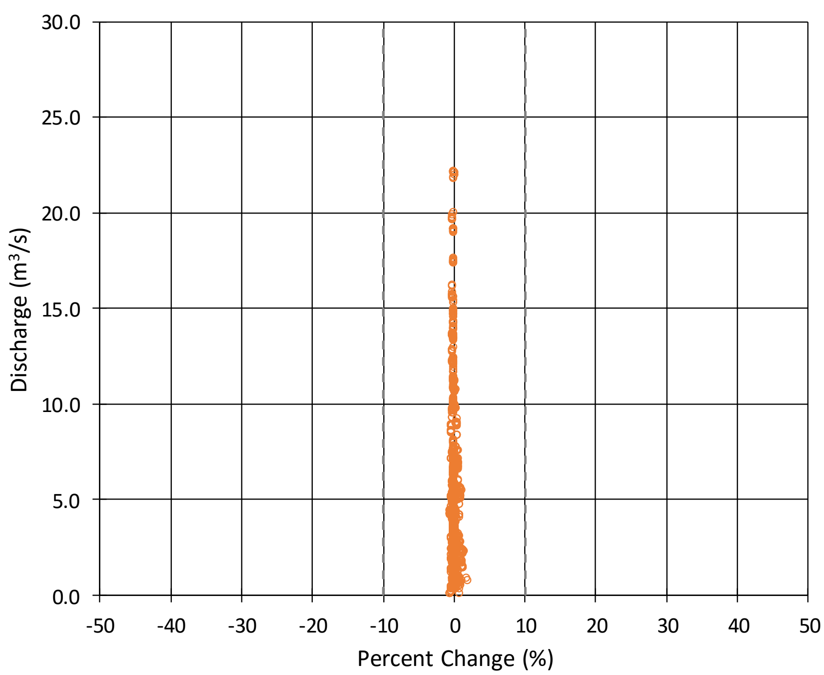

Figure 12-C-3.4-6 Closure phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at CC-4.5, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.

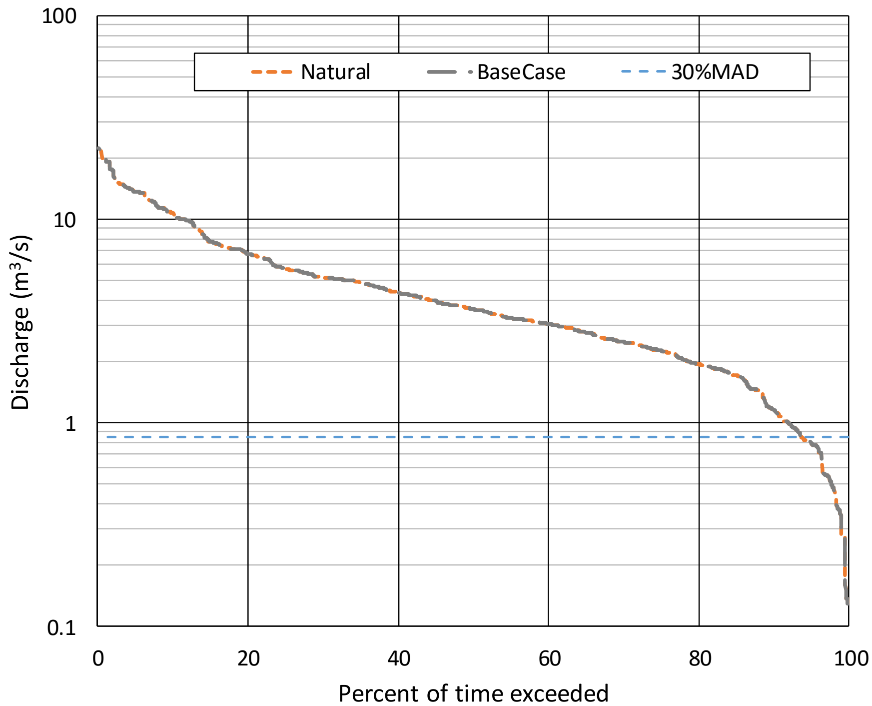

Figure 12-C-3.4-7 Natural and Base Case monthly discharge data for CC-4.5. Data shown are for the Closure phase of the Project and are presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Closure shown by dashed blue line.

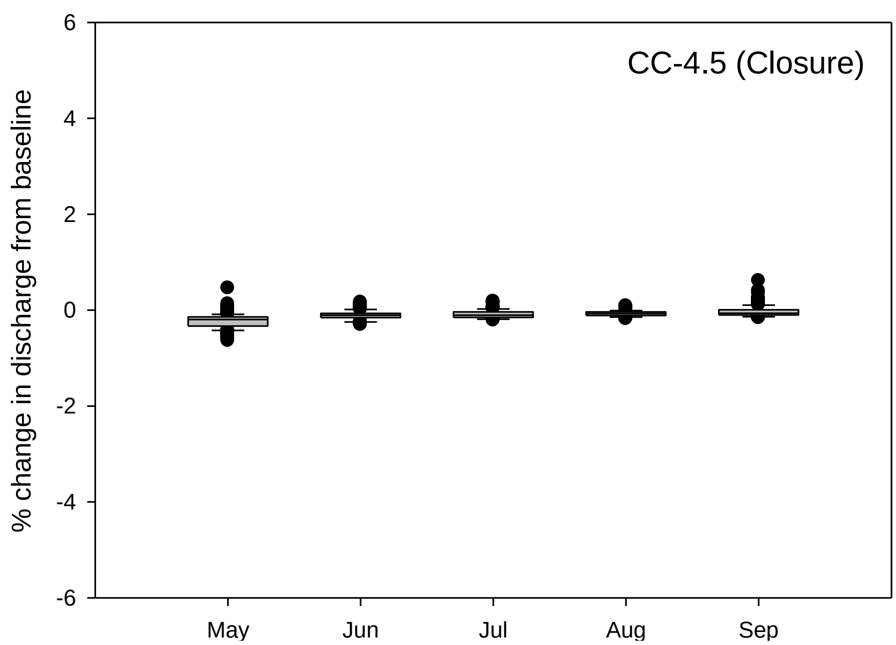

Figure 12-C-3.4-8 Box and Whisker Plot percent change summary for the Closure phase at CC-4.5. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

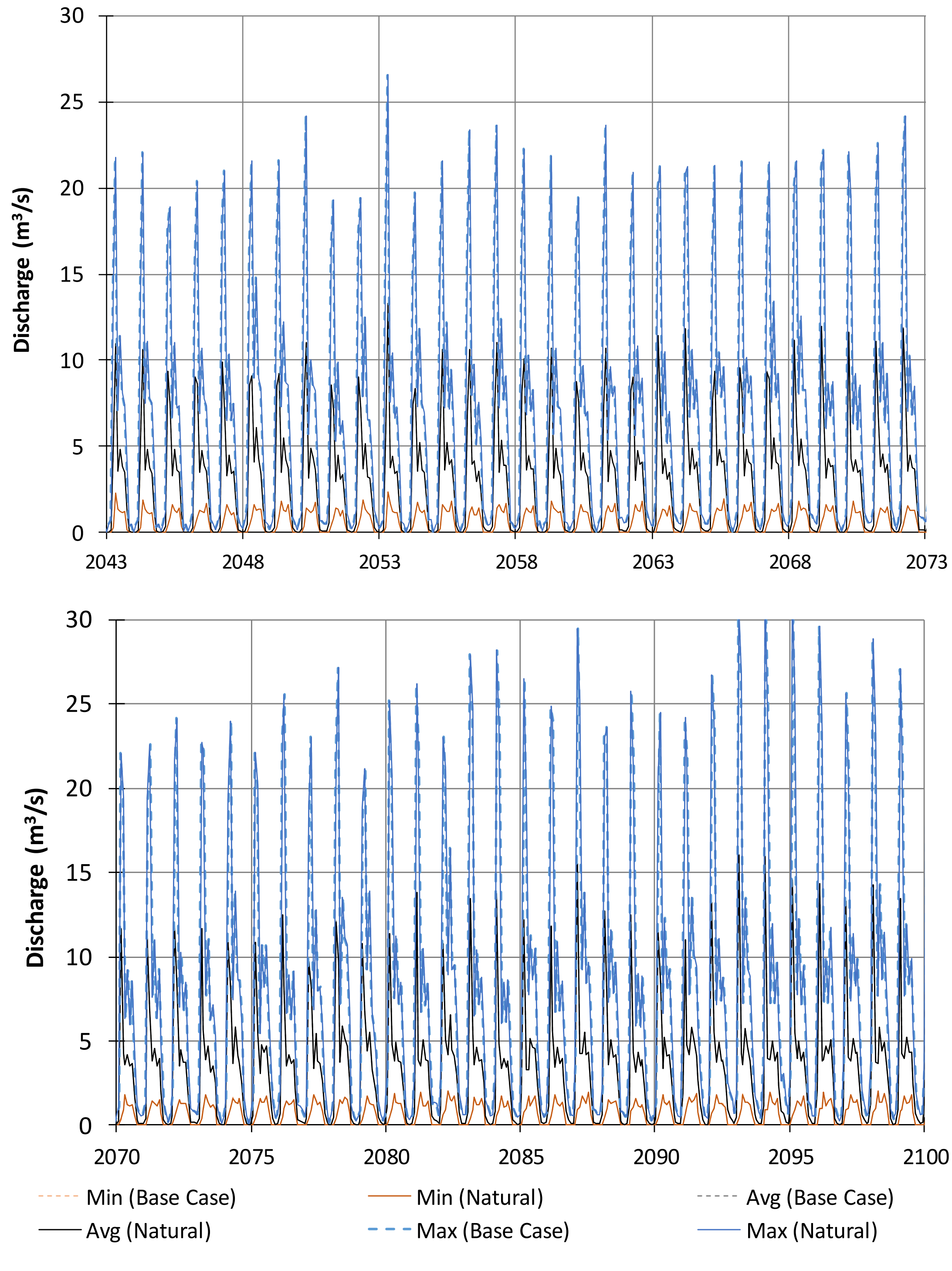

Figure 12-C-3.4-9 Time series plots showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the Post-closure phase of the Project and were computed from 28 WBM realizations. The upper panel shows output for 2043-2073 and the lower plot shows output from 2070-2100.

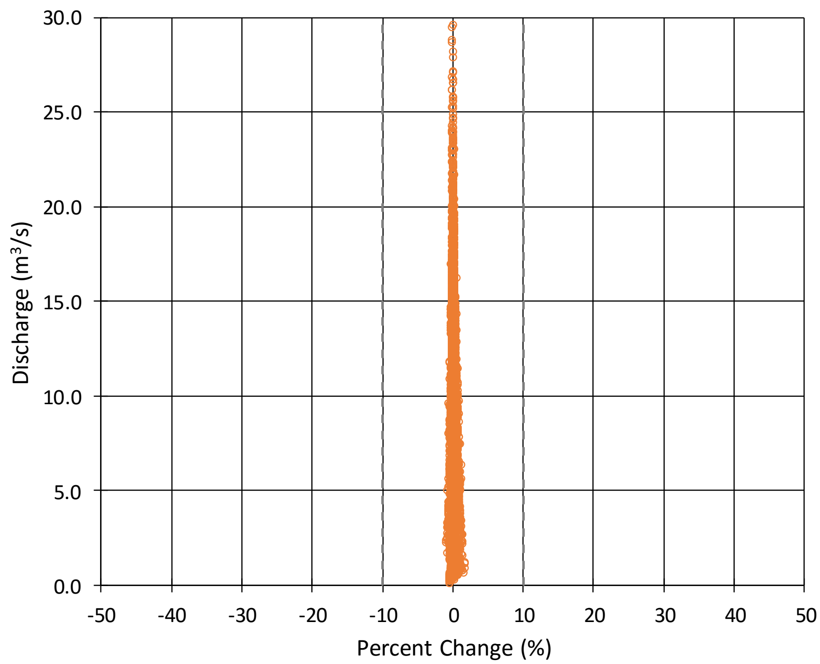

Figure 12-C-3.4-10 Post-closure phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at CC-4.5, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.

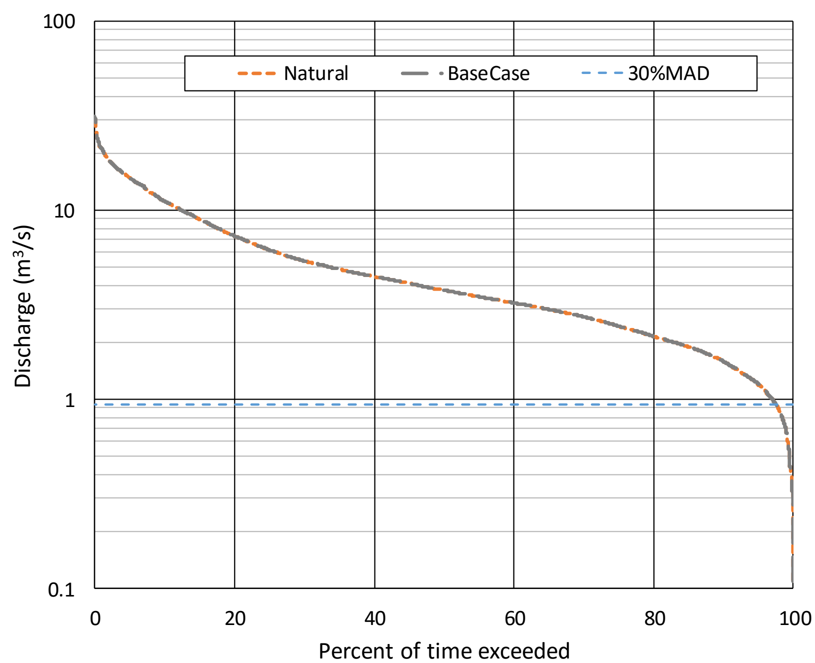

Figure 12-C-3.4-11 Natural and Base Case monthly discharge data for CC-4.5. Data shown are for Post-closure and presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Post-closure shown by dashed blue line.

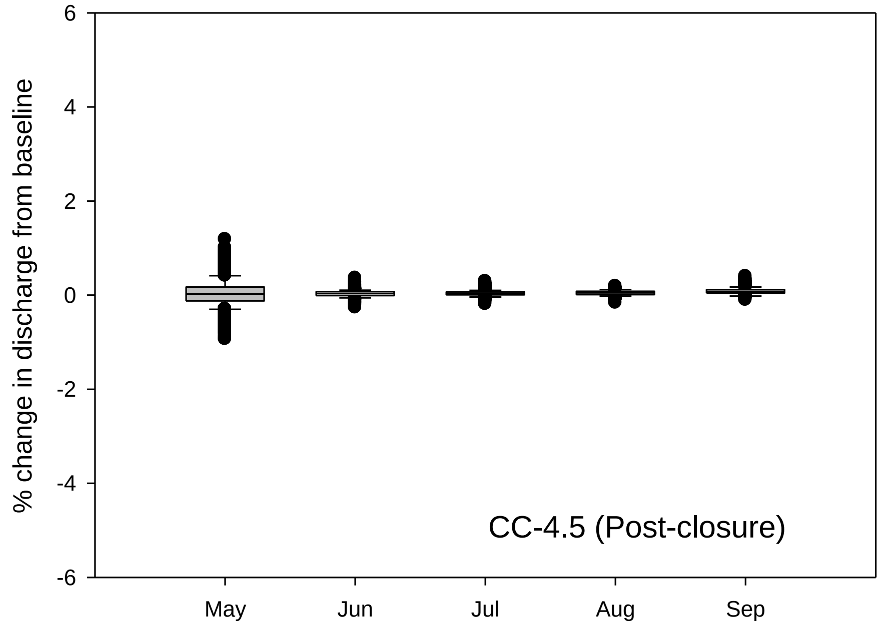

Figure 12-C-3.4-12 Box and Whisker Plot percent change summary for the Post-closure phase at CC-4.5. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

Appendix 12-C-3

Coffee Gold Water Balance Model Output

12-C-3.5. YT-24 Water Balance Node (YT-24 Tributary at the Mouth)

Table 12-C-3.5-1 End of Operations, Closure and Post-closure discharge data for the YT-24 Water Balance Model (WBM) node. Data shown are outputs from the Baseline (Natural Flow) Model.

	Discharge (m³/s)												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
End of Operations (2027 through 2032)													
Min	0.000	0.000	0.000	0.004	0.013	0.013	0.005	0.008	0.011	0.002	0.000	0.000	0.000
10th Percentile	0.000	0.000	0.000	0.048	0.021	0.017	0.015	0.016	0.023	0.003	0.000	0.000	-
Lower Quartile	0.000	0.000	0.000	0.071	0.052	0.028	0.030	0.026	0.029	0.005	0.001	0.000	-
Median	0.001	0.001	0.001	0.104	0.097	0.043	0.047	0.039	0.041	0.009	0.001	0.001	-
Mean	0.001	0.001	0.002	0.106	0.104	0.050	0.058	0.047	0.044	0.012	0.002	0.002	0.036
Upper Quartile	0.002	0.001	0.004	0.146	0.145	0.066	0.077	0.063	0.048	0.013	0.004	0.003	-
90th Percentile	0.003	0.003	0.006	0.178	0.214	0.093	0.142	0.087	0.093	0.021	0.006	0.005	-
Max	0.004	0.006	0.009	0.226	0.245	0.107	0.183	0.149	0.101	0.060	0.008	0.006	0.245
Closure (2033 through 2042)													
Min	0.000	0.000	0.000	0.004	0.013	0.012	0.005	0.008	0.010	0.001	0.000	0.000	0.000
10th Percentile	0.000	0.000	0.000	0.048	0.020	0.016	0.014	0.015	0.023	0.003	0.000	0.000	-
Lower Quartile	0.000	0.000	0.000	0.069	0.051	0.029	0.030	0.025	0.028	0.005	0.001	0.000	-
Median	0.000	0.000	0.001	0.104	0.097	0.042	0.046	0.038	0.040	0.008	0.001	0.001	-
Mean	0.001	0.001	0.002	0.106	0.103	0.049	0.058	0.047	0.044	0.012	0.002	0.002	0.036
Upper Quartile	0.002	0.001	0.004	0.146	0.140	0.063	0.077	0.063	0.047	0.013	0.004	0.003	-
90th Percentile	0.004	0.003	0.006	0.179	0.213	0.090	0.143	0.081	0.094	0.020	0.007	0.005	-
Max	0.004	0.006	0.009	0.226	0.244	0.108	0.185	0.152	0.110	0.060	0.008	0.006	0.244
Long-term Monitoring (2043 through 2100)													
Min	0.000	0.000	0.000	0.003	0.003	0.009	0.005	0.007	0.010	0.002	0.000	0.000	0.000
10th Percentile	0.000	0.000	0.000	0.077	0.018	0.017	0.015	0.016	0.020	0.006	0.000	0.000	-
Lower Quartile	0.000	0.000	0.001	0.107	0.034	0.027	0.030	0.024	0.027	0.010	0.001	0.001	-
Median	0.001	0.001	0.004	0.157	0.065	0.038	0.046	0.038	0.039	0.015	0.003	0.001	-
Mean	0.001	0.001	0.008	0.160	0.081	0.044	0.056	0.045	0.046	0.022	0.005	0.003	0.039
Upper Quartile	0.002	0.002	0.010	0.204	0.105	0.057	0.072	0.059	0.054	0.028	0.007	0.004	-
90th Percentile	0.004	0.003	0.022	0.255	0.157	0.082	0.106	0.086	0.089	0.048	0.011	0.007	-
Max	0.015	0.008	0.119	0.437	0.363	0.127	0.263	0.197	0.169	0.142	0.049	0.024	0.437

Table 12-C-3.5-2 End of Operations, Closure and Post-closure discharge data for the YT-24 WBM node. Data shown are outputs from the Base Case (With Project) Model.

	Discharge (m³/s)												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
End of Operations (2027 through 2032)													
Min	0.000	0.000	0.000	0.004	0.015	0.014	0.006	0.009	0.011	0.002	0.000	0.000	0.000
10th Percentile	0.000	0.000	0.000	0.049	0.026	0.019	0.017	0.017	0.026	0.005	0.000	0.000	-
Lower Quartile	0.000	0.000	0.001	0.072	0.061	0.032	0.034	0.028	0.033	0.007	0.001	0.000	-
Median	0.001	0.001	0.001	0.102	0.120	0.048	0.052	0.044	0.043	0.012	0.001	0.001	-
Mean	0.001	0.001	0.003	0.108	0.123	0.054	0.064	0.051	0.048	0.015	0.002	0.002	0.039
Upper Quartile	0.002	0.001	0.004	0.148	0.170	0.071	0.085	0.071	0.053	0.018	0.004	0.003	-
90th Percentile	0.003	0.003	0.007	0.179	0.242	0.101	0.141	0.091	0.100	0.028	0.006	0.005	-
Max	0.004	0.007	0.011	0.227	0.288	0.117	0.203	0.158	0.115	0.069	0.008	0.006	0.288
Closure (2033 through 2042)													
Min	0.000	0.000	0.000	0.004	0.017	0.013	0.005	0.008	0.010	0.002	0.000	0.000	0.000
10th Percentile	0.000	0.000	0.000	0.047	0.026	0.017	0.015	0.015	0.023	0.004	0.000	0.000	-
Lower Quartile	0.000	0.000	0.001	0.067	0.058	0.030	0.032	0.026	0.029	0.007	0.001	0.000	-
Median	0.001	0.000	0.001	0.103	0.110	0.044	0.047	0.040	0.040	0.012	0.001	0.001	-
Mean	0.001	0.001	0.002	0.104	0.113	0.051	0.060	0.048	0.046	0.014	0.002	0.002	0.037
Upper Quartile	0.002	0.001	0.004	0.139	0.153	0.065	0.080	0.065	0.049	0.017	0.004	0.003	-
90th Percentile	0.004	0.003	0.007	0.169	0.228	0.094	0.148	0.083	0.094	0.025	0.007	0.005	-
Max	0.004	0.006	0.009	0.214	0.257	0.111	0.189	0.154	0.116	0.068	0.008	0.006	0.257
Long-term Monitoring (2043 through 2100)													
Min	0.000	0.000	0.000	0.003	0.003	0.009	0.005	0.007	0.010	0.002	0.000	0.000	0.000
10th Percentile	0.000	0.000	0.000	0.082	0.019	0.017	0.016	0.016	0.020	0.008	0.001	0.000	-
Lower Quartile	0.000	0.000	0.001	0.116	0.038	0.029	0.031	0.025	0.028	0.012	0.001	0.001	-
Median	0.001	0.001	0.005	0.164	0.079	0.040	0.049	0.040	0.041	0.018	0.004	0.002	-
Mean	0.002	0.002	0.011	0.170	0.093	0.047	0.061	0.048	0.050	0.026	0.006	0.003	0.043
Upper Quartile	0.002	0.002	0.014	0.220	0.123	0.060	0.078	0.063	0.059	0.034	0.008	0.004	-
90th Percentile	0.004	0.004	0.028	0.271	0.187	0.087	0.119	0.094	0.095	0.053	0.014	0.008	-
Max	0.020	0.010	0.136	0.475	0.410	0.132	0.287	0.212	0.188	0.152	0.062	0.030	0.475

Table 12-C-3.5-3 End of Operations, Closure and Post-closure percent change data for the YT-24 WBM node. Data shown are computed from Natural and Base Case Model outputs.

	Percent Change (%)												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
End of Operations (2027 through 2032)													
Min	-9.7	-9.7	-9.7	-9.9	-2.2	-2.9	-2.8	-2.8	-3.2	4.1	-9.7	-9.7	-9.9
10th Percentile	-1.6	-1.5	-1.4	-7.6	4.1	0.2	-2.2	-0.7	-0.8	11.1	-1.1	-1.6	-
Lower Quartile	-0.9	0.6	-0.6	-2.9	12.9	3.7	3.5	3.4	2.7	18.6	1.3	-0.9	-
Median	4.5	4.6	9.7	1.8	19.7	10.8	14.6	12.5	11.3	29.8	10.5	4.5	-
Mean	17.7	17.1	14.4	2.6	23.3	9.9	11.0	10.0	9.1	34.1	17.1	15.9	15.2
Upper Quartile	18.8	18.0	23.1	7.5	30.9	16.2	16.5	15.4	14.9	49.1	23.4	22.1	-
90th Percentile	59.4	46.0	33.9	14.2	47.9	17.7	18.5	18.2	16.7	62.3	44.9	45.8	-
Max	149.9	197.2	140.6	22.7	69.7	20.2	20.0	19.7	18.3	91.7	139.2	135.2	197.2
Closure (2033 through 2042)													
Min	-10.9	-10.9	-10.9	-7.9	4.0	1.8	1.2	0.2	-2.0	5.1	-10.9	-10.9	-10.9
10th Percentile	-1.7	-1.5	-1.2	-5.7	5.5	2.3	2.3	1.4	0.5	8.5	-1.2	-1.7	-
Lower Quartile	-1.0	0.7	1.4	-4.8	7.3	3.1	3.0	2.1	1.8	11.6	0.5	-0.9	-
Median	5.1	5.0	5.5	-3.0	10.1	3.7	3.4	3.1	2.8	19.8	9.0	4.9	-
Mean	13.0	16.7	8.7	-2.0	14.3	4.1	3.5	2.9	3.8	26.4	14.1	14.5	10.0
Upper Quartile	17.3	15.8	12.0	-0.2	19.7	5.0	3.8	3.5	3.4	31.2	22.3	20.1	-
90th Percentile	33.2	47.5	21.7	3.9	30.2	5.9	4.7	3.9	7.4	39.2	40.0	30.3	-
Max	127.2	176.6	128.4	6.9	41.8	8.0	6.9	5.2	45.7	197.2	70.6	183.5	197.2
Long-term Monitoring (2043 through 2100)													
Min	-9.0	-5.0	-5.0	-6.1	-0.2	0.9	0.6	-0.7	-2.3	1.1	-5.9	-6.8	-9.0
10th Percentile	-0.6	1.8	5.4	-3.2	3.5	2.7	2.2	2.3	2.5	6.8	3.1	-0.2	-
Lower Quartile	2.5	7.1	11.9	1.9	5.7	3.4	3.0	3.0	3.3	10.1	10.2	2.9	-
Median	12.1	18.5	19.3	7.1	11.1	4.9	5.4	4.0	6.7	16.1	26.4	14.3	-
Mean	24.2	31.8	24.7	6.7	14.6	5.7	6.3	5.4	6.6	20.2	35.2	28.3	17.5
Upper Quartile	30.9	43.5	32.6	11.5	20.3	7.8	9.6	7.7	10.2	26.7	45.2	36.7	-
90th Percentile	65.9	80.9	46.5	15.1	31.5	10.2	11.3	10.6	11.4	38.7	83.6	77.9	-
Max	198.2	197.5	179.2	23.8	65.7	13.8	14.4	13.8	14.0	127.4	193.5	197.5	198.2

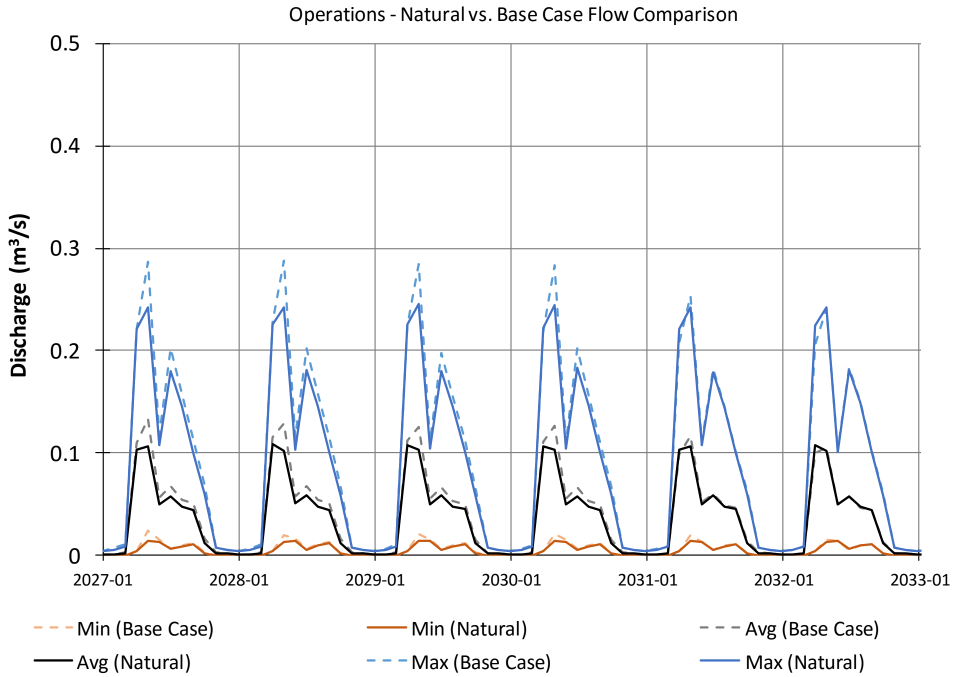

Figure 12-C-3.5-1 Time series plot showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the End of Operations phase of the Project and were computed from 28 WBM realizations.

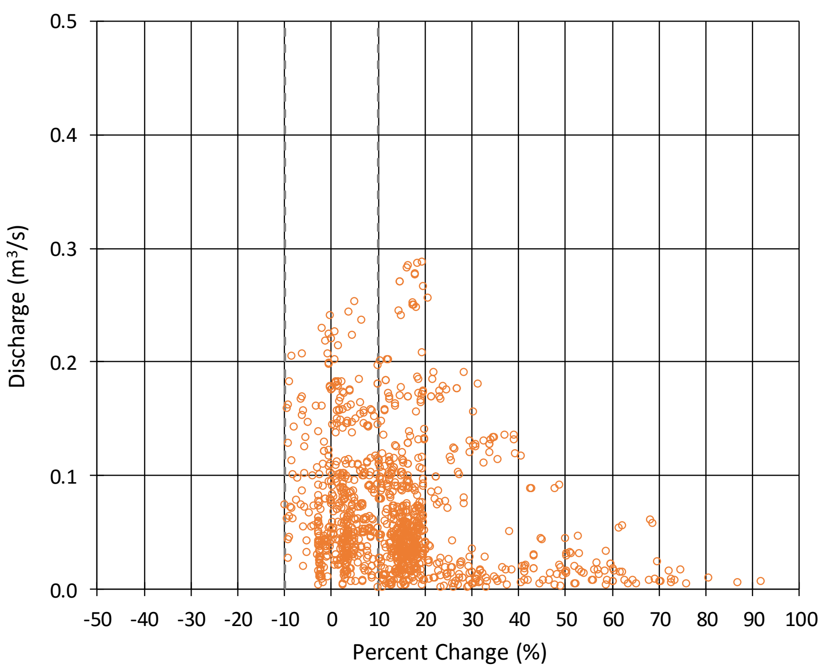

Figure 12-C-3.5-2 End of Operations phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at YT-24, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.

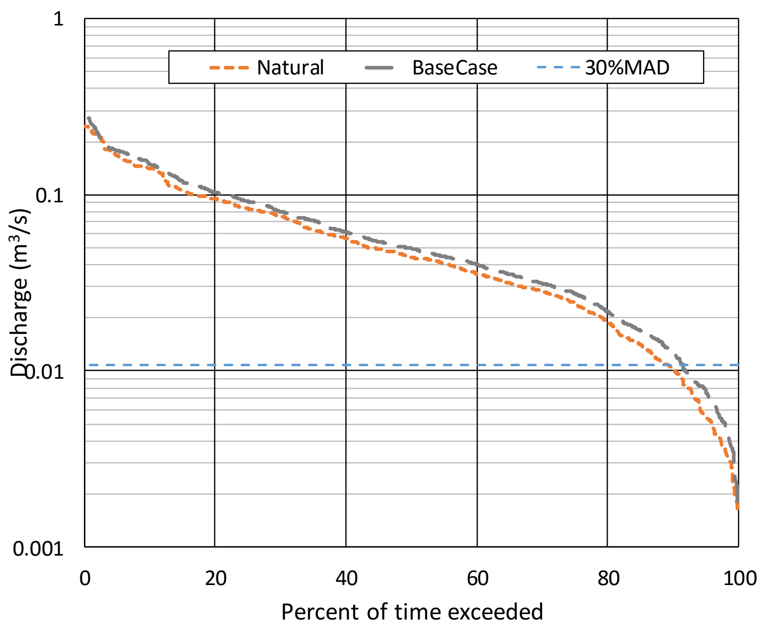

Figure 12-C-3.5-3 Natural and Base Case monthly discharge data for YT-24. Data shown are for the End of Operations phase and are presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Operations shown by dashed blue line.

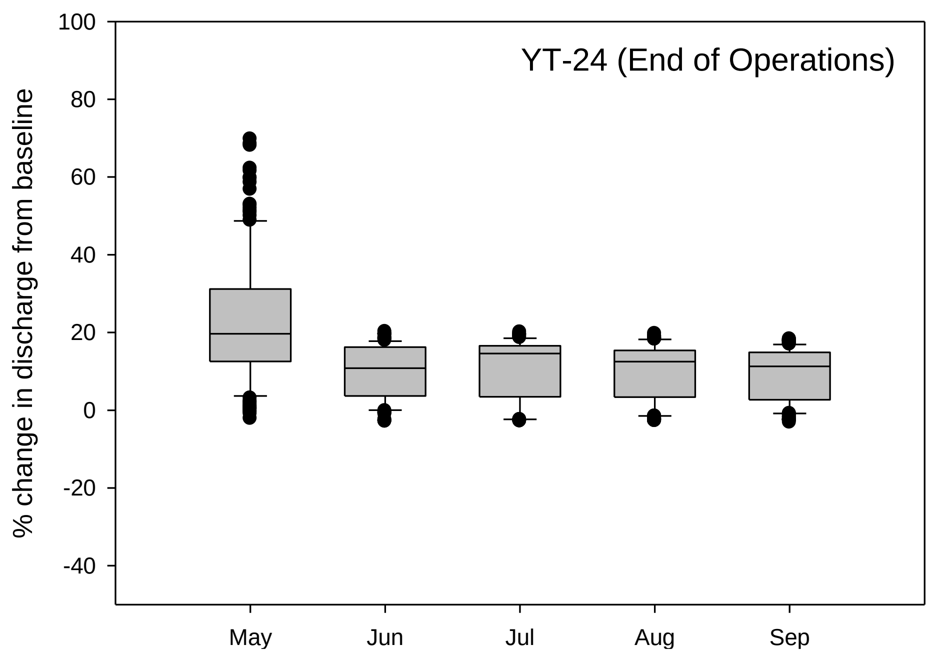

Figure 12-C-3.5-4 Box and Whisker Plot percent change summary for the End of Operations phase at YT-24. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

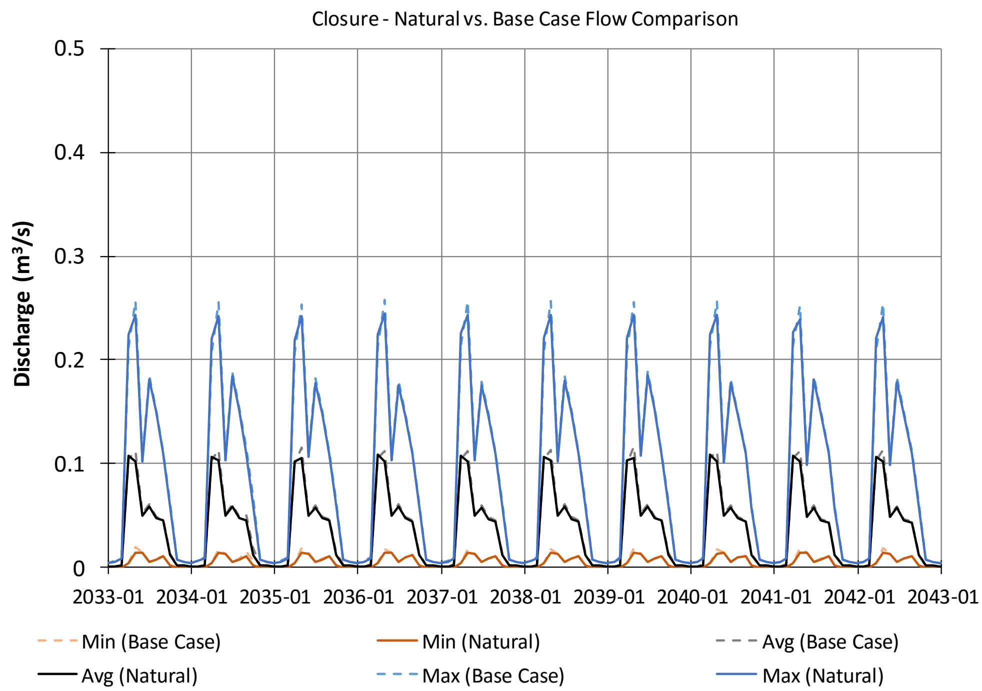

Figure 12-C-3.5-5 Time series plot showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the Closure phase of the Project and were computed from 28 WBM realizations.

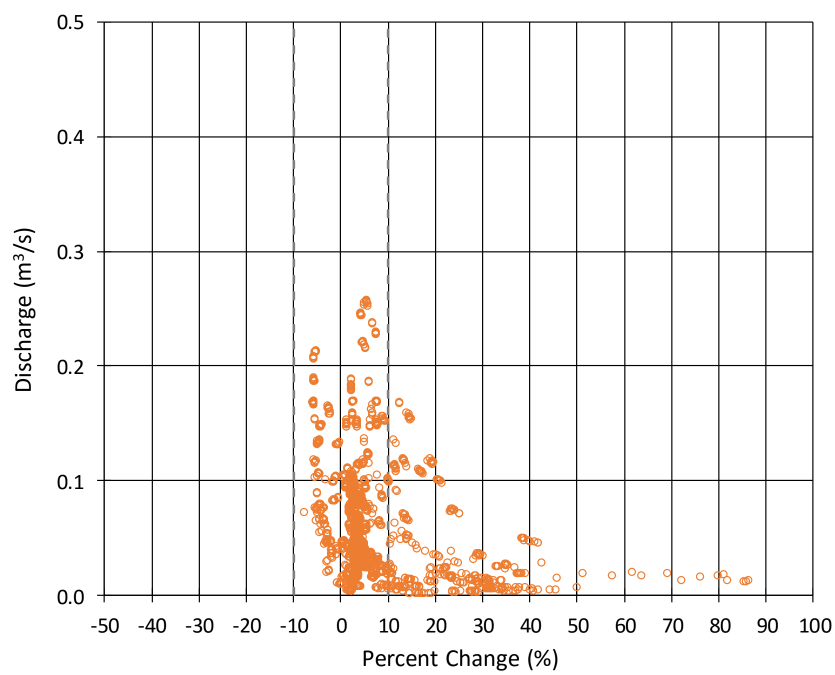

Figure 12-C-3.5-6 Closure phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at YT-24, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.

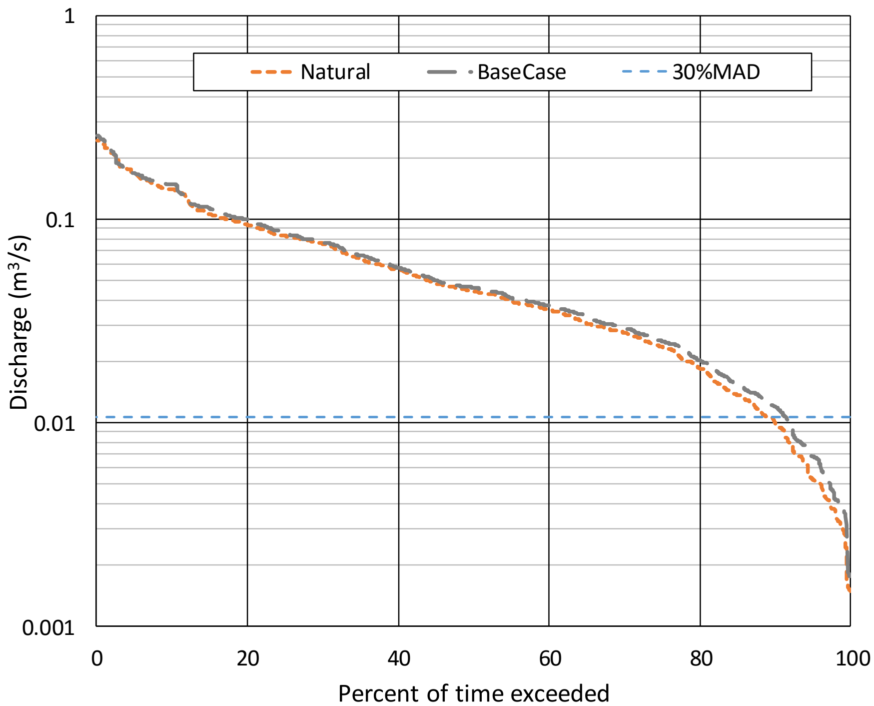

Figure 12-C-3.5-7 Natural and Base Case monthly discharge data for YT-24. Data shown are for the Closure phase of the Project and are presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Closure shown by dashed blue line.

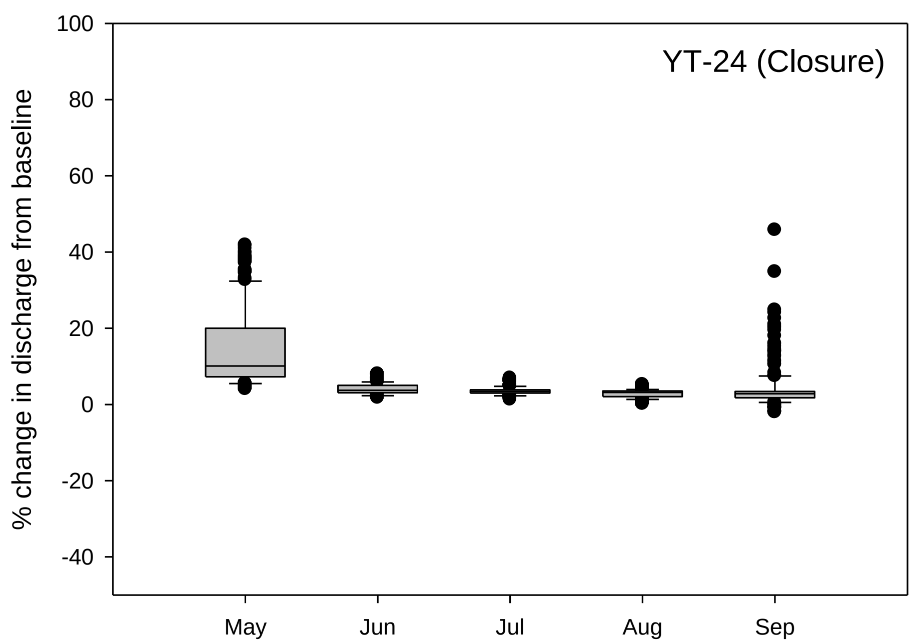

Figure 12-C-3.5-8 Box and Whisker Plot percent change summary for the Closure phase at YT-24. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

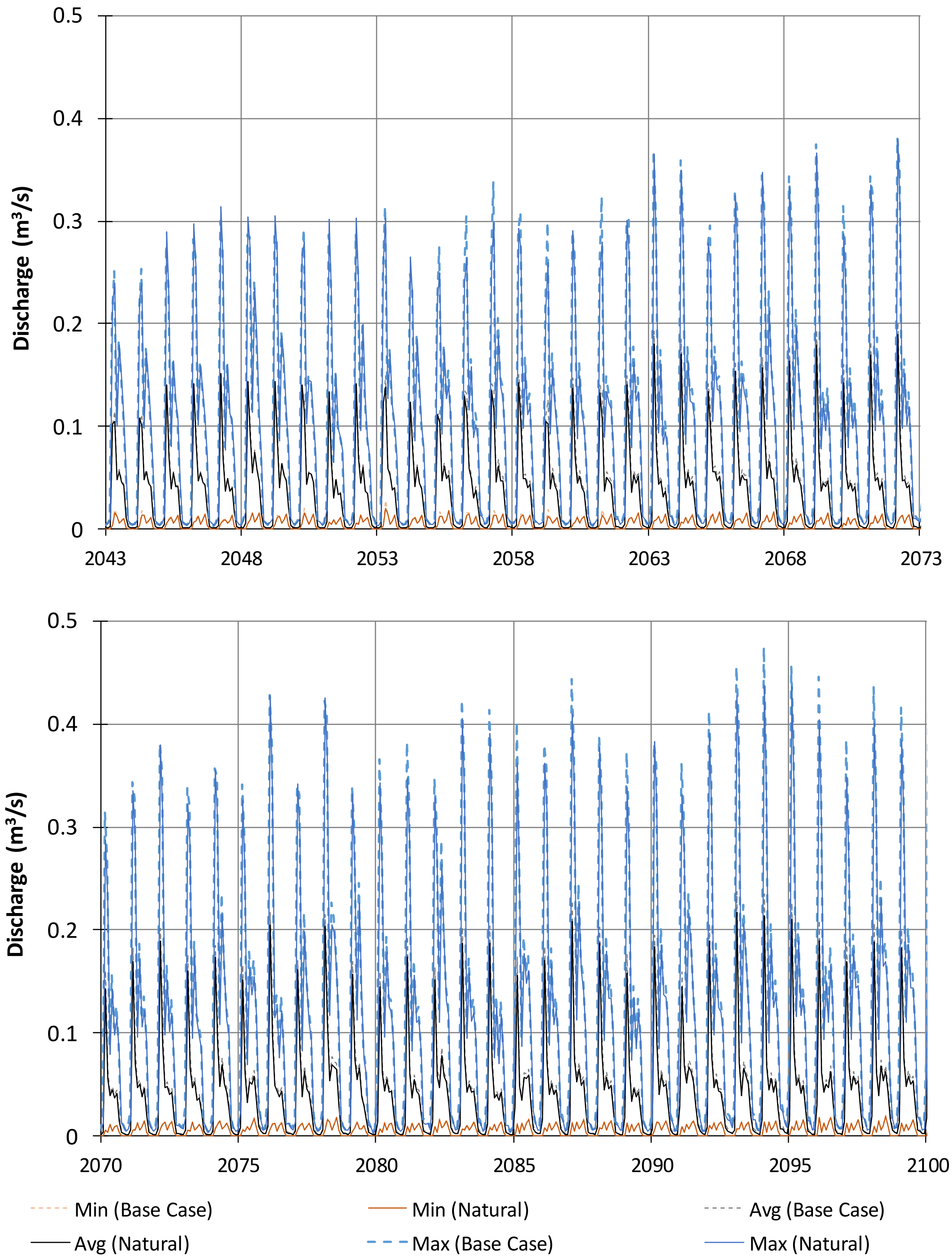

Figure 12-C-3.5-9 Time series plots showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the Post-closure phase of the Project and were computed from 28 WBM realizations. The upper panel shows output for 2043-2073 and the lower plot shows output from 2070-2100.

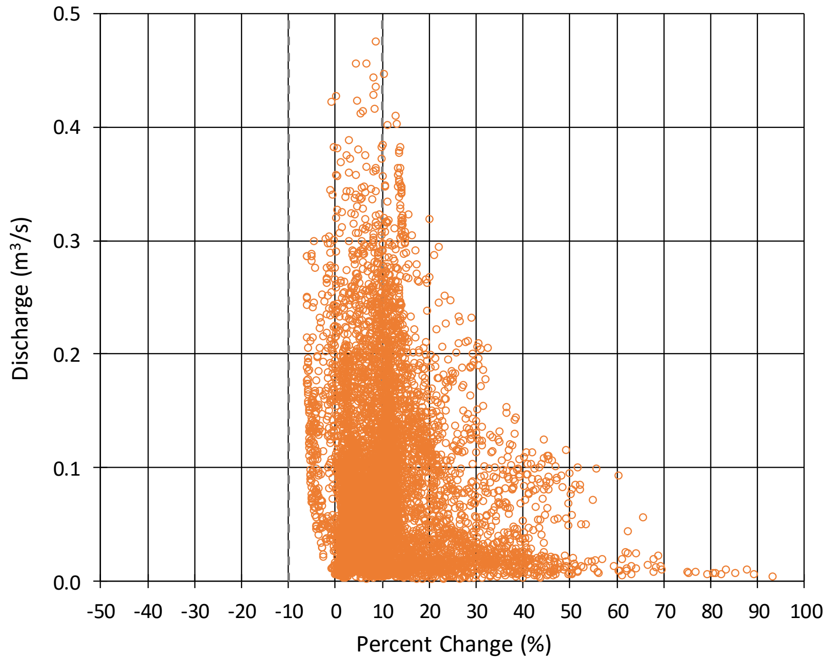

Figure 12-C-3.5-10 Post-closure phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at YT-24, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.

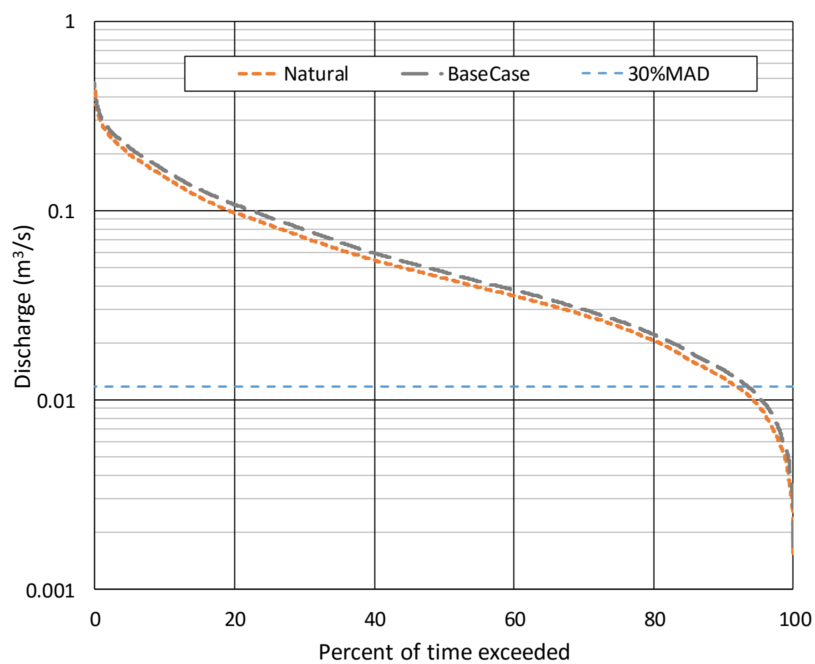

Figure 12-C-3.5-11 Natural and Base Case monthly discharge data for YT-24. Data shown are for Post-closure and presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Post-closure shown by dashed blue line.

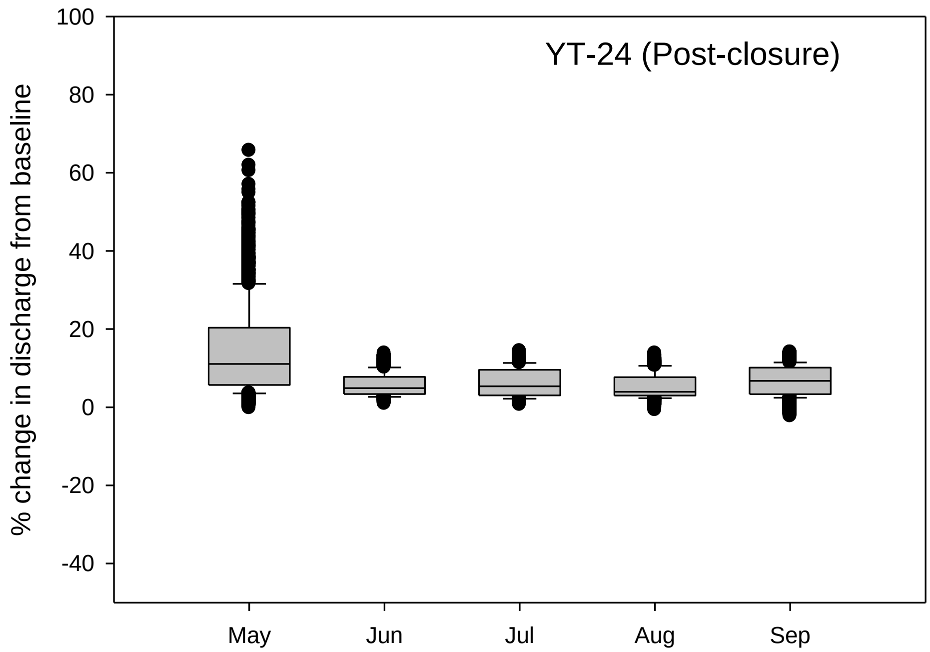

Figure 12-C-3.5-12 Box and Whisker Plot percent change summary for the Post-closure phase at YT-24. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

Appendix 12-C-3

Coffee Gold Water Balance Model Output

12-C-3.6. HC-2.5 Water Balance Node (Upper Halfway Creek)

Table 12-C-3.6-1 End of Operations, Closure and Post-closure discharge data for the HC-2.5 Water Balance Model (WBM) node. Data shown are outputs from the Baseline (Natural Flow) Model.

	Discharge (m^3/s)												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
End of Operations (2027 through 2032)													
Min	0.004	0.003	0.002	0.009	0.107	0.061	0.051	0.045	0.048	0.028	0.011	0.007	0.002
10th Percentile	0.005	0.003	0.002	0.019	0.130	0.089	0.065	0.067	0.081	0.038	0.014	0.008	-
Lower Quartile	0.006	0.004	0.003	0.038	0.215	0.109	0.099	0.089	0.088	0.047	0.015	0.009	-
Median	0.007	0.005	0.005	0.076	0.315	0.128	0.129	0.118	0.106	0.056	0.019	0.011	-
Mean	0.008	0.006	0.007	0.066	0.289	0.151	0.150	0.125	0.118	0.064	0.021	0.013	0.085
Upper Quartile	0.009	0.006	0.011	0.089	0.352	0.166	0.189	0.145	0.128	0.076	0.028	0.015	-
90th Percentile	0.011	0.007	0.014	0.103	0.411	0.249	0.311	0.199	0.197	0.095	0.032	0.018	-
Max	0.015	0.022	0.023	0.129	0.477	0.395	0.398	0.292	0.240	0.169	0.037	0.026	0.477
Closure (2033 through 2042)													
Min	0.004	0.003	0.002	0.009	0.107	0.059	0.051	0.044	0.049	0.027	0.011	0.007	0.002
10th Percentile	0.005	0.003	0.002	0.019	0.131	0.088	0.062	0.067	0.079	0.038	0.014	0.008	-
Lower Quartile	0.006	0.004	0.003	0.038	0.216	0.108	0.100	0.086	0.086	0.044	0.015	0.009	-
Median	0.007	0.005	0.005	0.076	0.311	0.125	0.127	0.115	0.102	0.054	0.019	0.011	-
Mean	0.008	0.006	0.007	0.065	0.289	0.149	0.150	0.124	0.117	0.063	0.021	0.013	0.084
Upper Quartile	0.009	0.006	0.011	0.090	0.354	0.164	0.187	0.145	0.128	0.077	0.030	0.015	-
90th Percentile	0.012	0.008	0.014	0.102	0.410	0.249	0.313	0.193	0.197	0.093	0.032	0.019	-
Max	0.015	0.022	0.023	0.130	0.478	0.393	0.400	0.297	0.251	0.169	0.037	0.027	0.478
Long-term Monitoring (2043 through 2100)													
Min	0.004	0.002	0.002	0.009	0.048	0.051	0.045	0.041	0.045	0.027	0.010	0.006	0.002
10th Percentile	0.006	0.004	0.004	0.043	0.090	0.075	0.064	0.065	0.073	0.046	0.016	0.010	-
Lower Quartile	0.008	0.005	0.005	0.085	0.141	0.093	0.094	0.081	0.084	0.056	0.021	0.012	-
Median	0.010	0.007	0.012	0.142	0.267	0.116	0.118	0.109	0.107	0.074	0.031	0.016	-
Mean	0.012	0.009	0.018	0.153	0.270	0.133	0.144	0.121	0.122	0.085	0.037	0.020	0.094
Upper Quartile	0.015	0.011	0.024	0.209	0.366	0.159	0.171	0.143	0.139	0.103	0.046	0.024	-
90th Percentile	0.020	0.015	0.041	0.274	0.457	0.217	0.258	0.198	0.203	0.137	0.065	0.035	-
Max	0.061	0.032	0.120	0.518	0.681	0.494	0.537	0.398	0.374	0.284	0.180	0.096	0.681

Table 12-C-3.6-2 End of Operations, Closure and Post-closure discharge data for the HC-2.5 WBM node. Data shown are outputs from the Base Case (With Project) Model.

	Discharge (m^3/s)												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
End of Operations (2027 through 2032)													
Min	0.001	0.001	0.001	0.006	0.160	0.080	0.079	0.065	0.062	0.018	0.003	0.002	0.001
10th Percentile	0.002	0.001	0.001	0.019	0.191	0.119	0.098	0.092	0.096	0.035	0.004	0.003	-
Lower Quartile	0.002	0.001	0.001	0.031	0.269	0.139	0.124	0.111	0.111	0.044	0.005	0.003	-
Median	0.002	0.001	0.002	0.061	0.361	0.163	0.164	0.149	0.127	0.058	0.007	0.003	-
Mean	0.002	0.002	0.003	0.056	0.342	0.180	0.180	0.152	0.137	0.065	0.009	0.004	0.094
Upper Quartile	0.003	0.002	0.005	0.080	0.395	0.204	0.218	0.175	0.149	0.079	0.011	0.005	-
90th Percentile	0.003	0.002	0.008	0.084	0.481	0.275	0.330	0.225	0.214	0.097	0.017	0.006	-
Max	0.005	0.011	0.012	0.121	0.556	0.359	0.418	0.324	0.265	0.178	0.022	0.011	0.556
Closure (2033 through 2042)													
Min	0.001	0.001	0.001	0.006	0.122	0.082	0.082	0.063	0.066	0.018	0.003	0.002	0.001
10th Percentile	0.002	0.001	0.001	0.021	0.193	0.119	0.102	0.093	0.099	0.034	0.004	0.003	-
Lower Quartile	0.002	0.001	0.001	0.038	0.253	0.139	0.129	0.111	0.110	0.043	0.005	0.003	-
Median	0.002	0.001	0.002	0.066	0.362	0.164	0.165	0.152	0.128	0.057	0.007	0.003	-
Mean	0.002	0.002	0.004	0.068	0.340	0.183	0.184	0.156	0.141	0.065	0.009	0.004	0.096
Upper Quartile	0.003	0.002	0.006	0.086	0.405	0.211	0.219	0.186	0.153	0.079	0.010	0.005	-
90th Percentile	0.004	0.002	0.009	0.119	0.479	0.277	0.342	0.231	0.219	0.096	0.016	0.007	-
Max	0.006	0.015	0.019	0.193	0.566	0.367	0.432	0.338	0.271	0.182	0.025	0.016	0.566
Long-term Monitoring (2043 through 2100)													
Min	0.001	0.001	0.001	0.008	0.070	0.068	0.069	0.058	0.058	0.020	0.003	0.002	0.001
10th Percentile	0.002	0.001	0.001	0.075	0.122	0.107	0.092	0.085	0.096	0.051	0.006	0.003	-
Lower Quartile	0.002	0.002	0.003	0.132	0.172	0.128	0.121	0.104	0.109	0.065	0.009	0.004	-
Median	0.003	0.003	0.011	0.192	0.280	0.154	0.156	0.140	0.130	0.087	0.018	0.006	-
Mean	0.005	0.005	0.022	0.197	0.288	0.171	0.178	0.151	0.146	0.096	0.025	0.010	0.108
Upper Quartile	0.006	0.005	0.029	0.259	0.374	0.206	0.208	0.178	0.161	0.116	0.033	0.012	-
90th Percentile	0.010	0.010	0.058	0.323	0.471	0.262	0.303	0.237	0.230	0.154	0.055	0.021	-
Max	0.057	0.043	0.194	0.554	0.716	0.456	0.584	0.446	0.400	0.322	0.183	0.095	0.716

Table 12-C-3.6-3 End of Operations, Closure and Post-closure percent change data for the HC-2.5 WBM node. Data shown are computed from Natural and Base Case Model outputs.

	Percent Change (%)												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
End of Operations (2027 through 2032)													
Min	-69.6	-69.6	-69.6	-49.9	6.7	-10.8	2.7	6.4	-8.0	-48.6	-69.6	-69.6	-69.6
10th Percentile	-69.6	-69.6	-69.6	-27.0	9.1	8.5	9.1	11.8	5.6	-15.7	-69.4	-69.6	-
Lower Quartile	-69.6	-69.6	-68.1	-19.9	12.3	19.1	14.6	17.3	10.3	-4.0	-69.0	-69.6	-
Median	-69.6	-69.6	-58.5	-15.7	16.8	26.1	23.2	23.6	17.2	2.6	-66.8	-69.6	-
Mean	-69.3	-68.2	-58.6	-15.1	22.2	24.4	26.3	24.6	19.1	2.0	-60.5	-68.6	-18.5
Upper Quartile	-69.6	-69.4	-50.3	-10.0	28.3	31.7	37.3	29.7	27.1	8.7	-57.4	-69.6	-
90th Percentile	-68.5	-65.5	-47.2	-0.2	47.3	39.1	46.9	40.6	35.7	19.6	-39.6	-67.6	-
Max	-64.0	-51.0	-35.0	9.0	68.1	44.5	72.2	52.2	51.9	33.6	-3.0	-56.6	72.2
Closure (2033 through 2042)													
Min	-69.6	-69.6	-69.6	-49.9	-7.8	-9.2	3.1	9.2	-6.1	-49.8	-69.6	-69.6	-69.6
10th Percentile	-69.6	-69.6	-69.6	-22.4	4.2	9.7	10.2	14.1	7.6	-18.1	-69.3	-69.6	-
Lower Quartile	-69.6	-69.6	-68.0	-15.1	11.6	20.7	15.9	20.3	13.3	-2.3	-68.6	-69.6	-
Median	-69.6	-69.6	-58.3	-9.9	17.3	28.0	26.7	27.5	21.6	4.2	-65.7	-69.6	-
Mean	-69.1	-67.8	-55.0	3.2	21.5	27.6	29.3	29.2	23.2	2.4	-60.8	-68.2	-15.4
Upper Quartile	-69.6	-69.4	-47.8	8.2	27.1	35.9	40.4	36.1	32.8	9.1	-57.5	-69.5	-
90th Percentile	-68.5	-64.0	-35.6	59.1	49.8	43.4	51.7	46.0	40.6	20.5	-44.0	-67.8	-
Max	-59.0	-26.5	14.8	122.6	76.6	61.5	83.4	80.1	56.9	34.5	0.6	-39.1	122.6
Long-term Monitoring (2043 through 2100)													
Min	-69.6	-69.6	-69.6	-24.5	-14.1	-10.1	0.7	6.4	-6.2	-38.7	-69.4	-69.6	-69.6
10th Percentile	-69.6	-69.6	-67.5	6.5	-3.3	18.6	12.5	16.0	9.1	-1.0	-65.4	-69.6	-
Lower Quartile	-69.6	-69.5	-47.7	15.1	0.9	24.6	16.1	19.8	13.9	5.8	-57.3	-69.4	-
Median	-68.7	-63.1	-17.0	31.7	6.8	31.5	26.9	25.1	21.9	15.6	-43.7	-63.4	-
Mean	-61.2	-53.9	-6.6	37.8	11.9	31.9	28.9	26.8	22.9	14.5	-39.5	-56.1	-3.5
Upper Quartile	-58.6	-45.5	30.4	58.6	20.5	38.8	40.0	31.7	30.1	23.9	-26.5	-45.9	-
90th Percentile	-40.4	-26.5	63.5	80.5	37.7	45.9	50.4	40.4	38.1	30.1	-8.1	-33.8	-
Max	61.5	114.9	185.5	145.1	56.8	68.0	71.0	67.5	67.7	54.2	49.0	39.4	185.5

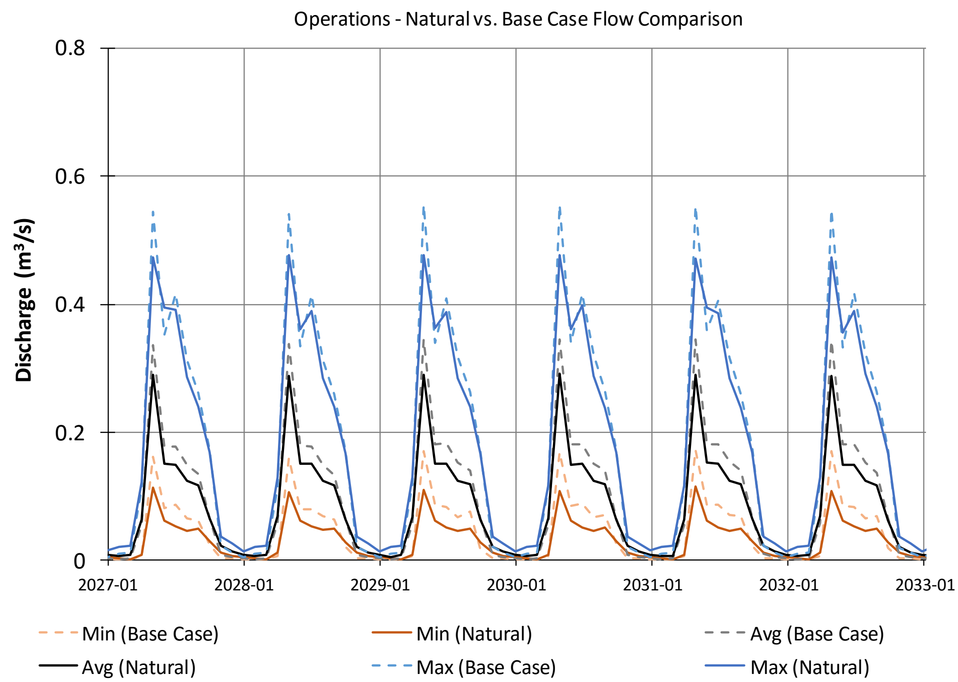

Figure 12-C-3.6-1 **Time series plot showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the End of Operations phase of the Project and were computed from 28 WBM realizations.**

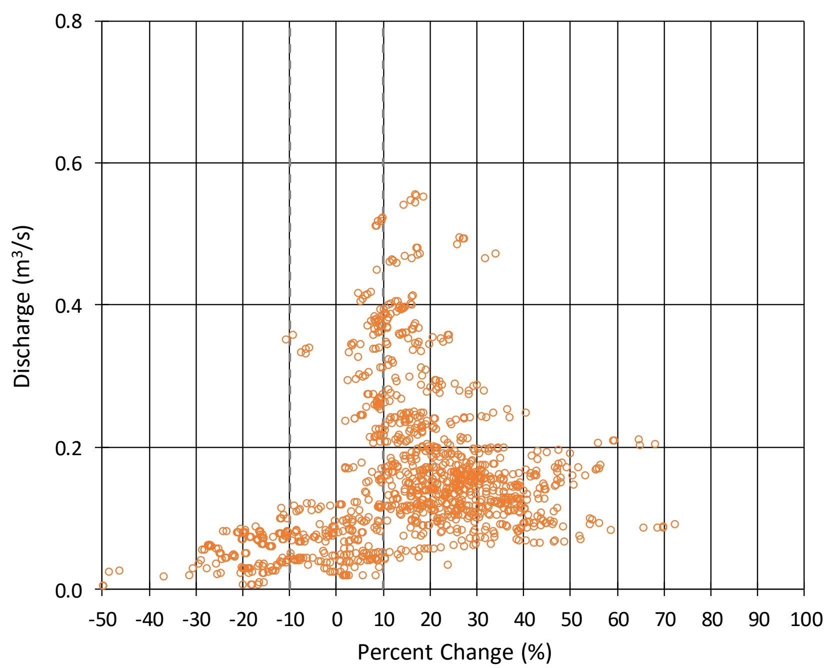

Figure 12-C-3.6-2 **End of Operations phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at HC-2.5, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.**

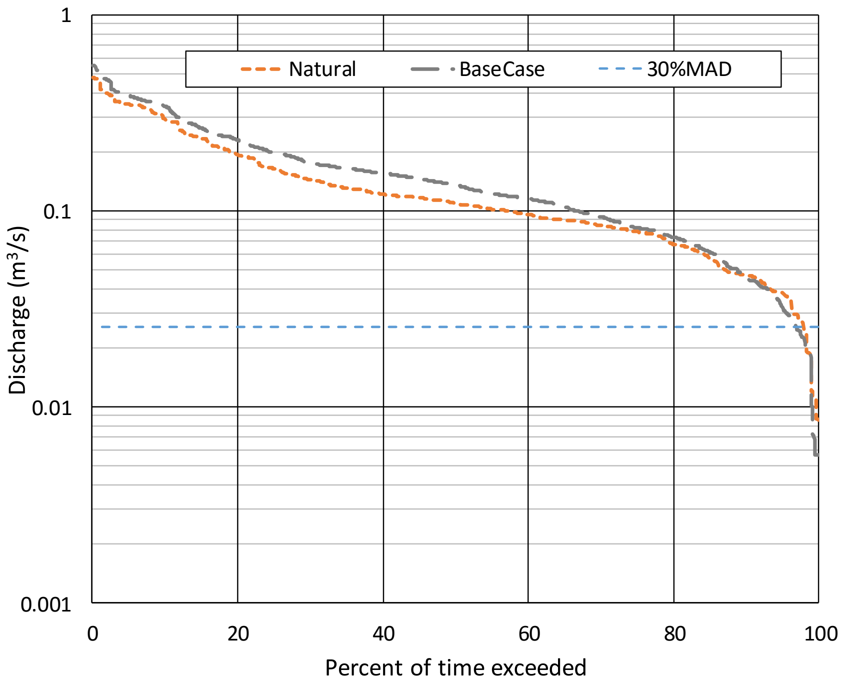

Figure 12-C-3.6-3 Natural and Base Case monthly discharge data for HC-2.5. Data shown are for the End of Operations phase and are presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Operations shown by dashed blue line.

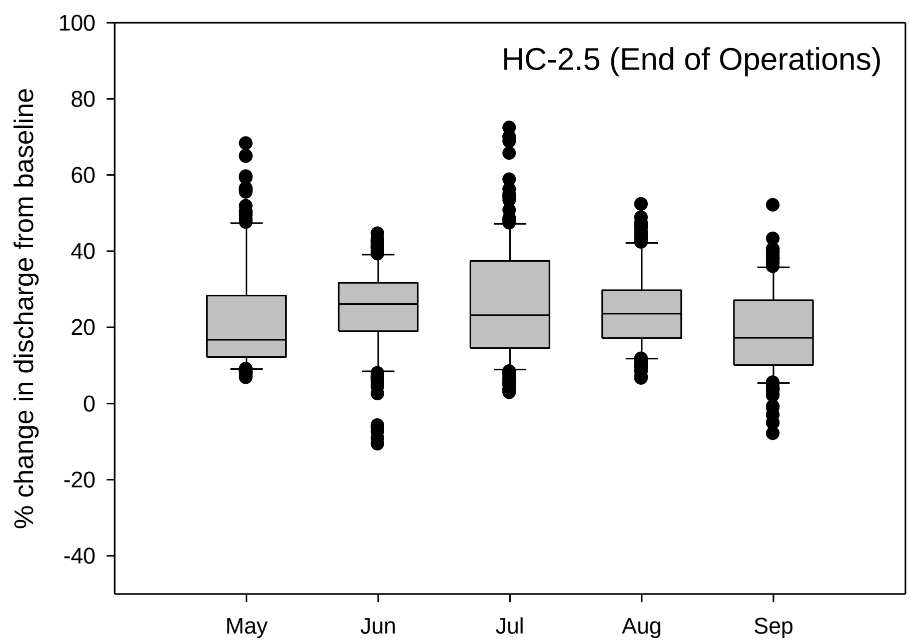

Figure 12-C-3.6-4 Box and Whisker Plot percent change summary for the End of Operations phase at HC-2.5. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

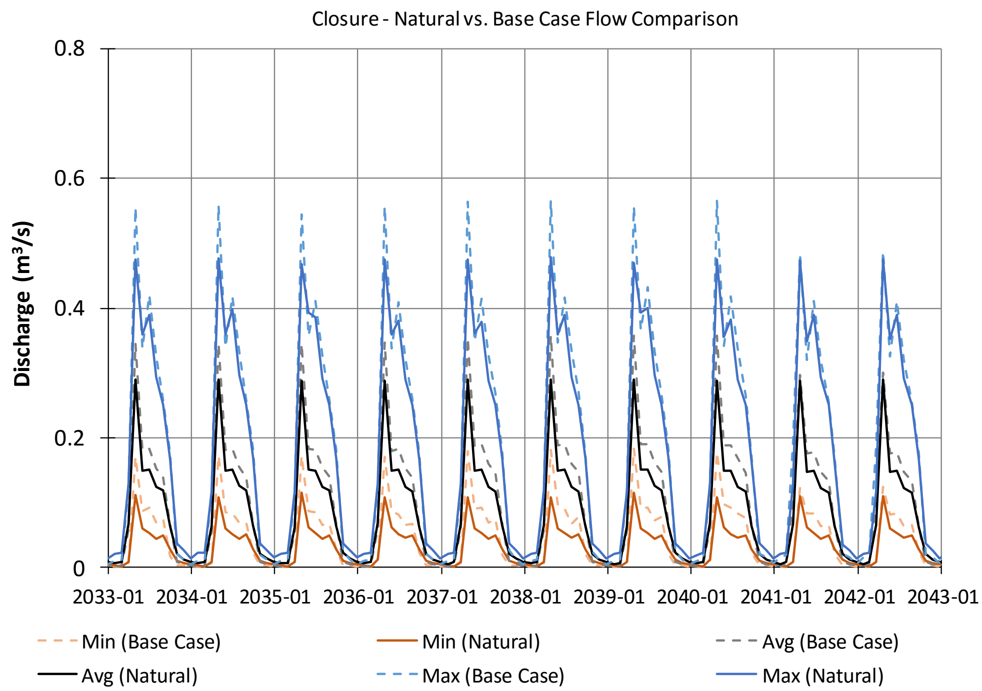

Figure 12-C-3.6-5 Time series plot showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the Closure phase of the Project and were computed from 28 WBM realizations.

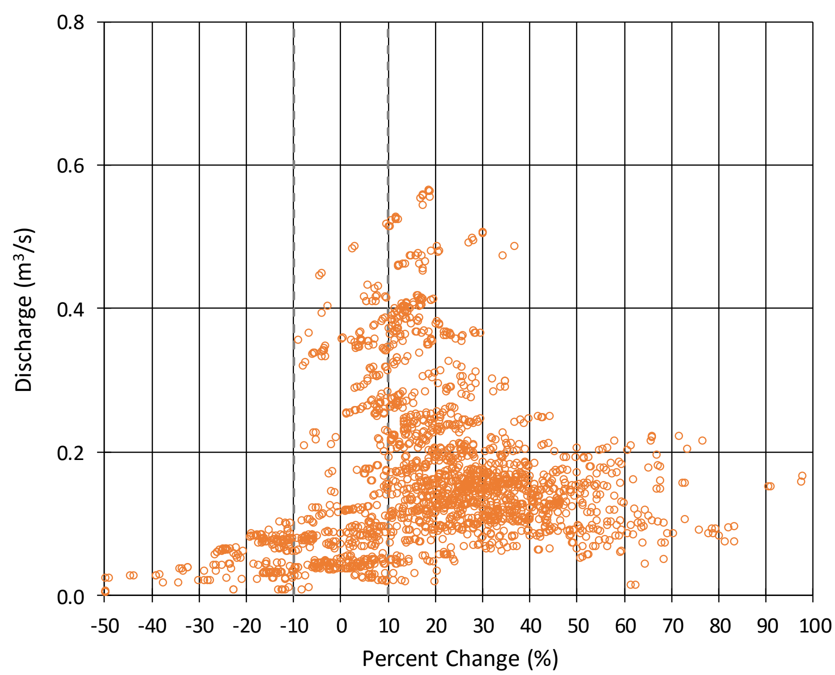

Figure 12-C-3.6-6 Closure phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at HC-2.5, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.

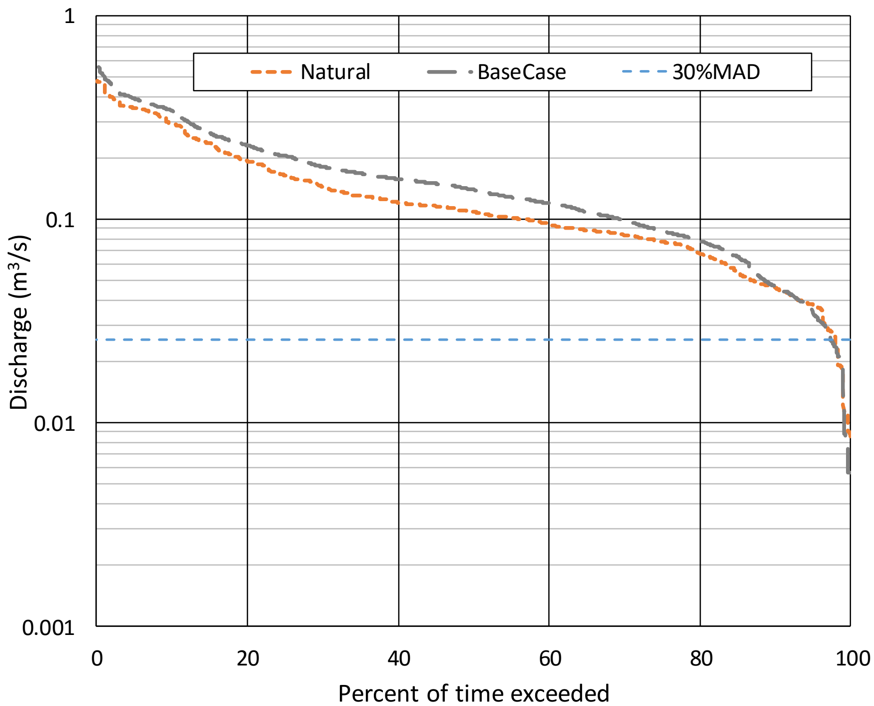

Figure 12-C-3.6-7 Natural and Base Case monthly discharge data for HC-2.5. Data shown are for the Closure phase of the Project and are presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Closure shown by dashed blue line.

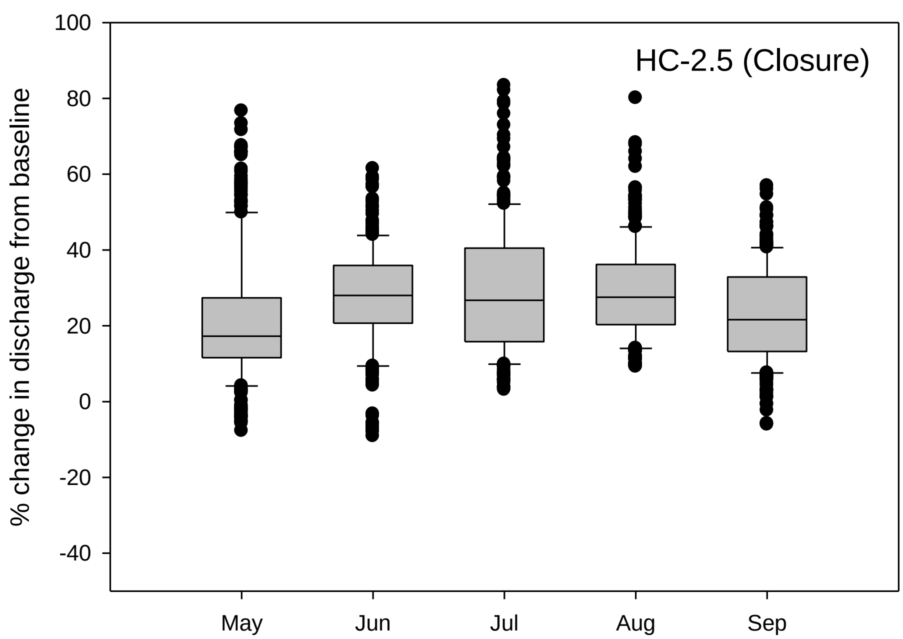

Figure 12-C-3.6-8 Box and Whisker Plot percent change summary for the Closure phase at HC-2.5. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

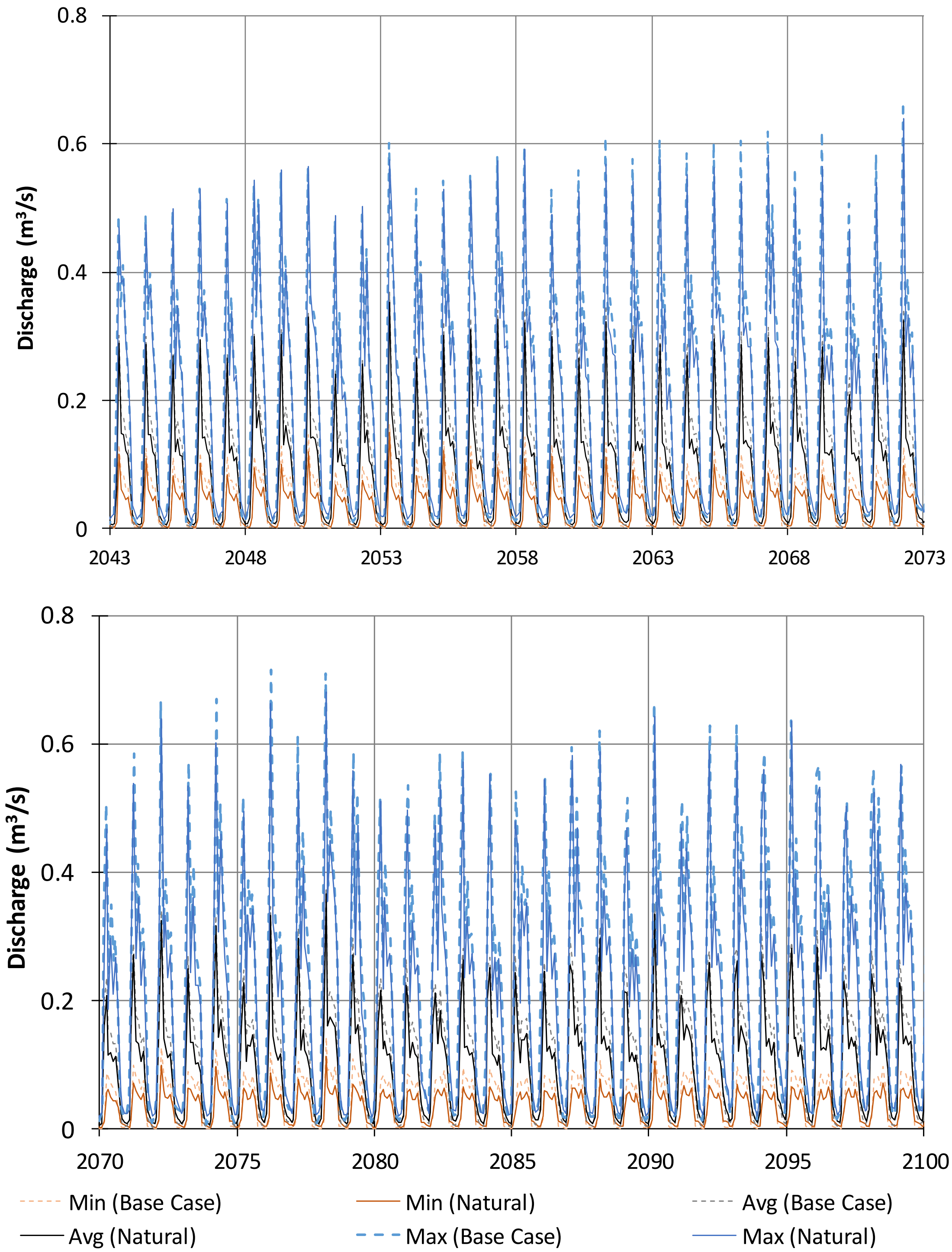

Figure 12-C-3.6-9 **Time series plots showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the Post-closure phase of the Project and were computed from 28 WBM realizations. The upper panel shows output for 2043-2073 and the lower plot shows output from 2070-2100.**

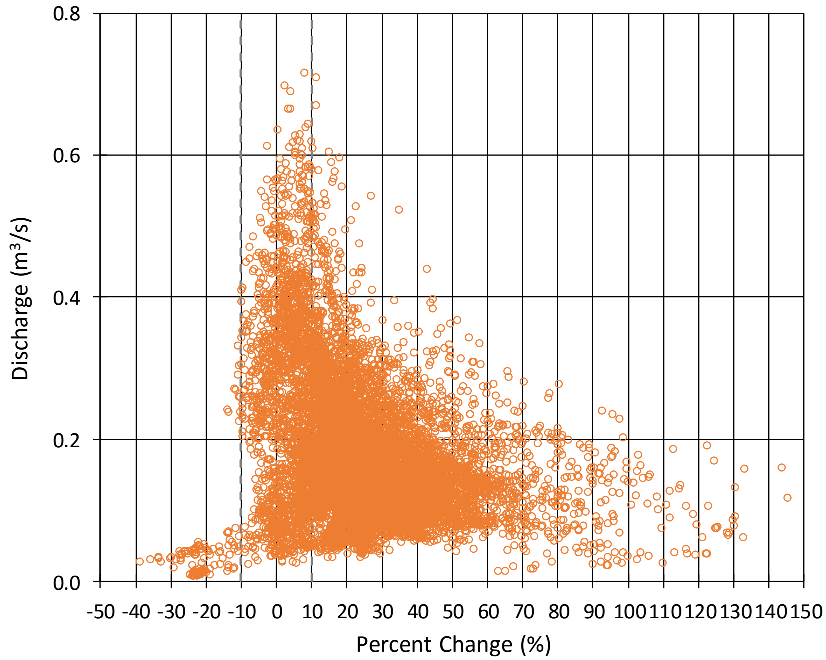

Figure 12-C-3.6-10 Post-closure phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at HC-2.5, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.

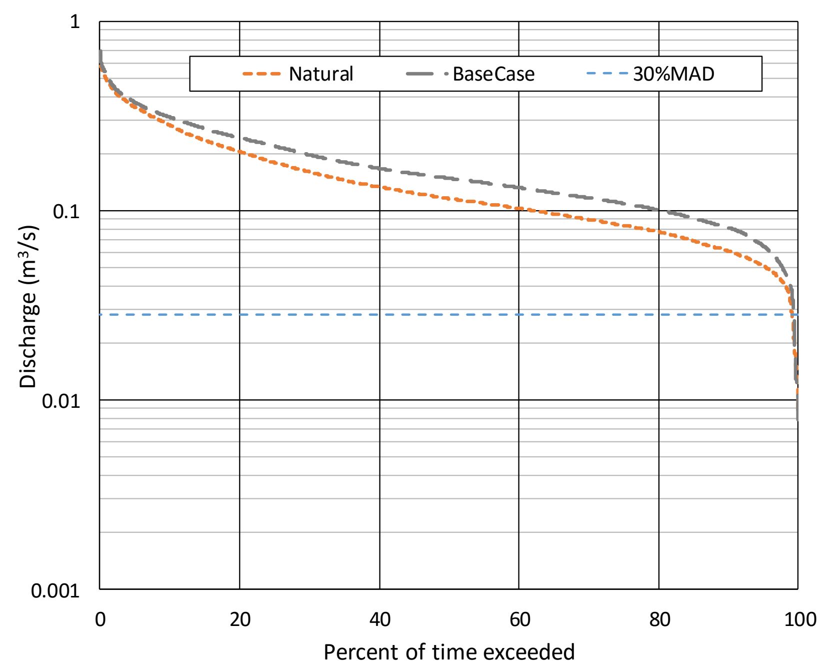

Figure 12-C-3.6-11 Natural and Base Case monthly discharge data for HC-2.5. Data shown are for Post-closure and presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Post-closure shown by dashed blue line.

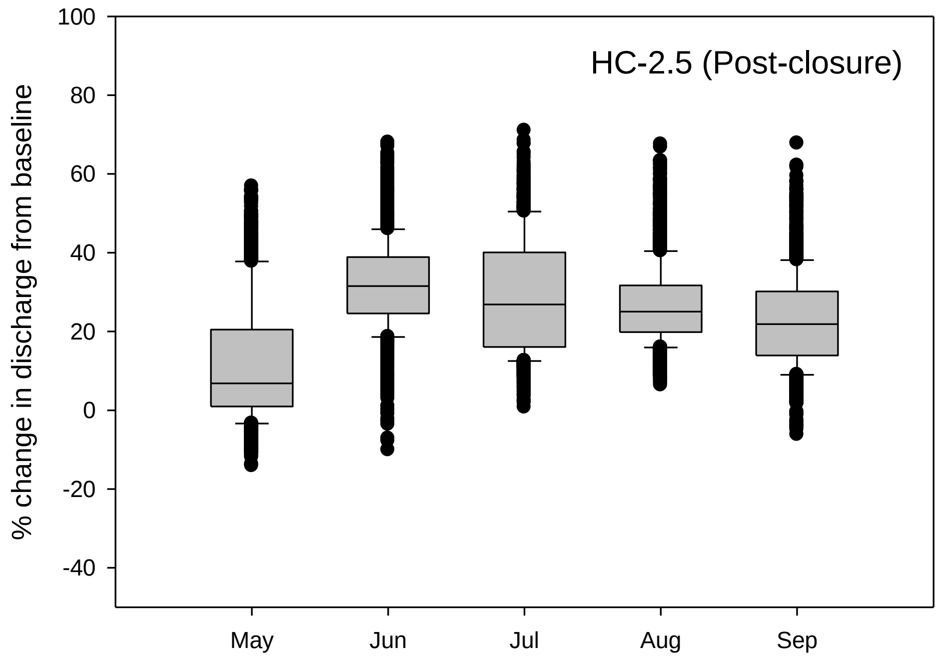

Figure 12-C-3.6-12 Box and Whisker Plot percent change summary for the Post-closure phase at HC-2.5. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

Appendix 12-C-3

Coffee Gold Water Balance Model Output

12-C-3.7. HC-5.0 Water Balance Node (Halfway Creek at the Mouth)

Table 12-C-3.7-1 End of Operations, Closure and Post-closure discharge data for the HC-5.0 Water Balance Model (WBM) node. Data shown are outputs from the Baseline (Natural Flow) Model.

	Discharge (m^3/s)												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
End of Operations (2027 through 2032)													
Min	0.003	0.002	0.001	0.012	0.156	0.094	0.078	0.066	0.076	0.032	0.009	0.005	0.001
10th Percentile	0.004	0.002	0.002	0.038	0.193	0.137	0.102	0.106	0.131	0.047	0.011	0.006	-
Lower Quartile	0.004	0.003	0.002	0.070	0.350	0.174	0.161	0.145	0.140	0.059	0.013	0.007	-
Median	0.005	0.003	0.004	0.154	0.538	0.206	0.214	0.193	0.175	0.074	0.018	0.008	-
Mean	0.006	0.004	0.007	0.132	0.481	0.241	0.250	0.207	0.197	0.090	0.022	0.010	0.137
Upper Quartile	0.006	0.004	0.010	0.184	0.590	0.270	0.313	0.242	0.217	0.111	0.034	0.011	-
90th Percentile	0.008	0.005	0.019	0.213	0.704	0.405	0.524	0.341	0.338	0.135	0.037	0.016	-
Max	0.011	0.027	0.032	0.254	0.818	0.604	0.685	0.499	0.413	0.273	0.050	0.027	0.818
Closure (2033 through 2042)													
Min	0.003	0.002	0.001	0.012	0.156	0.091	0.078	0.064	0.076	0.032	0.008	0.005	0.001
10th Percentile	0.004	0.002	0.002	0.038	0.191	0.135	0.098	0.105	0.127	0.048	0.011	0.006	-
Lower Quartile	0.004	0.003	0.002	0.072	0.349	0.172	0.162	0.139	0.138	0.058	0.012	0.007	-
Median	0.005	0.003	0.004	0.155	0.534	0.200	0.208	0.189	0.169	0.071	0.018	0.008	-
Mean	0.006	0.004	0.007	0.131	0.479	0.239	0.250	0.206	0.196	0.089	0.022	0.010	0.137
Upper Quartile	0.006	0.004	0.011	0.185	0.594	0.266	0.314	0.242	0.217	0.110	0.034	0.011	-
90th Percentile	0.009	0.006	0.019	0.213	0.704	0.403	0.527	0.329	0.337	0.135	0.038	0.019	-
Max	0.011	0.027	0.032	0.254	0.821	0.602	0.688	0.508	0.436	0.272	0.049	0.027	0.821
Long-term Monitoring (2043 through 2100)													
Min	0.003	0.002	0.001	0.011	0.071	0.077	0.066	0.059	0.069	0.032	0.007	0.005	0.001
10th Percentile	0.004	0.003	0.003	0.084	0.141	0.117	0.100	0.102	0.116	0.062	0.013	0.007	-
Lower Quartile	0.005	0.003	0.004	0.172	0.219	0.150	0.153	0.131	0.137	0.079	0.020	0.009	-
Median	0.007	0.005	0.011	0.272	0.426	0.188	0.194	0.179	0.177	0.109	0.035	0.012	-
Mean	0.009	0.007	0.022	0.289	0.437	0.214	0.241	0.201	0.204	0.128	0.045	0.019	0.151
Upper Quartile	0.011	0.007	0.031	0.392	0.599	0.260	0.290	0.241	0.233	0.160	0.060	0.025	-
90th Percentile	0.018	0.011	0.060	0.508	0.759	0.357	0.436	0.339	0.347	0.219	0.088	0.041	-
Max	0.086	0.040	0.203	0.958	1.153	0.750	0.941	0.687	0.651	0.482	0.267	0.146	1.153

Table 12-C-3.7-2 End of Operations, Closure and Post-closure discharge data for the HC-5.0 WBM node. Data shown are outputs from the Base Case (With Project) Model.

	Discharge (m³/s)												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
End of Operations (2027 through 2032)													
Min	0.003	0.002	0.001	0.010	0.210	0.114	0.110	0.086	0.091	0.027	0.009	0.005	0.001
10th Percentile	0.004	0.002	0.002	0.038	0.251	0.172	0.136	0.131	0.150	0.048	0.011	0.006	-
Lower Quartile	0.004	0.003	0.002	0.065	0.396	0.209	0.185	0.168	0.165	0.059	0.012	0.007	-
Median	0.005	0.003	0.003	0.139	0.588	0.240	0.251	0.225	0.197	0.078	0.014	0.008	-
Mean	0.006	0.004	0.006	0.123	0.533	0.270	0.280	0.234	0.216	0.093	0.017	0.009	0.149
Upper Quartile	0.006	0.004	0.008	0.174	0.631	0.306	0.350	0.271	0.233	0.114	0.021	0.010	-
90th Percentile	0.008	0.005	0.014	0.192	0.784	0.424	0.554	0.370	0.356	0.138	0.027	0.013	-
Max	0.011	0.019	0.023	0.243	0.898	0.567	0.703	0.531	0.437	0.282	0.032	0.019	0.898
Closure (2033 through 2042)													
Min	0.003	0.002	0.001	0.010	0.172	0.115	0.111	0.084	0.094	0.027	0.008	0.005	0.001
10th Percentile	0.004	0.002	0.002	0.040	0.253	0.172	0.138	0.133	0.151	0.049	0.010	0.006	-
Lower Quartile	0.004	0.003	0.002	0.069	0.398	0.210	0.191	0.164	0.167	0.059	0.011	0.007	-
Median	0.005	0.003	0.003	0.146	0.572	0.237	0.244	0.226	0.196	0.073	0.014	0.008	-
Mean	0.006	0.004	0.006	0.134	0.531	0.272	0.284	0.238	0.219	0.092	0.016	0.009	0.151
Upper Quartile	0.006	0.004	0.008	0.186	0.638	0.310	0.350	0.278	0.238	0.116	0.021	0.010	-
90th Percentile	0.008	0.006	0.015	0.234	0.777	0.431	0.557	0.368	0.360	0.136	0.026	0.015	-
Max	0.011	0.022	0.029	0.311	0.910	0.575	0.720	0.544	0.450	0.284	0.034	0.024	0.910
Long-term Monitoring (2043 through 2100)													
Min	0.003	0.002	0.001	0.010	0.093	0.094	0.090	0.076	0.083	0.027	0.007	0.005	0.001
10th Percentile	0.004	0.003	0.003	0.116	0.172	0.152	0.127	0.122	0.140	0.068	0.011	0.007	-
Lower Quartile	0.005	0.003	0.004	0.215	0.248	0.184	0.181	0.154	0.162	0.088	0.015	0.009	-
Median	0.007	0.005	0.013	0.322	0.435	0.225	0.232	0.209	0.200	0.123	0.027	0.011	-
Mean	0.009	0.007	0.028	0.333	0.455	0.253	0.275	0.231	0.228	0.140	0.038	0.016	0.168
Upper Quartile	0.010	0.007	0.039	0.445	0.609	0.306	0.328	0.275	0.254	0.172	0.047	0.018	-
90th Percentile	0.014	0.011	0.077	0.557	0.778	0.403	0.487	0.377	0.373	0.237	0.079	0.031	-
Max	0.084	0.043	0.277	0.994	1.205	0.711	0.988	0.735	0.677	0.520	0.265	0.146	1.205

Table 12-C-3.7-3 End of Operations, Closure and Post-closure percent change data for the HC-5.0 WBM node. Data shown are computed from Natural and Base Case Model outputs.

	Percent Change (%)												
	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Ann
End of Operations (2027 through 2032)													
Min	-19.0	-27.5	-27.8	-22.2	4.0	-7.1	1.6	3.8	-4.6	-32.3	-45.0	-32.2	-45.0
10th Percentile	0.0	-2.4	-26.0	-12.4	5.4	5.2	5.4	6.9	3.6	-7.3	-37.4	-19.1	-
Lower Quartile	0.0	0.0	-19.1	-9.9	7.4	11.5	8.8	10.3	6.1	-0.9	-30.8	-7.9	-
Median	0.0	0.0	-2.7	-6.7	9.8	16.2	13.9	14.5	10.5	3.6	-21.3	0.0	-
Mean	-0.8	-1.5	-9.1	-6.3	14.1	15.3	16.3	15.1	11.8	4.6	-18.1	-5.9	2.9
Upper Quartile	0.0	0.0	0.0	-2.6	17.1	20.0	23.0	18.2	17.0	12.0	-7.9	0.0	-
90th Percentile	0.0	0.0	0.0	1.3	31.1	25.0	29.6	25.7	21.9	17.1	0.0	0.0	-
Max	0.0	0.0	0.3	11.8	45.3	29.1	47.1	35.2	34.8	33.6	53.5	0.0	53.5
Closure (2033 through 2042)													
Min	-19.1	-27.7	-27.6	-22.0	-5.1	-6.0	1.8	5.4	-3.5	-33.2	-45.0	-32.3	-45.0
10th Percentile	0.0	-2.5	-25.6	-10.8	2.5	6.2	6.0	8.3	4.4	-9.3	-39.9	-20.2	-
Lower Quartile	0.0	0.0	-15.4	-7.0	6.9	12.6	9.4	12.1	7.9	0.3	-30.7	-7.9	-
Median	0.0	0.0	0.0	-3.5	10.3	17.4	16.1	16.8	13.1	4.8	-22.2	0.0	-
Mean	-0.8	-1.3	-7.2	2.7	13.6	17.3	18.1	18.0	14.3	4.7	-18.7	-5.7	4.6
Upper Quartile	0.0	0.0	0.0	5.2	16.3	22.5	25.0	22.1	20.1	10.9	-8.5	0.0	-
90th Percentile	0.0	0.0	0.0	29.1	34.0	27.5	32.4	29.2	25.3	19.7	-2.8	0.0	-
Max	0.0	1.0	23.8	58.0	50.9	39.8	54.3	54.0	37.8	32.5	81.1	0.0	81.1
Long-term Monitoring (2043 through 2100)													
Min	-46.6	-32.0	-15.5	-10.6	-9.2	-6.6	0.4	3.8	-3.6	-26.1	-44.3	-43.1	-46.6
10th Percentile	-17.6	-6.0	-6.4	3.8	-2.1	11.4	7.4	9.4	5.3	-0.4	-32.8	-30.0	-
Lower Quartile	-6.4	-1.5	-2.0	8.5	0.6	15.1	9.6	11.9	8.3	4.4	-26.8	-19.6	-
Median	0.0	0.0	2.5	16.2	4.1	19.5	16.2	15.4	13.3	10.6	-19.9	-9.0	-
Mean	-4.1	1.2	17.1	19.4	7.6	19.9	17.8	16.4	14.0	10.3	-17.7	-11.3	7.6
Upper Quartile	0.0	0.0	29.5	29.0	13.1	24.4	24.9	19.6	18.4	16.7	-10.6	-0.5	-
90th Percentile	0.0	3.5	56.9	41.1	24.1	29.2	32.0	25.7	23.9	21.8	-0.1	0.0	-
Max	119.6	190.7	199.9	68.3	37.8	43.9	47.6	42.8	43.2	37.6	42.9	74.6	199.9

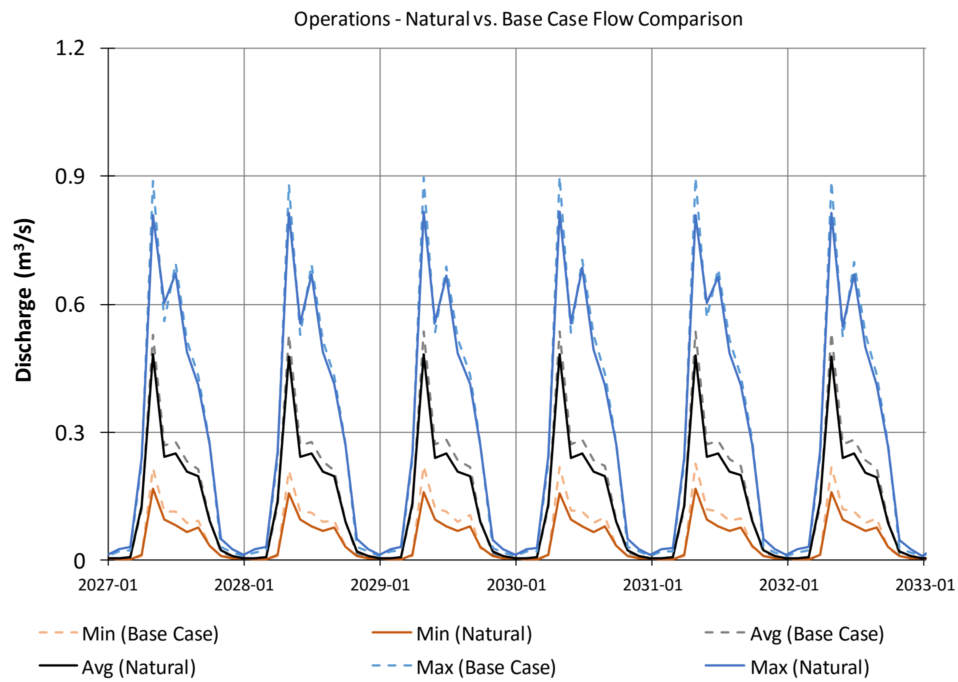

Figure 12-C-3.7-1 Time series plot showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the End of Operations phase of the Project and were computed from 28 WBM realizations.

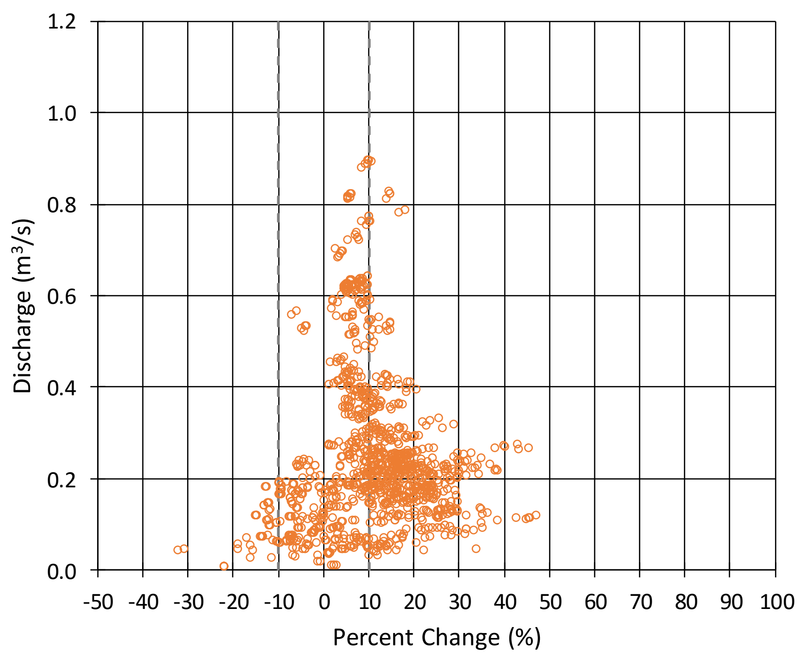

Figure 12-C-3.7-2 End of Operations phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at HC-5.0, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.

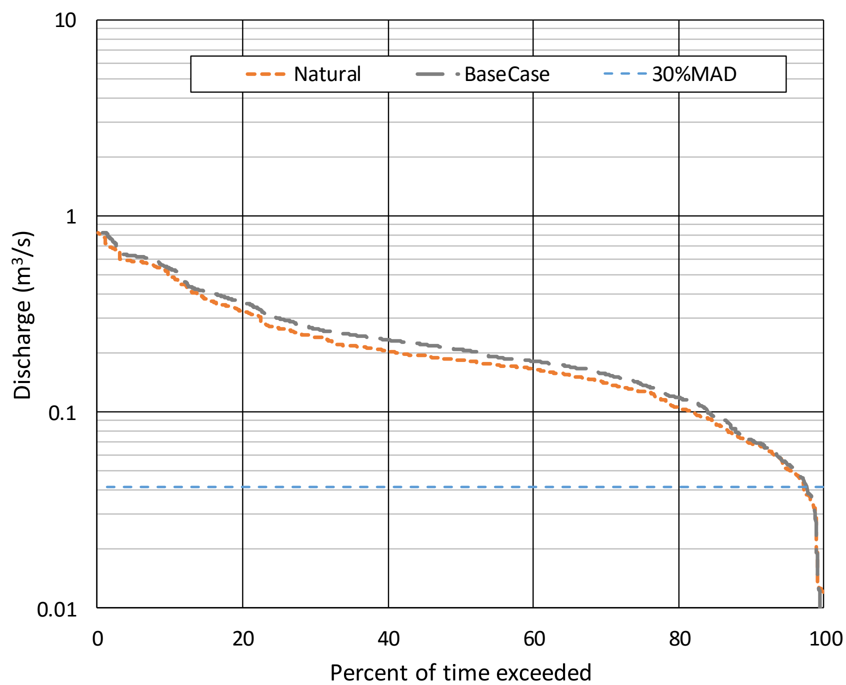

Figure 12-C-3.7-3 Natural and Base Case monthly discharge data for HC-5.0. Data shown are for the End of Operations phase and are presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Operations shown by dashed blue line.

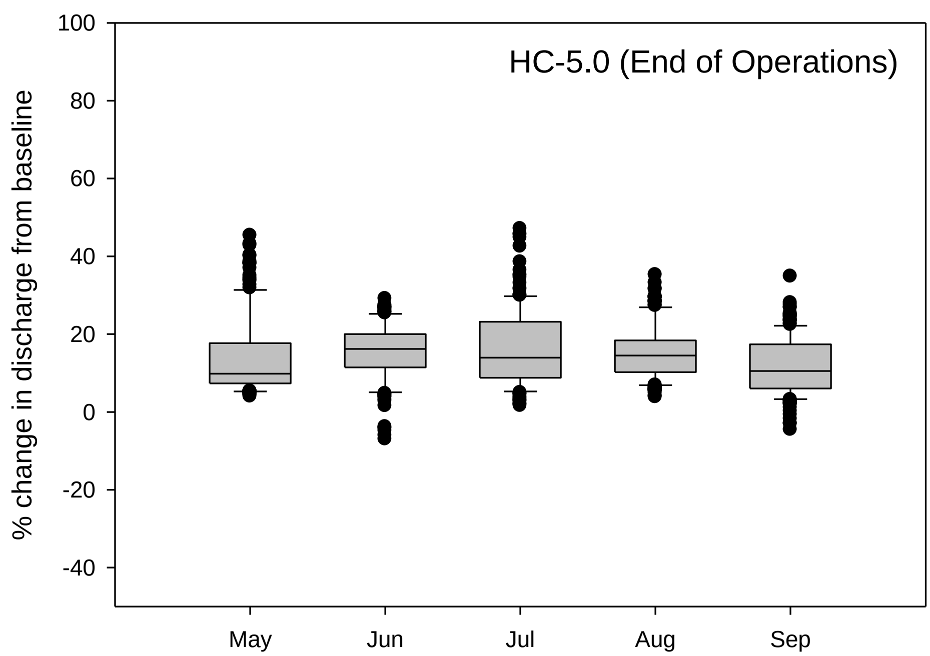

Figure 12-C-3.7-4 Box and Whisker Plot percent change summary for the End of Operations phase at HC-5.0. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

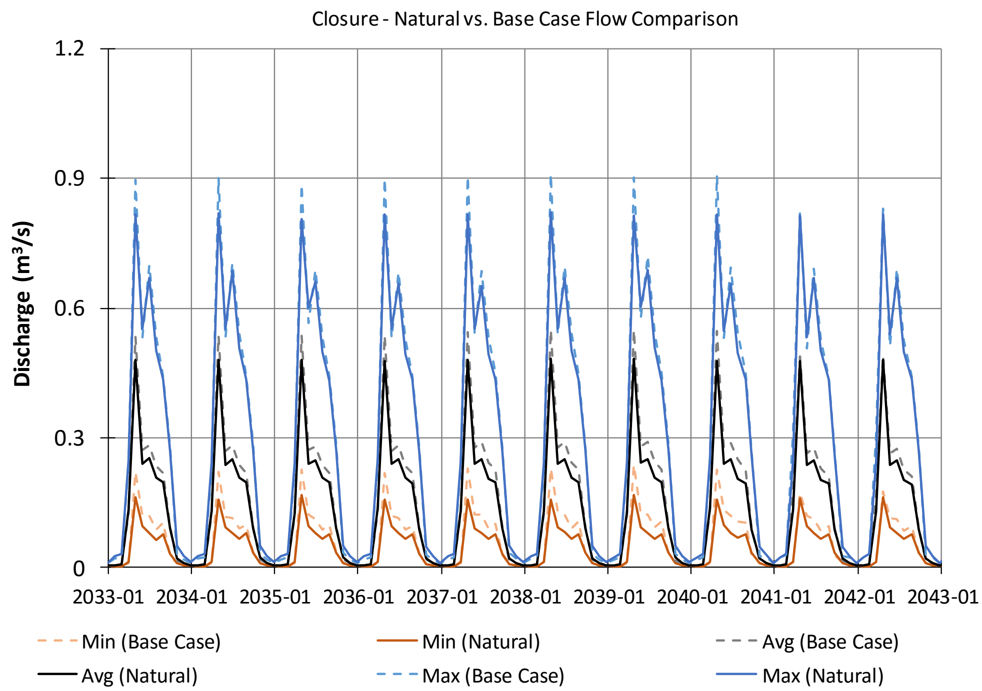

Figure 12-C-3.7-5 Time series plot showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the Closure phase of the Project and were computed from 28 WBM realizations.

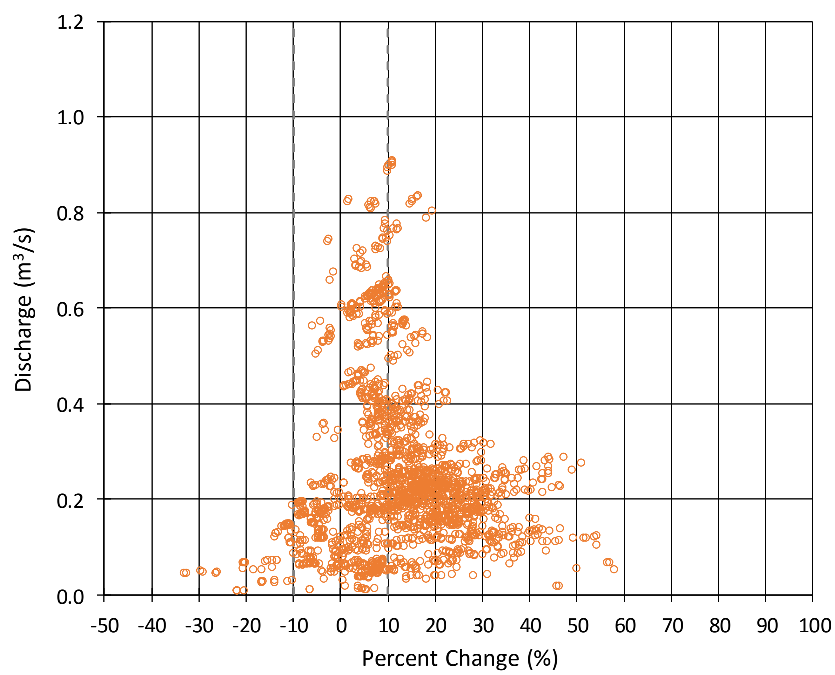

Figure 12-C-3.7-6 Closure phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at HC-5.0, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.

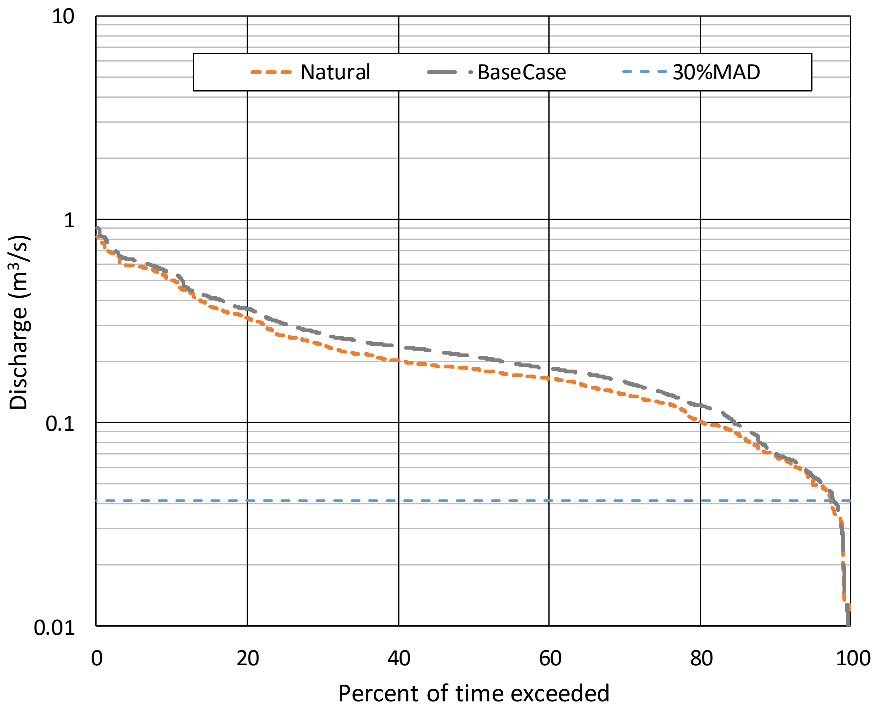

Figure 12-C-3.7-7 Natural and Base Case monthly discharge data for HC-5.0. Data shown are for the Closure phase of the Project and are presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Closure shown by dashed blue line.

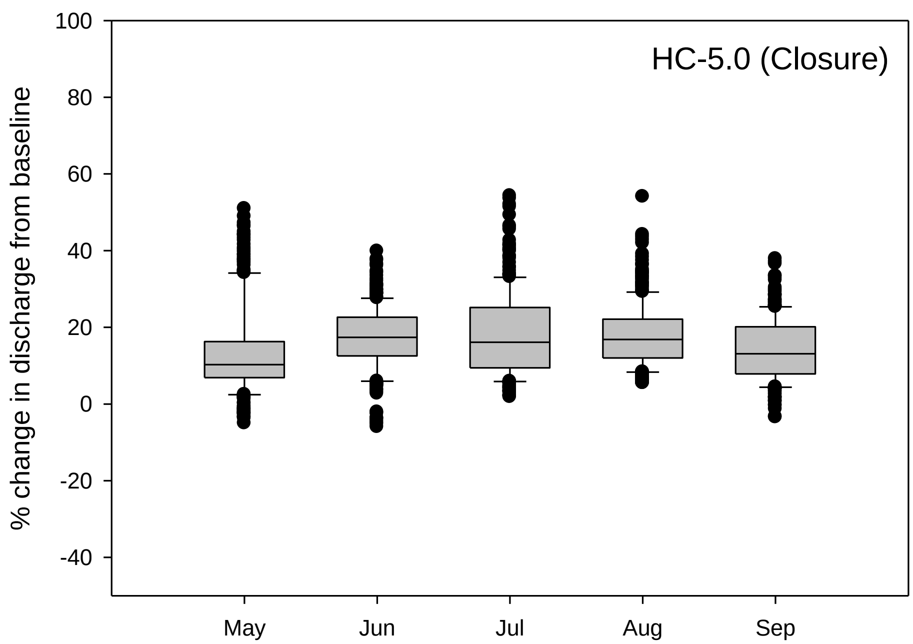

Figure 12-C-3.7-8 Box and Whisker Plot percent change summary for the Closure phase at HC-5.0. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

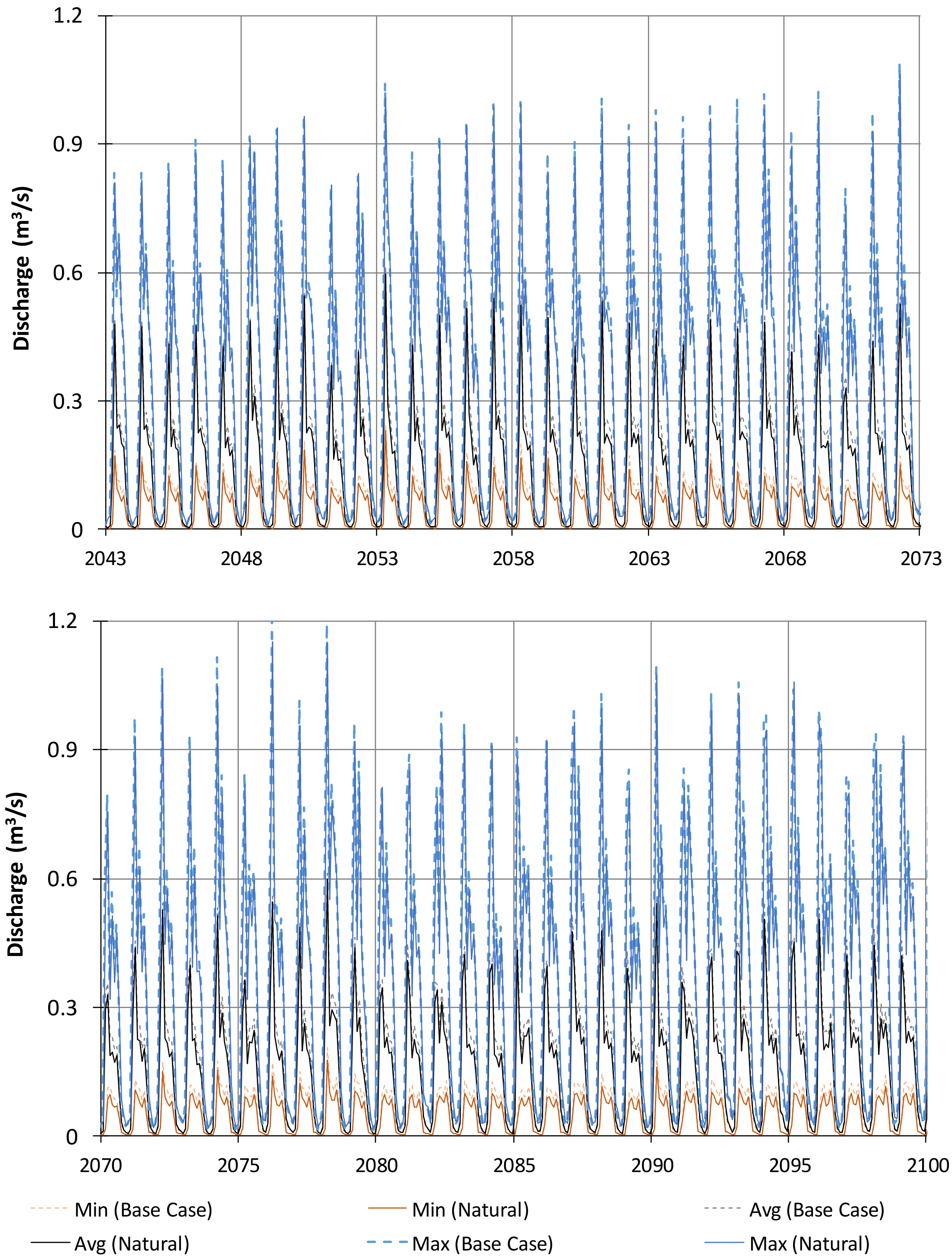

Figure 12-C-3.7-9 Time series plots showing Natural and Base Case monthly discharge data for three statistics (average, min, max). Data shown are for the Post-closure phase of the Project and were computed from 28 WBM realizations. The upper panel shows output for 2043-2073 and the lower plot shows output from 2070-2100.

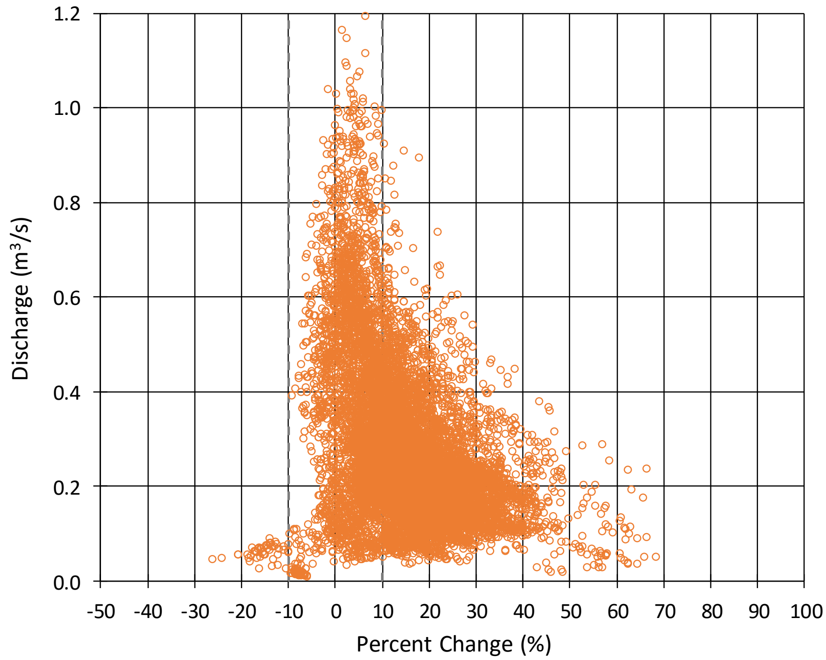

Figure 12-C-3.7-10 Post-closure phase monthly WBM output presented in discharge vs. percent change format. Apr-Oct data are shown for 28 WBM realizations at HC-5.0, noting that +/-10 percent change thresholds are shown with dashed vertical grey lines.

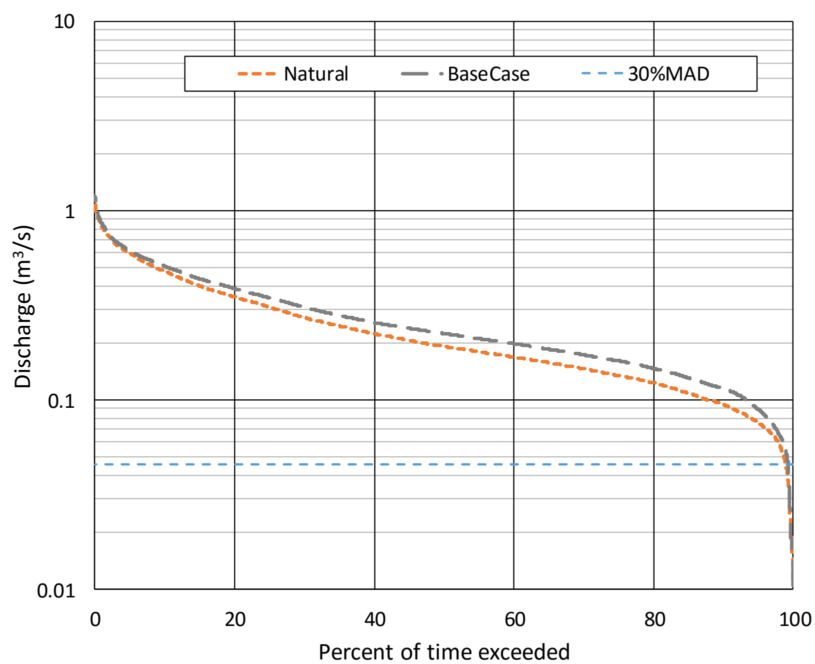

Figure 12-C-3.7-11 Natural and Base Case monthly discharge data for HC-5.0. Data shown are for Post-closure and presented in flow duration curve format. Further, data shown are for the open water period (i.e., Apr-end Oct) with 30% MAD for Post-closure shown by dashed blue line.

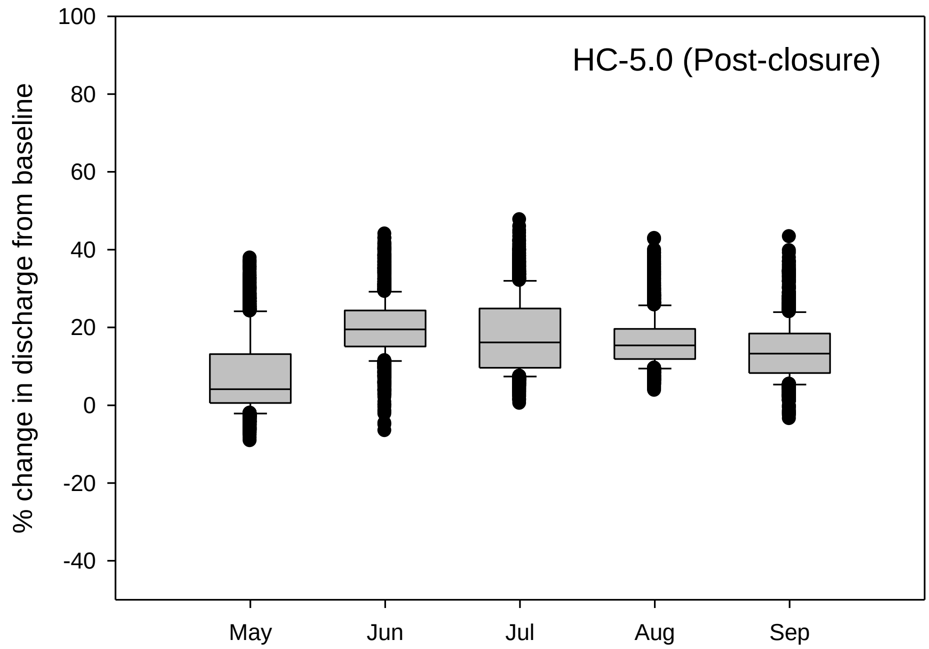

Figure 12-C-3.7-12 Box and Whisker Plot percent change summary for the Post-closure phase at HC-5.0. Median and upper/lower quartile data is shown by shaded box, 5th and 95th percentile data shown with tails and outliers by shaded circles.

Appendix 12-C-4: Proposed Water Quality Benchmark Objectives

GOLDCORP

TECHNICAL MEMORANDUM

To: Jennie Gjertsen **Date:** **March 22, 2017**

From: David Flather **Project #: A362-2**

Subject: Coffee Gold Project – Proposed Water Quality Benchmark Objectives for the Receiving Environment in Support of YESAA Project Proposal

1.0 Overview

In this memorandum, proposed water quality benchmark objectives for the receiving environment are proposed in support of the YESAA Project Proposal Application for the Coffee Gold Project (Project). Water quality objectives are proposed for five receiving catchments potentially influenced by the project (Figure 1-1), namely:

- Halfway Creek (at station HC-2.5);
- Latte Creek (at station CC-1.5);
- YT-24 (at formerly named station ML-1.0);
- Coffee Creek (at station CC-4.5 downstream of the confluence with Latte Creek); and
- Yukon River (as represented at station YUK-5.0)

At this stage, the objectives are proposed in support of the environmental assessment and may undergo further refinement during the Water Use License process. As such, they are defined as "benchmark" objectives. Ultimately, and following further consultation with First Nations and government regulators, as well as incorporation of refinements to the water management and mine plan, it is envisioned that these proposed benchmark objectives will provide a basis for the development final water quality objectives for the project. Final water quality objectives will be used in the derivation of effluent quality standards for the project for all mine contact waters as part of licensing.

For Halfway Creek, water quality benchmark objectives are developed for station HC-2.5, located downstream of the proposed Alpha Waste Rock Storage Facility (Figure 1-1). The Halfway Creek catchment will receive most of the mine contact water discharges from the project. For Latte Creek, water quality benchmark objectives have been developed for station CC-1.5, located in the main stem of Latte Creek and immediately downstream of the confluence with a small ephemeral drainage that will receive intermittent pit dewatering discharges during operations and pit overflow at closure. Similarly, The YT-24 drainage will also receive intermittent pit dewatering discharges during operations and pit overflow at closure into its headwaters; benchmark water quality objectives are established for station YT-24 (formerly named ML-1.0).

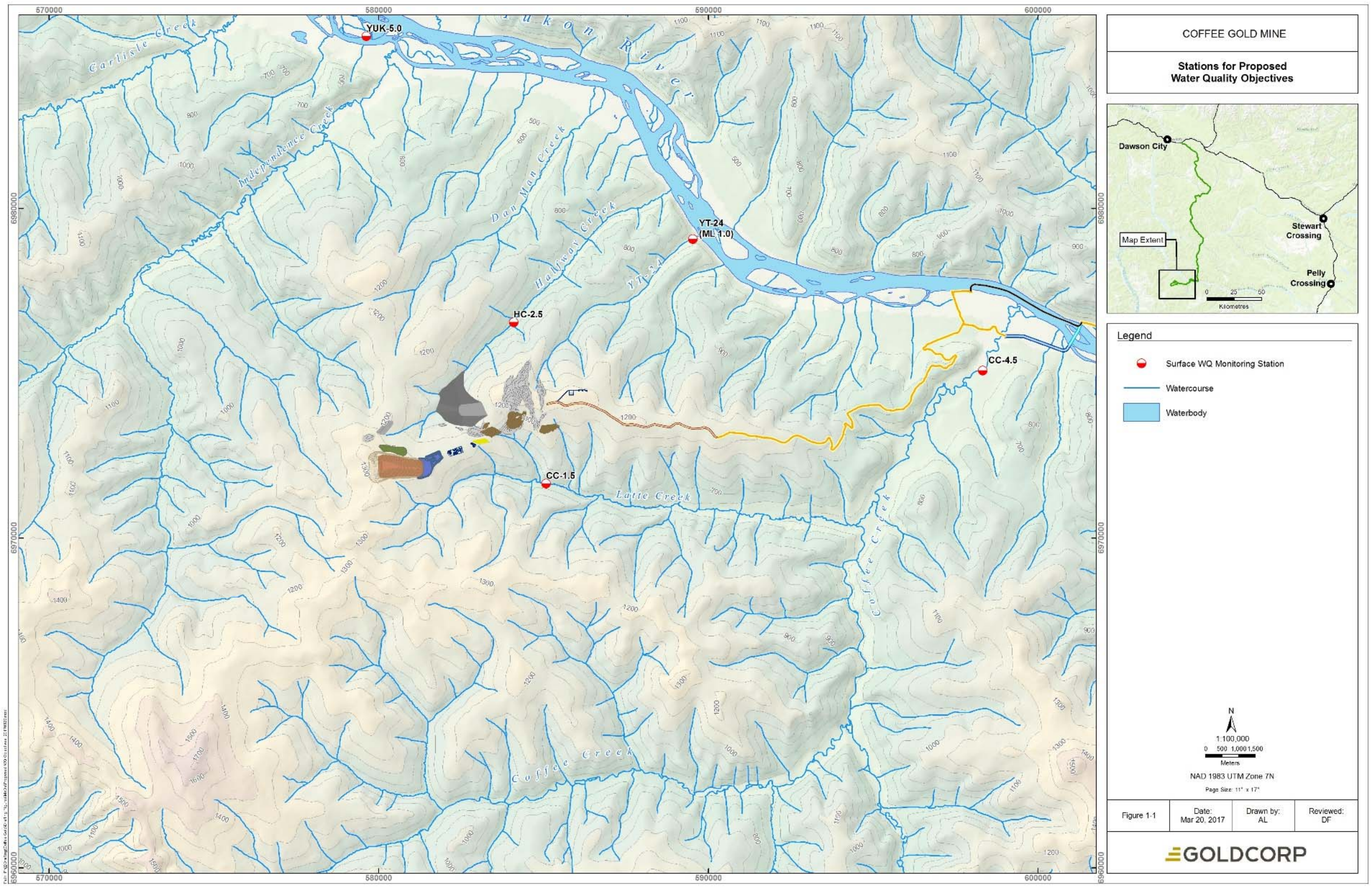

Figure 1-1: Location of Key Water Quality Monitoring Stations for Development of Water Quality Benchmark Objectives in Project Drainages for Environmental Assessment.

For the three catchments (Halfway, Latte and YT-24) receiving direct discharges of mine contact water, benchmark water quality objectives have been developed using both generic water quality guidelines and site-specific water quality objectives. Generic guidelines established by the Canadian Council of Ministers of the Environment (CCME) and/or British Columbia Ministry of Environment (BCMOE) for the protection of aquatic life are proposed when background concentrations are lower than the respective generic guideline. Site-specific water quality objectives are proposed for those parameters naturally elevated in the baseline, including Al, Cu, Fe and U, and are established employing the background concentration procedure as described in CCME (2003) using data collected from 2010 to 2015 for each station. In these instances, the site-specific objective was established using the 95th percentile value from all data collected.

Site-specific, non-degradation benchmark water quality objectives are also developed for lower Coffee Creek and the Yukon River. These non-degradation site-specific objectives are established using data from station CC-4.5 in Coffee Creek and station YUK-5.0 in the Yukon River (Figure 1-1). Non-degradation objectives have been determined using the 90th percentile (P90) of the measured data at each station and are typically much lower than generic water quality guidelines. In instances where the calculated P90 naturally exceeded the corresponding generic guideline for a given parameter, the non-degradation value was determined using the 95th percentile (P95) value of the data.

Baseline water quality data and statistical summaries used for characterization of station HC-2.5 in Halfway Creek, station CC-1.5 in Latte Creek, station YT-24 (ML-1.0), station CC-4.5 in Coffee Creek and station YUK-5.0 in Yukon River are summarized in detail in Appendix A to this memorandum. In addition, a full baseline water quality description is provided in Appendix 12-A.

2.0 Derivation of Benchmark Water Quality Objectives for Halfway Creek, Latte Creek and YT-24

As described previously, water quality objectives for the Coffee Gold Project have been established for the protection of aquatic life for Halfway Creek, Latte Creek, andYT-24. For most parameters, generic water quality guidelines as published in CCME and BCMOE have been adopted. The objectives selected are based on chronic guidelines, (e.g. long-term or 30-day average concentrations) not maximum allowable concentrations with the sole exception being iron which only has a maximum allowable concentration guideline. A number of parameters have hardness dependent criteria and include SO_4, Cd, Cu, Pb, Ni, Ag and Zn. As such, characterization of the hardness for each receiving stream was performed prior to calculation of the appropriate water quality objective.

Water quality objectives for those parameters naturally elevated in the baseline in certain drainages, including Al, Cu, Fe and U, were established employing the background concentration procedure as described in CCME (2003) using the 95th percentile of data collected from 2010 to 2015 for each station.

Rationale for the proposed water quality objective for each parameter is summarized in the remainder of Section 2.0 below. A summary of the proposed objectives for Halfway Creek, Latte Creek and YT-24 is provided in Section 2.20.

2.1 Hardness

For Halfway Creek, Latte Creek and YT-24, water quality is characterized by seasonally comparatively soft to moderately soft waters (between 40 mg/L and 80 mg/L) during open water periods of May to September) and hard waters (ranging from approximately 90 mg/L to 200 mg/L) during lower flow periods and winter low flows. In establishing hardness values for the calculation of hardness dependent benchmark guidelines for SO_4, Cd, Cu, Pb, Ni, Ag and Zn, a conservative approach was adopted that used the lower 25th percentile of the hardness values for each station. For HC-2.5, CC-1.5 and YT-24 these hardness values (expressed as $CaCO_3$) are 65 mg/L, 82 mg/L, and 57 mg/L, respectively (Appendix A).

2.2 Sulphate

British Columbia's approved sulphate water quality guideline for protection of aquatic life is proposed as the water quality objective for the Project (Table 2-1). Increased water hardness has been shown to decrease the toxicity of sulphate to sensitive species, therefore the BC guideline is dependent on the hardness of the water.

Table 2-1
BC Hardness Dependent Sulphate Guideline.

Water hardness (mg/L as $CaCO_3$)	Sulphate guideline (mg/L)
Very soft (0-30)	128
Soft to moderately soft (31-75)	218
Moderately soft/hard to hard (76-180)	309
Very hard (181-250)	429
>250	need to determine based on site water*

* BCMOE (2013) recommends that additional toxicity testing on several species is required if natural background water hardness is greater than 250 mg/L.

As described above, in determining a receiving water benchmark for hardness dependent parameters, the 25th percentile hardness value for each station was conservatively applied (Appendix A). For HC-2.5, CC-1.5 and YT-24 these hardness values (expressed as $CaCO_3$) are 65 mg/L, 82 mg/L, and 57 mg/L, respectively.

Based on Table 2-1, the proposed sulphate benchmark guideline for each station are as follows:

HC-2.5 = **218 mg/L**

CC-1.5 = **309 mg/L**

YT-24 = **218 mg/L**

2.3 Nitrate-N, Nitrite-N and Ammonia-N

Generic BCMOE working 30-day (e.g. chronic) guidelines for nitrate-N, nitrite-N and ammonia-N are adopted for the Coffee Gold Project. For ammonia-N, the approved guidelines are based on temperature and pH; for each drainage and location, a conservative temperature value of 7°C was assumed for each catchment based on the maximum measured temperature in the database for the period of 2010 to 2015. The pH value assumed for each station is based on the mean pH for that station. For Halfway Creek, Latte Creek and YT-24, assumed pH values are 7.7, 7.8 and 7.7, respectively. The proposed water quality benchmark objectives for each location for nitrate-N, and nitrite-N are **3.0 mg/L and 0.02 mg/L, respectively.** The nitrite-N objective used is based on chloride concentrations below 2.0 mg/L in all catchments.

Based on the temperature and pH values assumed for each catchment, the ammonia-N guidelines for each station are as follows:

HC-2.5 = **1.91 mg/L**

CC-1.5 = **1.63 mg/L**

YT-24 = **1.91 mg/L**

2.4 Weak Acid Dissociable CN

The approved BCMOE 30-day average guideline of **5.0 µg/L** for CN_{WAD} is proposed as the water quality objective for HC-2.5, CC-1.5 and YT-24.

2.5 Dissolved Aluminum

The CCME guideline for Al is based on total Al and is a function of pH. At pH values < 6.5 the total Al guideline is 5.0 µg/L. Conversely, for pH values ≥ 6.5, the total Al guideline is 100 µg/L. The BCMOE proposes an Al guideline based on dissolved Al. The BCMOE chronic or 30-day average guideline for dissolved Al is 50 µg/L for water bodies with pH values ≥ 6.5 as occurs in project area streams. For the purposes of establishing water quality benchmark Al guidelines for the Coffee Gold Project, dissolved Al is considered the more appropriate parameter for evaluating potential effects on aquatic biota.

As described in Lorax (2016), baseline water quality data for Halfway Creek, Latte Creek and YT-24 indicate that existing concentrations of dissolved Al often exceeds the generic guideline of 50 µg/L, particularly at stations HC-2.5 and CC-1.5 during high flow conditions. (Figure 2-1 to 2-2; Appendix A).

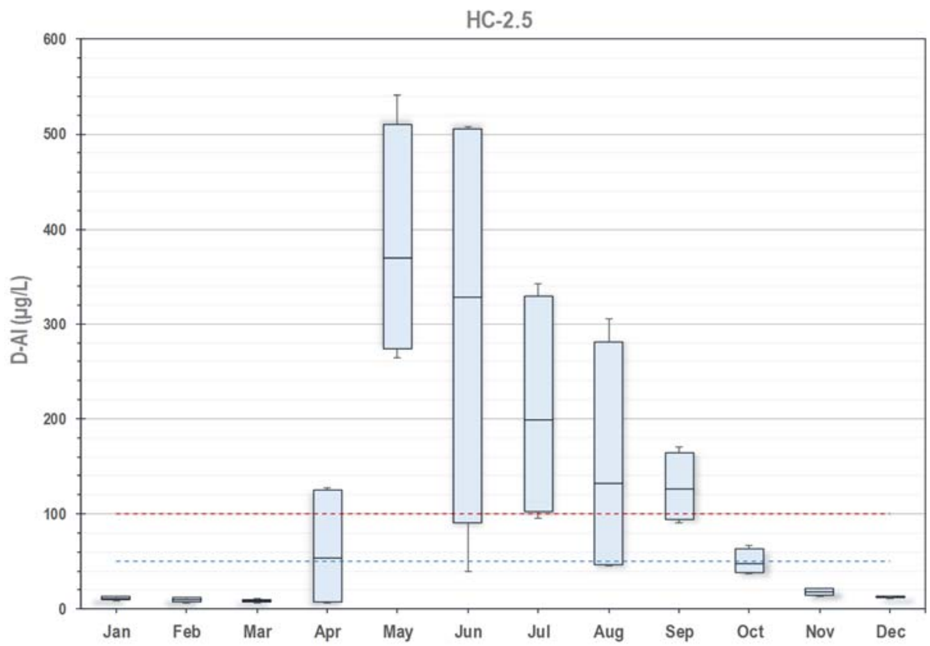

Figure 2-1: **Dissolved Al Box and Whisker plots for Halfway Creek at HC-2.5 compared to BCMOE short-term guideline value (red dashed line) and chronic guideline (blue dashed line) for the protection of aquatic life. Box defines 95th and 5th percentile; horizontal line in box represents mean; upper and lower whisker define max and min, respectively. Data from the period October 2010 to December 2015**

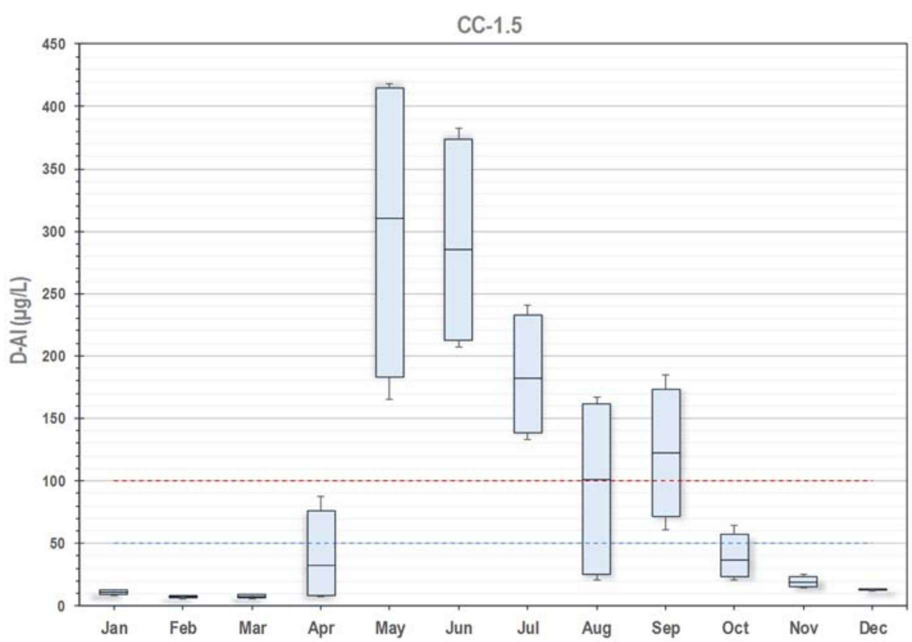

Figure 2-2: **Dissolved Al Box and Whisker plots for Latte Creek at CC-1.5 compared to BCMOE short-term guideline value (red dashed line) and chronic guideline (blue dashed line) for the protection of aquatic life.**

YT-24 also experiences elevated dissolved Al above 50 µg/L, although concentrations are not as elevated compared to Halfway Creek or Latte Creek. Dissolved Al mean and 95th percentile concentrations range from 88 µg/L to 205 µg/L, respectively (Appendix A).

As such, the proposed water quality objective for Al has been developed by establishing the upper limit of the observed background concentration. In this case, defining the upper limit of dissolved Al considered the 95th percentile of the data. Based on the above, the proposed Al water quality objectives for each station are as follows (Appendix A):

HC-2.5 = **403 µg/L**

CC-1.5 = **351 µg/L**

YT-24 = **205 µg/L**

2.6 Antimony

CCME currently does not have a proposed guideline for the protection of aquatic life for Sb. British Columbia does not have an approved aquatic life water quality guideline for Sb, but has a working guideline of 9 µg/L for the protection of aquatic life. Accordingly, the water quality benchmark proposed for Sb at HC-2.5, CC-1.5 and YT-24 is **9 µg/L**.

2.7 Arsenic

The CCME chronic guideline for total As for the protection of aquatic life is **5.0 µg/L**. This guideline is proposed as the water quality benchmark objective for As at HC-2.5 in Halfway Creek CC-1.5 in Latte Creek and YT-24.

2.8 Cadmium

The proposed water quality objective for Cd is based on the most recently updated CCME (2014) guideline revision for Cd. The long-term (chronic) guideline for Cd is hardness dependent based on toxicity testing data that has shown a reduction in Cd toxicity with increasing hardness. As discussed previously, in determining a receiving water benchmark for hardness dependent parameters, the 25th percentile hardness value for each station was conservatively applied (Appendix A). For HC-2.5, CC-1.5, YT-24 these hardness values (expressed as $CaCO_3$) are 65 mg/L, 82 mg/L, and 57 mg/L, respectively. For Cd, the proposed water quality benchmark for each location has been calculated using the following equation:

$$Cd_{\text{water quality objective}} = 10^{\{0.83(\log[\text{hardness}]) - 2.46\}}$$

As such, the proposed total Cd benchmark guideline for each station are as follows:

HC-2.5 = **0.11 µg/L**

CC-1.5 = **0.13 µg/L**

YT-24 = **0.10 µg/L**

2.9 Copper

The chronic water quality guideline for total Cu for the protection of aquatic life is a hardness dependent guideline based on toxicity testing data that has shown a reduction in Cu toxicity with increasing hardness. For water with hardness <82 mg/L as $CaCO_3$, the Cu guideline is 2.0 µg/L.

In determining a receiving water benchmark for hardness dependent parameters for the project, the 25th percentile hardness value for each station was conservatively applied (Appendix A). For HC-2.5, CC-1.5, YT-24 these hardness values (expressed as $CaCO_3$) are 65 mg/L, 82 mg/L, and 57 mg/L, respectively and indicate that a generic Cu benchmark guideline of 2.0 µg/L would apply for all receivers.

As presented in Appendix A, total Cu at each of the above stations routinely exceeds the generic total Cu guideline during the ice-free periods; when surface flows decrease, total Cu values are typically measured below 2.0 µg/L in all catchments. Despite these routine exceedances, Cu toxicity or deleterious effects of elevated Cu concentrations in these receivers is not anticipated owing to the concomitant elevated concentrations of dissolved organic carbon (DOC), most notably during the ice-free periods. Copper-organic complexes are known to reduce the toxicity of Cu to aquatic organisms.

Since the mid to late 1990's numerous studies have concluded that the potential effects of Cu to aquatic organisms are strongly dependent on the concentration of the free metal ion and weak complexes, and not on the total concentration of copper. In oxic freshwaters at circum-neutral pH (e.g., 7.0 to 8.0), Cu(II) is proposed to be the dominant species where it may exist as free aquo ions (Cu^{2+}), hydrolysis products [$Cu_2(OH)_2^{2+}$], Cu-organic complexes, and as complexes with other inorganic ligands (e.g., carbonate, chloride, and sulfate complexes) (Campbell, 1995; Mansilla-Rivera and Nriagu, 1999). Of particular importance and relevance to Coffee Gold, is the understanding that Cu complexes strongly with natural organic matter and these complexes are often the dominant species in freshwater environments (Bazzi *et. al*., 2002).

The effects to aquatic flora and fauna from Cu depend on several site-specific variables, including the overall Cu loading, the assimilative capacity of the receiving environment, and the sensitivity of the various biological receptors. The assimilative capacity of a given system for Cu loadings is a function of both dilution and the nature of Cu-ligand (e.g., copper complexes) reactions in the receiving environment. The toxicity of Cu is known to be affected by numerous physicochemical variables, including pH, hardness, alkalinity, TSS and DOC (Miller, 1980; Luider *et.al*., 2004). The formation of Cu-organic complexes can strongly limit Cu bioavailability and toxicity (Luider *et.al*., 2004). Accordingly, the toxicity of Cu is expected to be attenuated in receiving environments characterized by an abundance of strong Cu-complexing ligands (e.g., humic and fulvic acids) in comparison to systems absent of significant complexation capacity (e.g., soft-water streams with minimal dissolved organic carbon). In a study on a mine-affected receiving stream, experiencing elevated Cu loadings into DOC-enriched surface waters (e.g., DOC 7 to 17 mg/L), toxicity testwork and water effects ratio testing indicated a notable reduction in Cu induced aquatic effects due to limited bioavailability of Cu in the presence of DOC (Martin and Goldblatt, 2007). Indeed, site specific water quality objectives were established that ranged between 42 to 88 µg/L, over which ecological sustainability was predicted (Martin and Goldblatt, 2007; Appendix B for full publication cited).

At the Coffee Project, dissolved organic carbon in project area streams is seasonally elevated with concentrations typically ranging between 10 and 20 mg/L throughout the ice-free period (Appendix 12-A). As such, Cu-organic complexes are anticipated to limit Cu availability to aquatic biota.

In establishing a total Cu water quality benchmark objective for project streams, the 95th percentile was calculated for all data generated from HC-2.5, CC-1.5 and YT-24 and are as follows:.

HC-2.5 = **3.0 µg/L**

CC-1.5 = **3.0 µg/L**

YT-24 = **3.4 µg/L**

2.11 Iron

The BCMOE has proposed total and dissolved maximum allowable Fe concentrations the protection of aquatic life of **1,000 µg/L** and **350 µg/L, respectively**. Observed water quality in Halfway Creek, Latte Creek and YT-24 has not measured total or dissolved Fe concentrations greater than the guideline and therefore the generic guidelines for total and dissolved Fe are proposed for these catchments.

2.12 Lead

The CCME guideline for total Pb is a hardness dependent guideline based on toxicity testing data that has shown a reduction in Pb toxicity with increasing hardness. As discussed previously, in determining a receiving water benchmark for hardness dependent parameters, the 25th percentile hardness value for each station was conservatively applied (Appendix A). For HC-2.5, CC-1.5 and YT-24 these hardness values (expressed as $CaCO_3$) are 65 mg/L, 82 mg/L, and 57 mg/L, respectively. For Pb, the proposed water quality benchmark for each location has been calculated using the following equation:

$$\text{Benchmark total Pb } (\mu g/L) = e^{\{1.273[\ln(\text{hardness})]-4.705\}}$$

As such, the proposed total Pb benchmark guideline for each station are as follows:

HC-2.5 = **1.8 µg/L**

CC-1.5 = **2.5 µg/L**

YT-24 = **1.5 µg/L**

2.13 Mercury

The CCME chronic guideline for total Hg for the protection of aquatic life is **0.026 µg/L**. This guideline is proposed as the water quality benchmark objective for Hg at HC-2.5, CC-1.5 and YT-24.

2.14 Molybdenum

The CCME chronic water quality guideline for total Mo for the protection of aquatic life is **73 µg/L**. This guideline is proposed as the water quality benchmark objective for Mo at HC-2.5, CC-1.5 and YT-24.

2.15 Nickel

The CCME guideline for total Ni is a hardness dependent guideline based on toxicity testing data that has shown a reduction in Ni toxicity with increasing hardness. As discussed previously, in determining a receiving water benchmark for hardness dependent parameters, the 25th percentile hardness value for each station was conservatively applied (Appendix A). For HC-2.5, CC-1.5 and YT-24 these hardness values (expressed as $CaCO_3$) are 65 mg/L, 82 mg/L, and 57 mg/L, respectively. For Ni, the proposed water quality benchmark for each location has been calculated using the following equation:

$$\text{Benchmark total Ni } (\mu g/L) = e^{\{0.76[\ln(\text{hardness})]+1.06\}}$$

As such, the proposed total Ni benchmark guideline for each station are as follows:

HC-2.5 = **69 µg/L**

CC-1.5 = **82 µg/L**

YT-24 = **61 µg/L**

2.16 Selenium

The BCMOE approved 30-day working guideline for Se for the protection of aquatic life is **2.0 µg/L**. This value is the proposed benchmark for each location at HC-2.5, CC-1.5 and YT-24.

2.17 Silver

The CCME approved chronic total Ag guideline for the protection of aquatic life is **0.25 µg/L**. This value is the proposed benchmark for each location at HC-2.5, CC-1.5 and YT-24.

2.18 Uranium

At the Coffee Creek Gold Project, uranium (U) shows natural enrichment in numerous project area streams. During winter base flow periods, and following periods of prolonged limited precipitation during spring/summer periods, total U concentrations reach maxima of between 80 to 100 µg/L in Halfway Creek at Station HC-2.5 and 30 to 35 µg/L in Latte Creek at Station CC-1.5 (Figure 2-3 and Figure 2-4, respectively).

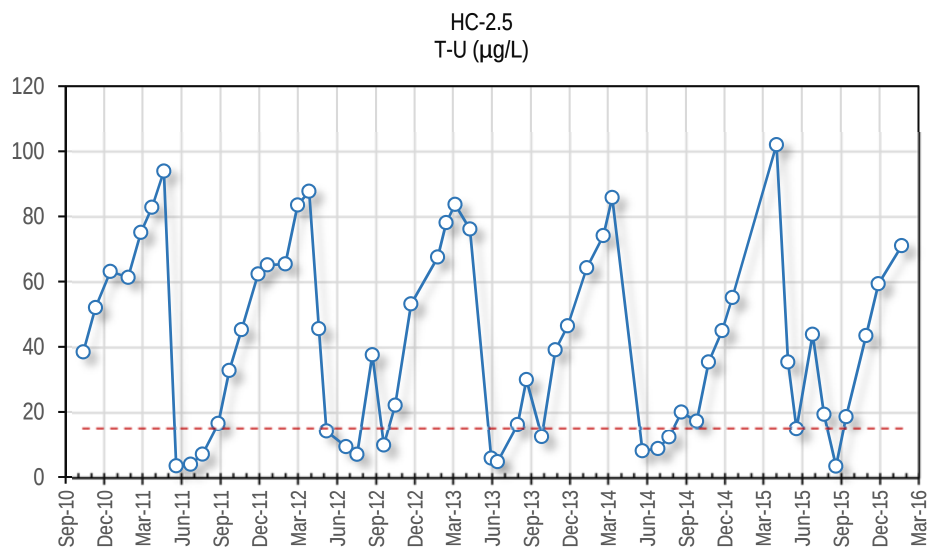

Figure 2-3: Background total U in Halfway Creek at HC-2.5 for the period October 2010 to December 2015 compared to generic CCME guideline value (red dashed line) for the protection of aquatic life.

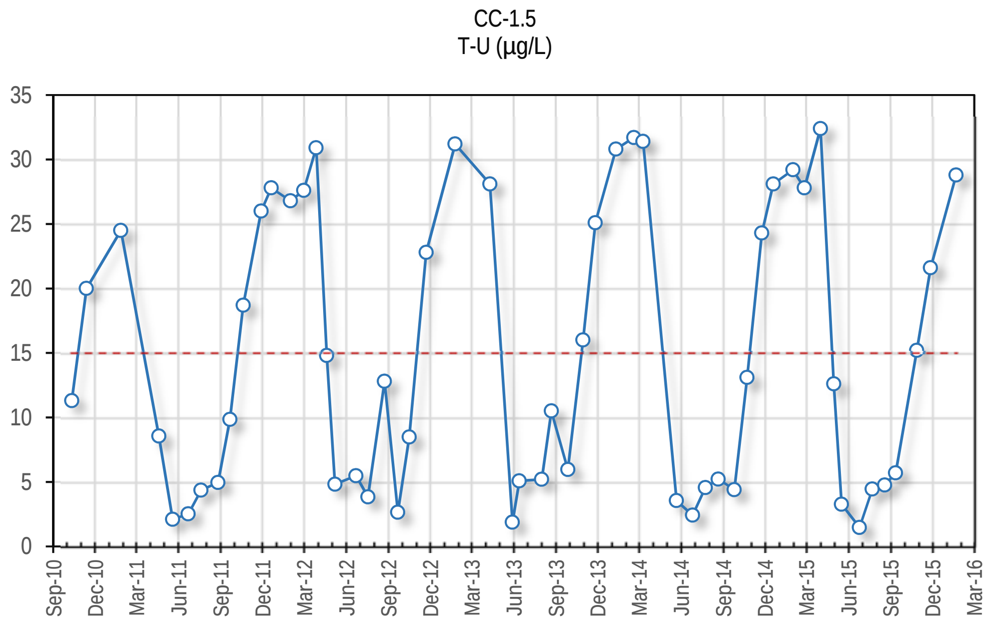

Figure 2-4: Background total U in Latte Creek at station CC-1.5 for the period October 2010 to December 2015 compared to generic CCME guideline value (red dashed line) for the protection of aquatic life.

These observed values are considerably higher than the generic CCME guideline of 15 µg/L for the protection of aquatic life. The high magnitude values can be attributed to the input of U-enriched groundwater which sustains base flow conditions during the ice-up period and is an important contributor to flow during prolonged dry periods. Generally, during the freshet and summer periods, the introduction of surface runoff dilutes the groundwater signature, resulting in lower U concentrations. However, summer values well in excess of 15 µg/L have been measured in 2012, 2013, 2014 and 2015 at station HC-2.5 when precipitation has been limited (Figure 2-3). Conversely, YT-24 does not receive significant groundwater inputs and total U concentrations have been measured to narrowly range between a minimum of 0.45 µg/L and a maximum of 2.8 µg/L with a 95th percentile value of 1.9 µg/L (Appendix A).

In natural systems, the bioavailability of U is strongly influenced by its speciation (Markich, 2002). In oxic surface waters at circumneutral pH, such as those at the Coffee Creek project, U(VI) is predicted to be the dominant species. U(VI) can be present in a variety of forms including free uranyl ions (e.g., UO_2^{2+} and UO_2OH^+), inorganic complexes (U-carbonates) and organic complexes (e.g., U complexes with DOC). Available evidence in the primary literature suggests that UO_2^{2+} and UO_2OH^+ are the most bioavailable forms of U(VI) (Markich, 2002). U-carbonate complexes and U-organic complexes show decreased bioavailability. In particular, DOC (in the form of fulvic and humic acids) is a very effective complexing agent of U in freshwaters, and can greatly decrease U bioavailability and toxicity (Trenfield *et al*., 2011; Turner *et al*., 2012; full articles provided in Appendix B).

The seasonal changes in U concentration described above are accompanied by seasonal shifts in other parameters that have relevance to U bioavailability. Bicarbonate alkalinity (HCO_3^-), for example, shows congruent maxima with U during the winter period (i.e., groundwater source). In contrast, concentrations of dissolved organic carbon (DOC) are highest during the ice-free months owing to the enrichment of DOC in terrestrial runoff (Figure 2-5 and Figure 2-6).

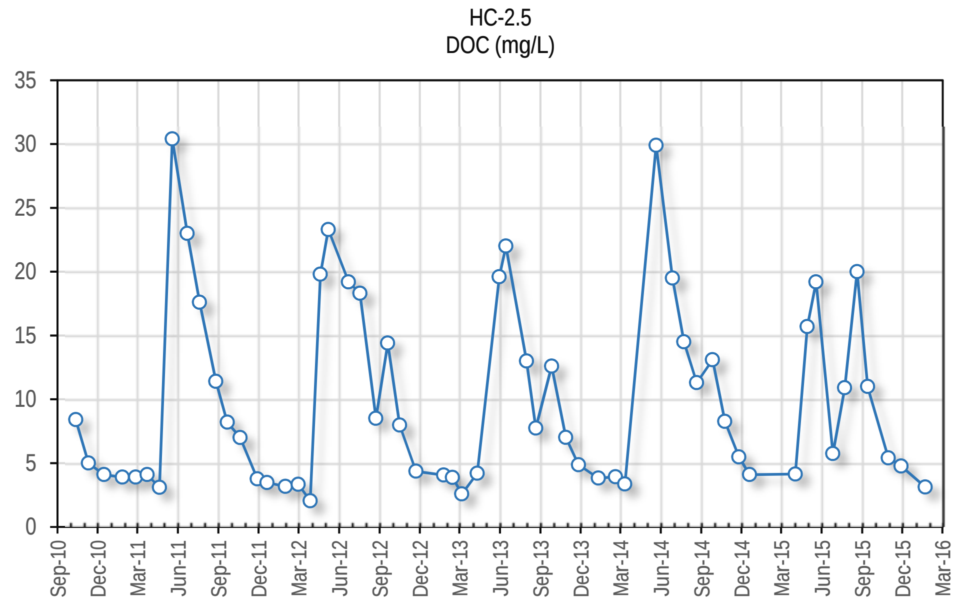

Figure 2-5: Dissolved organic carbon in Halfway Creek at station HC-2.5 for the period October 2010 to December 2015

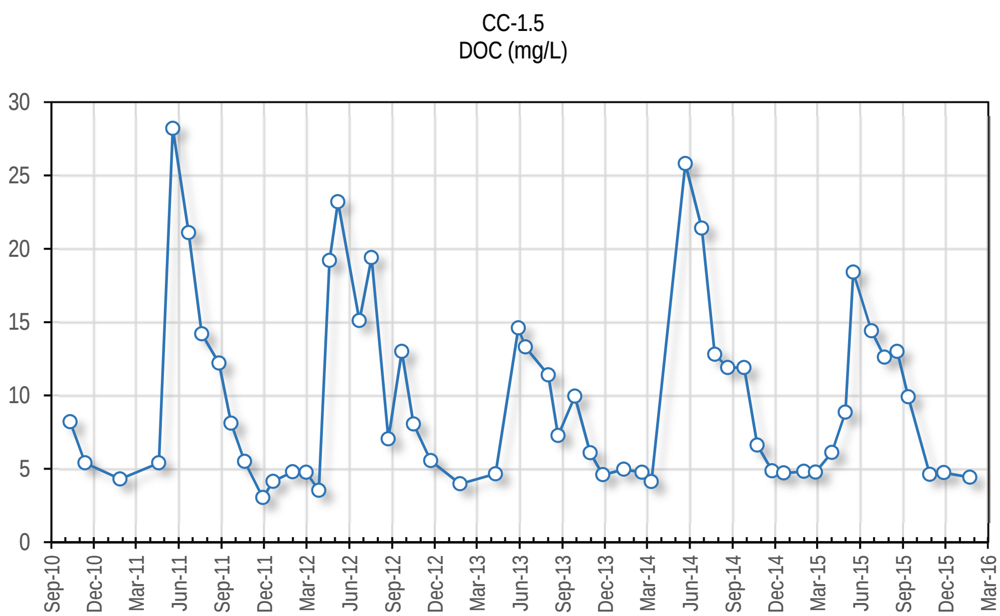

Figure 2-6: Dissolved organic carbon in Latte Creek at station CC-1.5 for the period October 2010 to December 2015

These seasonal cycles will have a corresponding effect on U speciation and bioavailability. Specifically, during the winter period, U can be expected to be dominated by U-carbonate complexes, while during the summer period, U-DOC complexes will become dominant. For both the winter and summer periods in project area streams at the Coffee Creek project, U bioavailability will be reduced by complexation with carbonate and DOC, respectively.

Site-specific chronic toxicity testing was performed in February 2016, using water collected from HC-2.5 and CC-1.5. At that time, total U concentrations in test waters were 78 µg/L and 31 µg/L for HC-2.5 and CC-1.5, respectively. Toxicity testing was completed at Nautilus Environmental (Burnaby, BC). The chronic toxicity tests conducted on these samples were performed using *Ceriodaphnia dubia*. Methods for the toxicity tests using *C. dubia* were conducted according to procedures described by Environment Canada (2007). Results of the toxicity testing indicated there were no adverse effects on survival or reproduction of *C. dubia* in either of the winter low flow site water samples tested despite U concentrations in excess of 75 µg/L (see Appendix C1 for full report). Winter low flow waters had correspondingly low DOC concentrations of approximately 4.0 mg/L for each station.

Uranium complexation with DOC can be expected to result in a pronounced reduction in U bioavailability to aquatic taxa. This conclusion is based on studies in the primary literature that have examined the relationship between DOC concentration and U toxicity. In a toxicity study using fish, invertebrates and algae, for example, U toxicity was reduced by up to a factor of 10 to 20 in waters containing 10 to 20 mg/L DOC, relative to control (DOC-free) water (Trenfield *et al*., 2011; Appendix B). Site waters at the Coffee Creek project show similar levels of DOC during the ice-free months, with values typically ranging between 10 to 20 mg/L between May and September (at CC-1.5 and HC-2.5). To evaluate the potential reduction in U toxicity from DOC, a second round of chronic toxicity testing using *C. dubia* was performed on site waters collected at HC-2.5 and CC-1.5 during June, 2016. However, for this test, individual chronic toxicity tests were performed on site waters spiked with increasing U concentrations (e.g. 0, 10, 20, 40, 80, 160 and 320 µg/L). There were no adverse effects on survival in any of the samples tested; the resulting LC values were therefore greater than the highest concentration tested (e.g. >351 µg/L for HC-2.5 spiked with 320 µg/L and naturally containing 21 µg/L U at the time of sample collection in June 2016). For the sample prepared with laboratory water (sample "Lab"), there were observed adverse effects on reproduction; the resulting IC25 and IC50 values were 106.2 and 141.6 µg/L U, respectively (see Appendix C2 for full report). Conversely, there were no adverse effects on reproduction in any samples CC1.5 or HC2.5 at all U concentrations.

Given the naturally enriched U at station HC-2.5 and CC-1.5, and the seasonal cycle of DOC enrichment, the proposed water quality benchmark for U for these stations has been developed by establishing the upper limit of the observed background concentration. Defining the upper limit of U for each receiver was accomplished by calculating the 95th percentile of the data. The 95th percentile values for total U at HC-2.5 and CC-1.5 are **86 µg/L** and **31 µg/L**, respectively (Appendix A; Figure 2-7 and Figure 2-8). Toxicity testing to date provides site specific support that the proposed objectives are protective of the aquatic environment.

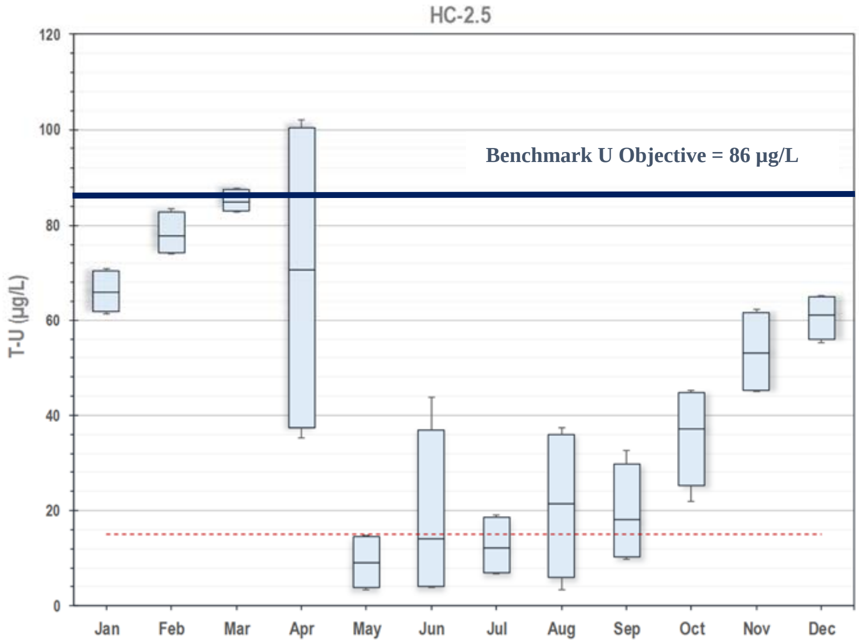

Figure 2-7: Proposed total U benchmark water quality objective for Halfway Creek HC-2.5. Box and whisker plots for monthly total U statistics. Box defines 95th and 5th percentile; horizontal line in box represents mean; upper and lower whisker defines max and min, respectively. Data from the period October 2010 to December 2015

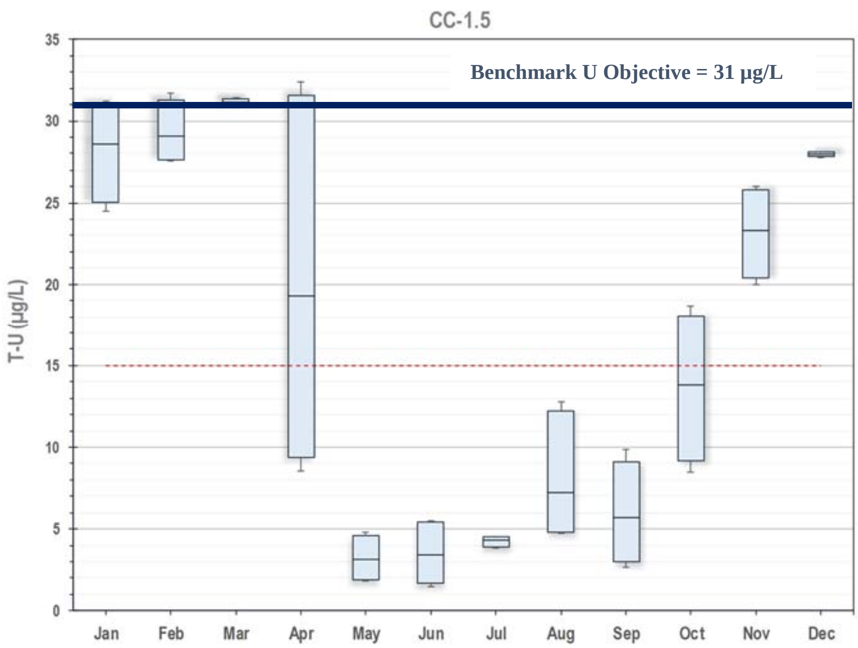

Figure 2-8: Proposed total U benchmark water quality objective for Latte Creek CC-1.5. Box and whisker plots for monthly total U statistics. Box defines 95th and 5th percentile; horizontal line in box represents mean; upper and lower whisker define max and min, respectively. Data from the period October 2010 to December 2015

For YT-24, the generic CCME guideline for the protection of aquatic life of **15 µg/L** is proposed.

2.19 Zinc

The previous CCME chronic guideline for total Zn for the protection of aquatic life was 30 µg/L. More recently (2016), CCME has prepared a revised guideline for freshwater for Zn that is in draft form. The revised Zn chronic guideline includes provisions for hardness and pH in the calculation of a benchmark concentration for the protection of aquatic life:

$$\text{Benchmark Zn } (\mu g/L) = e^{\{0.995[\ln(\text{hardness})]-0.847(\text{pH})+4.932\}}$$

As discussed previously, in determining a receiving water benchmark for hardness dependent parameters, the 25th percentile hardness value for each station was conservatively applied (Appendix A). For HC-2.5, CC-1.5 and YT-24 these hardness values (expressed as $CaCO_3$) are 65 mg/L, 82 mg/L, and 57 mg/L, respectively. To account for pH in the determination, the mean pH value from all the data for each station was also used in the calculations. For HC-2.5, CC-1.5, and YT-24, the mean pH values assumed were 7.7, 7.8, and 7.7, respectively (Appendix A).

As such, the proposed total Zn benchmark guideline for each station are as follows:

HC-2.5 = **13 µg/L**

CC-1.5 = **15 µg/L**

YT-24 = **11 µg/L**

2.20 Summary of Proposed Water Quality Benchmark Objectives for Halfway Creek, Latte Creek and YT-24

Table 2-2 provides a summary of the proposed water quality benchmark objectives for Halfway Creek, Latte Creek, and YT-24.

Table 2-2
Summary of Proposed Water Quality Benchmark Objectives for Halfway Creek, Latte Creek and YT-24

Parameter List		Units	Halfway Creek	Latte Creek	YT-24	Regulatory Source
Dissolved Parameters	SO_4	mg/L	218	309	218	BC WQO
	Nitrate-N	mg/L	3	3	3	BC WQO
	Nitrite-N	mg/L	0.02	0.02	0.02	BC WQO
	NH_3-N	mg/L	1.91	1.63	1.91	BC WQO
	CN_{WAD}	µg/L	5	5	5	BC WQO
	Al (diss)	µg/L	403	351	205	SSWQO
Total Metals	Sb	µg/L	9	9	9	BC WQO
	As	µg/L	5	5	5	CCME
	Cd	µg/L	0.11	0.13	0.1	CCME
	Cu	µg/L	3	3	3.4	SSWQO
	Fe	µg/L	1000	1000	1000	BC WQO
	Fe (dissolved)	µg/L	350	350	350	BC WQO
	Pb	µg/L	1.8	2.5	1.5	CCME
	Hg	µg/L	0.026	0.026	0.026	CCME
	Mo	µg/L	73	73	73	CCME
	Ni	µg/L	69	82	61	CCME
	Se	µg/L	2	2	2	BC WQO
	Ag	µg/L	0.25	0.25	0.25	CCME
	U	µg/L	86	31	15	SSWQO/CCME
	Zn	µg/L	13	15	11	CCME (draft)

Note: all metals and metalloids are as total unless otherwise noted

3.0 Derivation of Benchmark Water Quality Objectives for Coffee Creek and Yukon River

As indicated previously, non-degradation water quality objectives are proposed for Coffee Creek (CC-4.5) and Yukon River (YUK-5.0) (Figure 1-1). Non-degradation objectives have been determined using the 90th percentile (P90) of the measured data at each station and are typically much lower than generic water quality guidelines (Table 3-1). In instances where the P90 exceeded the corresponding generic guideline, the non-degradation value was determined using the 95th percentile (P95) value of the data. Examples where the P95 value is used include:

- Total Cu – both CC-4.5 and YUK-5.0;
- Total Fe –YUK-5.0;
- Total Zn –YUK-5.0; and
- Dissolved Al – CC-4.5

Table 3-1
Summary of Proposed Water Quality Benchmark Objectives for Coffee Creek and Yukon River

Parameter List		Units	Proposed Water Quality Objectives		CC-4.5 Generic Guideline (for comparison only)	YUK-5.0 Generic Guideline (for comparison only)	Regulatory Source for Generic Guideline
			Coffee Creek CC-4.5	Yukon River YUK-5.0			
Dissolved Parameters	SO_4	mg/L	77	25	218	309	BC WQO
	Nitrate-N	mg/L	0.6	0.2	3	3	BC WQO
	Nitrite-N	mg/L	0.05	0.05	0.02	0.02	BC WQO
	NH_3-N	mg/L	0.04	0.03	1.91	1.02	BC WQO
	CN_{WAD}	µg/L	non-detectable	non-detectable	5	5	BC WQO
Total Metals and Metalloids	Sb	µg/L	0.14	0.2	9	9	BC WQO
	As	µg/L	0.6	1.3	5	5	CCME
	Cd	µg/L	0.05	0.21	0.12	0.14	CCME
	Cu	µg/L	4.2 [1]	5.5 [1]	2.84	3.48	BC WQO
	Fe	µg/L	349	2066 [1]	1000	1000	BC WQO
	Pb	µg/L	0.21	1.1	2.06	2.66	CCME
	Hg	µg/L	0.01	0.01	0.026	0.026	CCME
	Mo	µg/L	0.74	1.3	73	73	CCME
	Ni	µg/L	1.5	4.6	73	86	CCME
	Se	µg/L	0.1	0.56	2	2	BC WQO
	Ag	µg/L	0.007	0.02	0.25	0.25	CCME
	U	µg/L	3.6	1	15	15	CCME
	Zn	µg/L	5.2	17 [1]	17	13.5	CCME (draft)
Dissolved Metals and Metalloids	Al	µg/L	263 [1]	45	50	50	BC WQO
	Sb	µg/L	0.12	0.12			
	As	µg/L	0.49	0.54			
	Cd	µg/L	0.031	0.06			
	Cu	µg/L	3.3	1.7			
	Fe	µg/L	203	59	350	350	BC WQO
	Pb	µg/L	0.055	0.06			
	Hg	µg/L	0.01	0.01			
	Mo	µg/L	0.68	1.25			
	Ni	µg/L	1.3	1.7			
	Se	µg/L	0.12	0.5			
	Ag	µg/L	0.005	0.005			
	U	µg/L	3.8	1			
	Zn	µg/L	2.2	2.8			

All values for CC-4.5 and YUK-5.0 are 90th percentile of data unless otherwise noted.
1: based on 95th percentile of data
DL = detection limit

Water quality objectives have also been proposed for dissolved constituents for all metals and metalloids. Dissolved objectives are proposed to be utilized in unison with the total metal objectives and are designed to account for differences in concentrations owing to potentially intermittent periods of elevated total suspended solids (TSS). For Coffee Creek and Yukon River, elevated TSS can correspond with elevated total metal concentrations; however, dissolved concentrations typically are poorly correlated to totals in these receivers.

It should be noted that in 2017, additional water quality monitoring stations will be established in Coffee Creek and Yukon River. Specifically, a new station in Coffee Creek will be established immediately downstream of the confluence of Latte Creek. In addition, three new stations will be established in Yukon River, each station located immediately downstream of the confluence with Coffee Creek, YT-24 and Halfway Creek, respectively.

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APPENDIX A
STATISTICAL SUMMARIES

CC-1.5

CC-4.5

HC-2.5

YT-24 (station ML-1)

YUK-5.0

	CC-1.5											
	CC-1.5	CC-1.5	CC-1.5	CC-1.5	CC-1.5	CC-1.5	CC-1.5	CC-1.5	CC-1.5	CC-1.5	CC-1.5	CC-1.5
	MIN	P5	P10	P25	MEAN	P50	P75	P90	P95	MAX	COUNT	COUNT <DL
Physical Parameters												
pH (s.u.)	7.0	7.1	7.4	7.6	7.8	7.9	8.0	8.2	8.3	8.3	55	0
Cond-L (uS/cm)	58	70	90	159	439	448	708	781	816	861	55	0
TSS (mg/L)	<2	1.00	1.00	1.00	7.4	1.00	3.3	16	34	155	55	32
TDS (mg/L)	32	73	84	123	302	308	470	520	548	620	55	0
T-Alk (mg/L)	13	19	26	43	113	110	180	202	214	231	55	0
T-Hard (mg/L)	26	38	45	82	227	218	369	408	425	469	55	0
Anions												
Sulphate (mg/L)	<1	11	16	31	111	117	186	203	233	248	54	1
Cl (mg/L)	<1	0.50	0.50	0.51	0.98	0.70	0.81	1.1	1.5	10	54	13
F (mg/L)	0.030	0.032	0.038	0.047	0.071	0.072	0.094	0.11	0.12	0.12	55	0
Nutrients												
T-NH3 (mg/L)	<0.01	0.0050	0.0062	0.011	0.028	0.015	0.023	0.040	0.050	0.45	55	5
NO2+NO3 (mg/L)	0.056	0.060	0.066	0.10	0.19	0.18	0.23	0.32	0.39	0.40	20	0
NO2 (mg/L)	<0.004	0.0020	0.0020	0.0020	0.011	0.0050	0.01	0.05	0.05	0.05	54	34
NO3 (mg/L)	<0.042	0.0400	0.0577	0.1600	0.21	0.22	0.28	0.34	0.34	0.40	55	18
D-P (mg/L)	<0.004	0.0020	0.0021	0.0026	0.0048	0.0042	0.0061	0.0076	0.0098	0.016	48	5
TOC (mg/L)	3.7	4.3	4.5	5.3	10	7.3	14	20	23	30	55	0
DOC (mg/L)	3.0	4.1	4.3	4.8	9.8	7.3	13	19	22	28	55	0
WAD-CN (mg/L)	<0.001	0.00050	0.00050	0.00050	0.00080	0.00071	0.00096	0.0012	0.0015	0.0023	54	20
Total Metals												
T-Al (ug/L)	6.9	10	12	18	190	62	215	436	660	2320	55	0
T-Sb (ug/L)	0.035	0.074	0.083	0.095	0.11	0.10	0.11	0.13	0.15	0.20	55	0
T-As (ug/L)	0.28	0.52	0.58	0.66	0.95	0.82	1.1	1.5	1.6	3.8	55	0
T-Ba (ug/L)	16	22	25	31	57	60	83	89	91	99	55	0
T-Be (ug/L)	<0.02	0.0100	0.0100	0.0100	0.024	0.014	0.032	0.048	0.059	0.095	55	24
T-Bi (ug/L)	<0.01	0.0050	0.0050	0.0050	0.0075	0.0050	0.0050	0.020	0.020	0.049	55	52
T-B (ug/L)	<20	10.0	10.0	35	41	50	50	50	50	50	55	55
T-Cd (ug/L)	<0.01	0.0050	0.0060	0.0090	0.020	0.015	0.026	0.045	0.051	0.070	55	4
T-Ca (mg/L)	6.8	10	12	22	60	59	97	109	111	122	55	0
T-Cr (ug/L)	<0.2	0.100	0.10	0.15	0.44	0.28	0.53	0.65	1.2	4.1	55	6
T-Co (ug/L)	0.019	0.021	0.021	0.029	0.12	0.045	0.12	0.30	0.49	1.2	55	0
T-Cu (ug/L)	0.93	0.96	1.00	1.1	1.7	1.5	2.0	2.7	3.0	4.5	55	0
T-Fe (ug/L)	4.1	5.9	7.4	11	199	71	195	326	793	3140	55	0
T-Pb (ug/L)	<0.01	0.0050	0.0062	0.011	0.11	0.039	0.083	0.26	0.44	1.8	55	4
T-Li (ug/L)	<1	0.79	0.94	1.2	2.0	2.1	2.7	3.2	3.2	4.6	55	1
T-Mg (mg/L)	2.2	3.0	3.6	6.7	19	18	31	34	36	40	55	0
T-Mn (ug/L)	1.1	2.0	2.5	3.6	24	7.3	18	63	92	304	55	0
T-Hg (ug/L)	<0.004	0.0020	0.0020	0.0029	0.0075	0.0100	0.0100	0.0100	0.011	0.020	55	36
T-Mo (ug/L)	<0.1	0.060	0.095	0.14	0.26	0.24	0.37	0.39	0.46	1.0	55	1
T-Ni (ug/L)	0.36	0.40	0.42	0.45	0.79	0.57	0.89	1.4	1.8	2.8	55	0
T-K (mg/L)	0.57	0.73	0.94	1.3	3.3	3.4	4.9	5.8	5.9	6.4	55	0
T-Se (ug/L)	<0.08	0.048	0.052	0.075	0.15	0.11	0.22	0.32	0.33	0.37	55	1
T-Si (ug/L)	1130	2455	3078	4910	5000	5260	5545	6010	6349	7480	55	0
T-Ag (ug/L)	<0.01	0.0050	0.0050	0.0050	0.0059	0.0050	0.0050	0.0084	0.0099	0.017	55	42
T-Na (mg/L)	0.52	0.95	1.3	1.9	4.1	4.4	5.9	6.5	6.8	11	55	0
T-Sr (ug/L)	54	77	94	169	484	468	769	895	926	1100	55	0
T-Tl (ug/L)	<0.004	0.0020	0.0020	0.0030	0.0042	0.0030	0.0040	0.0053	0.011	0.031	55	2
T-U (ug/L)	1.5	2.3	2.9	4.8	15	13	26	30	31	32	55	0
T-Zn (ug/L)	0.20	0.32	0.40	0.58	1.8	1.1	1.8	4.5	5.8	9.5	55	0
Dissolved Metals												
D-Al (ug/L)	6.5	7.8	8.6	13	101	35	166	262	351	418	55	0
D-Sb (ug/L)	0.052	0.071	0.077	0.093	0.10	0.11	0.11	0.12	0.12	0.14	55	0
D-As (ug/L)	0.27	0.45	0.54	0.59	0.79	0.69	0.95	1.2	1.3	1.5	55	0
D-Ba (ug/L)	17	21	24	29	56	60	81	90	93	94	55	0
D-Be (ug/L)	<0.02	0.0100	0.0100	0.0100	0.020	0.010	0.029	0.042	0.046	0.061	55	27
D-Bi (ug/L)	<0.01	0.0050	0.0050	0.0050	0.0051	0.0050	0.0050	0.0050	0.0053	0.0070	55	52
D-B (ug/L)	<20	10.0	10.0	15.0	38	50	50	50	50	50	55	55
D-Cd (ug/L)	<0.01	0.0050	0.0056	0.0075	0.020	0.012	0.024	0.039	0.062	0.11	55	5
D-Ca (mg/L)	9.4	10	12	21	58	53	96	107	111	118	55	0
D-Cr (ug/L)	<0.2	0.100	0.10	0.15	0.29	0.20	0.46	0.55	0.60	0.76	55	3
D-Co (ug/L)	0.020	0.022	0.022	0.026	0.061	0.038	0.064	0.12	0.20	0.30	55	0
D-Cu (ug/L)	0.79	0.96	1.0	1.1	1.5	1.5	1.9	2.1	2.4	2.7	55	0
D-Fe (ug/L)	3.7	4.6	5.0	7.5	74	17	125	183	281	333	55	0
D-Pb (ug/L)	<0.01	0.0050	0.0050	0.0070	0.061	0.015	0.041	0.097	0.17	0.96	55	10
D-Li (ug/L)	0.60	0.75	0.84	1.2	1.9	2.1	2.7	2.9	3.0	3.8	55	0
D-Mg (mg/L)	2.5	3.3	3.8	6.6	18	17	30	34	35	40	55	0
D-Mn (ug/L)	1.5	1.8	2.2	2.9	11	4.5	10	16	52	84	55	0
D-Hg (ug/L)	<0.00002	0.0020	0.0020	0.0021	0.0066	0.0084	0.0100	0.0100	0.0100	0.014	45	30
D-Mo (ug/L)	<0.1	0.055	0.090	0.13	0.24	0.24	0.34	0.41	0.46	0.62	55	3
D-Ni (ug/L)	0.37	0.39	0.41	0.45	0.69	0.58	0.83	1.1	1.4	1.8	55	0
D-K (mg/L)	0.58	0.76	0.88	1.3	3.2	3.4	4.9	5.7	5.9	6.3	55	0
D-Se (ug/L)	<0.08	0.040	0.046	0.071	0.15	0.13	0.24	0.32	0.33	0.35	55	4
D-Si (ug/L)	1380	2309	3272	4635	4879	5110	5590	5786	5956	7140	55	0
D-Ag (ug/L)	<0.01	0.0050	0.0050	0.0050	0.0051	0.0050	0.0050	0.0050	0.0060	0.0070	55	50
D-Na (mg/L)	0.71	1.1	1.3	2.1	4.2	4.3	5.8	6.6	6.9	13	55	0
D-Sr (ug/L)	62	86	96	162	481	468	767	884	908	1100	55	0
D-Tl (ug/L)	<0.004	0.0020	0.0020	0.0020	0.0029	0.0030	0.0030	0.0040	0.0042	0.0080	55	7
D-U (ug/L)	1.5	2.2	2.8	4.6	15	13	26	30	31	33	55	0
D-Zn (ug/L)	0.30	0.34	0.45	0.60	1.6	1.0	2.0	3.8	4.7	10	55	0

	CC-4.5											
	CC-4.5	CC-4.5	CC-4.5	CC-4.5	CC-4.5	CC-4.5	CC-4.5	CC-4.5	CC-4.5	CC-4.5	CC-4.5	CC-4.5
	MIN	P5	P10	P25	MEAN	P50	P75	P90	P95	MAX	COUNT	COUNT <DL
Physical Parameters												
pH (s.u.)	4.8	7.0	7.3	7.4	7.5	7.6	7.7	7.8	7.9	8.0	56	0
Cond-L (uS/cm)	42	77	98	147	202	208	263	297	307	328	56	0
TSS (mg/L)	<2	1.00	1.00	1.00	8.3	1.00	1.9	8.8	41	200	56	38
TDS (mg/L)	36	82	90	118	143	149	173	193	199	210	56	0
T-Alk (mg/L)	8.8	17	26	39	47	49	58	65	66	79	56	0
T-Hard (mg/L)	22	42	46	71	94	95	122	138	145	153	56	0
Anions												
Sulphate (mg/L)	<1	5.3	15	29	46	44	67	77	80	94	56	2
Cl (mg/L)	<1	0.50	0.50	0.60	0.99	0.84	1.0	1.4	1.8	5.0	56	7
F (mg/L)	0.030	0.040	0.048	0.052	0.058	0.059	0.063	0.072	0.075	0.080	56	0
Nutrients												
T-NH3 (mg/L)	<0.01	0.0059	0.0081	0.013	0.022	0.017	0.023	0.042	0.048	0.13	56	1
NO2+NO3 (mg/L)	0.063	0.079	0.086	0.11	0.27	0.22	0.38	0.48	0.51	0.65	20	0
NO2 (mg/L)	<0.004	0.0020	0.0020	0.0020	0.010	0.0050	0.01	0.05	0.05	0.05	56	36
NO3 (mg/L)	<0.04	0.0573	0.0751	0.1613	0.32	0.30	0.45	0.57	0.65	0.85	56	24
D-P (mg/L)	<0.004	0.0020	0.0020	0.0020	0.0038	0.0033	0.0047	0.0061	0.0085	0.011	47	11
TOC (mg/L)	4.0	5.7	5.9	6.9	11	9.0	13	18	24	29	56	0
DOC (mg/L)	3.5	5.3	5.5	6.7	11	8.5	13	18	23	30	56	0
WAD-CN (mg/L)	<0.001	0.00050	0.00050	0.00050	0.00081	0.00069	0.0010	0.0013	0.0015	0.0020	55	18
Total Metals												
T-Al (ug/L)	24	27	29	32	224	61	140	331	1140	4080	56	0
T-Sb (ug/L)	0.051	0.073	0.079	0.085	0.11	0.10	0.11	0.14	0.16	0.62	56	0
T-As (ug/L)	0.20	0.24	0.25	0.28	0.46	0.37	0.47	0.60	1.2	2.9	56	0
T-Ba (ug/L)	31	35	38	43	59	56	74	85	90	96	56	0
T-Be (ug/L)	<0.02	0.0100	0.0100	0.0100	0.018	0.0100	0.019	0.029	0.050	0.12	56	29
T-Bi (ug/L)	<0.01	0.0050	0.0050	0.0050	0.0121	0.0050	0.0050	0.020	0.025	0.25	56	52
T-B (ug/L)	<20	10.0	10.0	20	39	50	50	50	50	50	56	56
T-Cd (ug/L)	0.0050	0.0070	0.0080	0.0092	0.023	0.014	0.027	0.050	0.060	0.12	56	0
T-Ca (mg/L)	5.8	10	12	18	24	25	31	36	38	44	56	0
T-Cr (ug/L)	<0.2	0.100	0.17	0.20	0.56	0.30	0.49	0.68	1.7	8.2	56	3
T-Co (ug/L)	0.023	0.025	0.027	0.033	0.16	0.053	0.100	0.23	0.83	2.5	56	0
T-Cu (ug/L)	1.1	1.2	1.3	1.4	2.3	2.0	2.6	3.3	4.2	8.0	56	0
T-Fe (ug/L)	8.4	10	12	17	257	47	130	349	1610	4900	56	0
T-Pb (ug/L)	<0.01	0.0058	0.0070	0.011	0.11	0.034	0.080	0.21	0.49	1.8	56	3
T-Li (ug/L)	<1	0.50	0.50	0.50	0.72	0.61	0.77	1.0	1.1	2.7	56	15
T-Mg (mg/L)	2.0	3.7	3.9	6.2	8.1	8.1	10	11	12	14	56	0
T-Mn (ug/L)	0.42	0.76	0.83	1.2	12	5.6	9.9	28	50	157	56	0
T-Hg (ug/L)	<0.004	0.0020	0.0020	0.0027	0.0076	0.0100	0.0100	0.0100	0.013	0.021	56	35
T-Mo (ug/L)	0.22	0.40	0.42	0.47	0.59	0.55	0.63	0.74	0.89	2.0	56	0
T-Ni (ug/L)	0.59	0.63	0.67	0.74	1.1	0.91	1.1	1.5	2.3	6.4	56	0
T-K (mg/L)	0.80	0.93	1.0	1.2	1.3	1.4	1.4	1.6	1.9	2.2	56	0
T-Se (ug/L)	<0.08	0.055	0.058	0.067	0.083	0.080	0.099	0.11	0.12	0.14	56	1
T-Si (ug/L)	1950	3470	4155	4788	4968	5055	5363	5640	5875	7950	56	0
T-Ag (ug/L)	<0.01	0.0050	0.0050	0.0050	0.0062	0.0050	0.0050	0.0070	0.015	0.033	56	43
T-Na (mg/L)	0.70	1.6	2.0	2.9	3.6	3.8	4.1	4.6	5.5	9.9	56	0
T-Sr (ug/L)	33	60	67	99	127	128	161	179	184	215	56	0
T-Tl (ug/L)	<0.004	0.0020	0.0020	0.0020	0.0051	0.0027	0.0047	0.0071	0.016	0.068	56	18
T-U (ug/L)	0.50	1.2	1.2	1.6	2.5	2.4	3.1	3.6	4.2	9.5	56	0
T-Zn (ug/L)	0.26	0.31	0.40	0.59	2.4	1.2	2.5	5.2	11	17	56	0
Dissolved Metals												
D-Al (ug/L)	23	24	26	30	87	47	106	222	263	390	56	0
D-Sb (ug/L)	0.043	0.068	0.070	0.082	0.100	0.097	0.11	0.12	0.13	0.35	56	0
D-As (ug/L)	0.21	0.24	0.25	0.27	0.36	0.34	0.43	0.49	0.55	0.61	56	0
D-Ba (ug/L)	23	30	33	40	57	54	74	88	91	108	56	0
D-Be (ug/L)	<0.02	0.0100	0.0100	0.0100	0.014	0.0100	0.015	0.022	0.030	0.039	56	33
D-Bi (ug/L)	<0.01	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0063	56	54
D-B (ug/L)	<20	10.0	10.0	17.5	38	50	50	50	50	50	56	56
D-Cd (ug/L)	<0.01	0.0058	0.0070	0.0088	0.016	0.012	0.020	0.031	0.040	0.066	56	1
D-Ca (mg/L)	6.1	10	12	18	24	24	31	36	38	49	56	0
D-Cr (ug/L)	0.10	0.10	0.14	0.18	0.29	0.26	0.36	0.50	0.60	0.70	56	0
D-Co (ug/L)	0.022	0.024	0.026	0.032	0.067	0.045	0.072	0.16	0.20	0.27	56	0
D-Cu (ug/L)	1.1	1.3	1.3	1.5	2.0	1.9	2.4	3.0	3.3	4.8	56	0
D-Fe (ug/L)	7.0	8.3	9.1	15	72	35	89	203	265	381	56	0
D-Pb (ug/L)	<0.01	0.0050	0.0050	0.0058	0.041	0.016	0.023	0.055	0.069	1.2	56	13
D-Li (ug/L)	<1	0.50	0.50	0.50	0.64	0.60	0.72	0.85	0.88	1.5	56	21
D-Mg (mg/L)	1.7	3.2	3.8	6.0	8.1	8.2	11	12	12	15	56	0
D-Mn (ug/L)	0.20	0.57	0.84	1.2	5.6	4.0	6.9	12	16	37	56	0
D-Hg (ug/L)	<0.00002	0.0020	0.0020	0.0022	0.0061	0.0048	0.0100	0.0100	0.0100	0.013	44	27
D-Mo (ug/L)	0.26	0.33	0.39	0.49	0.55	0.56	0.60	0.68	0.72	0.96	56	0
D-Ni (ug/L)	0.59	0.64	0.66	0.72	0.93	0.85	1.1	1.3	1.5	1.9	56	0
D-K (mg/L)	0.71	0.86	0.97	1.2	1.3	1.3	1.5	1.6	1.7	2.3	56	0
D-Se (ug/L)	<0.08	0.042	0.053	0.066	0.082	0.080	0.090	0.12	0.13	0.16	56	3
D-Si (ug/L)	1660	2608	3840	4535	4826	5045	5380	5595	5715	7450	56	0
D-Ag (ug/L)	<0.01	0.0050	0.0050	0.0050	0.0053	0.0050	0.0050	0.0050	0.0053	0.018	56	53
D-Na (mg/L)	0.71	1.5	2.0	2.8	3.4	3.7	4.2	4.3	4.4	6.3	56	0
D-Sr (ug/L)	33	56	68	97	128	131	159	182	193	217	56	0
D-Tl (ug/L)	<0.004	0.0020	0.0020	0.0020	0.0029	0.0020	0.0031	0.0050	0.0053	0.0060	56	17
D-U (ug/L)	0.44	1.0	1.2	1.5	2.4	2.2	3.1	3.8	4.2	9.5	56	0
D-Zn (ug/L)	0.19	0.27	0.31	0.55	1.2	1.1	1.6	2.2	2.6	3.6	56	0

	HC-2.5											
	HC-2.5	HC-2.5	HC-2.5	HC-2.5	HC-2.5	HC-2.5	HC-2.5	HC-2.5	HC-2.5	HC-2.5	HC-2.5	HC-2.5
	MIN	P5	P10	P25	MEAN	P50	P75	P90	P95	MAX	COUNT	COUNT <DL
Physical Parameters												
pH (s.u.)	6.4	6.9	7.2	7.7	7.7	7.8	8.0	8.1	8.1	8.3	59	0
Cond-L (uS/cm)	28	38	65	129	249	256	373	405	411	483	58	0
TSS (mg/L)	<2	1.00	1.00	1.00	6.1	1.00	2.7	8.9	25	111	58	36
TDS (mg/L)	22	55	72	111	165	168	222	244	254	300	59	0
T-Alk (mg/L)	6.8	11	23	45	82	86	123	132	135	154	59	0
T-Hard (mg/L)	16	23	35	65	124	130	181	197	198	235	59	0
Anions												
Sulphate (mg/L)	<1	0.50	4.3	18	43	43	68	76	81	108	59	5
Cl (mg/L)	<1	0.50	0.50	0.50	1.2	0.60	0.88	1.1	1.7	24	59	27
F (mg/L)	0.030	0.035	0.039	0.051	0.061	0.061	0.071	0.080	0.081	0.090	58	0
Nutrients												
T-NH3 (mg/L)	<0.01	0.0067	0.0084	0.011	0.020	0.015	0.024	0.038	0.050	0.11	58	3
NO2+NO3 (mg/L)	0.069	0.096	0.13	0.22	0.32	0.31	0.43	0.47	0.49	0.52	18	0
NO2 (mg/L)	<0.004	0.0020	0.0020	0.0020	0.01	0.0050	0.01	0.05	0.05	0.05	58	39
NO3 (mg/L)	<0.106	0.0896	0.1145	0.2903	0.36	0.38	0.46	0.52	0.56	0.63	58	14
D-P (mg/L)	<0.004	0.0020	0.0020	0.0026	0.0045	0.0035	0.0051	0.0093	0.011	0.015	48	7
TOC (mg/L)	2.7	3.2	3.7	4.2	11	7.4	14	22	25	33	58	0
DOC (mg/L)	2.0	3.1	3.4	4.1	10	7.4	14	20	23	30	58	0
WAD-CN (mg/L)	<0.001	0.00050	0.00050	0.00050	0.00084	0.00074	0.0011	0.0015	0.0017	0.0022	57	22
Total Metals												
T-Al (ug/L)	8.9	10	11	15	191	63	215	439	771	2260	58	0
T-Sb (ug/L)	0.11	0.16	0.25	0.43	0.53	0.54	0.66	0.78	0.83	1.2	58	0
T-As (ug/L)	0.56	0.59	0.64	0.77	1.2	1.1	1.3	1.6	1.8	4.7	58	0
T-Ba (ug/L)	22	27	28	32	43	45	53	55	57	58	58	0
T-Be (ug/L)	<0.02	0.0100	0.0100	0.0100	0.023	0.010	0.026	0.056	0.066	0.11	58	28
T-Bi (ug/L)	<0.01	0.0050	0.0050	0.0050	0.0062	0.0050	0.0050	0.0050	0.014	0.036	58	52
T-B (ug/L)	<20	10.0	10.0	50	41	50	50	50	50	50	58	58
T-Cd (ug/L)	<0.01	0.0050	0.0050	0.0060	0.015	0.0095	0.017	0.040	0.049	0.069	58	9
T-Ca (mg/L)	4.4	6.3	9.4	17	30	32	44	47	48	56	59	0
T-Cr (ug/L)	<0.2	0.100	0.100	0.12	0.53	0.29	0.67	0.88	1.5	5.6	58	11
T-Co (ug/L)	0.017	0.018	0.021	0.027	0.15	0.049	0.15	0.38	0.67	1.5	58	0
T-Cu (ug/L)	0.51	0.64	0.65	0.79	1.4	1.2	1.9	2.4	3.0	4.8	58	0
T-Fe (ug/L)	5.0	6.7	7.7	10	201	40	202	441	906	2900	58	0
T-Pb (ug/L)	<0.01	0.0050	0.0064	0.014	0.091	0.034	0.073	0.15	0.41	1.4	58	5
T-Li (ug/L)	0.57	0.60	0.70	0.97	1.3	1.3	1.7	1.9	1.9	3.0	58	0
T-Mg (mg/L)	1.2	1.7	2.7	5.6	12	12	17	19	19	24	59	0
T-Mn (ug/L)	0.91	1.4	1.8	2.6	15	6.3	13	54	74	106	58	0
T-Hg (ug/L)	<0.004	0.0020	0.0020	0.0047	0.0080	0.0100	0.0100	0.0100	0.011	0.020	58	41
T-Mo (ug/L)	0.12	0.20	0.33	0.84	1.4	1.7	1.9	2.0	2.2	3.0	58	0
T-Ni (ug/L)	0.29	0.32	0.33	0.37	1.1	0.51	1.0	1.5	1.9	20	58	0
T-K (mg/L)	0.57	0.79	0.89	1.5	2.1	2.4	2.7	2.8	3.0	3.9	59	0
T-Se (ug/L)	0.043	0.051	0.057	0.073	0.095	0.093	0.12	0.13	0.14	0.16	58	0
T-Si (ug/L)	1670	2960	3668	5000	5159	5430	5690	5840	6330	7230	58	0
T-Ag (ug/L)	<0.01	0.0050	0.0050	0.0050	0.0057	0.0050	0.0050	0.0073	0.0082	0.020	58	49
T-Na (mg/L)	0.40	0.71	1.0	1.9	3.1	3.3	4.1	4.3	4.6	7.8	59	0
T-Sr (ug/L)	40	58	93	181	307	349	428	445	454	615	58	0
T-Tl (ug/L)	<0.004	0.0020	0.0020	0.0020	0.0037	0.0020	0.0039	0.0063	0.0082	0.036	58	27
T-U (ug/L)	3.3	4.6	7.0	15	42	41	65	83	86	102	58	0
T-Zn (ug/L)	<0.2	0.20	0.26	0.40	1.5	0.77	1.5	3.8	4.9	11	58	1
Dissolved Metals												
D-Al (ug/L)	6.8	7.9	8.8	12	114	43	151	321	403	541	58	0
D-Sb (ug/L)	0.080	0.16	0.23	0.40	0.52	0.54	0.68	0.78	0.82	1.0	58	0
D-As (ug/L)	0.57	0.62	0.64	0.76	1.00	1.0	1.2	1.3	1.3	1.5	58	0
D-Ba (ug/L)	18	23	25	30	41	43	53	57	57	59	58	0
D-Be (ug/L)	<0.02	0.0100	0.0100	0.0100	0.019	0.0100	0.023	0.042	0.051	0.069	58	29
D-Bi (ug/L)	<0.01	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	58	58
D-B (ug/L)	<20	10.0	10.0	20	40	50	50	50	50	50	58	58
D-Cd (ug/L)	<0.01	0.0050	0.0050	0.0053	0.013	0.0093	0.013	0.034	0.038	0.048	58	13
D-Ca (mg/L)	4.6	6.1	9.2	17	30	32	43	48	50	52	58	0
D-Cr (ug/L)	<0.2	0.100	0.100	0.10	0.34	0.25	0.50	0.77	0.83	0.90	58	11
D-Co (ug/L)	0.016	0.019	0.020	0.024	0.095	0.036	0.11	0.33	0.37	0.39	58	0
D-Cu (ug/L)	0.47	0.61	0.69	0.76	1.4	1.2	1.8	2.2	2.4	4.6	58	0
D-Fe (ug/L)	3.7	4.5	5.0	6.0	97	22	132	308	346	504	58	0
D-Pb (ug/L)	<0.01	0.0050	0.0050	0.0053	0.025	0.011	0.029	0.057	0.073	0.19	58	13
D-Li (ug/L)	<1	0.50	0.61	0.81	1.3	1.3	1.6	1.9	2.0	2.9	58	3
D-Mg (mg/L)	1.1	1.6	2.7	5.7	11	12	17	19	19	23	58	0
D-Mn (ug/L)	0.80	1.1	1.3	1.8	10	5.2	10	28	45	60	58	0
D-Hg (ug/L)	<0.004	0.0020	0.0020	0.0036	0.0076	0.0100	0.0100	0.0100	0.0100	0.018	45	29
D-Mo (ug/L)	0.10	0.18	0.36	0.82	1.4	1.7	1.9	2.0	2.2	2.8	58	0
D-Ni (ug/L)	0.22	0.30	0.32	0.37	0.66	0.49	0.89	1.1	1.4	1.7	58	0
D-K (mg/L)	0.56	0.80	0.88	1.5	2.0	2.3	2.6	2.8	2.9	3.8	58	0
D-Se (ug/L)	<0.08	0.048	0.055	0.067	0.093	0.085	0.12	0.13	0.14	0.17	58	1
D-Si (ug/L)	1420	3007	3413	4983	5078	5400	5658	5863	5991	6830	58	0
D-Ag (ug/L)	<0.01	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0055	58	55
D-Na (mg/L)	0.41	0.73	1.0	1.9	3.0	3.4	4.0	4.3	4.6	5.9	58	0
D-Sr (ug/L)	41	54	95	182	307	350	421	461	473	588	58	0
D-Tl (ug/L)	<0.004	0.0020	0.0020	0.0020	0.0025	0.0020	0.0029	0.0040	0.0040	0.0050	58	32
D-U (ug/L)	2.0	3.7	6.9	15	42	41	65	84	93	96	58	0
D-Zn (ug/L)	<0.2	0.15	0.22	0.32	1.2	0.80	1.4	2.2	2.5	16	58	3

	YT-24											
	ML-1.0	ML-1.0	ML-1.0	ML-1.0	ML-1.0	ML-1.0	ML-1.0	ML-1.0	ML-1.0	ML-1.0	ML-1.0	ML-1.0
	MIN	**P5**	**P10**	**P25**	**MEAN**	**P50**	**P75**	**P90**	**P95**	**MAX**	**COUNT**	**COUNT <DL**
Physical Parameters												
pH (s.u.)	7.2	7.3	7.5	7.6	7.7	7.7	7.8	7.9	7.9	8.0	12	0
Cond-L (uS/cm)	50	73	93	110	134	134	153	173	201	235	12	0
TSS (mg/L)	<2	1.00	1.00	1.08	11	2.4	5.9	42	50	56	12	4
TDS (mg/L)	50	67	80	89	102	102	108	130	146	164	12	0
T-Alk (mg/L)	15	21	27	35	42	44	49	49	58	70	12	0
T-Hard (mg/L)	28	38	47	57	67	67	77	83	96	111	12	0
Anions												
Sulphate (mg/L)	<1	6.1	11	13	19	17	23	32	36	41	12	1
Cl (mg/L)	0.54	0.55	0.55	0.61	0.79	0.73	0.87	0.96	1.2	1.5	12	0
F (mg/L)	0.040	0.048	0.055	0.067	0.072	0.076	0.083	0.085	0.087	0.089	12	0
Nutrients												
T-NH3 (mg/L)	0.010	0.012	0.014	0.015	0.018	0.018	0.020	0.023	0.024	0.026	12	0
NO2+NO3 (mg/L)	0.028	0.21	0.36	0.39	0.46	0.46	0.55	0.64	0.67	0.69	12	0
NO2 (mg/L)	0.002	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.03	0.05	12	0
NO3 (mg/L)	<0.056	0.1826	0.3157	0.3888	0.4525	0.4595	0.5515	0.6448	0.669	0.694	12	11
D-P (mg/L)	<0.004	0.0020	0.0021	0.0028	0.0050	0.0042	0.0052	0.0081	0.011	0.015	12	2
TOC (mg/L)	9.6	10	11	12	14	13	17	17	19	20	12	0
DOC (mg/L)	8.3	9.8	11	11	14	13	15	19	19	19	12	0
WAD-CN (mg/L)	<0.001	0.00060	0.00070	0.00076	0.0010	0.0011	0.0012	0.0014	0.0015	0.0015	12	1
Total Metals												
T-Al (ug/L)	49	50	50	56	157	72	118	185	533	950	12	0
T-Sb (ug/L)	0.095	0.13	0.15	0.16	0.19	0.19	0.20	0.23	0.30	0.38	12	0
T-As (ug/L)	0.39	0.40	0.40	0.48	0.59	0.51	0.59	0.68	1.0	1.4	12	0
T-Ba (ug/L)	32	33	35	37	42	39	43	54	58	63	12	0
T-Be (ug/L)	<0.02	0.0111	0.012	0.014	0.023	0.017	0.026	0.028	0.046	0.068	12	1
T-Bi (ug/L)	<0.01	0.0050	0.0050	0.0050	0.0075	0.0050	0.0050	0.0185	0.020	0.020	12	12
T-B (ug/L)	<20	10.0	10.0	10.0	23	20	28	50	50	50	12	12
T-Cd (ug/L)	<0.01	0.0050	0.0051	0.0060	0.011	0.0066	0.0093	0.025	0.032	0.037	12	1
T-Ca (mg/L)	8.2	11	14	17	19	19	23	24	27	30	12	0
T-Cr (ug/L)	0.26	0.27	0.27	0.28	0.52	0.42	0.49	0.53	1.2	2.1	12	0
T-Co (ug/L)	0.061	0.062	0.062	0.065	0.15	0.081	0.11	0.22	0.47	0.77	12	0
T-Cu (ug/L)	1.7	1.8	1.8	2.0	2.4	2.2	2.5	3.0	3.4	3.9	12	0
T-Fe (ug/L)	27	29	30	35	172	60	109	155	677	1310	12	0
T-Pb (ug/L)	<0.01	0.0056	0.0065	0.011	0.074	0.019	0.024	0.047	0.33	0.68	12	2
T-Li (ug/L)	<1	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	12	12
T-Mg (mg/L)	1.7	2.4	3.1	3.8	4.6	4.6	5.2	5.7	7.1	8.8	12	0
T-Mn (ug/L)	0.27	0.29	0.32	0.58	7.8	1.8	2.6	34	40	43	12	0
T-Hg (ug/L)	0.0028	0.0031	0.0034	0.0038	0.0047	0.0045	0.0054	0.0058	0.0070	0.0084	12	0
T-Mo (ug/L)	0.27	0.28	0.30	0.41	0.44	0.46	0.51	0.54	0.55	0.56	12	0
T-Ni (ug/L)	0.70	0.71	0.73	0.78	0.94	0.84	0.97	1.0	1.5	2.0	12	0
T-K (mg/L)	0.65	1.0	1.4	1.4	1.7	1.5	1.8	1.8	2.5	3.5	12	0
T-Se (ug/L)	0.057	0.057	0.058	0.067	0.078	0.074	0.085	0.11	0.11	0.11	12	0
T-Si (ug/L)	3330	3539	3735	4073	4378	4320	4520	5234	5466	5680	12	0
T-Ag (ug/L)	<0.01	0.0050	0.0050	0.0050	0.0067	0.0050	0.0057	0.0089	0.014	0.019	12	9
T-Na (mg/L)	1.1	1.4	1.7	2.0	2.4	2.5	2.8	3.1	3.5	4.0	12	0
T-Sr (ug/L)	38	61	82	100	119	107	135	164	191	223	12	0
T-Tl (ug/L)	<0.004	0.0020	0.0020	0.0020	0.0036	0.0030	0.0033	0.0049	0.0082	0.012	12	1
T-U (ug/L)	0.45	0.52	0.59	0.73	0.98	0.84	0.98	1.1	1.9	2.8	12	0
T-Zn (ug/L)	<0.44	0.24	0.26	0.36	1.2	0.46	0.85	1.9	4.5	7.7	12	1
Dissolved Metals												
D-Al (ug/L)	44	46	48	50	88	61	85	170	205	241	12	0
D-Sb (ug/L)	0.11	0.13	0.14	0.18	0.18	0.19	0.20	0.21	0.21	0.22	12	0
D-As (ug/L)	0.37	0.38	0.39	0.45	0.52	0.49	0.57	0.66	0.72	0.80	12	0
D-Ba (ug/L)	24	28	32	35	41	39	44	54	58	64	12	0
D-Be (ug/L)	<0.02	0.0100	0.0100	0.012	0.018	0.015	0.025	0.027	0.029	0.032	12	3
D-Bi (ug/L)	<0.01	0.0050	0.0050	0.0050	0.0052	0.0050	0.0050	0.0050	0.0059	0.0070	12	11
D-B (ug/L)	<20	10.0	10.0	10.0	16.7	10.0	20	20	34	50	12	12
D-Cd (ug/L)	<0.01	0.0050	0.0050	0.0058	0.0085	0.0060	0.0090	0.016	0.018	0.020	12	2
D-Ca (mg/L)	8.1	10	13	16	19	19	22	25	28	33	12	0
D-Cr (ug/L)	0.21	0.24	0.27	0.30	0.39	0.35	0.41	0.51	0.64	0.80	12	0
D-Co (ug/L)	0.056	0.057	0.058	0.063	0.098	0.079	0.089	0.21	0.22	0.23	12	0
D-Cu (ug/L)	1.7	1.8	1.9	2.0	2.3	2.2	2.4	2.6	3.3	4.3	12	0
D-Fe (ug/L)	22	23	24	28	68	42	85	120	183	256	12	0
D-Pb (ug/L)	<0.01	0.0050	0.0050	0.0050	0.016	0.0076	0.013	0.030	0.054	0.082	12	2
D-Li (ug/L)	<1	0.50	0.50	0.50	0.52	0.50	0.50	0.50	0.60	0.72	12	11
D-Mg (mg/L)	1.5	2.3	3.0	3.7	4.5	4.2	5.2	5.9	7.3	8.9	12	0
D-Mn (ug/L)	0.12	0.15	0.18	0.22	4.4	0.48	1.5	9.1	22	36	12	0
D-Hg (ug/L)	0.0028	0.0029	0.0031	0.0047	0.0056	0.0057	0.0067	0.0078	0.0082	0.0086	12	0
D-Mo (ug/L)	0.20	0.29	0.38	0.40	0.47	0.49	0.53	0.54	0.61	0.71	12	0
D-Ni (ug/L)	0.63	0.68	0.72	0.74	0.90	0.82	0.93	1.2	1.3	1.5	12	0
D-K (mg/L)	0.63	0.99	1.3	1.4	1.6	1.5	1.8	1.9	2.7	3.7	12	0
D-Se (ug/L)	0.057	0.058	0.059	0.065	0.074	0.071	0.087	0.092	0.093	0.094	12	0
D-Si (ug/L)	3040	3524	3938	4123	4212	4345	4480	4552	4574	4590	12	0
D-Ag (ug/L)	<0.01	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0051	0.0052	12	11
D-Na (mg/L)	1.0	1.5	1.9	2.0	2.5	2.4	2.8	3.1	4.0	5.1	12	0
D-Sr (ug/L)	34	59	82	99	120	112	138	158	193	235	12	0
D-Tl (ug/L)	<0.004	0.0020	0.0020	0.0020	0.0025	0.0021	0.0030	0.0030	0.0033	0.0037	12	4
D-U (ug/L)	0.45	0.51	0.58	0.73	0.97	0.78	0.96	1.1	2.0	3.0	12	0
D-Zn (ug/L)	0.20	0.21	0.22	0.25	0.58	0.39	0.74	1.2	1.4	1.6	12	0

	YUK-5.0											
	YUK-5.0	YUK-5.0	YUK-5.0	YUK-5.0	YUK-5.0	YUK-5.0	YUK-5.0	YUK-5.0	YUK-5.0	YUK-5.0	YUK-5.0	YUK-5.0
	MIN	P5	P10	P25	MEAN	P50	P75	P90	P95	MAX	COUNT	COUNT <DL
Physical Parameters												
pH (s.u.)	7.7	7.7	7.8	7.9	7.9	8.0	8.0	8.1	8.1	8.1	45	0
Cond-L (uS/cm)	129	160	162	170	191	187	213	227	234	283	45	0
TSS (mg/L)	<2	1.00	1.00	2.00	26	9.2	24.9	96	105	193	45	6
TDS (mg/L)	88	91	94	102	114	110	124	132	144	154	45	0
T-Alk (mg/L)	44	61	62	67	75	72	84	92	95	114	45	0
T-Hard (mg/L)	15	74	81	87	94	91	104	112	116	146	45	0
Anions												
Sulphate (mg/L)	16	17.90	18.2	19	21	21	23	25	26	28	45	0
Cl (mg/L)	<1	0.50	0.50	0.50	0.69	0.55	0.8	1.0	1.1	1.9	45	19
F (mg/L)	0.080	0.082	0.085	0.098	0.104	0.110	0.110	0.120	0.128	0.15	45	0
Nutrients												
T-NH3 (mg/L)	<0.01	0.0064	0.0067	0.009	0.016	0.014	0.020	0.031	0.034	0.04	45	1
NO2+NO3 (mg/L)	0.003	0.007	0.012	0.02	0.05	0.02	0.07	0.11	0.11	0.14	17	0
NO2 (mg/L)	<0.004	0.0020	0.0020	0.0020	0.010	0.005	0.01	0.05	0.05	0.05	45	26
NO3 (mg/L)	<0.0066	0.0146	0.0160	0.0200	0.07	0.037	0.10	0.20	0.20	0.20	45	27
D-P (mg/L)	<0.004	0.0020	0.0020	0.0020	0.0033	0.0023	0.0030	0.0053	0.0059	0.025	41	17
TOC (mg/L)	<1	1.2	1.4	2	4	3	4	7	10	17	45	2
DOC (mg/L)	<1	1.0	1.4	2	4	3	4	6	9	16	45	3
WAD-CN (mg/L)	<0.001	0.00050	0.00050	0.00050	0.00062	0.00050	0.0007	0.0009	0.0010	0.0015	45	26
Total Metals												
T-Al (ug/L)	2	7	9	27	262	88	216	617	1035	2900	45	0
T-Sb (ug/L)	0.05	0.08	0.09	0.09	0.17	0.11	0.14	0.20	0.49	1.14	45	0
T-As (ug/L)	0.15	0.22	0.26	0.38	0.7	0.48	0.65	1.3	1.7	3.8	45	0
T-Ba (ug/L)	33	40	42	46	62	53	68	94	105	193	45	0
T-Be (ug/L)	<0.02	0.0100	0.0100	0.0100	0.020	0.010	0.015	0.042	0.059	0.15	45	26
T-Bi (ug/L)	<0.01	0.0050	0.0050	0.0050	0.0093	0.0050	0.0070	0.020	0.022	0.054	45	36
T-B (ug/L)	<20	10.0	10.0	50	41	50	50	50	50	50	45	45
T-Cd (ug/L)	0.0	0.0202	0.0228	0.0250	0.081	0.0370	0.076	0.213	0.248	0.61	45	0
T-Ca (mg/L)	4.3	20	23	24	26	25	29	31	32	40	45	0
T-Cr (ug/L)	<0.2	0.10	0.10	0.10	0.6	0.20	0.53	1.6	2.2	6	45	9
T-Co (ug/L)	0.007	0.012	0.017	0.034	0.29	0.074	0.26	0.86	1.29	3.0	45	0
T-Cu (ug/L)	0.28	0.39	0.5	0.7	1.7	0.9	1.6	4.0	5.5	12	45	0
T-Fe (ug/L)	7.2	15	22	49	487	112	362	1240	2066	5840	45	0
T-Pb (ug/L)	0.0	0.0122	0.0180	0.056	0.36	0.095	0.374	1.10	1.30	3.3	45	0
T-Li (ug/L)	<1	0.93	1.18	1.30	1.6	1.51	1.8	2.1	2.3	4.7	45	1
T-Mg (mg/L)	1.1	5.8	6.0	6.7	7.1	7.1	7.8	8	9	11	45	0
T-Mn (ug/L)	0.65	1.61	2.34	5.68	28	11.0	27.6	81	113	234	45	0
T-Hg (ug/L)	<0.004	0.0020	0.0020	0.0020	0.0067	0.0100	0.0100	0.0100	0.0100	0.020	45	39
T-Mo (ug/L)	0.08	0.73	0.75	0.93	1.06	1.10	1.18	1.32	1.4	1.9	45	0
T-Ni (ug/L)	0.19	0.40	0.46	0.88	2.0	1.12	1.9	4.6	5.3	15	45	0
T-K (mg/L)	0.1	0.7	0.8	0.8	0.9	0.9	0.9	1.1	1.3	1.5	45	0
T-Se (ug/L)	0.06	0.244	0.272	0.299	0.374	0.343	0.402	0.56	0.60	0.75	45	0
T-Si (ug/L)	620	2580	2774	2920	3325	3220	3480	4020	4588	6190	45	0
T-Ag (ug/L)	<0.01	0.0050	0.0050	0.0050	0.0095	0.0050	0.0080	0.0192	0.026	0.078	45	32
T-Na (mg/L)	0.23	1.6	1.7	1.8	2.1	2.0	2.2	2.4	3.2	5.0	45	0
T-Sr (ug/L)	18	102	106	112	121	119	131	145	150	188	45	0
T-Tl (ug/L)	<0.004	0.0020	0.0020	0.0020	0.0065	0.0030	0.0060	0.0151	0.021	0.062	45	13
T-U (ug/L)	0.2	0.8	0.9	1.0	1.1	1.0	1	1	1	2	45	0
T-Zn (ug/L)	0.6	1.09	1.15	1.62	6.2	2.80	7.1	14.4	17	56	45	0
Dissolved Metals												
D-Al (ug/L)	1.0	1	2	4	20	19	26	45	58	94	45	0
D-Sb (ug/L)	0.07	0.08	0.08	0.09	0.11	0.10	0.11	0.12	0.14	0.32	45	0
D-As (ug/L)	0.12	0.16	0.25	0.35	0.40	0.43	0.49	0.54	0.6	0.6	45	0
D-Ba (ug/L)	36	37	39	40	50	43	53	71	75	91	45	0
D-Be (ug/L)	<0.02	0.0100	0.0100	0.0100	0.010	0.010	0.010	0.010	0.010	0.020	45	42
D-Bi (ug/L)	<0.01	0.0050	0.0050	0.0050	0.0051	0.0050	0.0050	0.0050	0.0050	0.0070	45	43
D-B (ug/L)	<20	10.0	10.0	20.0	38	50	50	50	50	50	45	44
D-Cd (ug/L)	0.0	0.0130	0.0137	0.0175	0.0311	0.0230	0.035	0.059	0.080	0.125	45	0
D-Ca (mg/L)	17.3	21.6	22	23	26	26	29	31	33	39	45	0
D-Cr (ug/L)	<0.2	0.10	0.10	0.10	0.12	0.10	0.11	0.14	0.19	0.36	45	30
D-Co (ug/L)	<0.01	0.006	0.007	0.009	0.022	0.014	0.024	0.04	0.07	0.10	45	1
D-Cu (ug/L)	0.22	0.36	0.4	0.6	0.9	0.8	1.0	1.7	2.1	2.7	45	0
D-Fe (ug/L)	<2	2	3	6	25	14	25	59	106	153	45	1
D-Pb (ug/L)	<0.01	0.0050	0.0050	0.0064	0.024	0.0140	0.038	0.062	0.071	0.078	45	11
D-Li (ug/L)	0.8	1.04	1.10	1.21	1.36	1.31	1.48	1.7	1.8	2.0	45	0
D-Mg (mg/L)	5.1	5.8	6.1	6.4	7.1	7.0	7.6	8	9	12	45	0
D-Mn (ug/L)	0.120	0.26	0.38	0.96	4.1	2.38	4.4	11.5	17	21	45	0
D-Hg (ug/L)	<0.004	0.0020	0.0020	0.0020	0.0057	0.0033	0.0100	0.0100	0.0100	0.010	38	32
D-Mo (ug/L)	0.72	0.74	0.83	1.00	1.09	1.10	1.17	1.25	1.35	2.1	45	0
D-Ni (ug/L)	0.17	0.33	0.45	0.68	1.02	0.88	1.21	1.7	2.3	2.9	45	0
D-K (mg/L)	0.70	0.73	0.7	0.8	0.9	0.9	0.9	1.0	1.1	1.4	45	0
D-Se (ug/L)	0.176	0.239	0.254	0.295	0.360	0.329	0.390	0.513	0.59	0.75	45	0
D-Si (ug/L)	2450	2512	2652	2820	3045	3020	3190	3352	3644	4590	45	0
D-Ag (ug/L)	<0.01	0.0050	0.0050	0.0050	0.0051	0.0050	0.0050	0.0050	0.0050	0.0100	45	44
D-Na (mg/L)	1.50	1.7	1.7	1.8	2.1	2.0	2.2	2.5	2.8	3.4	45	0
D-Sr (ug/L)	81	106	107	111	123	119	134	142	149	194	45	0
D-Tl (ug/L)	<0.004	0.0020	0.0020	0.0020	0.0023	0.0020	0.0020	0.0030	0.0041	0.0049	45	28
D-U (ug/L)	0.6	0.8	0.9	0.9	1.0	1.0	1	1	1	2	45	0
D-Zn (ug/L)	0.2	0.36	0.45	0.79	1.65	1.50	1.95	2.8	3.1	7.8	45	0

APPENDIX B
KEY PUBLICATIONS CITED

Environmental Science & Technology
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Dissolved Organic Carbon Reduces Uranium Bioavailability and Toxicity. 2. Uranium[VI] Speciation and Toxicity to Three Tropical Freshwater Organisms

Melanie A. Trenfield,[*,†,‡] Jack C. Ng,[‡] Barry N. Noller,[§] Scott J. Markich,[⊥] and Rick A. van Dam[†]

[†]Environmental Research Institute of the Supervising Scientist, Department of Sustainability, Environment, Water, Population and Communities, GPO Box 461, Darwin, Northern Territory, Australia 0801

[‡]The University of Queensland, National Research Centre for Environmental Toxicology, Coopers Plains, Queensland, Australia 4108

[§]The University of Queensland, Centre for Mined Land Rehabilitation, St Lucia, Queensland, Australia 4072

[⊥]Aquatic Solutions International, Dundas, New South Wales, Australia 2117

S Supporting Information

ABSTRACT: The influence of dissolved organic carbon (DOC) on the toxicity of uranium (U) to three Australian tropical freshwater species, the Northern Trout Gudgeon (*Mogurnda mogurnda*), green hydra (*Hydra viridissima*) and unicellular green alga (*Chlorella* sp.) was assessed. Exposures were conducted in synthetic soft water without DOC and with DOC added in the form of standard Suwannee River Fulvic Acid (SRFA). Organisms were exposed to a range of U concentrations at a range of DOC concentrations (0−20 mg L^{-1}). U toxicity was up to 20 times less in water containing 20 mg L^{-1} DOC, relative to DOC-free test waters. U toxicity was also assessed using natural water from a tropical Australian billabong containing 10 mg L^{-1} DOC. U toxicity was up to ten times less in the billabong water, relative to DOC − free test waters. SRFA was twice as effective at reducing U toxicity as the billabong water at equivalent DOC concentrations. Geochemical speciation modeling confirmed the decreased U toxicity that resulted from both DOC sources was primarily due to a decrease in the free uranyl ion (UO_2^{2+}) through complexation with DOC. A predictive model is presented for each of the organisms that can be used to predict U toxicity at a given U and DOC concentration.

INTRODUCTION

Nuclear power is re-emerging as an alternative to carbon intensive energy sources[1] and in Australia, the growth in U exploration and mining activity may result in increased amounts of U being transferred to freshwater ecosystems. With its capacity for migration in natural waters, U poses a potential risk to aquatic biota.[2] The Alligator Rivers Region (ARR) in northern Australia is an historical and current focal point for U exploration and mining.[3] The only operational mine in the region, the Ranger Uranium mine, is located in the Magela Creek catchment. Under strict regulation it discharges site runoff waters containing U (~10 μg L^{-1}) and other metals into the adjacent Magela Creek where background U < 0.05 μg L^{-1}.[4] However, concentrations of up to 100 μg L^{-1} have been measured in some discharge waters.[3] A map of the region can be seen in the companion paper.[5]

Ecological risks from metal contaminants should, ideally, be assessed using site-specific guidelines that account for the influence of local physicochemical characteristics on both metal mobility and ecotoxicity.[6] Effects of pH, water hardness and alkalinity on the toxicity of U have been reasonably well studied for representative freshwater organisms.[7−11] Dissolved organic carbon (DOC), in the form of fulvic and humic acids, is known to be an important complexing agent for metals, such as U, in aquatic systems.[12] Through U complexation and a subsequent decrease in the proportion of toxic U species such as UO_2^{2+} and UO_2OH^+, DOC could contribute to the lowering of U toxicity to freshwater biota. DOC also has the potential to accumulate on cell surfaces and influence the interaction of toxicants at the cell-solution interface.[13] Only two studies, however, have investigated the influence of DOC on U toxicity to freshwater biota.[8,14]

This current study has quantified the effect of DOC from two sources on the toxicity of U in soft, acidic freshwater to three Australian tropical species - the northern trout gudgeon, *Mogurnda mogurnda*, the green alga, *Chlorella* sp. and the green hydra, *Hydra viridissima*. The influence of these sources of DOC on the bioavailability of U[VI] at relatively constant pH (6 ± 0.1), alkalinity (4.3 ± 0.2 mg L^{-1}) and hardness (4.1 ± 0.5 mg L^{-1}), has been inferred using geochemical speciation modeling. A local DOC source was assessed and compared with a standard freshwater DOC (Suwannee River Fulvic Acid; SRFA) to determine if the standard DOC could be used as a surrogate for a site-specific freshwater DOC. Concentration−response relationships are reported for each of the DOC sources that can be used to estimate a toxic effect for each of the organisms tested, based on a given U and DOC concentration, provided similar physicochemical conditions exist.

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Table 1. Physicochemical Variables of Synthetic Magela Creek Water (SMCW) and Sandy Billabong Water (SBW) Tests

physicochemical variable (units)	water type	*M. mogurnda*[a]	*H. viridissima*[a]	*Chlorella sp.*[b]
pH	SMCW[c]	6.2 (6.0−6.4)	6.1 (6.0−6.2)	6.2 (6.0−6.4)
	SBW[d]	6.2 (5.9−6.4)	6.1 (5.8−6.4)	6.0 (5.9−6.3)
EC (μS cm^{-1})	SMCW	27 (17−37)	23 (16−30)	50 (40−60)
	SBW	44 (15−45)	42 (15−45)	54 (41−75)
T (°C)	SMCW	26.0 (26−26.5)	26.0 (26−26.5)	28.5 (28−29)
	SBW	27.0 (26.5−27.5)	27.0 (26.5−27.5)	28.5 (28−29)
dissolved oxygen (%)	SMCW	103 (93−113)	99 (95−103)	105 (95−115)
	SBW	96 (90−114)	94 (89−109)	95 (90−104)
		All species		
alkalinity (mg L^{-1} as $CaCO_3$)[e]	SMCW	4.1 (3−6)		
	SBW	4.5 (3−6)		
hardness (mg L^{-1} $CaCO_3$)[f]	SMCW	3.6 (3−3.9)		
	SBW	4.6 (3.5−6)		

[a] Physical parameters were monitored on both new and old water at 24 h intervals. Values are the median (range) compiled from three SMCW tests and two SBW tests for each species. [b] Physical parameters were monitored at 0 and 72 h only. [c] For *M. mogurnda* and *H. viridissima*: pH & EC n = 672, DO & Temp n = 96; *Chlorella* sp.: pH & EC n = 120, DO & Temp n = 24. [d] *M. mogurnda* and *H. viridissima* pH & EC n = 448, DO & Temp n = 64, *Chlorella* sp; pH & EC n = 40, DO & Temp n = 16. [e] Mean (range), measured at 0 h for all species, SMCW: n = 14, SBW: n = 6. [f] Mean (range) of hardness for all species (values not used in modeling), SMCW: n = 22, SBW: n = 12.

MATERIALS AND METHODS

General Laboratory Procedures. All equipment used to hold test organisms or media was made of chemically inert materials (e.g., Teflon, glass or polyethylene). All plastic and glassware was soaked in 5% nitric acid for 24 h before undergoing a detergent wash (Gallay Clean A powder, Gallay Scientific, Burwood, Australia) and rinse in a laboratory dishwasher using reverse osmosis (RO) water. All glassware (except volumetric flasks) was silanized with 2% dimethyldichlorosilane in 1,1, 1-trichloroethane (Coatasil, AJAX, Seven Hills, Australia,) to reduce U adsorption to the glass. All reagents used were analytical grade and stock solutions were made up in Milli-Q water (18 Ωcm^{-1}, Millipore Ltd., Billerica, MA, USA).

Test Organisms. All three test species were originally collected from within Kakadu National Park (located in the ARR) and cultured in the laboratory for at least eight years, with periodic culture renewals.[15] The *M. mogurnda* broodstock was held in filtered mains water (typical pH 7−7.5, electrical conductivity [EC] 75−100 μS cm^{-1}, alkalinity ~45 mg L^{-1} $CaCO_3$, hardness ~40 mg L^{-1} Ca CO_3 at 27 ± 1 °C on a 12:12 h day/night cycle (36W cool white triphosphor lighting, 30−50 μmol m^{-2}s^{-1}). Egg masses were removed to a separate hatching system prior to testing.[11] *H. viridissima* was cultured at 27 ± 1 °C on a 12:12 h day/night cycle (30W Grolux lighting, 30−50 μmol m^{-2}s^{-1}), using 3 μm filtered natural water collected from Magela Creek (latitude 12° 40′ 28″, longitude 132° 55′ 52″). *Chlorella* sp. was cultured in MBL medium [9] at 28.0 ± 1 °C on a 12:12 h day/night cycle (36 W cool white triphosphor lighting; 100−140 μmol m^{-2}s^{-1}).

Preparation of Standard DOC Solutions for U Toxicity Tests. The SRFA (Standard I, 1S101F, International Humic Substances Society, University of Minnesota) was the standard DOC source used in this study.[16] A detailed description of the characteristics of this FA have been provided.[5] SRFA was dissolved into a synthetic soft water, hereafter referred to as synthetic Magela Creek water (SMCW), to achieve DOC concentrations of 0, 1, 5, 10, and 20 mg L^{-1}, a range typical of that found naturally in freshwater.[17] The composition and pH of SMCW (Table 1 and Supporting Information Table S1) represents the mean inorganic composition and pH of the fresh surface waters of Magela Creek during the wet season when release of water from the Ranger mine site may occur.[8] Uranium-containing test solutions were prepared 48 h prior to the beginning of a test to allow equilibration of U with DOC. At 24 h prior to the beginning of a test, solutions were pH adjusted to 6.0 ± 0.15 using 0.05 M NaOH or H_2SO_4. Each species was tested on three separate occasions at a range of U concentrations for each of the DOC concentrations listed above (*M. mogurnda*: 0−14 mg L^{-1}; *H. viridissima*: 0−1.14 mg L^{-1}; *Chlorella* sp: 0−1.5 mg L^{-1}). U concentration ranges were selected in order to obtain a full toxic response for each organism at each DOC concentration and were all within the solubility limits of uranyl sulfate.

Preparation of Sandy Billabong Water for U toxicity Tests. A 160 L sample of Sandy Billabong water (SBW) was collected into eight 22 L polyethylene containers in the late dry season, December 2008. SBW was used as the source of natural DOC because its inorganic composition was similar to that of SMCW (see the Supporting Information, Table S1) with a higher concentration of DOC (10 mg L^{-1}) relative to other waterbodies of similar water quality in the region. The characteristics of this DOC source are described by Trenfield et al. (2011).[5] Within 24 h of collection, SBW was prefiltered (3 μm, Sartopure PP2MidiCaps and Gamet peristaltic pump) then filtered through a 0.45 μm membrane (Quickfilter, polyethersulfone filter cartridges) and stored in 5 L polyethylene bottles at 4 ± 1 °C until required for testing. A 100 L sample of filtered SBW was set aside and used for natural organic matter isolation and characterization, the results of which are presented by Trenfield et al. (2011).[5] A range of DOC concentrations (0, 1, 5, and 10 mg L^{-1}) was achieved by diluting the SBW with SMCW, which has a similar inorganic composition to the billabong water. Two tests, each assessing the above DOC concentrations and a range of U concentrations (*M. mogurnda*: 0−6.1 mg L^{-1}; *H. viridissima*: 0−0.48 mg L^{-1}; *Chlorella* sp: 0−0.57 mg L^{-1}) were conducted for each species.

General Toxicity Test Method. The following methods for toxicity testing were adapted from.[15]

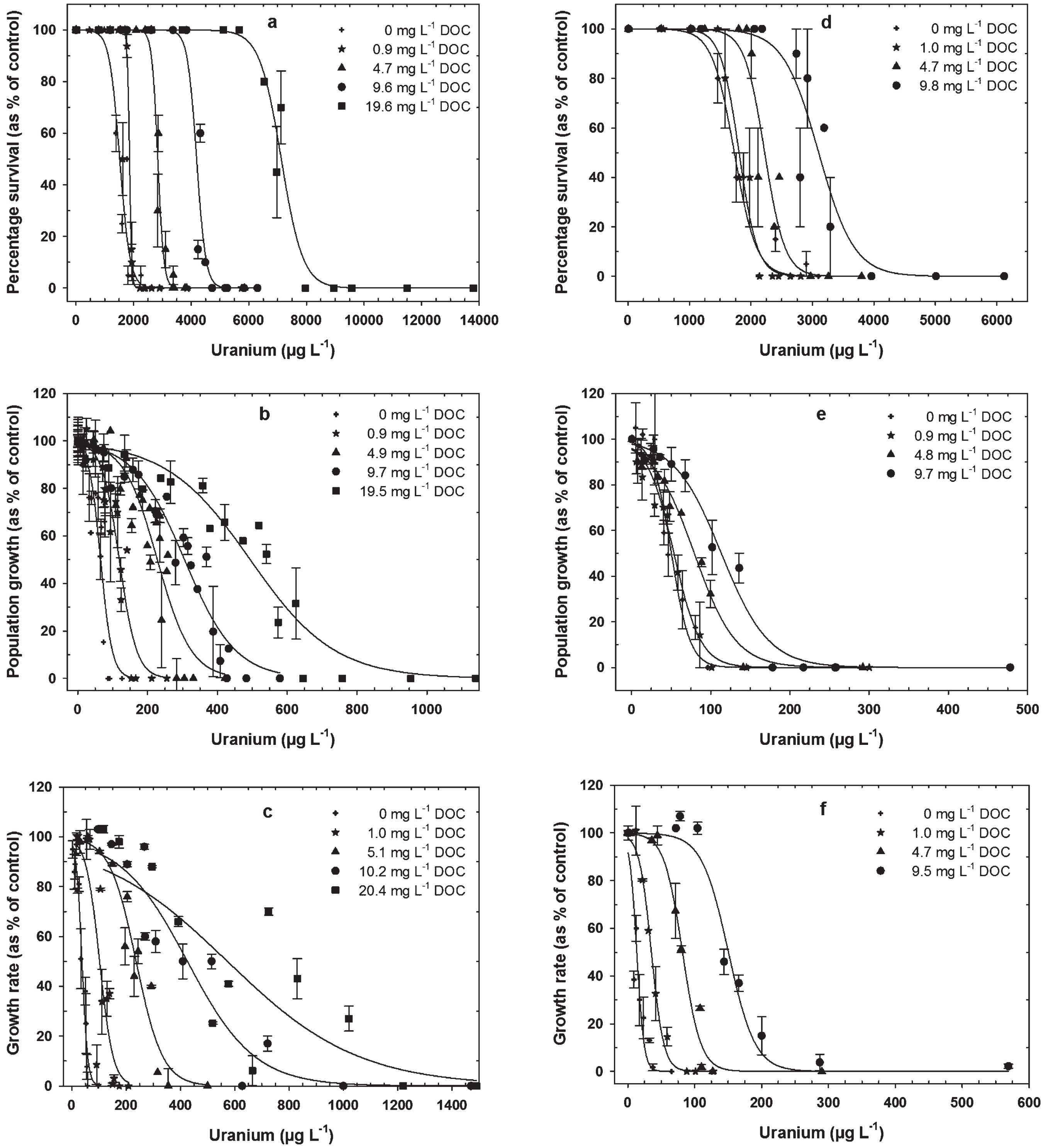

Figure 1. Effect of Suwannee River fulvic acid (SRFA) on the toxicity of uranium (U) to (a) *M. mogurnda*, (b) *H. viridissima*, and (c) *Chlorella* sp. in synthetic Magela Creek water (SMCW) (3 pooled tests for each species), and effect of natural dissolved organic carbon on U toxicity in Sandy Billabong Water (diluted in SMCW) to (d) *M. mogurnda*, (e) *H. viridissima*, and (f) *Chlorella* sp. (2 pooled tests for each species). Each value represents the mean ± standard error of 2 replicates.

M. mogurnda. The sac-fry survival tests involved acute exposure of five fry to a 30 mL control treatment, or one of seven U concentrations at each DOC concentration for 96 h at 27 ± 1 °C. Each DOC concentration (containing both control and U treatments) was tested simultaneously. Treatments were conducted in duplicate in plastic Petri dishes with 24 h renewal of test solutions. Selected fry were less than 10 h old and free of overt disease or deformity. Fry survival was monitored every 24 h using a microscope to observe heartbeat. Dead fry were removed. Fry were not fed over the test duration. Percentage survival of

Table 2. Uranium Toxicity to Three Tropical Freshwater Species at Increasing Dissolved Organic Carbon (DOC) Concentrations in (i) Synthetic Magela Creek Water (SMCW) Supplemented with Suwannee River Fulvic Acid (SRFA) and (ii) Sandy Billabong Water (SBW) Containing 10 mg L^{-1} DOC Diluted to 0, 1, and 5 mg L^{-1} DOC with SMCW; Toxicity End Points are 96-h Survival (*Mogurnda mogurnda*), 96-h population growth (*Hydra viridissima*) and 72-h Cell Division (*Chlorella* sp.)

		LC_{50} or IC_{50} μg L^{-1} U[a] (95% CL)[b]				
		DOC[c]				
water type	species	0 mg L^{-1}	1 mg L^{-1}	5 mg L^{-1}	10 mg L^{-1}	20 mg L^{-1}
SMCW + SRFA	*Mogurnda mogurnda* (northern trout gudgeon)	1520 (1430−1610)	1860 (1820−1900)	2840 (2790−2880)	4190 (4040−4290)	7130 (6980−7270)
	Hydra viridissima (green hydra)	67 (57−73)	120 (109−128)	230 (213−243)	311 (289−323)	505 (456−533)
	Chlorella sp. (unicellular alga)	38 (32−43)	124 (73−132)	256 (215−258)	468 (334−517)	744 (319−827)
SBW	*Mogurnda mogurnda* (northern trout gudgeon)	1730 (1660−1800)	1810 (1740−1870)	2220 (2110−2340)	3100 (2890−3310)	
	Hydra viridissima (green hydra)	50 (45−56)	54 (49−58)	79 (73−85)	113 (103−124)	
	Chlorella sp. (unicellular alga)	13 (8−19)	35 (32−38)	82 (76−88)	150 (138−163)	

[a] LC_{50}:the concentration that results in 50% mortality (for *M. mogurnda*), IC_{50}: the concentration that results in 50% inhibition of the test response relative to the control response (for *H. viridissima* and *Chlorella* sp.). [b] 95% confidence limits. [c] DOC: dissolved organic carbon.

exposed fry was compared to that of the control. A test was considered valid if the survival in controls was ≥80%, with variability in the controls (expressed as the coefficient of variation, CV) of less than 20%.

H. viridissima. The *H. viridissima* population growth tests involved chronic exposure of five hydra to a 30 mL control treatment, or one of seven U concentrations at each DOC concentration for 96 h at 27 ± 1 °C. Each DOC concentration (containing both control and U treatments) was tested simultaneously. Treatments were conducted in duplicate in plastic Petri dishes with 24 h renewal of test solutions. Each hydra was fed 3−5 artemia (*Artemia salina*) daily. Hydra were selected on the basis that they were free of deformity and each hydroid had one tentacled bud, a characteristic of optimal health.[15] Population growth rates were compared to that of the control. A test was considered valid if there were 15 or more healthy hydra in each of the control replicates at 96 h (equivalent to a daily growth rate ≥0.275 day^{-1}, where growth rate is [(ln (final number) − ln (starting number))/4]), with variability in the controls (expressed as the coefficient of variation, CV) of less than 20%.

Chlorella sp. The *Chlorella* sp. growth test involved the chronic exposure of a standard number of algal cells ($2-4 \times 10^4$ cells/mL) to a 30 mL control volume or one of four U concentrations at each DOC concentration for 72 h at 28 ± 1 °C. Treatments were prepared in duplicate in silanized 100 mL Erlenmeyer flasks. To each flask, 26 mM sodium nitrate (15 mg L^{-1} NO_3) and 1.3 mM potassium dihydrogen phosphate (0.15 mg L^{-1} PO_4) and 1 mM HEPES buffer (pH 6.0) were added. Tests were conducted using exponentially growing cells from a 4-day old culture. Cells were rinsed three times in SMCW (pH 6 ± 0.15) and concentrated using centrifugation [15] in order to remove the nutrient-enriched culture medium, which may lower toxicity due to its ability to strongly complex trace metals.[18] Algal growth was measured by counting the cells at 48 and 72 h using an automatic particle counter (Coulter Multisizer II) and calculating the cell division rate (growth rate − doublings d^{-1}) using linear regression analysis. Growth rates of algae exposed to U were expressed as a percentage of the control growth rate. A test was considered valid if the cell division rate in controls was 1.4 ± 0.3 doublings day^{-1}, with CV of less than 20%.

Physicochemical Analyses. Details of the instruments and methods used have been described previously.[5] The pH, dissolved oxygen and conductivity of the test solutions (Table 1) were measured at the commencement and termination of *Chlorella* sp. tests and daily on new and 24-h old water for *H. viridissima* and *M. mogurnda* tests. DOC was analyzed immediately after the initiation of each test, on subsamples of each treatment. A comprehensive suite of analytes (see Table S1 in the Supporting Information) was measured in a Milli-Q blank and control samples from each test using Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) or Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). U was measured in all treatments of each test using ICP-MS. Alkalinity and hardness were determined for control samples across all DOC treatments at the commencement of tests (Table 1). Nitrate (NO_3^-) and phosphate (PO_4^{3-}) were measured using Flow Injection Analysis (Lachat Quikchem FIA+, 8000 series) (see Table S1 in the Supporting Information).

Geochemical Speciation Modeling. The speciation of U[VI] in the test solutions was calculated using the HARPHRQ geochemical speciation code,[19] with input parameters based on physicochemical data measured in the test solutions (pH, temperature, dissolved oxygen and total cation and anion concentrations; Table 1 and Table S1 in the Supporting Information). There were no precipitates observed in the test solutions (nor were any predicted to form) and measured U was generally within 75−90% of nominal concentrations (small losses were due to sorption). DOC concentrations were converted to FA molar concentrations using the number-average molecular weight (M_n) estimates (SRFA, 856 Da; and SBFA, 1075 Da) and carbon content (SRFA, 49.91%; and SBW, 51.45%) as reported in.[5] The conditional UO_2−FA stability constant (log $K = 6.8$) used for modeling SRFA-U speciation was determined by [20] and corrected to zero ionic strength and 25 °C for HARPHRQ. A conditional stability constant (log K) of 4.98 was calculated for UO_2-SBFA based on differences in acidity of the two FAs.[5]

Statistical Analyses. For each test organism, toxicity data were pooled from three SMCW tests and from two SBW tests, and presented as a function of the control response. For each organism and DOC source, nonlinear (3-parameter sigmoidal) regression was used to generate U concentration−response curves for each DOC concentration (SigmaPlot 11.0). U concentrations at which there was 50% inhibition of growth (IC_{50}) or 50% reduction in survival (LC_{50}) and their 95% confidence limits were determined from the equation of the sigmoidal curve fits. Finally, relationships between DOC, key U species (as calculated by HARPHRQ) and U toxicity were examined for each organism, by incorporating all toxicity data into a generalized linear model with a Gaussian response distribution and associated logit link function (R 2.10.0, [21]). The most parsimonious models were determined by comparison of the Akaike Information Criterion (AIC, [22]).

RESULTS AND DISCUSSION

Water Chemistry. A summary of measured physicochemical data is shown in Table 1. For all experiments, there was minimal fluctuation in physicochemical parameters (pH ± 0.2, dissolved oxygen ±15% at 26−28 °C, conductivity <10% and temperature ±1.0).

Test Acceptability Criteria. All tests met acceptability criteria: *Chlorella* sp. control growth rate mean ± CV was 1.40 ± 0.3 doublings d^{-1}; *H. viridissima* control growth rate was 0.36 ± 0.07 (mean ± CV); and *M. mogurnda* control survival was 100% for all tests.

Effect of Standard DOC on U Toxicity. With increasing DOC, in the form of SRFA, U became less toxic to each of the test species (Figure 1a-c, Table 2). In the presence of around 5 mg L^{-1} DOC, which is the average value of DOC for creeks and rivers worldwide,[23] the toxicity of U to *M. mogurnda* was almost halved compared to that in water without DOC (Table 2). A DOC concentration of around 20 mg L^{-1}, typical of higher DOC concentrations found in floodplain environments,[24] reduced U toxicity to *M. mogurnda* 4-fold compared to that in water without DOC (Table 2). Although DOC reduced U toxicity to *M. mogurnda*, once survival began to decline, the rate of mortality was similar across all DOC concentrations (Figure 1a). The LC_{50}s for U at all five DOC concentrations corresponded with a narrow predicted free UO_2^{2+} concentration range of 16−21 μg L^{-1}, similar to a previously reported LC_{50} for *M. mogurnda* of 13 μg L^{-1} UO_2^{2+} in low DOC water[11] (based on HARPHRQ modeling). This suggests a similar and rapid mechanism (<24 h) of U toxicity to *M. mogurnda* once the toxic threshold is reached, supported by observations which showed that the majority of fry mortality occurred within the first 24 h of the 96 h U exposures, regardless of the DOC concentration.

For *H. viridissima* and *Chlorella* sp., the addition of as little as 1 mg L^{-1} DOC reduced U toxicity to these organisms 2- and 3-fold, respectively, whereas 5 mg L^{-1} DOC reduced toxicity four- and 7-fold, respectively (Table 2). U toxicity in the presence of 20 mg L^{-1} DOC was reduced most for *Chlorella* sp. (20-fold, Table 2). For both species, the extent of growth inhibition with increasing U was more gradual as DOC increased. The variation in response of *Chlorella* sp. and *H. viridissima* for each DOC concentration may be due to the increased complexity of the test systems for these organisms, which involved the addition of nutrients (see Table S1 in the Supporting Information) and live food, respectively.

Effect of Local DOC on U Toxicity. Similarly to SRFA, U became less toxic to each of the test species in the presence of increasing concentrations of DOC (up to 10 mg L^{-1}) in SBW (Figure 1d-f, Table 2). U toxicity to *M. mogurnda* and *H. viridissima* in SMCW at 0 mg L^{-1} DOC for SBW testing was similar to that for the SRFA tests (Table 2). However, *Chlorella* sp. was more sensitive to U at 0 mg L^{-1} DOC for the SBW tests compared to the SRFA tests (Table 2). This difference in toxicity appeared to be due to a difference in mean pH between the 0 mg L^{-1} DOC treatments of the SRFA tests (pH 6.2) and SBW tests (pH 6.0) which resulted in over twice as much UO_2^{2+} being present in SBW compared with SRFA in SMCW (Figure 3). For *M. mogurnda* and *H. viridissima* in SBW containing 5 and 10 mg L^{-1} DOC there was around a 1.5- and 2-fold reduction in U toxicity, respectively, for both species. For *M. mogurnda*, the rate of mortality following the onset of mortality was similar across DOC concentrations (Figure 1d), as was the case in the presence of SRFA. The local DOC reduced U toxicity most for *Chlorella* sp., with 1, 5, and 10 mg L^{-1} DOC reducing U toxicity by approximately 3-, 6-, and 12-fold, respectively (Table 3). A previous study using natural Magela Creek water reported 3- to 4-fold reduction in U toxicity to *Chlorella* sp. between 0 and 8 mg L^{-1} DOC,[14] although other key physicochemical variables were unable to be as tightly controlled as in the present study.

Comparison of the Extent of Reduction of U Toxicity by Each DOC Source. The percentage reduction in U toxicity based on the difference in IC_{50} or LC_{50} values at background DOC with those at 1, 5, 10, and 20 mg L^{-1} DOC of SRFA and at 1, 5, and 10 mg L^{-1} DOC SBW is shown in Figure 2a−c. DOC is represented in terms of FA concentration in order to account for the specific carbon content and molecular weight of each FA.[5] Based on the slopes of the regressions, the extent of reduction in U toxicity for *M. mogurnda* and *H. viridissima* in the presence of the SRFA standard was almost twice that of SBW. For *Chlorella* sp., there was a similar reduction in U toxicity by SRFA and SBW over the DOC range of 0−10 mg L^{-1} (0−23 μM FA). The greater reduction in toxicity brought about by SRFA for *M. mogurnda* and *H. viridissima* is likely to be a result of the increased capacity of SRFA to bind U (having a greater log K), compared to that of the FA in SBW.[5] The difference in their ameliorative capacity may also be a result of SRFA being an isolated and purified FA standard, while SBW DOC, having been tested as an in situ DOC source, contained a small proportion of humic acids in addition to FAs.[5] Humic acids can have less complexing ability than FAs, generally having less proton-dissociating groups as well as these groups often being weaker acids than those of FAs.[17] It may be argued that the SRFA standard is not representative of SRFA in its natural state, due to humic substance (HS) isolation procedures that may chemically and structurally alter the natural HS. While this is potentially a concern, FA isolated from SBW using the same extraction procedure as that for SRFA had a lower binding capacity for U than for the SRFA.[5]

Effect of Each DOC Source on the Speciation of U. U speciation modeling showed the decrease in U toxicity in the presence of increasing concentrations of the DOC sources was explained primarily by a reduction in the concentration of UO_2^{2+} and an increase in UO_2FA (Figures 3a−c). The other U species

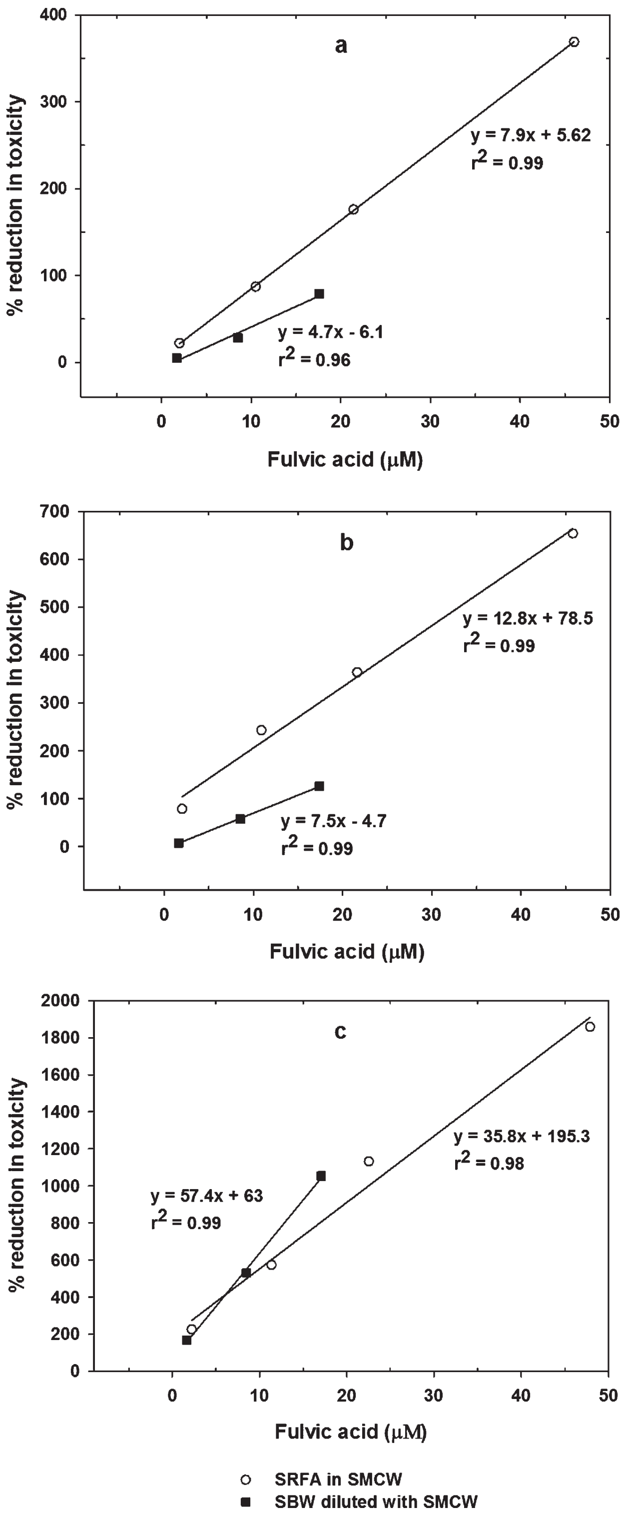

Figure 2. Relationship between fulvic acid concentration and percent reduction in U toxicity for Suwannee River fulvic acid (SRFA) and Sandy Billabong water (SBW). Reduction in toxicity is based on the difference between IC_{50} or LC_{50} values at background DOC with values at 1, 5, 10, and 20 mg L^{-1} DOC for SRFA and at 1, 5, and 10 mg L^{-1} DOC for SBW (a) *M. mogurnda*, (b) *H. viridissima* ,and (c) *Chlorella* sp.

thought to be a key bioavailable form of U, UO_2OH^+,[8] also decreased with increasing DOC (see the Supporting Information Table S2 and S3). Speciation modeling for each of the organisms

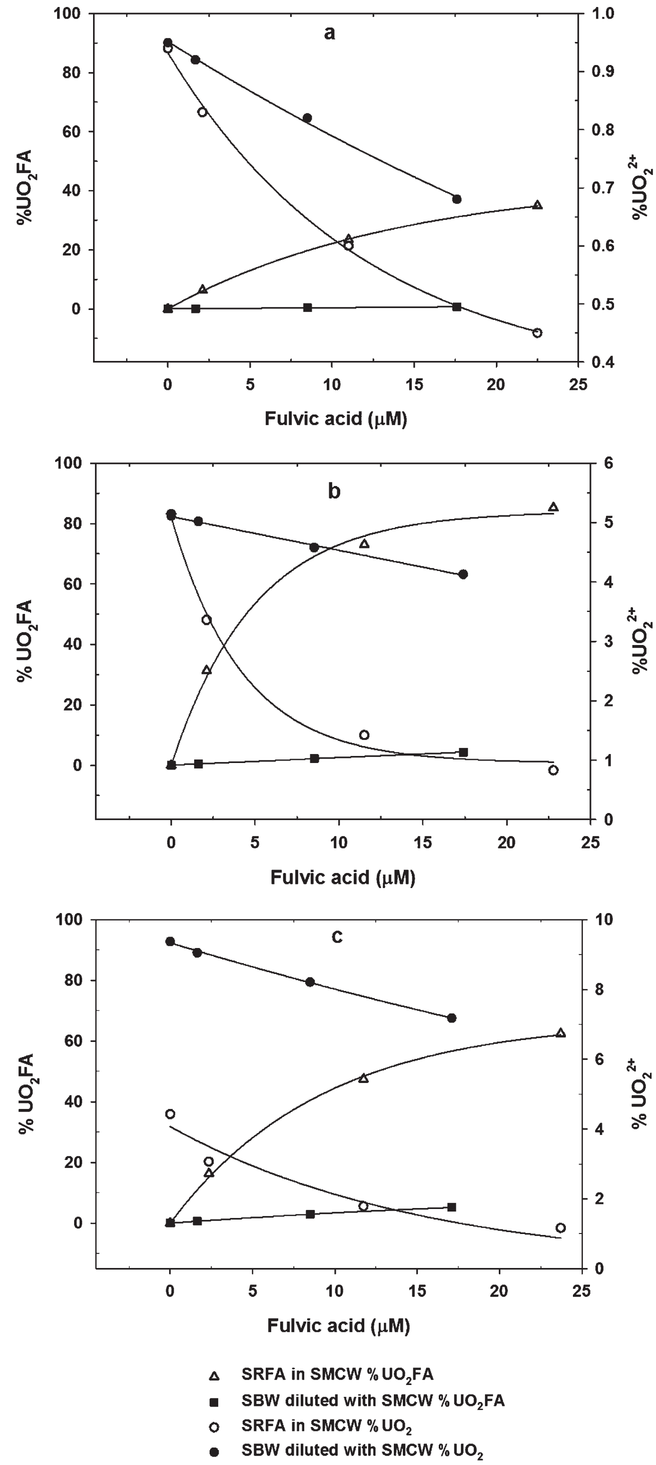

Figure 3. The proportion of bound U (UO_2FA) and free U (UO_2^{2+}) as calculated by the HARPHRQ model for: (a) *M. mogurnda*, (b) *H. viridissima*, and (c) *Chlorella* sp. Points represent the U concentration that results in a 50% effect at each FA concentration (IC_{50}/LC_{50}), with these concentrations being derived from the equations of the sigmoidal curve fits in Figure 1.

showed that a much greater proportion of UO_2FA was formed in the presence of SRFA than SBW at corresponding FA concentrations. This was also reflected by a more marked decrease in $\%UO_2^{2+}$ occurring in the presence of SRFA. In Figure 3a, the

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Table 3. Model Equations from the Best-Fitting Generalized Linear Models for Describing the Influence of Uranium (U) Concentration (as Filtered U, Uranyl Ion, or Uranyl Hydroxy Ion) and Dissolved Organic Carbon (DOC) on Toxicity

Organism	DOC[a]	model based on filtered U	r^{2b}	model based on UO_2^{2+} or UO_2OH^+	r^2
M. mogurnda	SRFA	0.0016U-0.423DOC+2.816	0.53	$0.657UO_2-0.223DOC-3.822$	0.62
	SBW	0.0036U-0.577DOC-0.868	0.71	$0.557UO_2-0.054DOC-5.883$	0.72
H. viridissima	SRFA	−0.00052U+0.00939DOC+0.2236	0.50	$-0.05UO_2-0.004DOC+0.37$	0.70
	SBW	−0.0014U+0.0112DOC+0.293	0.66	$-0.05UO_2-0.005DOC+0.391$	0.81
Chlorella sp.	SRFA	−0.0014U+0.048DOC+0.797	0.41	$-0.16UO_2+0.03DOC+1.14$	0.52
	SBW	−0.0043U+0.0994DOC+0.658	0.45	$-0.018UO_2OH+0.131DOC+0.896$	0.64

[a] SRFA: Suwannee River fulvic acid, SBW: Sandy Billabong water. [b] Regression coefficients (r^2) are based on linear regressions of observed versus predicted toxicity values.

30−40% of UO_2FA complex formed in the presence of 22.5 μM SRFA (10 mg L^{-1} DOC), was equivalent to the complexation of 1400 μg L^{-1} U, whereas at 20 mg L^{-1} DOC, SRFA was estimated to bind over 3000 μg L^{-1} U (results not shown). In comparison, the 0.7% of UO_2FA complex formed in SBW containing 10 mg L^{-1} DOC (18 μM FA), was equivalent to only 22 μg L^{-1} U.

According to HARPHRQ calculations for SBW, the role of carbonate in binding U remained constant with increasing DOC (see Table S3 in the Supporting Information), whereas for the SRFA, increasing DOC greatly reduced the proportion of UO_2CO_3 formed, with SRFA apparently out-competing carbonate for the complexation of UO_2^{2+} (see Table S2 in the Supporting Information). In SBW test waters, regardless of the DOC concentration, the majority of U was present in the form of $(UO_2)_3(OH)_5^+$ and $(UO_2)_2(OH)_3CO_3^-$ for *M. mogurnda*, UO_2OH^+ for *Chlorella* sp. and UO_2OH^+, UO_2CO_3 and $(UO_2)_2(OH)_3CO_3^-$ for *H. viridissima* (see Table S3 in the Supporting Information). In SRFA test waters, these complexes were dominant only at low DOC concentrations. Above 5 mg L^{-1} DOC, the formation of UO_2FA complex exceeded U bound as inorganic complexes.

For each of the test organisms, the most parsimonious model describing the influence of DOC and various U species on U toxicity incorporated the species UO_2^{2+} and UO_2OH^+. These species have been shown previously to be bioavailable U species that contribute to U toxicity.[8,25] While the best-fitting model incorporated both UO_2^{2+} and UO_2OH^+, the strong correlation between these two species resulted in their influence on toxicity being found to be nonsignificant. Hence a model combining both species was not appropriate. When these two U species were each modeled individually with DOC, both were predicted to be highly significant in causing toxicity ($p < 2 \times 10^{-16}$, $\alpha = 0.05$). However, in most cases, a model incorporating UO_2^{2+} provided the best agreement with observed toxicity (highest r^2). In one exception, U toxicity in SBW to *Chlorella* sp. was most effectively explained by UO_2OH^+, and in this instance UO_2OH^+ was substituted for UO_2^{2+} in the model. These models, along with models based on (0.45 μm) filtered U, DOC and toxicity, are described for each organism and DOC source in Table 3. The models, in particular those incorporating specific U species rather than filtered U, provide a reasonable predictive ability, with most explaining at least 50% of the variance in the response (Table 3). At the same time, however, the substantial unexplained variability highlights the complex nature of factors influencing the toxicity of U.

Importance of Incorporating a Relevant DOC Source in U Toxicity Studies. The present study clearly demonstrated the importance of DOC as a factor influencing the speciation and toxicity of U in aquatic environments. However, the large differences in the capacity of the two DOC sources to complex U and to reduce U toxicity to two of the organisms suggest that a standard DOC such as SRFA may not represent a suitable surrogate for local DOCs. Consequently, depending on precise assessment objectives, use of site-specific waters containing local DOC to assess DOC-related effects on the toxicity of metals may be more appropriate, particularly where other key physicochemical variables (e.g., pH, hardness, alkalinity) can be adequately controlled. Of the various physicochemical variables that have been shown to influence U toxicity, DOC and pH appear to be the key driving variables in the acidic soft freshwaters of the Alligator Rivers Region. Future studies will aim to understand the combined influence of pH and DOC and to more specifically address the cellular mode of action of DOC in relation to its influence on U toxicity.

■ ASSOCIATED CONTENT

S Supporting Information. The inorganic composition of SBW is presented in Table S1. Table S2 and S3 show predicted speciation of U for SRFA and SBW, respectively (PDF). This material is available free of charge via the Internet at http://pubs.acs.org/.

■ AUTHOR INFORMATION

Corresponding Author

*Phone: + 61 8 8920 1156; Fax: + 61 8 8920 1195; e-mail: Melanie.Trenfield@environment.gov.au.

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Evaluation of DGT techniques for measuring inorganic uranium species in natural waters: Interferences, deployment time and speciation

Geraldine S.C. Turner[a], Graham A. Mills[b], Peter R. Teasdale[c], Jonathan L. Burnett[d], Sean Amos[d], Gary R. Fones[a,*]

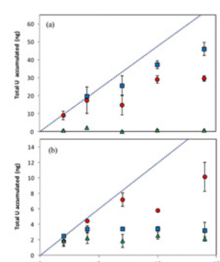
[a] *School of Earth and Environmental Sciences, University of Portsmouth, Burnaby Building, Burnaby Road, Portsmouth, Hampshire, PO1 3QL, UK*
[b] *School of Pharmacy and Biomedical Sciences, University of Portsmouth, St Michael's Building, White Swan Road, Portsmouth, Hampshire, PO1 2DT, UK*
[c] *Environmental Futures Centre, Griffith University, Gold Coast Campus, Queensland 4222, Australia*
[d] *AWE Aldermaston, Reading, Berkshire, RG7 4PR, UK*

HIGHLIGHTS

- ► The adsorbents Chelex-100, Metsorb and MnO_2 were investigated for use with DGT.
- ► All three adsorbents performed well in low ionic strength solutions.
- ► MnO_2 resin was found to be the most suitable for marine deployments.
- ► DGT is able to measure isotopic ratios of U down to concentrations of 0.1 μg L^{-1}.
- ► DGT underestimated U concentrations by at least 50% if the DBL was not taken into account.

GRAPHICAL ABSTRACT

In situ field deployment of DGT devices – manganese dioxide (■) best suited for sea water monitoring (a) up to 7 days and Metsorb (●) best suited for fresh water monitoring (b) of inorganic uranium species up to 7 days.



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ABSTRACT

Three adsorbents (Chelex-100, manganese dioxide [MnO_2] and Metsorb), used as binding layers with the diffusive gradient in thin film (DGT) technique, were evaluated for the measurement of inorganic uranium species in synthetic and natural waters. Uranium (U) was found to be quantitatively accumulated in solution (10–100 μg L^{-1}) by all three adsorbents (uptake efficiencies of 80–99%) with elution efficiencies of 80% (Chelex-100), 84% (MnO_2) and 83% (Metsorb). Consistent uptake occurred over pH (5–9), with only MnO_2 affected by pH < 5, and ionic strength (0.001–1 mol L^{-1} $NaNO_3$) ranges typical of natural waters, including seawater. DGT validation experiments (5 days) gave linear mass uptake over time ($R^2 \geq 0.97$) for all three adsorbents in low ionic strength solution (0.01 M $NaNO_3$). Validation experiments in artificial sea water gave linear mass uptake for Metsorb ($R^2 \geq 0.9954$) up to 12 h and MnO_2 ($R^2 \geq 0.9259$) up to 24 h. Chelex-100 demonstrated no linear mass uptake in artificial sea water after 8 h. Possible interferences were investigated with SO_4^{2-} (0.02–200 mg L^{-1}) having little affect on any of the three DGT binding layers. PO_4^{3-} additions (5 μg L^{-1}–5 mg L^{-1}) interfered by forming anionic uranyl phosphate complexes that Chelex-100 was unable to accumulate, or by directly competing with the uranyl species for binding sites, as with MnO_2 and the Metsorb. HCO_3^- (0.1–500 mg L^{-1}) additions formed anionic species which interfered with the performance of the Chelex-100 and the MnO_2, and the Ca^{2+} (0.1–500 mg L^{-1}) had the affect of forming labile calcium uranyl species which aided uptake of U by all three resins. DGT field deployments in sea water (Southampton Water, UK) gave a linear mass uptake of U over time with Metsorb and MnO_2 (4 days). Field deployments in fresh water (River Lambourn, UK) gave linear uptake

* Corresponding author. Tel.: +44 2392 842252.
E-mail address: gary.fones@port.ac.uk (G.R. Fones).

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for up to 7 and 4 days for Metsorb and MnO_2 respectively. Field deployment of the Metsorb-DGT samplers with various diffusive layer thicknesses (0.015–0.175 cm) allowed accurate measurements of the diffusive boundary layer (DBL) and allowed DBL corrected concentrations to be determined. This DBL-corrected U concentration was half that determined when the effect of the DBL was not considered. The ability of the DGT devices to measure U isotopic ratios with no isotopic fractionation was shown by all three resins, thereby proving the usefulness of the technique for environmental monitoring purposes.

1. Introduction

Uranium (U) is a primordial radioactive element, originating from the three naturally occurring decay chains (^{235}U, ^{238}U and ^{230}Th), with three important isotopes: ^{238}U (99.276%), ^{235}U (0.718%) and ^{234}U (0.0056%) [1]. It is released in the environment *via* anthropogenic nuclear processes, such as nuclear power generation, nuclear weapons testing and accidental releases, or *via* natural processes such as weathering or erosion of rocks and sediments containing U. It is highly toxic and important to monitor due to its chemical and radiological properties [2].

U is predominantly found in the 6+ state as the uranyl ion (UO_2^{2+}) at pH < 4–5, and at pH > 7 occurs as the stable uranyl carbonates $UO_2(CO_3)_2^{2-}$, $UO_2(CO_3)_3^{4-}$ or its complexes, although U(IV) is also found under reducing conditions [3]. Partitioning between the solid and the solution phases, which is mediated by chemical characteristics such as pH, redox potential, ionic strength, presence of complexing ligands ($OH^- > CO_3^{2-} > HPO_4^{2-} > H_2PO_4^- > F^- > SO_4^{2-} > Cl^-$), surfactants or flocculating agents, is important in natural waters [4]. These all act to influence the oxidation states of the radionuclide and will affect reactions with other dissolved components and sediment–solution interactions.

Table 1 shows the concentration of U in a range of natural environments; typical marine concentrations are 3 $\mu g\,L^{-1}$, while estuarine concentrations can be as low as 0.3 $\mu g\,L^{-1}$, with typical fresh water values of 0.1–0.3 $\mu g\,L^{-1}$. The higher dissolved sea water concentrations are due to the formation of stable soluble uranyl carbonate complexes. The largest global sink for U is oceanic sediments, with oceanic carbonates solubilising fluvial and ground water inputs of U. The low environmental concentrations of U can be challenging to detect using conventional analytical techniques such as mass spectroscopy, particularly in complex matrices such as marine or estuarine waters. Isotopic ratios of $^{235}U/^{238}U$ are of interest as a tool to identify pollution sources. ^{235}U occurs in very low concentrations, even when enriched, and is normally below limits of detection without any form of pre-concentration; by precipitation, ion-exchange, solvent extraction or extraction chromatography [5]. Pre-concentration and radiochemical separation require large volume (up to 5 L) [6] grab samples of water. These approaches that use considerable sample processing can also introduce contamination and chemical transformations each time the sample is handled or during storage [7].

Alternative measurement approaches include bio-monitoring [8,9], technologies based on the redox reactions between analyte and a chelate [10] and fibre optical methods [11]. As many of these techniques have poor limits of detection they can be used only to indicate the presence of U or, during a pollution event where environmental concentrations are elevated. Passive sampling is another approach [12]. This method avoids many of the sources of error associated with grab sampling by pre-concentrating the analyte *in situ*. Furthermore, passive samplers can be used to measure time-weighted averaged (TWA) concentrations over the deployment period, which can be beneficial in investigations where concentrations fluctuate highly [12,13].

Diffusive gradients in thin films (DGT) are passive samplers that measure the labile, dissolved fraction of analytes *in situ* [14]. The device consists of three layers: (i) a binding agent, which contains a resin or functional groups selective to the target ions, held in a thin layer of hydrogel (binding gel); (ii) a layer of hydrogel of known thickness, which serves as the diffusive layer; and (iii) a protective outer membrane with a known pore size. A diffusive boundary layer (DBL) that forms on the exposed face of the device must also be accounted for and added to the diffusive layer. After deployment, the metal ions accumulated in the resin layer are eluted (*e.g.* in nitric acid) and the extract analysed by sensitive instrumental techniques, *e.g.* ICP-MS.

U has been measured in artificial and natural waters using DGT in five reported studies [15–19]. Li et al. [15,16] measured U uptake in artificial alkaline waters using a device that comprised a Whatman DE 81 membrane and Chelex-100 resin (BioRad; www3.bio-rad.com). In a later study they investigated the use of a Dowex 2 × 8-400 resin as the receiving phase [16]. Gregusova et al. [20] assessed a chelating ion-exchange resin, Spheron-Oxin® as a candidate binding phase, examining the effects of carbonate concentrations in artificial waters on the uptake of U. Vandenhove et al. [17] and Mihalik et al. [19] used a DGT containing Chelex-100 as a proxy for phyto-availability but did not undertake any further validation work. A recent study by Hutchins et al. [18] measured U in natural waters using a TiO_2-based resin, Metsorb (Graver Technologies; http://www.gravertech.com).

In this study we compared the uptake of U using a DGT device containing either Chelex-100 resin, Metsorb resin, or manganese dioxide (MnO_2), as described by Burnett et al. [21]. MnO_2 is a natural scavenger of metals and radionuclides from waters and is stable in the presence of high radiation levels. It has applications in the remediation of nuclear aquatic waste and pre-concentration of radionuclides in sea water [22]. An MnO_2 precipitate has been used previously in passive samplers to study sediment redox profiles through remobilisation of the MnO_2 within the gels [23] and with DGT to measure ^{226}radium [24,25]. The performance of each resin in the presence of complexing agents such as HCO_3^-, PO_4^{3-} and SO_4^{2-} and common ionic interference Ca^{2+} were evaluated [26]. Experiments to assess the accumulation of U over time for artificial sea water and low ionic strength water were undertaken. Two 14-day field deployments in carbonate rich river water and in a marine harbour were used to validate laboratory results.

2. Experimental

Chemicals were of analytical grade or better and supplied by Fisher Scientific (Loughborough, U.K.), unless otherwise specified. Milli-Q (ultra-pure) water (>18.2 MΩ cm, Millipore, Watford, U.K.) was used as the laboratory water. All U ICP-MS standards and experimental working solutions were prepared in low density polyethylene (LDPE) or polystyrene (PS) containers with polypropylene lids (PP) from a 1000 $mg\,L^{-1}$ in 2% HNO_3 (Spex Certiprep, Fisher Scientific) U stock solution unless otherwise stated. The ICP-MS internal standard was prepared from a 1000 $mg\,L^{-1}$ in 2% HNO_3 (Spex Certiprep) bismuth stock solution. These solutions were adjusted to a given pH by addition of either 1 M HNO_3 or 1 M NaOH, and to a given ionic strength by addition of $NaNO_3$, with the pH monitored throughout experiments. Solutions were equilibrated with atmospheric CO_2 for 24 h before use unless otherwise

Table 1
Examples of U concentrations found in the aquatic environment.

Environment	Concentration ($\mu g\,L^{-1}$)	Reference
Fluvial		
General	0.3 (dissolved), 3.0 (particulate)	[52]
Alafia River, Tampa Bay, Florida, USA	0.52	[52]
Euphrates River, Dhi Qar Province, Southern Iraq	1.5–4.3	[53]
River Fal, south-west England	0.19–1.34	[54]
Marine		
Open ocean	3.2	[52]
Sea surface	0.5–3.0	[55]
Estuarine		
Tampa Bay Estuary, Florida, USA	3.81	[52]
Gironde Estuary, SW France	0.32–3.37	[56]
Ground water/pore water		
Sarzal region of the Semispaltinsk nuclear test site, Kazakhsatn	1.1–95.5	[57]
Southern Nares Abyssal Plain, North Atlantic	0.1–0.5	[58]
Sediments		
Black Sea	0.5–1.2 ($g\,kg^{-1}$)	[59]
Ortigas River, Spain	0.001–0.01 ($g\,kg^{-1}$)	[60]

specified. All readings were undertaken in triplicate with containers open to the atmosphere to ensure continuing equilibration with the atmospheric pCO_2 (*i.e.* to ensure a constant inorganic carbon concentration throughout the experiments). All plastic apparatus was soaked for 24 h in 10% HNO_3 and rinsed three times in Milli-Q water prior to use.

2.1. Preparation of DGT devices

Polyacrylamide (PAM) diffusive gels (thickness 0.4, 0.8, 1.2 and 1.6 mm) were prepared according to Zhang and Davison [27]. The gels contained 15% (v/v) acrylamide solution (Acros Organics, ThermoFisher, Loughborough, U.K.) and 0.3% (v/v) of patented agarose cross-linker (DGT Research Ltd., Lancaster, U.K.). N,N,N′,N′-tetramethylenediamine (TEMED, Acros Organics) was used as the catalyst and a freshly prepared solution of 10% ammonium persulphate (Acros Organics) was used as the initiator for polymerisation. The diffusive gels were stored in either 0.01 M $NaNO_3$ or 0.4 M NaCl prior to either fresh water or sea water deployments, respectively.

The 0.4 mm thick PAM binding gels were prepared with either 2 g Chelex-100 resin (Na form, 75–150 μm particle size, BioRad Laboratories, Hemel Hemstead, U.K.), 1 g MnO_2 resin (prepared after Burnett et al. [21] using pre-filtered material supplied by TisKem International (Bruz, France) or 1 g Metsorb HMRP powder (TiO_2 with an organic binder, <50 μm; Graver Technologies, Glasgow, USA) in 10 mL gel solution prior to polymerisation. The Chelex-100 gel was prepared according to Zhang and Davison [27], and the MnO_2 and the Metsorb gels were prepared according to the method described by Bennett et al. [28].

DGT device mouldings were obtained from DGT Research Ltd. and washed for 24 h in 10% HNO_3, and then rinsed three times in Milli-Q water prior to use. The devices were assembled according to Davison et al. [14] and stored at 4 °C in zip lock plastic bags, containing 1–2 mL of water (matrix matched to deployment site) to ensure the diffusion properties of the gels were not altered, and to prevent the gels drying out. A disk of (0.2 μm pore size) Supor polyethylene sulfone (Pall Corporation, Portsmouth, U.K.) was used as the outer membrane.

2.2. Analysis of DGT devices

After exposure, the Metsorb and MnO_2 binding gels were removed from the DGT devices and eluted (48 h) with 1 M H_2O_2/HNO_3 (2 mL) solution (100 mL made by combining 90 mL 1.1 M HNO_3 and 10 mL H_2O_2). The Chelex-100 binding gels were eluted (48 h) with 2 M HNO_3 (2 mL). After the sea water deployments, the binding gels were first washed (5 mL) in Milli-Q water for 1 h to remove excess salts [28]. The eluents were then diluted 10 fold with Milli-Q water prior to instrumental analysis. U was determined in all solutions by ICP-MS using an Agilent 7500ce series instrument (Agilent Technologies Inc., Japan). Total U was measured under normal plasma conditions in 'no gas mode', with the sample introduction system fitted with a micromist nebuliser. The instrument blank for U was 6 $ng\,L^{-1}$ while the limit of detection (calculated by the Agilent Chemstation software) for U was 2 $ng\,L^{-1}$, with a measurement standard deviation better than 3%. Laboratory blanks were undertaken in triplicate for each experiment and the average concentration per disk was determined for MnO_2 gel disks as 0.06 ± 0.001 ng and 0.3 ± 0.05 ng for ^{238}U and ^{235}U respectively; for the Chelex-100 gel disks as 0.06 ± 0.003 ng and 0.2 ± 0.08 ng for ^{238}U and ^{235}U respectively; and for the Metsorb gel disks as 0.03 ± 0.02 ng and 0.3 ± 0.1 ng for ^{238}U and ^{235}U respectively. Bismuth ($m/z = 209$; 25 $\mu g\,L^{-1}$) was used as an internal standard to compensate for any potential instrument drift. The certified reference materials SLRS-5 and NASS-4 (National Research Council Canada, Canada) were analysed directly for SLRS-5 and after a 20-fold dilution for NASS-4 and were found to be within 1% of the stated values.

$^{235/238}U$ isotopic ratios were measured using an Agilent microflow (100 $\mu L\,min^{-1}$) PTFE self aspirating nebuliser, to eliminate any signal pulses caused by the peristaltic pump using the micromist concentric nebuliser. Isotopic ratios were determined with 3% standard deviation as low as 0.1 $\mu g\,L^{-1}$ total U (0.000725 $\mu g\,L^{-1}$ ^{235}U). The certified reference material U005a (New Brunswick Laboratories, DoE, Washington, USA) was analysed and was found to be within 99.5% of the isotopic value (0.0000342 $^{235/238}U$).

2.3. Calculation of time-weighted average concentrations

The concentration of U measured by the ICP-MS in $\mu g\,L^{-1}$ from the eluent was multiplied by the dilution factor (×10) to give the U concentration (Ce). The absolute mass (M) of the U in the resin gel was then calculated using Eq. (1), where M is calculated taking into account the gel volume (Vg, cm^3), the eluent volume (Ve, mL), the measured concentration of U in the eluent (Ce, $ng\,mL^{-1}$) and the elution factor (fe) [27].

$$M = \frac{Ce(Vg + Ve)}{fe} \quad (1)$$

M from Eq. (1) is then used to calculated the TWA concentrations (Eq. (2)) where the concentration (C_{DGT}, $ng\,mL^{-1}$) was calculated using the mass of the analyte in the binding gel (M, ng), the thickness of the diffusive path length (diffusive gel and filter membrane)

(Δg, cm), the diffusion coefficient of the analyte (D, $cm^2\,s^{-1}$) (as determined at different pHs for U by Hutchins et al. [18]), deployment time (t, s) and the area of the sample exposure window (A, cm^2).

$$C_{DGT} = \frac{M\Delta g}{DtA} \quad (2)$$

The diffusion coefficients (D) were corrected for temperature (T, C) using the Stokes–Einstein equation (Eq. (3)) [29] and the viscosity of water (η, mPa s) [30]:

$$\frac{D_1\eta_1}{T_1} = \frac{D_2\eta_2}{T_2} \quad (3)$$

Diffusion coefficients used for sea water were 10% lower than fresh water [14], due to increased viscosity of higher ionic strength solutions.

The diffusive boundary layer (δ) thickness was calculated using Eq. (4) after Warnken et al. [31]. A straight line plot of *1/M vs* Δg has a slope (m) of $1/(DC_{DGT}At)$ and an intercept (b) of $\delta/(DC_{DGT}At)$. The intercept (m) divided by the slope (b) of this plot gives the diffusive boundary layer thickness δ, as per Eq. (5).

$$\frac{1}{M} = \frac{\Delta g}{DC_{DGT}At} + \frac{\delta}{DC_{DGT}At} \quad (4)$$

$$\delta = \frac{m}{b} \quad (5)$$

The thickness of the DBL was included in the C_{DGT} calculations for the field trials. The sampling area (A) was 3.8 cm^2 instead of the 3.14 cm^2 used in the laboratory trials, as described by Warnken et al. [31].

The DGT equation (Eq. (2)) was used in conjunction with the limits of detection for the ICP-MS to produce a matrix of minimum deployment times for varying diffusion coefficients (changes in temperature and pH) with changing solution concentration for fresh water deployments (Table S1). Marine deployments were calculated to take approximately 110% of the time required for fresh water deployments due to a reduction (10%) in the diffusion coefficient.

2.4. Comparison of the performance of Chelex-100, Metsorb, and MnO_2 resins

2.4.1. Uptake of U and elution efficiencies of the test resins

The uptake efficiencies of the three test resins for U were determined using a batch method. Disks (0.19 cm^3) of each resin gel were placed in Fisher brand PS vials (30 mL) and a solution (20 mL, 0.01 M $NaNO_3$ at pH 7 ± 0.2) containing 10, 25, 50 and 100 $\mu g\,L^{-1}$ of U (VI) was added. The vials were shaken (48 h) on a rotating table (IKA® KS 130 Basil, Sigma–Aldrich Ltd., Gillingham, U.K.) at a set speed of 240 revolutions min^{-1}. One mL aliquots were taken and acidified (using 20 μL 6 M HCl) before and after resin gel exposure to determine the mass balance and percentage uptake of U. To determine the elution efficiencies, the gels were removed from the solutions and placed into new PS vials containing 2 M HNO_3 (2 mL) for the Chelex-100 gels or 1 M HNO_3 H_2O_2 (2 mL) for the Metsorb and MnO_2 gels. The tubes were then agitated (48 h) on the rotating table and the resin gel removed. Control experiments containing 20 mL of 100 $\mu g\,L^{-1}$ of U, 0.01 M $NaNO_3$ at pH 7 ± 0.2 with no resin gels showed no sorption of U to the vessel.

2.4.2. Effect of pH and ionic strength on uptake of U

A batch method was used as per Section 2.4.1. A 0.19 cm^3 disk of each resin gel was placed in a PS vial (30 mL) and exposed to solutions (20 mL) containing 100 $\mu g\,L^{-1}$ of U (VI) in 0.01 M $NaNO_3$ at pH 3, 4, 5, 7, 8 and 10 (to test the effect of pH) or 100 $\mu g\,L^{-1}$ of U (VI) in 0.01, 0.1, 0.4, 0.7 and 1 M $NaNO_3$ at pH 7 (to test the effect of ionic strength). The vials were shaken (48 h) on a rotating table. One mL aliquots of the solution were taken and acidified (using 20 μL 6 M HCl) before and after resin gel exposure to determine the mass balance and percentage uptake of the U. Solutions were made up in the PS vials in triplicate for each pH value tested here with no addition of resin gels, to assess the sorption of U to the PS vials.

2.4.3. Mass accumulation of U over time

To measure the uptake of U over time, DGT devices were exposed (5 days) in square polypropylene tanks (5 L) to 0.01 M $NaNO_3$ (low ionic strength water) plus 0.983 mM L^{-1} $NaHCO_3{}^-$ to buffer the solution to pH 7.7 (a similar pH to the freshwater field test site) or an artificial sea water solution (prepared following [32]) containing 100 $\mu g\,L^{-1}$ U. Devices were removed in triplicate at the time intervals of 4, 8, 12, 24, 48, 72, 96 and 120 h, and the resin gels eluted as per Section 2.2. Two aliquots (1 mL) of the solution were taken daily from the exposure tank. One was filtered though a 0.2 μm filter and acidified (20 μL 6 M HCl), the other was acidified (20 μL 6 M HCl) with no filtration to ensure no precipitates were formed in the solution that may affect DGT uptake.

2.4.4. Effect of interferences and ligands on uptake of U

Effect of the presence of calcium (Ca^{2+}) as a potential interference in water and the complexants bicarbonate ($HCO_3{}^-$), phosphate ($PO_4{}^{3-}$) and sulphate ($SO_4{}^{2-}$) were tested for all three resin gels. Table S2 details the concentrations used, which exceed typical environmental concentrations to ensure any effect from an episodic event (*e.g.* heavy rain, or flooding) can be seen. The $HCO_3{}^-$ and $SO_4{}^{2-}$ concentrations are double those seen in some fluvial systems [33], with Ca^{2+} five times that found in the River Lambourn and approximately that found in sea water. The $PO_4{}^{3-}$ concentrations were similar to sewage effluent inputs into the Lambourn [34,35] and five times higher than a typical Thames tributary [36]. An acid washed PP container (3 L) containing a 0.01 M $NaNO_3$, 100 $\mu g\,L^{-1}$ U solution (3 L) plus either an interferent or ligand (concentrations detailed in supplementary information – Table S2) was equilibrated for 24 h at pH 6.5 ± 0.2 for the Ca^{2+}, $SO_4{}^{2-}$ and $PO_4{}^{3-}$ additions, and pH 8.1 ± 0.3 for the $HCO_3{}^-$ additions. DGT devices containing each type of resin gel were then deployed (96 h) in triplicate, then removed and eluted as per Section 2.2. One mL aliquots of the exposure tank solution were taken daily and acidified (using 20 μL 6 M HCl) to measure the concentration of U. Eq. (2) was used to calculate the C_{DGT}, and this was compared to U concentrations in the grab samples. An agreement between these two measurements showed these devices to be working well.

In order to assess sorption of U to the polypropylene tank, a continuously stirred 5 L solution containing 100 $\mu g\,L^{-1}$ U, 0.01 M $NaNO_3$ at pH 7 was left for 10 days with no DGT devices deployed. Two aliquots (1 mL) of the solution were taken daily from the exposure tank. One was filtered though a 0.2 μm filter and acidified (20 μL 6 M HCl), the other was acidified (20 μL 6 M HCl) with no filtration as per Section 2.4.3.

2.4.5. Field deployments

Two field sites (fresh water and marine) were used in this study. The fresh water site (51.446933 N, −1.3838275 W) was located on the River Lambourn near Boxford, Berkshire, U.K. The river has a chalk fed aquifer catchment and an average pH of 7.9–8 [34]. DGT devices were deployed between perspex plates (15 cm × 7 cm, 8 devices per plate) and attached to a rope and float and weighted to the river bed. The marine site was located adjacent to the National Oceanography Centre, Southampton, U.K. (50.891313 N, −1.3938260 W). This site is a well mixed estuarine site with a salinity of 29–33 (dependent upon tidal fluctuations and freshwater inputs) and is a moderate flow site with tidal fluctuations agitating the water. The devices were deployed as above at 1 m below the water surface. Ropes were used to attach the exposure plate to the dock pontoon.

Three DGT devices containing each resin gel were removed on days 2, 4, 7, 10 and 14. To assess the presence of the diffusive boundary layer, DGT devices containing the Metsorb gel were deployed for 5 days with diffusive layer PAM gel thicknesses (including 0.015 cm to account for the Supor membrane) of 0.015, 0.055, 0.095, 0.135 and 0.175 cm, as per Warnken et al. [31]. Diffusion coefficients calculated by Hutchins et al. [18] were used for the TWA calculations. Spot samples of water (20 mL) were collected at the exposure sites and were filtered (0.2 μm pore size Supor filters) and acidified *in situ* with 6 M HCl (40 μL). Water temperature and pH were recorded each time a device was removed so that diffusion coefficients could be corrected for variations in environmental conditions.

Procedural DGT blanks (3 per resin) were prepared along with the deployed devices and exposed to the field environment during deployment and retrieval of the sample devices. The blanks were then eluted and analysed with the samples as above.

3. Results and discussion

3.1. Uptake and elution efficiencies

Uptake and elution efficiencies were measured by exposing the Chelex-100, Metsorb and MnO_2 binding gels to known masses of U and then eluting the bound element. Uptake by Chelex-100 and MnO_2 was >80% of the U in solution for a range of concentrations (10–100 μg L^{-1}), with the Metsorb resin accumulating >90% of the U in solution. Using 2 M HNO_3 as the eluent, Chelex-100 had an elution efficiency of 80 ± 6%, which is higher than found by Li et al. [15] but comparable to other studies measuring trace metals using DGT with Chelex-100 resins [37]. Using 1 M HNO_3/1 M H_2O_2 as the eluent MnO_2 had an elution efficiency of 84 ± 4% and Metsorb 83 ± 3%. Using 1 M $NaCO_3$/1 M H_2O_2 as eluent, Metsorb had an elution efficiency of 70 ± 3%. Hutchins et al. [18] used 1 M NaOH/H_2O_2 solution to elute the U, with an efficiency of 95.2 ± 0.4%. Sodium hydroxide was not used here as the sodium acts as a signal suppressor with the ICP-MS. The low standard deviations for the elution step indicated that the procedure was reproducible.

3.2. Effect of pH and ionic strength on uptake

Over the range of ionic strengths tested there was consistent uptake of U by all three resins. However, when deployed in DGT devices containing Metsorb, that included a PAM layer, Hutchins et al. [18] observed a 24% decrease in U uptake in higher ionic strength solutions. The effect of increasing the ionic strength of a solution may act to hinder U diffusion through the PAM gel rather than uptake by the resin gel.

Fig. 1 shows the effect of changing pH on U uptake by the Chelex-100, Metsorb and MnO_2 binding gels. There was found to be no sorption of the U to the PS vials observed in the experiments containing no resin gels. U accumulation by the MnO_2 resin decreased to ≈60% at pH 5, ≈30% at pH 4 and ≈10% at pH 3. As MnO_2 has a point of zero charge (pzc) at about pH 2.25 [38], and a negative charge throughout the pH range tested, a change in surface charge should not be causing this decrease above pH 3 as U exists as the uranyl cation over this pH range. At acidic pH values in which the E_h drops below +0.8 V the MnO_2 can form $Mn_2O_{3(s)}$ or even soluble Mn^{2+} therefore reducing the number of binding sites [21]. There were no obvious colour changes observed for the MnO_2 resin gels upon immersion in the pH 3 solution that would be indicative of a phase change of the manganese, however, Burnett et al. [39] observed a similar response of U uptake by MnO_2 at low pHs. Yao

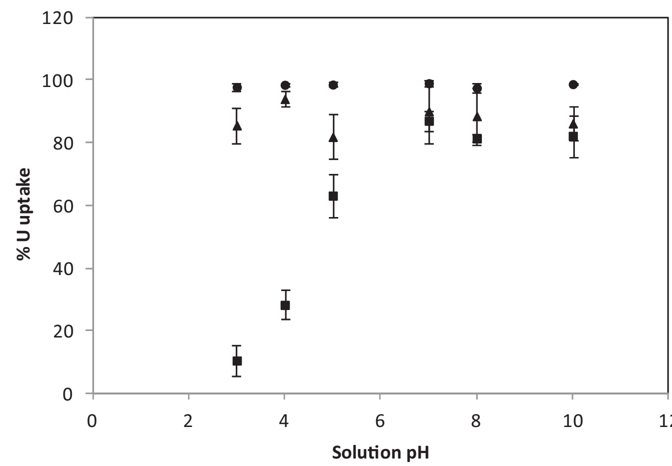

Fig. 1. Uptake of U from a 100 μg L^{-1} solution by the three resin gels manganese dioxide (■), Metsorb (●) and Chelex-100 (▲) across a range of pH values. Error bars are the standard deviation of triplicate readings.

and Millero [40] identified the requirement for further work to fully characterise ion interactions with the MnO_2 surface.

Surface complexation and hydrolysis is the mechanism by which U is sorbed to Metsorb (TiO_2) [41,42]. TiO_2 is amphoteric and has a pzc at pH 6 [38] to 7 [41,43] and can therefore sorb both anions and cations on the positively and negatively charged surfaces respectively, allowing the Metsorb to operate over a wide range of pH values. The Chelex-100 resin was not adversely affected by changing pH, although previous studies have shown lower pH's inhibit U accumulation [15,16]. Chelex-100 acts as a cation exchanger in solutions with a pH > 3–4, and an anion exchanger in solutions with a pH < 3–4 [44]. The predominant U species in this experiment were cationic uranyl UO_2^{2+} species with increasing anionic hydroxide or carbonate species present only at high pH values (>7.5). Li et al. [15,16] found that with pH < 5 the ability of the Chelex-100 to accumulate U decreased but this was not observed in our experiments. In the environmental pH range (5–8), there was no effect on U accumulation by either Chelex-100 or Metsorb.

3.3. Effect of interferences and ligands on uptake

All speciation distributions were calculated using Visual Minteq, version 3, beta (© 2010 KTH, Department of Land and Water Resources Engineering, Stockholm, Sweden) for each ligand tested. This was undertaken in order to support the experimental work outlined in Section 2.4.4. The DGT concentration of the solution over the deployment period was calculated using Eq. (2), and compared as a ratio to the concentration measured directly by grab samples. A ratio of 1:1 shows that the technique is working correctly and is unaffected by the ligand. All inorganic U complexes formed were initially assumed to be fully labile in this study.

Ca ions were not calculated to form any complexes with U, except in the presence of atmospheric carbon dioxide at pH ≥ 6.5, when calcium will form soluble $CaUO_2(CO_3)_3^{2-}$ and $Ca_2UO_2(CO_3)_3$ complexes [45,46] (Fig. S1). Increasing the Ca concentration increased U adsorption from 80% for Chelex-100 and 85% for Metsorb and MnO_2 at ln 4 (natural log 4), to 100% at ln 10 (natural log 10) for all three resin gels. The lower uptake at Ca concentration of ln 4 is commensurate with the uptake data discussed in Section 3.1 in the absence of complexing ligands. The U species at this Ca concentration are predominantly hydroxide and carbonate. Using Visual Minteq 100% of the U was calculated to occur in the dissolved phase, so increases in U uptake by the Metsorb and MnO_2 maybe as a result of decreasing UO_2OH^+ and $UO_2(OH)_2$ which do not interact with these resins. As all three resins exhibited an increase in uptake in the presence of calcium, the $Ca_2UO_2(CO_3)_{3(aq)}$ and $CaUO_2(CO_3)_3^{2-}$ species that form may be more labile than the $UO_2CO_{3(aq)}$ and hydroxide species predominant at lower Ca concentrations, with $Ca_2UO_2(CO_3)_{3(aq)}$ being the more labile of the two. Yao and Millero [40] showed that anion uptake (PO_4^{3-}) by MnO_2 is enhanced in the presence of divalent cations (such as Ca^{2+} or Mg^{2+}) due to the surface charge of the MnO_2 being reversed by the exchange of H^+ for metal ions in solution, which may account for the increase in uptake of the U species by this resin with increasing Ca concentrations. As Chelex-100 also shows increasing U uptake with increasing Ca concentration it is unlikely that cation exchange is the sole uptake mechanism. The increase could be due also to chelation or cation assisted uptake, as with the MnO_2, or a combination of all three. The decrease in uptake observed at the very high Ca concentration (ln 13 or 500 μg L^{-1}) for all three resins, in particular MnO_2 for which there is a decrease from 100% to 70%, could be as a result of competition for binding sites between the U species and Ca, as at this concentration 97% of the Ca is predicted (using Visual Minteq) to occur as the free metal ion Ca^{2+}. The Metsorb uptake was above 0.8 at all Ca^{2+} concentrations.

PO_4^{3-} showed a significant influence on the distribution of U between the dissolved and precipitated phases (Fig. S2a–c), with a marked decrease in dissolved U when the phosphate in this experiment was ≥1 mg L^{-1}. This is the point at which the U hydroxide complexes become less dominant in the speciation distribution with the uranyl phosphate complexes $UO_2PO_4^-{}_{(s)}$ and $UO_2HPO_{4(aq)}$ (Fig. S2c). PO_4^{3-} complexation with U becomes particularly important if the total phosphate:carbonate ratio is greater than 10^{-1} [47]; at 5 mg L^{-1} PO_4^{3-} addition in this experiment the total phosphate: total carbonate ratio is 0.3. Fig. S2b shows that all three resins accumulated U at expected ratios similar to that of Fig. 1 (0.8–1.0) in the presence of PO_4^{3-} concentrations up to and including 1 mg L^{-1}. At 5 mg L^{-1} the accumulation of U by the resins decreases to 60% for Chelex-100, 40% for the MnO_2 and 50% for the Metsorb. The decrease observed for the Metsorb [48] and the MnO_2 [40] is most likely as a result of direct competition for binding sites by the PO_4^{3-}, and Chelex-100 (which is the least affected by the phosphate additions) decrease can be attributed to the decrease in the cationic species UO_2OH^+ and UO_2^{2+}, and a concurrent increase in anionic $UO_2HPO_4^-$.

There was only a minor effect on U uptake with increasing SO_4^{2-} concentrations (Fig. S3), with uranyl sulphate complexes only occurring at high SO_4^{2-} concentrations (>20 mg L^{-1}) due to the preferential carbonate complexes formed with dissolved CO_2. SO_4^{2-} interaction with the resins may be increased by the presence of divalent cations in a more complex matrix [40], such as may occur in the field.

Carbonate speciation with the uranyl ion accounts for 90–100% of U in the oceans [49]. It is important to understand any impact complexation between U and carbonate may have on the uptake of the DGT devices used in this study. Gregusova et al. [20] conducted experiments to observe changes in U uptake with increasing HCO_3^- concentrations. For both the Chelex-100 and Spheron-Oxin® resins, a decrease in U uptake with increasing carbonate concentrations was observed, potentially as a result of the increasingly anionic species formed. In this study a similar decrease in DGT performance was noted with increasing bicarbonate concentration by the DGT devices containing Chelex-100, Metsorb and MnO_2 (Fig. S4a). The MnO_2 sorbed less of the carbonate bound U than Metsorb or Chelex-100 and was particularly affected by increasing concentrations of the calculated uranyl carbonate species $UO_2(CO3)_3^{4-}$, as shown in Fig. S4b. As stated previously, adsorption of anions by MnO_2 may be made possible through the presence of divalent cations, which were not present in this experiment. Gregusova et al. [20] observed that DGT devices containing Chelex-100 as the binding phase accumulated decreasing concentrations of U when the total carbonate concentration exceeded 30 mg L^{-1}. A similar decrease of U sorption by Chelex-100 has been observed in this experiment. Total carbonate concentrations higher than 30 mg L^{-1} yield more anionic species with the neutral uranyl carbonate species $UO_2(OH)_2$ and $UO_3CO_{3(aq)}$ decreasing, which will affect the ability of the U to bind to the Chelex-100. The Metsorb resin is affected by very high total carbonate concentrations only (≥100 mg L^{-1}). The decrease in adsorption of U may be as a result of competition with other anionic species present in the solution such as $NaCO_3^-$ and HCO_3^-.

The PP tank containing a 5 L 100 μg L^{-1} U solution with no DGT devices deployed showed a reduction in concentration of non-filterable U by 19% from 69 μg L^{-1} to 56 μg L^{-1}, and an initial reduction in 0.2 μm filtered U by 40% from 62 μg L^{-1} to 44 μg L^{-1} was observed, after which a stable concentration was attained. During the 10 day trial there was also a pH decrease by 0.25 units. The sorption of U observed between pH 6 and 7 is similar to that observed by Hutchins et al. [18] and was attributed to the neutral species more readily binding to the PP container. This decrease did not affect the results as an average concentration across the experimental period was used.

3.4. Mass accumulation over time

3.4.1. Laboratory deployments

DGT deployments for all three test resins in the low ionic strength solution (Fig. 2) accumulated U as predicted by the DGT equation (Eq. (2)). The predominant species present at pH 7.7 is $UO_2(CO_3)_2^{2-}$ with no significant precipitates forming and the filtered and non-filtered grab samples in close agreement. None of the devices appeared to be capacity limited under these experimental conditions. Using the DGT equation and taking into account the U depletion gives a DGT uptake: solution concentration ratio of 1:1 for the entire deployment period for Chelex-100 and Metsorb, with a slight decrease in U accumulation by the MnO_2 at 5 days.

Deployments in artificial sea water (Fig. 3) showed that DGTs with the MnO_2 resin had a linear uptake of U as predicted by the DGT equation for 24 h up to 0.6 μg U. The DGT deployment time for the device with Metsorb resin was linear and in agreement with the DGT equation for about 10–12 h, with 0.25 μg U accumulated. The Chelex-100 was unable to accumulate U as predicted by the DGT equation past 4 h, accumulating 0.15 μg U, potentially due to ionic interferences and the anionic nature of the U species present. The Metsorb and Chelex results agree well with the findings of Hutchins et al. [19].

3.4.2. Field deployments

The marine site had an average U concentration of 3 μg L^{-1} over the deployment period, which is similar to concentrations found at other marine sites (Table 1). Fig. 4a shows that the MnO_2 DGT accumulated U at the marine site in agreement with the DGT equation for 2 days (4 days within errors). As the response for both the MnO_2 and TiO_2 resins is increasing over the deployment time, it is unlikely that saturation of either resin has been achieved and is affecting uptake. It is likely that biofouling on the outer membrane inhibited accumulation in agreement with the DGT equation (Eq. (2)) past 2 days, by retarding diffusion of the U. Fresh water inputs (salinity measurements varied throughout the deployment time from *salinity* = 27–32) to the marine site in this study could also have been responsible for the longer field deployment times than predicted in the laboratory trials due to decreased ionic competition. U in sea water exists predominantly as the soluble uranyl carbonate anion, $UO_2(CO_3)_2^{2-}$, which was taken up by all three resin gels under laboratory conditions, with MnO_2 being the most affected by increasing predominance of anionic U species The Chelex-100, as per laboratory experiments, did not accumulate U in agreement with the DGT equation.

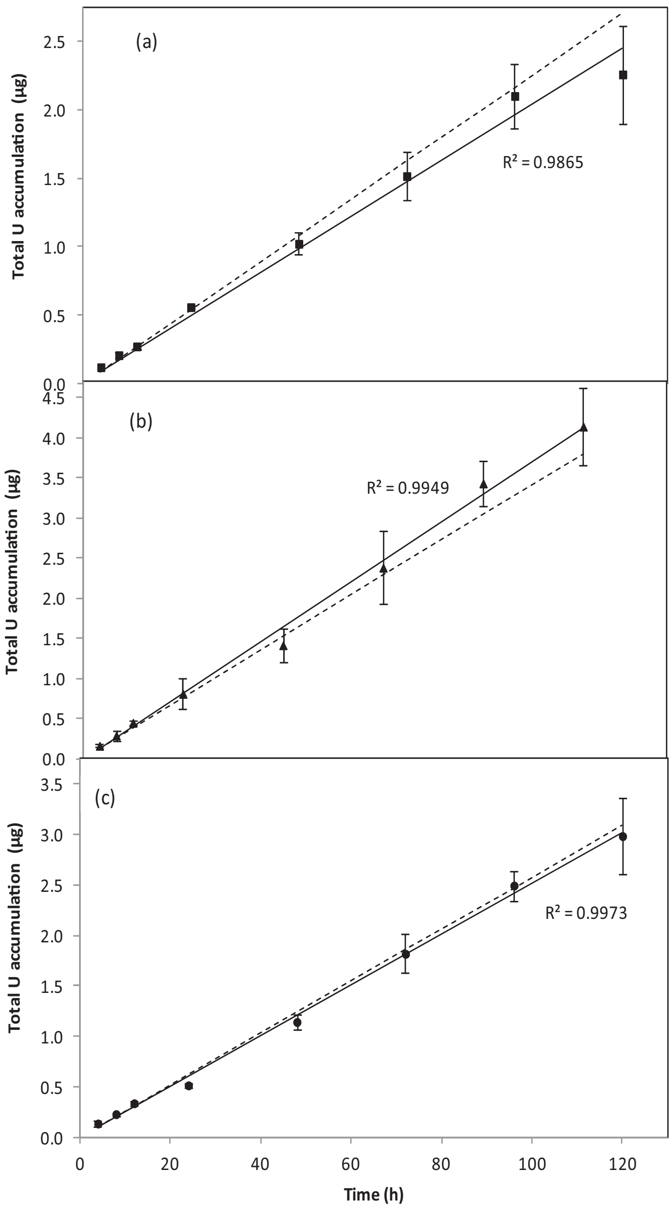

Fig. 2. Mass accumulation with time in 0.01 M $NaNO_3$. Solution pH 7.7 ± 0.05 with 120 h deployment time: (a) manganese dioxide resin gel (■) average concentration 75 μg L^{-1}, average temperature 15 °C, calculated diffusion coefficient 2.52×10^{-6} cm^2 s^{-1}; (b) Chelex-100 resin gel (▲), average concentration 83 μg L^{-1}, average temperature 20 °C, calculated diffusion coefficient 3.21×10^{-6} cm^2 s^{-1}; (c) Metsorb resin gel (●) average concentration 75 μg L^{-1}, average temperature 18 °C, calculated diffusion coefficient 2.74×10^{-6} cm^2 s^{-1}. Dashed line (—) represents model U uptake calculated from DGT equation (Eq. (2)) using the average solution concentration; and the solid line represents the linear regression of U uptake during the linear uptake phase. Error bars are the standard deviation of triplicate measurements.

Another explanation for the U accumulation past day 2 not agreeing with the DGT equation could be a reduction in available binding sites, as opposed to complete saturation. Competing ions in sea water (in particular in coastal waters where they occur in higher concentrations), could begin to fill the resin binding sites prior to U diffusing through the PAM. The diffusion coefficient of U is approximately half that exhibited by transition metals and other anions present such as phosphate (diffusion coefficient of PO_4^{3-} in water at 25 °C, pH 6.5 is 6.05×10^{-6} cm^2 s^{-1} [48]; the U diffusion coefficient for equivalent conditions is 3.7×10^{-6} cm^2 s^{-1} [28]). This could lead to the binding sites on non-specific resins, such as the resins examined here, filling up faster in the presence of complex matrices such as sea water. The transition metals show an increase in the diffusion coefficients with increasing atomic mass, so it follows that as U has a high mass, it should have a higher rate of diffusion. As U does not continue the trend of increasing rate of diffusion with mass, the lower diffusion rates may in part be explained by steric effects of complexes formed and through interaction of the U with the PAM gel. Gregusova et al. [20] found that for up to 8 h, the DGT sampler underestimated the U concentration in solution. It was explained through a reaction between traces of acrylic acid groups in the gel formed during the polymerisation process, and the transient uranyl ions. Upon saturation (~200 ng per disk) of these weak binding sites within the gel, predicted uptake of the U was observed [50]. No such artefact was observed during this study; however, deployment times were longer.

The fresh water site had an average U concentration of 0.4 μg L^{-1} over the deployment period, which is similar to U concentrations found at other fresh water sites (Table 1). The results for the field fresh water deployments (Fig. 4b) show that all three resins accumulated 80% of predicted U, as per the DGT equation for the first 2 days. The Metsorb device continued to accumulate U at 80% of predicted values until day 7, after which the accumulated U decreases to 60% of the predicted value until day 14. The Chelex-100 and MnO_2 devices accumulated decreasing concentrations of predicted U concentrations throughout the deployment. Li et al. [15,16] showed that Chelex-100 was only able to measure ~50% of dissolved U concentrations as predicted by the DGT equation in alkaline waters for up to 3 days.

The DBL for each site was calculated according to Warnken et al. [31] (using diffusive layer thicknesses of 0.015, 0.055, 0.095, 0.135–0.175 cm) and found to be 0.035 ± 0.019 cm at the marine site, and 0.046 ± 0.006 cm at the fresh water site (Fig. S5). This is in agreement with the study by Warnken et al. [31] who showed that diffusive boundary layers can be as high as 0.15 cm in quiescent waters, and 0.044 cm in well stirred, turbulent solutions. The DBL is an important contributing factor to the diffusive layer thickness (Δg) in the DGT equations, and has been shown in this study to be present even in fast flowing waters. The concentrations of U calculated using the DGT equations were reduced by 50% in the marine site and 30% in the fresh water site without accounting for the effect of the DBL. The difference in DBL at the two sites could be attributed to the build up of pond weed at the freshwater site around the devices, which required clearing daily.

Table 2
Results of $^{235/238}U$ isotopic ratio analysis for each resin tested and the spot samples for the marine and freshwater field site. Natural $^{235/238}U$ isotopic ratio is 0.00725.

Resin	Marine			Fresh water		
	Average isotopic ratio	RSD[a] (%)	Accuracy[b] (%)	Average isotopic ratio	RSD[a] (%)	Accuracy[b] (%)
Metsorb	0.00738 ± 0.0004	5.72	−1.79	0.00718 ± 0.0005	9.59	0.97
Chelex-100	0.00782 ± 0.0017	22.68	−7.86	0.00762 ± 0.0015	20.04	−5.10
MnO_2	0.00724 ± 0.0003	3.69	0.14	0.00752 ± 0.0006	7.57	−3.72
Grab	No data			0.00726 ± 0.0009	11.79	−0.14

[a] Standard deviation calculated as a % of the mean (precision).
[b] Calculated as (actual reading – measured/actual) × 100.

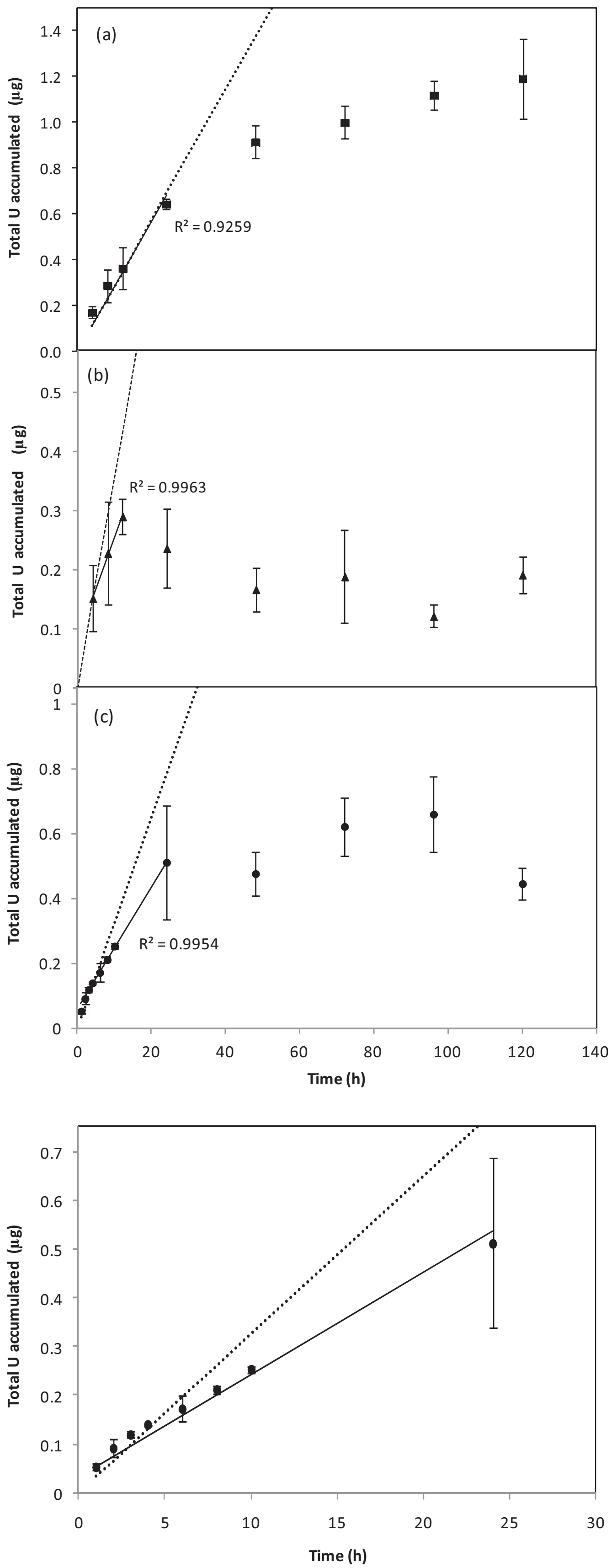

Fig. 3. Mass accumulation with time in artificial sea water. Solution pH 8.2 with 120 h deployment time: (a) manganese dioxide resin gel (■), average U solution concentration 102 μg L^{-1}, average temperature 18 °C, pH 8.1 calculated diffusion coefficient 2.26 × 10^{-6} cm^2 s^{-1}; (b) Chelex-100 resin gel (▲), average U solution concentration 115 μg L^{-1}, average temperature 18 °C, pH 8.1, calculated diffusion coefficient 2.26 × 10^{-6} cm^2 s^{-1}; (c) Metsorb resin gel (●), average U solution concentration 103 μg L^{-1}, average temperature 20 °C, pH 8.1, calculated diffusion coefficient 2.65 × 10^{-6} cm^2 s^{-1}. Dashed line represents model U uptake calculated from DGT equation (2). Error bars are the standard deviation of triplicate measurements. Shorter time intervals have been measured here initially and shown in the inset graph.

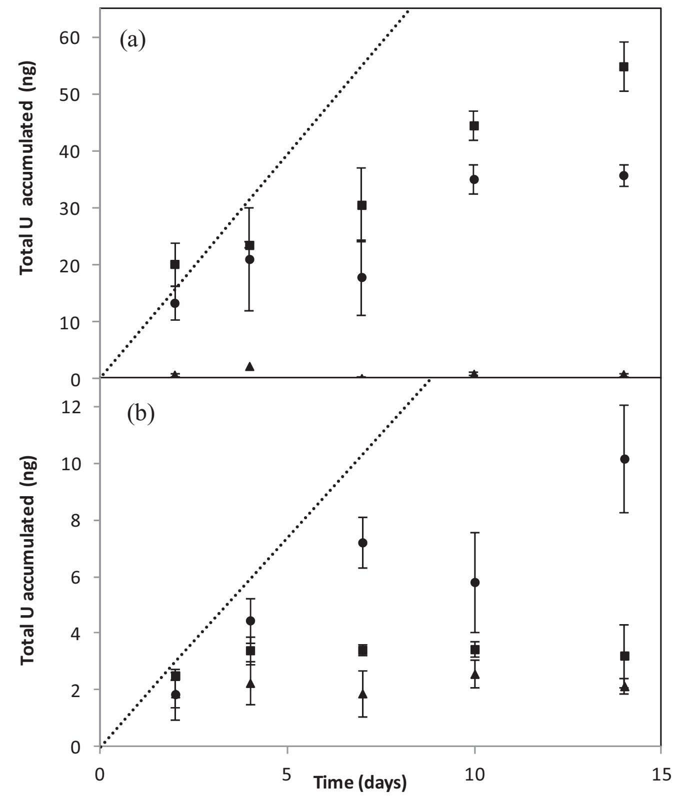

Fig. 4. Mass accumulation with time in field trials, 14-day deployment for manganese dioxide (■), Metsorb (●) and Chelex-100 (▲): (a) marine deployment, average pH 8.2, average temperature 11 °C, bulk solution concentration from spot sampling 3.0 μg L^{-1}, calculated diffusion coefficient 1.03 × 10^{-6} cm^2 s^{-1}; (b) fresh water deployment, average pH 7.9, average temperature 13 °C, bulk solution concentration from spot sampling 0.4 μg L^{-1}, calculated diffusion coefficient 1.59 × 10^{-6} cm^2 s^{-1}. Dashed line represents model U uptake calculated from DGT equation (2). Error bars are the standard deviation of triplicate measurements.

$^{235/238}$U isotopic ratios were also analysed for all field samples as shown in Table 2. It was found that this ratio could be determined accurately after 2 days of deployment at both sites. The concentration of U in the River Lambourn averaged 0.4 μg L^{-1} throughout the deployment period, meaning U ratios were also detectable in the grab samples as no dilution was required prior to ICP-MS analysis. The marine site U concentration averaged 3.0 μg L^{-1} over the deployment period; however, with the 20 fold dilution required for direct analysis of the grab samples by ICP-MS, the concentration was reduced to 0.15 μg L^{-1}. This is at the limit of detection for the isotopic technique and meant that reproducible isotopic ratios were not possible. The Metsorb and the MnO_2 resins had better precision and accuracy for this technique than the Chelex-100. In this study, the ability to analyse the grab water samples provided a comparison for the DGT technique and showed that the U isotopic signature was conserved during uptake by all three test resins. This has important implications for the application of DGT to long-term monitoring of radionuclides in aquatic systems and could be used as a tool for tracing pollution events and for measuring anthropogenic U additions to natural systems. The measurement of U isotopic signatures in and around nuclear installations is also a requirement of the U.K. Environmental Permitting Regulations 2010 [51]. Both field sites were found to have a natural $^{235/238}U$ ratio of 0.00725.

4. Conclusions

The application of DGT to the measurement of U in natural waters using Chelex-100, Metsorb and MnO_2 resins was investigated. It was found that in the laboratory all three resins performed well in low ionic strength solutions, but only the MnO_2 resin was suitable for long term marine deployments. All three resins showed a good performance across an environmentally relevant range of ionic strengths, pHs and interfering and complexing agents. The complexing agent that was observed to have the most affect on U uptake by the resin gels was the HCO_3^- additions. Increasing the anionic strength of the solution inhibited uptake by the Chelex-100 and the MnO_2, whilst appearing to compete for binding sites on the Metsorb. The PO_4^{3-} additions only interfered with U uptake for very high PO_4^{3-} concentrations due to precipitation with insoluble species, anionic interferences (Chelex-100 and MnO_2) or direct competition for binding sites (Metsorb). Up to 250 mg L^{-1} Ca^{2+} additions, the Ca formed increasingly labile species with the U, enhancing the uptake. At 250 mg L^{-1} Ca^{2+} additions, the uptake of U by all three resins was reduced as a likely result of competition for binding site by the Ca^{2+}. The marine (average *salinity* = 30) deployment showed the U uptake by the Metsorb and MnO_2 DGTs to be linear and in agreement with the DGT equation for 4 days. Laboratory tests showed that Metsorb would be unable to predict U concentrations in sea water (*salinity* = 35) past 24 h, but the deployment time was extended in the field due to a lower salinity. The fresh water trials showed that the Metsorb DGT predicted the U concentration for 4 days and then 75% of total U up to 7 days. At the same fresh water deployment, the MnO_2 DGT predicted U concentrations for the first 2 days only. The Chelex-100 was found to be unsuitable for U measurements in the field as a result of oversaturation by competing ions as it was predicted to only accumulate cationic forms of U. A new application of DGT investigated in this study was the measurement of isotopic ratios of U down to concentrations of 0.1 $\mu g L^{-1}$. The isotopic ratio of U was conserved by all three resin gels. Another important factor investigated was the effect of the DBL. It was found that without the inclusion of the DBL, DGT calculations underestimated U concentrations by at least 50%. Further work is necessary to find a suitable actinide specific resin for inclusion into DGT devices in order to eliminate any effects by competing ions. In future research the use of a combined Metsorb/MnO_2 binding agent should be investigated for DGT measurements of U in a range of natural waters.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.aca.2012.06.011.

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SPECIATION, BEHAVIOR, AND BIOAVAILABILITY OF COPPER DOWNSTREAM OF A MINE-IMPACTED LAKE

ALAN J. MARTIN* and ROBERT GOLDBLATT
Lorax Environmental Services, 2289 Burrard Street, Vancouver, British Columbia V6J 3H9, Canada

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Abstract—A combination of Cu speciation analysis and toxicity testwork was conducted to assess the behavior, speciation, and bioavailability of Cu in a stream system rich in dissolved organic carbon (DOC) downstream of a mine-impacted lake (East Lake, ON, Canada). Elevated levels (~50 μg/L) of Cu exist in the lake due to the release of dissolved Cu to the water column from underlying sediments. Most of the Cu present in East Lake and downstream is present as filterable species that represent 74 to 100% of the total. Measurements of labile Cu as measured by diffusive gradients in thin films (DGT) suggest that most of the Cu is unavailable to aquatic biota. The DGT results indicate that 9 to 24% of Cu within the receiving environment is biologically available. Decreases in the labile Cu fraction with distance downstream of East Lake correlate well with increases in the concentration of DOC (r^2 = 0.79–0.95), presumably due to the progressive importance of Cu-organic complexes. The relationship between filterable Cu and SO_4^{2-} downstream of East Lake was linear (r^2 = 0.99) for all sampling periods, suggesting that decreases in filterable Cu concentration downstream of East Lake could be attributed solely to dilution (i.e., conservative behavior). Variations in the filterable Cu concentration resulting in 50% mortality (LC50 = 96–203 μg/L) and the concentration resulting in an inhibition of reproduction by 25% (IC25 = 75–156 μg/L) with respect to *Ceriodaphnia dubia* (7-d incubation) in Cu-spiked solutions could be explained by differences in labile-Cu concentrations as determined by DGT. The considerable complexation capacity afforded by lake and stream waters can be attributed to complexation of Cu with abundant DOC (7–17 mg/L). The relevance of the toxicity data to water-effect ratio testwork, and the associated development of site-specific water quality objectives, are discussed.

Keywords—Copper Speciation Diffusive gradients Thin films Water effect ratio

INTRODUCTION

The speciation and bioavailability of Cu in freshwater systems has received considerable attention given the toxic nature of Cu to aquatic taxa at higher concentrations and improvements in analytical and speciation techniques [1,2]. It is now widely accepted that the potential effects of Cu to aquatic biota are strongly dependent on the concentration of the free metal ion and weak complexes, and not on the total concentration [3,4]. In oxygenated freshwaters at circum-neutral pH, Cu(II) is proposed to be the dominant species where it may exist as free aquo ions (Cu^{2+}), hydrolysis products [$Cu_2(OH)_2^{2+}$], Cu-organic complexes, and as complexes with other inorganic ligands (e.g., carbonate, chloride, and sulfate complexes) [5]. In particular, Cu complexes with natural organic matter (e.g., Cu-fulvate species) have been shown to represent dominant species in both freshwater and marine environments [6–9].

The mining of Cu-bearing ores can result in the increased export of Cu to aquatic systems. Copper is commonly associated with gold and base metal ores where it may occur in sulfide minerals such as chalcopyrite ($CuFeS_2$), bornite (Cu_5FeS_4), covellite (CuS), and chalcocite (Cu_2S), as well as carbonate and oxide minerals such as azurite ($(Cu_3CO_3)_2(OH_2)$), malachite ($Cu_2CO_3(OH)_2$), and cuprite (Cu_2O) [10]. In mining environments, Cu can be introduced into aquatic receptors through several pathways. The weathering and oxidation of sulfide minerals (e.g., pyrite) present in tailings and waste rock, and associated development of acid rock drainage, can promote the dissolution of Cu-bearing mineral components. Copper release can also occur under neutral-pH conditions through the dissolution of treatment residues produced at high pH (e.g., Cu hydroxides produced through the neutralization of acidic drainages) and through the reductive dissolution of redox-sensitive secondary phases (e.g., Cu-bearing hydrous ferric oxides) that may form within the mill circuit as part of wastewater treatment or during post-depositional processes [11,12].

The effects to aquatic flora and fauna from mine-derived Cu depend on several site-specific variables, including the loading, the assimilative capacity of the receiving environment, and the sensitivity of the various biological receptors. In turn, the assimilative capacity of a system for Cu loadings reflects both dilution and the nature of Cu-ligand reactions in the receiving environment. The toxicity of Cu is affected by numerous physicochemical variables, including hardness, alkalinity, pH, dissolved organic matter, and suspended solids [13]. The formation of Cu-organic complexes can strongly limit Cu bioavailability and toxicity [14]. Accordingly, the toxicity of Cu is expected to be attenuated in receiving environments characterized by an abundance of strong Cu-complexing ligands (e.g., humic and fulvic acids) in comparison to systems absent of significant complexation capacity (e.g., soft-water streams with minimal dissolved organic carbon). Given the myriad of factors that influence the sensitivity of aquatic systems to Cu inputs, an understanding of site-specific characteristics is essential for the development of scientifically defensible and cost-effective strategies relating to the environmental management of Cu.

In the present paper, the speciation, behavior, and bioavailability of Cu in stream system rich in dissolved organic carbon (DOC) downstream of a mine-related Cu loading are described. The labile-Cu fraction in water samples was assessed by diffusive gradients in thin films (DGT). The DGT method measures free metal ions (Cu^{2+}) and labile metal–ligand complexes, and thus provides a proxy for the mobile and labile metal

* To whom correspondence may be addressed (ajm@lorax.ca).
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fraction [15]. The method detects free and kinetically labile metal complexes which exhibit dissociation kinetics within the time frame of their transport through diffusive gel layer (on the order of minutes). The method excludes particles, large colloids, and strong metal–ligand complexes. The technique has been shown to provide an effective method for determinations of labile Cu species in soft to hard freshwaters [1,16,17]. Copper values obtained using DGT have also been shown to conform reasonably well to predictions of labile Cu^{2+} with speciation models [18,19].

The primary objectives of the present study were to assess the fate and behavior of Cu in the downstream environment, to quantify the assimilative capacity of the aquatic environment for Cu inputs with regard to dilution and complexation, and to assess the utility of DGT for the study of Cu speciation and the development of site-specific water quality objectives. The system assessed herein presents an ideal setting for studying downstream changes in Cu behavior and bioavailability given the point-source loading of Cu to the system and the well-defined mine-related signature. Further, the complexation capacity afforded by the highly colored, allochthonous (terrestrially derived) DOC exported from catchments on the Canadian Shield of northern Ontario, Canada, presents an ideal scenario for assessing the nature of Cu-DOC interactions. The data have broad applicability to the assessment and management of Cu-contaminated freshwater systems, and highlight the need for site-specific information in assessing assimilative capacity and ecological risks.

MATERIALS AND METHODS

Environmental setting

Detour Lake Mine, located 200 km northeast of Timmins (ON, Canada), operated from 1983 to 1999 using a combination of open pit and underground mining methods. Gold was liberated from the ore via cyanidation and carbon-in-leach processing. The site has been in an active state of closure since 1998, with emphasis on mine-site reclamation and acid rock–drainage prevention. As part of the historic tailings circuit, East Lake (ON, Canada) served as a tertiary polishing pond for mine-related effluents prior to final discharge to the receiving environment (Fig. 1). The discharge from East Lake continues to serve as the final point of discharge for the mine site. Flows exiting the lake system are controlled via a control weir positioned at the outflow. Discharges from East Lake are required to meet regulatory compliance with respect to water quality parameters and toxicity to *Daphnia magna*.

Despite the absence of mining-related discharges to the East Lake system since January 2000, elevated concentrations of filterable Cu (2005 mean of ~35 μg/L) persist in the lake. Such enrichment has been attributed to the dissolution of Cu-bearing mine wastes in the lake and release to the water column [11]. In Martin et al. [11], high spatial-resolution sampling of lake bottom waters and interstitial waters demonstrates that Cu is released to pore waters in the interfacial sediment horizons within 5 cm of the benthic boundary. Such remobilization supports the diffusion-controlled transfer of dissolved Cu to the water column.

The mean annual flow from East Lake is 25,200 m^3/d, with mean monthly flows ranging from approximately 5,100 m^3/d (February) to 58,000 m^3/d (May). Discharges from East Lake feed a system of streams and lakes that extends for 26 km prior to entry into the Detour River (Fig. 1). Flows from East Lake drain into East Lake Creek that extends for approximately 1.5 km prior to entry into Good Friday Lake. Good Friday Lake connects to Sunday Lake via a 300-m stream channel. Sunday Lake feeds Sunday Creek that extends for approximately 20 km until its confluence with the Detour River. The Sunday Creek, Sunday Lake, and Good Friday Lake systems are fish bearing, hosting populations of walleye (*Stizostedion vitreum*), yellow perch (*Perca flavescens*), common white sucker (*Catostomus commersonii*), shorthead redhorse (*Moxostoma macrolepidotum*), and northern pike (*Esox lucius*). The passage of these fish populations into East Lake from downstream is restricted by the presence of a dam and control weir at the outlet of East Lake (Fig. 1).

Sample collection

For the assessment of Cu speciation and behavior downstream of East Lake, water samples were collected at nine locations in July 2001 and October 2002. Sampling occurred upstream of East Lake and upgradient of mine-related influences (station 1), at the East Lake outlet (station 2), and at six stations downstream of the lake discharge (stations 3–8) (Fig. 1). Control sites upstream of all mine-related inputs included the site upstream of East Lake (station 1) and on the Detour River upstream of the Sunday Creek confluence (station 9). At all sites, samples were collected from just below the water surface in acid-cleaned high density polyethylene containers. Aliquots were collected for total Cu, <0.45 μm Cu, <0.1 μm Cu, and labile Cu as defined by DGT. Samples for <0.45 μm Cu and <0.1 μm Cu were filtered immediately upon collection using acid-cleaned plastic syringes (50 ml) and syringe filters. Samples for total and filterable Cu were acidified with ultrapure nitric acid (Seastar, Sidney, BC, Canada) to pH <1.5. Samples for DGT analysis were kept cool and in the dark until DGT deployment under laboratory conditions.

Analytical methods

Total and filterable Cu were measured by graphite-furnace atomic absorption spectroscopy (GFAAS) at the University of British Columbia (Vancouver, BC, Canada). Quality assurance and quality control protocols involved the analysis of sample splits, blanks, and certified reference materials SLRS-2 (National Research Council of Canada, Ottawa, ON, Canada) and TM-21 (National Water Research Institute, Canada Centre for Inland Waters, Burlington, ON, Canada). Sulfate concentrations were measured using a Dionex ion chromatograph with a chemically suppressed conductivity detector (Sunnyvale, CA, USA). Total suspended solids content in water samples was measured gravimetrically.

Premade and assembled DGT units were supplied from DGT Research (Lancaster, UK) [16]. Each DGT unit consists of a 4-cm-diameter disk-shaped device that contains a filter membrane (0.14 mm in thickness, 0.45-μm pore-size cellulose acetate) underlain by a diffusive gel layer (0.8 mm in thickness), which is in turn underlain by a trace metal–adsorbing gel-embedded Chelex resin (Biorad, Hercules, CA, USA) [20]. Premade gels consist of an acrylamide monomer cross-linked with an agarose derivative. Metals diffuse from solution across the filter and gel layers to the underlying Chelex resin where metal sorption takes place.

The DGT samplers were deployed under controlled laboratory conditions. Evidence exists to indicate that higher precision is afforded by DGT deployments in laboratory settings in comparison to in situ applications [21]. Each water sample was kept cool and in the dark until DGT analysis. A 250-ml

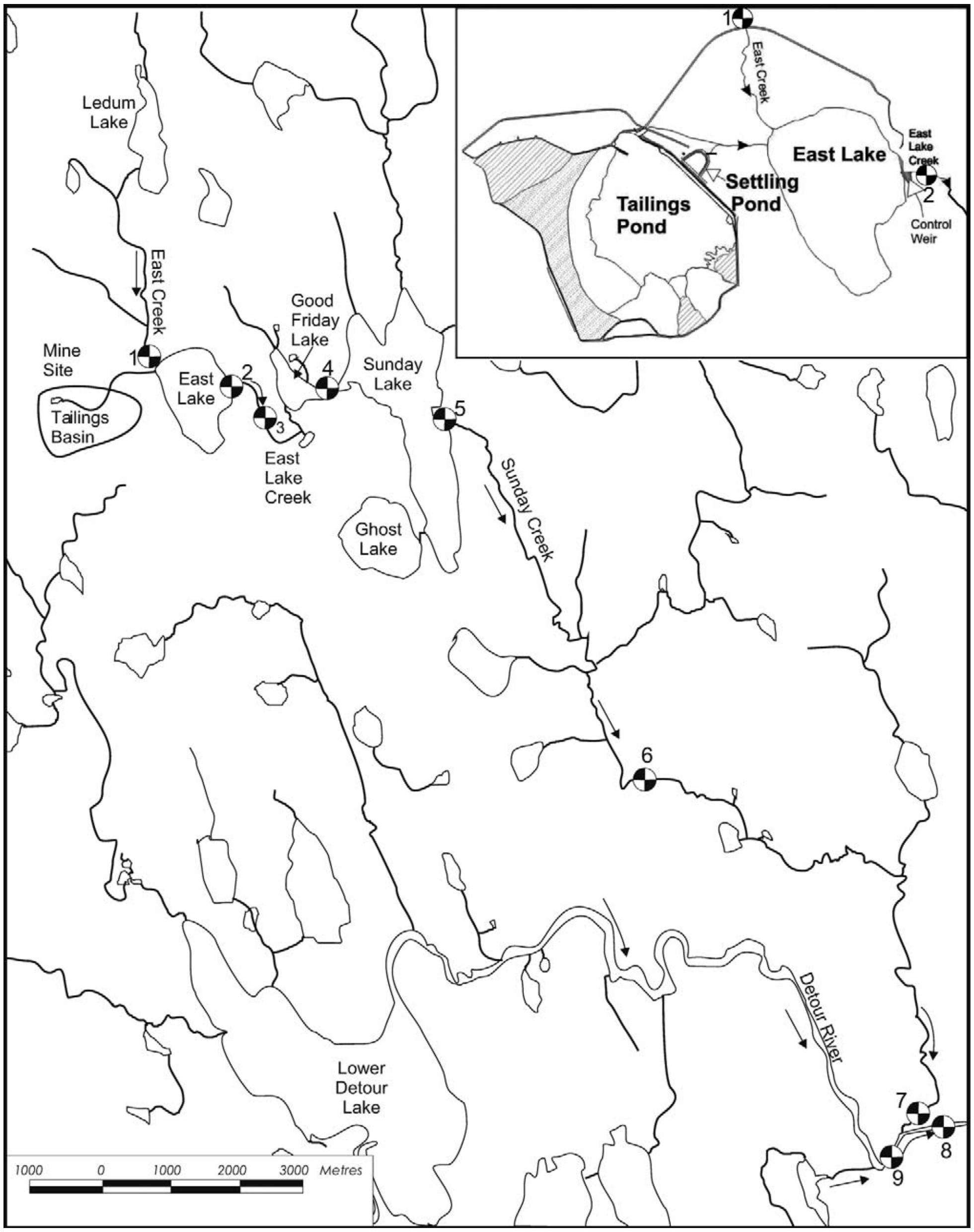

Fig. 1. East Lake, Good Friday Lake, Sunday Lake, and Sunday Creek (ON, Canada) drainage system showing locations of sampling stations for 2001 and 2002. Arrows indicate direction of stream flow. Inset shows detail of tailings pond and East Lake.

subsample was placed in an acid-cleaned polyethylene jar and allowed to reach 20°C. The DGT samplers were submerged in each subsample and incubated on a rocker table for approximately 24 h. After incubation, DGTs were rinsed with deionized water and stored in polyethylene bags in a refrigerator until extraction. Metals were extracted by removing the Chelex resin layer from the DGT assembly, placing it in 2-ml acid-cleaned polyethylene tubes, and filling with 1 ml of ultrapure 1 N nitric acid (Seastar). All extractions were conducted within a Class 100 laminar flow hood at Lorax Environmental Services (Vancouver, BC, Canada). Extraction was allowed to occur for at least 24 h before being analyzed for Cu by GFAAS at the University of British Columbia. Precision of DGT analyses was better than 7% (based on the standard deviation of triplicate DGT deployments in some solutions). The concentration of labile Cu in test waters was calculated from the Cu concentration in the Chelex extract based on Fick's first law of diffusion, as described by Zhang and Davison [20].

Samples for DOC were analyzed as per the method outlined in Gandhi et al. [22]. Samples for DOC were collected in 60 ml high-density polyethylene vials and kept cool and in the dark prior to analysis. For each sample, 100-μl aliquots were

Table 1. Laboratory parameters measured in station 1 (East Lake, ON, Canada) samples prior to acute and chronic toxicity testwork

	Dissolved oxygen (mg/L)	pH	Conductivity (μS/cm)	Hardness (mg/L as $CaCO_3$)
October 2001	9.4	7.5	70	50
April 2002	8.6	7.4	144	110
August 2002	8.7	7.6	95	50

transferred to a tin cup on a 60°C hot plate, with each aliquot being allowed to evaporate to dryness before the next aliquot was added. After transferring 15 to 20 aliquots, 50 μl of concentrated HCl was added to volatilize any inorganic carbonate. The tin cups were then sealed, and the carbon content determined via combustion and gas chromatography using a Carlo-Erba NA-1500 elemental analyzer (Milan, Italy) at the University of British Columbia.

Toxicity testwork

For the assessment of Cu bioavailability and toxicity, water samples were collected upstream of East Lake (station 1) in October 2001, April 2002, and August 2002. Samples for toxicity testing were collected in new collapsible 20-L polyethylene drinking water containers and sent to the toxicity laboratory at ESG International (now Stantec Consulting) in Guelph (ON, Canada).

Prior to toxicity testwork, initial conditions in the station 1 samples were characterized with respect to basic parameters (Table 1). Water samples collected from upstream of East Lake (station 1) were spiked with dissolved Cu to achieve concentrations ranging from 0 to 800 μg/L. After allowing a 24-h equilibration period following Cu addition, and prior to the introduction of organisms, subsamples were taken from each test concentration for Cu speciation analysis as described above for total Cu, filterable Cu (<0.45 μm, <0.1 μm), and DGT Cu. Survival and reproduction of *Ceriodaphnia dubia* were then monitored on each of the spiked solutions. The test organisms were neonates (<24 h old) from established *C. dubia* cultures. Organisms were fed once daily with 0.2 ml of YCT (yeast, cereal leaf, troutchow) and algae and transferred daily to new solutions of test water using a wide-bore pipette. At the time of transfer, observations were made for any deaths and for any neonates produced during the previous 24 h. Tests were ended after 7 d of observations. *Ceriodaphnia dubia* was selected given the use of this species in regulatory frameworks and the large amount of toxicity data available for this species.

The protocols for acute and chronic toxicity tests are consistent with those described by Environment Canada [23]. Toxicity tests were initiated the day after water was received at the laboratory and within 3 d of sample water collection. Sample water was pre-aerated for 20 min prior to initiating the tests. No adjustments of pH or hardness were required. Reference tests were run in the same month as the sample water tests using sodium chloride as the reference toxicant.

The test endpoints of the toxicity testwork were survival for acute toxicity and reproduction for chronic toxicity over the 7-d incubation period. For acute test results, the median lethal concentration (LC50), which is the concentration of Cu that is estimated to be lethal to 50% of the test organisms, was calculated for each test by nonlinear interpolation [24]. For chronic test results, the IC25 (the concentration of Cu that produces a 25% inhibition of reproduction) was calculated by linear interpolation. Values for LC50 and IC25 were calculated for total Cu, filterable Cu, and DGT Cu.

RESULTS AND DISCUSSION

Copper speciation and behavior

Most of the Cu present in the East Lake drainage system is present as filterable species (Fig. 2). For the 2001 sampling period, the <0.45-μm fraction accounted for on average 94% (range of 81–100%) of the total Cu inventory. The 2002 data

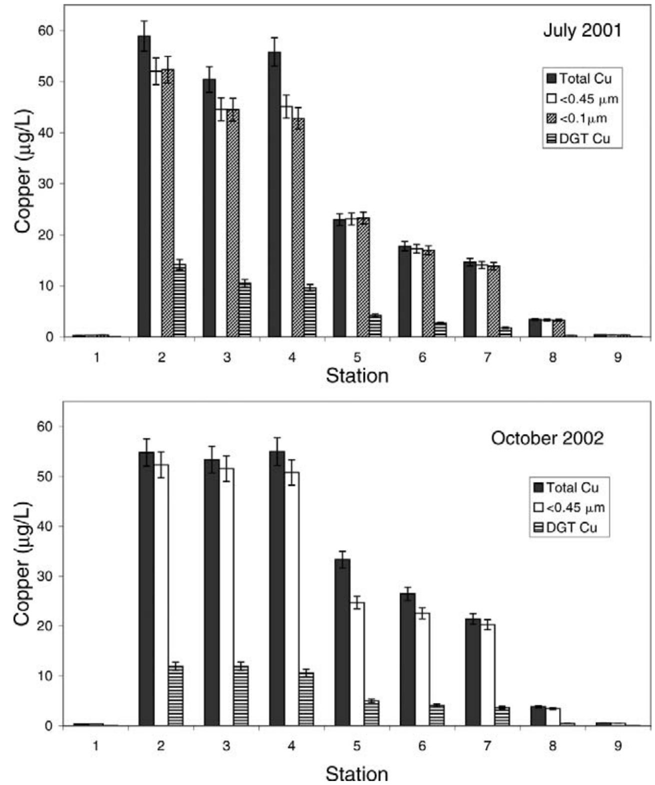

Fig. 2. Total-Cu, filterable-Cu (<0.45 μm and <0.1 μm), and diffusive gradients in thin films (DGT)-Cu concentrations upstream of East Lake (ON, Canada) (station 1), at the East Lake outlet (station 2), downstream of East Lake (stations 3 to 8), and upstream of the Detour River confluence (ON, Canada) (station 9) for July 2001 and October 2002. Note the <0.1-μm fraction was measured in 2001 only. Error bars represent ±1 standard deviation.

showed similar results, with filterable (<0.45 μm) species accounting for 90% (range of 74–100%) of the total. The difference in Cu concentration between the <0.45-μm and <0.1-μm fractions measured in 2001 was small (<5%), indicating the low abundance of colloidal species. The dominance of filterable species can be attributed to low stream turbidity during the 2001 and 2002 sampling periods (<3 mg/L total suspended solids) and the likely dominance of soluble Cu-organic complexes. The strongly stained surface waters within the drainage system host abundant DOC (7–17 mg/L), which likely represents the dominant ligand for Cu in the catchment. Lakes and streams in the region are also highly oligotrophic, which contributes to low particulate organic matter in the water column and lower importance of particulate-Cu complexes. Surface-water samples measured for chlorophyll *a* during the algal growing season in 2005 (June–October 2005) yielded values ranging from 0.5 to 2 μg/L (M. Aziz, Goldcorp, Vancouver, BC, Canada, unpublished data). Such values are typical to poorly productive lakes on the Canadian Shield, and fall well within the chlorophyll limits for oligotrophic systems [25].

The DGT results suggest that most of the Cu is unavailable to aquatic biota. Measurements of labile Cu as determined by DGT indicate that only 9 to 24% of Cu within the receiving environment downstream of East Lake is biologically available (Fig. 2). The relatively low proportion of labile Cu species is consistent with the presumed dominance of strong Cu-organic complexes which exhibit limited sequestration by DGT. The predominance of nonlabile Cu species is consistent with results for other systems where Cu speciation is predicted to be dominated

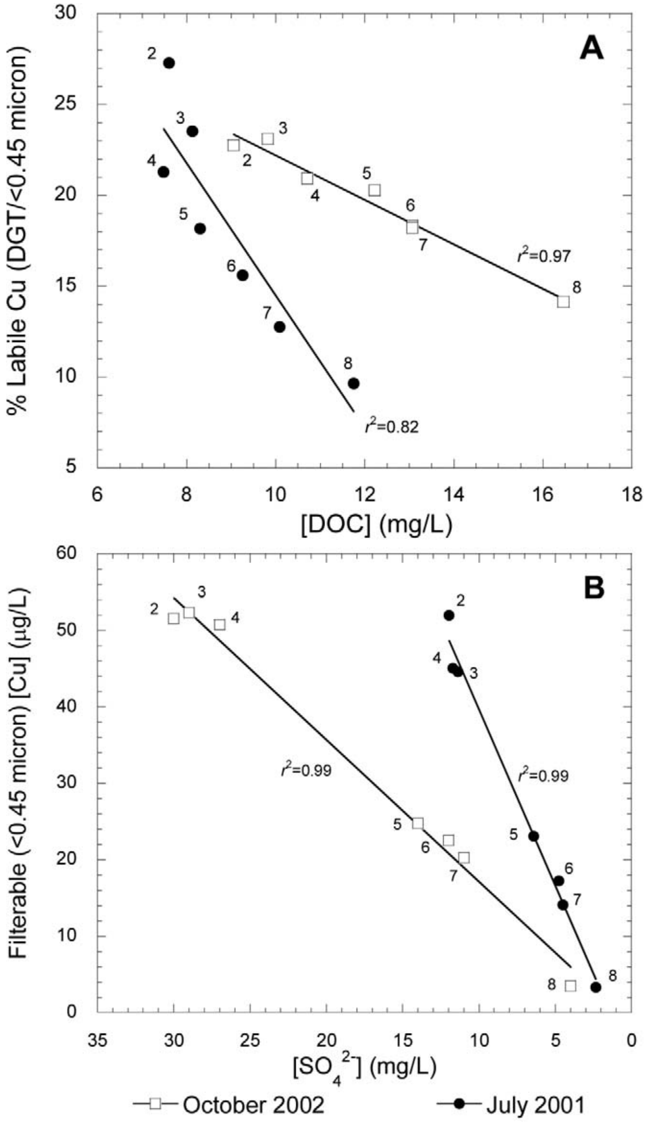

Fig. 3. (**A**) Scatter plot of percentage of labile Cu (diffusive gradient in thin films [DGT] fraction/<0.45-μm fraction) versus dissolved organic carbon (DOC) in water samples collected at the East Lake (ON, Canada) outlet (station 2) and downstream (stations 3 to 8). (**B**) Scatter plot of filterable Cu (<0.45 μm) versus sulfate in water samples collected within East Lake (station 2) and downstream (stations 3–8). The increasing DOC values and decreasing sulfate concentrations on the *x* axis represent increasing distance from the East Lake discharge. Station numbers are indicated by each point.

by humate or fulvate complexes [1,2,8]. Sigg et al. [2], for example, found 11 to 32% of Cu in the DOC-rich waters of the River Wyre to be associated with the DGT fraction.

For both 2001 and 2002, the proportion of labile Cu decreases downstream of East Lake. In July 2001, the proportion of DGT Cu decreased from 27% at the East Lake outlet (station 2) to 10% in the Detour River (station 8) (Fig. 2). Similarly, in October 2002, the labile fraction decreased from 23% at the East Lake outlet to 14% in the Detour River. Decreases in the labile-Cu fraction downstream of East Lake correlate well (r^2 values of 0.82–0.97) with increases in the concentration of DOC with distance downstream of East Lake (Fig. 3). The inverse relationship between DOC and labile Cu is suggested to reflect increased competition for Cu binding on DOC sorption sites with distance downstream. In this regard, the assimilative capacity for Cu increases with distance downstream of East Lake, presumably due to the progressive importance of Cu-organic complexes.

Values for DGT Cu in spiked solutions show a linear ($0.98 < r^2 < 0.99$) response for the October 2001, April 2002, and August 2002 samples (Fig. 4), yielding slopes translating to labile-Cu proportions of 17, 28, and 27%, respectively. The slopes of these curves provide a measure of the relative strength of the Cu-ligand complexes, where greater deviation of titration curves from the 1:1 line translates to less-labile Cu complexes [8]. These data indicate that water collected during October 2001 was more effective in complexing Cu (17% labile Cu) in comparison to April 2002 and August 2002 (28 and 27% labile Cu, respectively). The linearity of the DGT response curves shown in Figure 4 over the range of Cu addition (up to 800 μg/L) demonstrates that ligand saturation was not achieved in spiked solutions of water collected at station 1.

In order to quantify the influence of dilution on Cu concentrations downstream of East Lake, dissolved sulfate was measured at various points between the East Lake outlet (station 2) and the Detour River (station 8) in July 2001 and October 2002 (Fig. 3). Levels of sulfate are elevated in East Lake (approximately 12–29 mg/L) compared to background values (1–2 mg/L) due to inputs of sulfate-rich surface waters emanating from the tailings facility which is located 300 m upstream and west of East Lake (Fig. 1). Variations in sulfate concentrations in East Lake reflect seasonal variations in sulfate loadings from the tailings pond (timing of pond discharges) as well as seasonal variability in the volume of East Lake (controlled by the elevation of the spillway) and lake residence time. Sulfate behaves relatively conservatively in aerobic freshwaters, and therefore can serve as an effective tracer of dilution. Using sulfate as a proxy for dilution, the downstream trends for sulfate indicate that <10% dilution of East Lake discharges is realized upstream of Sunday Lake (Fig. 3). Considerable dilution occurs within Sunday Lake, downstream of which >50% dilution is evident. Sulfate concentrations decrease progressively downstream of Sunday Lake towards the Detour River (station 8), in which discharges from East Lake are diluted by >90%.

Downstream trends in filterable Cu values for both July 2001 and October 2002 exhibit a similar pattern to sulfate. For both periods, filterable (<0.45 μm) Cu levels decrease from approximately 50 μg/L in East Lake to 3.5 μg/L in the Detour River (Fig. 2). The relationship between filterable Cu and SO_4^{2-} was linear ($r^2 = 0.99$) for both the July 2001 and October 2002 periods (Fig. 3). Assuming SO_4^{2-} behaves conservatively, the congruent behavior of Cu and SO_4^{2-} indicates that decreases in filterable Cu concentration downstream of East Lake can be primarily attributed to dilution, rather than loss of dissolved Cu associated with nonconservative removal mechanisms (e.g., sorption to particulates, assimilation by biota, precipitation of secondary Cu phases). Conservative behavior of Cu is suggested to reflect the dominance of nonlabile Cu-organic complexes. The notion of conservative Cu behavior makes the robust assumption that Cu is not appreciably recycled between the sediments and water column.

Copper bioavailability and toxicity

Negligible mortality (≤10%) with regards to *C. dubia* was observed at filterable Cu concentrations <80 μg/L in Cu-spiked solutions of water collected upstream of East Lake (station 1) in October 2001, April 2002 and August 2002 (Fig.

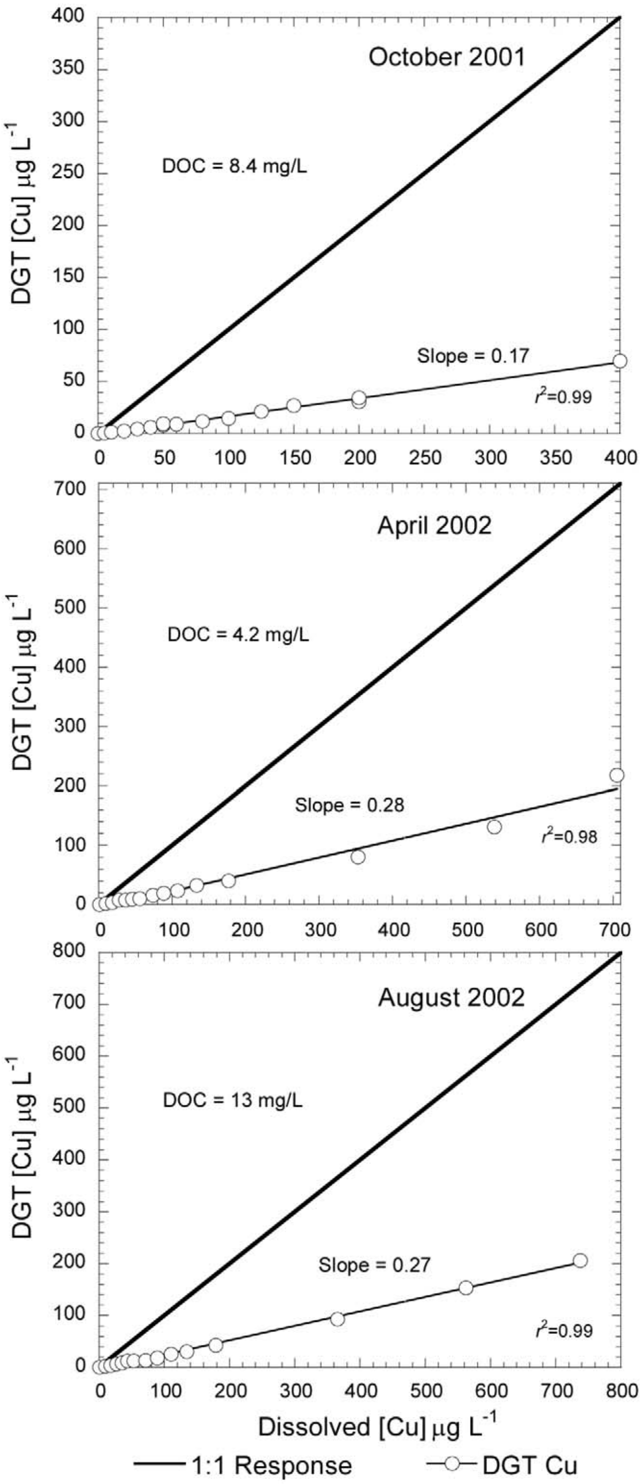

Fig. 4. Copper concentrations as defined by diffusive gradients in thin films (DGT) in East Creek (ON, Canada) water (station 1) spiked with various concentrations of dissolved Cu for samples collected in October 2001, April 2002, and August 2002. Each spiked solution corresponds to the samples in Figure 5 for toxicity testwork. Concentration of dissolved organic carbon (DOC) is indicated for each solution.

5). Such observations are consistent with the results from acute toxicity testwork using *Daphnia magna* (96 h LC50) at the East Lake discharge that also show that mortality has been negligible at Cu levels <90 μg/L during the closure period (M. Aziz, Goldcorp, Vancouver, BC, Canada, unpublished data). The LC50 values for the October 2001, April 2002, and August 2002 periods were 203, 96, and 119 μg/L, respectively (Fig. 5). The reproduction (i.e., chronic) response exhibited a pattern similar to the mortality response. The April and August 2002 results demonstrate that there was little effect on reproduction up to approximately 80 μg/L filterable Cu, above which chronic effects (i.e., decreased mean number of young produced) were observed (Fig. 5). Above 125 μg/L, reproduction for both the April 2002 and August 2002 solutions was significantly affected. The IC25 values for these periods were calculated by linear interpolation to be 75 and 89 μg/L, respectively. The October 2001 period was characterized by a higher IC25 value of 156 μg/L. This is consistent with the higher LC50 value observed during this time (Fig. 5).

Table 2 summarizes the acute and chronic toxicity thresholds for the various Cu species measured. In theory, DGT should normalize for Cu bioavailability and generate similar LC50s for the three spiked solutions. Indeed, the DGT-derived LC50s show reasonable interseason agreement. For all surveys, the range in DGT-Cu LC50s (20–30 μg/L) is similar to literature LC50 values (4–46 μg/L) for the same species tested in standard control water absent of DOC [26] (www.epa.gov/ecotox). The DGT range is slightly higher than the species mean acute value (SMAV = 11.5 μg/L filterable Cu, normalized to a water hardness of 50 mg/L) for *C. dubia* as reported by the U.S. Environmental Protection Agency (U.S. EPA) [27]. The SMAV represents the geometric mean of all available and acceptable acute values for the species. Accordingly, the DGT-Cu LC50 values for East Lake suggest that DGT provides a reliable, although conservative, proxy for Cu bioavailability in the East Lake system.

Variations in LC50 and IC25 values can be explained by differences in labile-Cu concentrations as determined by the DGT-inferred slopes in Figure 4. The high LC50 measured for the October 2001 sample (Fig. 5), for example, is consistent with the high proportion of nonlabile Cu species (Fig. 4). Similarly, the seasonal disparity between the IC25 results is consistent with the measured differences in Cu lability between these periods as inferred from DGT. The relationship between LC50 and percentage of labile Cu as defined by DGT yields an inverse relationship, where a 10% decrease in Cu lability translates to an approximately 100 μg/L increase in the LC50.

The response of DGT Cu to Cu addition can be used as a measure of complexation capacity, which can be defined as a measure of a testwater to decrease the concentration of the labile or free metal fraction [8]. In this regard, the complexation capacity can be defined by both the strength of metal–ligand complexes as well as the number of complexation sites. This is illustrated graphically for a hypothetical system in Figure 6. In this scheme, the slope of the curve reflects the strength of the Cu-ligand complexes, while the intercept of the saturation point on the *x*-axis represents the ligand capacity for metal sorption (number of complexation sites). The DGT response to Cu addition in the presence of a strong Cu-binding ligand, for example, yields a low slope that deviates significantly from the 1:1 response curve. Conversely, the presence of weaker ligands will result in less deviation from the 1:1 response. According to this scheme, a test water with high complexing strength but a low saturation point can be equally effective in ameliorating Cu toxicity as a solution with low strength and a high saturation point. Such differences relate to both the quality and quantity of the ligands present in solution. The considerations described here highlight the utility

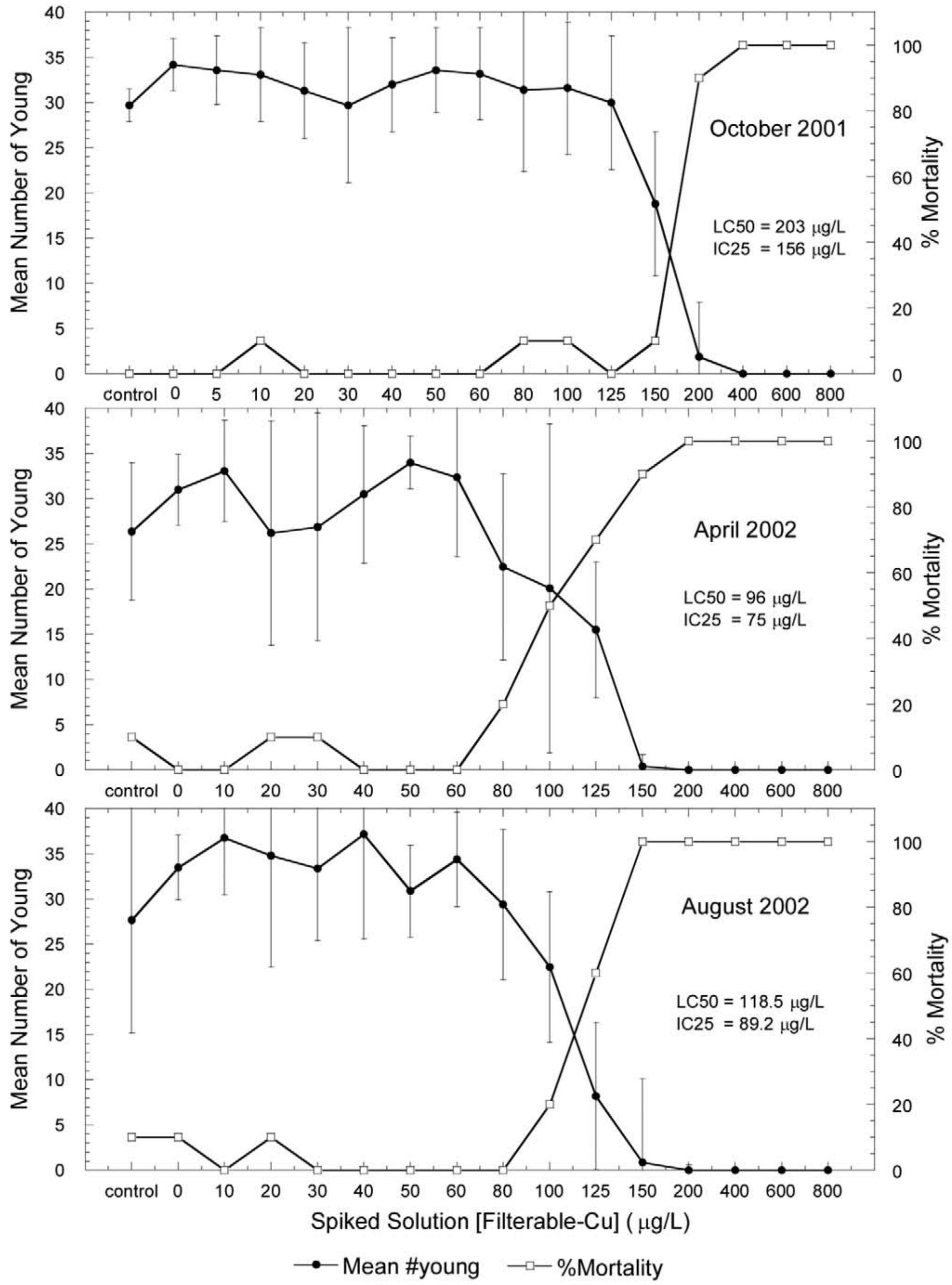

Fig. 5. Fecundity (mean number of young) and percentage of mortality of *Ceriodaphnia dubia* in East Creek (ON, Canada) water (station 1) spiked with various concentrations of dissolved Cu for water samples collected in October 2001, April 2002, and August 2002. Error bars represent ±1 standard deviation. LC50 equals the lethal concentration resulting in 50% mortality. IC25 = the concentration resulting in a 25% inhibition in reproduction.

of DGT as a tool for assessing complexation capacity that can be used to quantify both of these variables.

The considerable complexation capacity afforded by waters collected at station 1 can be attributed to abundance of DOC. However, in this system, DOC itself does not represent an ideal proxy for Cu bioavailability. As shown in Figure 3, scatter plots of DOC versus percentage of bioavailability yield linear, although contrasting, slopes. Therefore, although for a given sampling episode there is a reasonably strong negative relationship between percentage of labile Cu and [DOC] with distance downstream of East Lake, the relationship does not hold when data for multiple seasons are considered. The results highlight the importance of other variables that may affect Cu bioavailability and the strength of Cu-DOC complexes (pH, salinity).

Seasonal differences in Cu bioavailability in stream systems may reflect temporal variability in water composition (e.g., DOC, pH, temperature, salinity) and associated variations in metal–ligand competition. In addition to the influence of variable pH and salinity, seasonal variability in the quality of DOC is predicted to have an influence on Cu bioavailability in the East Lake drainage. Seasonal differences in DOC quality can reflect the relative proportion of groundwater and surface runoff to stream flow which may exhibit varying DOC composition, the availability of soluble organic carbon as it relates to seasonally varying rates of organic matter decomposition

Table 2. Acute (LC50, concentration resulting in 50% mortality to *Ceriodaphnia dubia*) and chronic (IC25, concentration resulting in a 25% inhibition in reproduction in *C. dubia*) threshold values for Cu measured in Cu-spiked solutions for water collected at station 1 (East Lake, ON, Canada) in October 2001, April 2002, and August 2002. Values are presented for both filterable Cu and labile Cu as defined by diffusive gradients in thin films (DGT)[a]

	Copper species	LC50	95% CL	IC25	95% CL	IC25/LC50 (%)
October 2001	Filterable Cu	203	178–233	156	137–167	76
	DGT Cu	30	27–33	24	21–25	80
April 2002	Filterable Cu	96	82–104	75	64–95	77
	DGT Cu	20	17–23	15	12–20	75
August 2002	Filterable Cu	119	72–134	89	56–91	76
	DGT Cu	23	14–31	16	13–19	70

[a] LC50 = concentration lethal to 50% of the organisms tested; 95% CL = 95% confidence limits; IC25 = concentration that inhibits reproduction by 25%.

in the litter and A-soil horizons and the seasonal changes in the productivity of phytoplankton and macrophytes [28].

Implications for site-specific water quality objective for copper

The toxicity testwork presented herein has direct relevance to water-effect ratio (WER) testwork in support for the development of site-specific water quality objectives. The WER procedure has been recommended for use in the United States and Canada for establishing ambient water quality guidelines, and a detailed guidance for using WER for metals was published in 1994 [29]. Use of WER is part of the formal, legally enforceable process for deriving aquatic site-specific water quality criteria. A procedure for determining the WER specifically for discharges of Cu was published in 2001 [27]. The procedure was intended to reflect the well-established effects that water quality characteristics such as hardness and DOC concentration have on the bioavailability and toxicity of Cu to aquatic organisms. Water-effect ratios have been applied to several sites in the United States, including the Lehigh River in Pennsylvania [30] and the Great Works River in Maine [31].

Water quality objectives using the WER method are derived by comparing toxicological data generated in standard laboratory water to the same toxicological data generated in site water. The ratio of toxicity (either chronic or acute) of a substance in laboratory water to toxicity of the substance in site water is termed the WER. The WER is then multiplied by the water quality guideline to obtain a site-specific water quality objective.

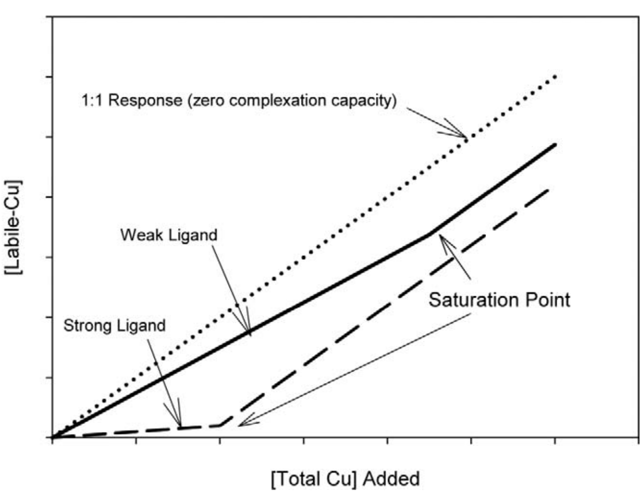

Fig. 6. Hypothetical response curves for labile Cu as a function of increasing Cu concentration in the presence of no ligand binding (1:1 response curve), weak ligand, and strong ligand. Arbitrary saturation points are indicated to show the Cu concentration at which sorptive capacity is attained.

The results from the acute and chronic toxicity testwork shown in Figure 5 were used to calculate a WER for each time period (Table 3). The LC50s derived for Cu-spiked solutions of station 1 water were divided by the SMAV for *C. dubia* (SMAV = 11.5 μg/L filterable Cu, normalized to a water hardness of 50 mg/L [27]) to achieve WERs ranging from 8.3 to 17.7. The WERs were then multiplied by the existing Ontario provincial water quality objective (PWQO = 5 μg/L) [32] (www.ene.gov.on.ca/gp/3303e.htm) to obtain site-specific water quality objectives ranging from 42 to 88 μg/L (Table 3). These values represent the range in concentration over which ecological sustainability is predicted. The high WERs calculated for waters collected in the East Lake drainage further highlight the assimilative capacity for Cu in this system. The range in site-specific water quality objectives generated here (42–88 μg/L) is greater than the filterable Cu values measured currently in East Lake (2005 mean = 35 μg/L).

CONCLUSION

The results presented here demonstrate the profound effect of DOC on Cu speciation and toxicity in a stream–lake system influenced by mine-related loadings, and exhibit how seasonal variables (quality and quantity of DOC) affect Cu bioavailability. Toxicity data for *C. dubia* in Cu-spiked solutions show that chronic and acute toxicity varies by at least a factor of two on a seasonal basis. Given that the present study captured only three periods (October, April, and August), it is likely that there are broader variations in Cu bioavailability on an annual basis. Although for a given time period the proportion of labile Cu correlates strongly with the concentration of DOC, contrasting slopes for different sampling periods demonstrate that DOC does not represent a reliable proxy for Cu bioavailability. In this manner DGT presents a suitable method for evaluating seasonal variations in Cu lability, as the technique implicitly considers the concentration and strength of various Cu-ligand complexes. Such considerations also highlight the potential limitations of Cu speciation models that do not account for seasonal variations in the quality of DOC.

The temporal and spatial variability in Cu bioavailability illustrated in the present study emphasizes the importance of site-specific variables that contribute to assimilative capacity. In the East Lake drainage, dilution as well as increased complexation capacity downstream, contribute to a net increase in assimilative capacity with distance from the East Lake discharge. Such information has direct relevance to the assess-

Table 3. Summary of information used to derive site-specific water quality objectives as per water effect ratio methods (all values in μg/L)[a]

	Copper species	LC50	SMAV	WER	PWQO	WQO
October 2001	Filterable Cu	203	11.5	17.7	5	88
April 2002	Filterable Cu	96	11.5	8.3	5	42
August 2002	Filterable Cu	119	11.5	10.3	5	52

[a] LC50 = concentration resulting in 50% mortality to *Ceriodaphnia dubia*; SMAV = species mean acute value normalized to water hardness of 50 mg/L (as $CaCO_3$) [27]; WER = water-effect ratio = LC50/SMAV; PWQO = Ontario provincial water quality objective; WQO = site-specific water quality objective (WQO = WER · PWQO).

ment of ecological risks and to the development of scientifically defensible and cost-effective management strategies. As part of management measures designed to ensure the protection of aquatic resources, DGT has been shown to be a useful tool for the development of site-specific water quality objectives.

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APPENDIX C1
TOXICITY TEST REPORT – February 2016

Nautilus Environmental

Toxicity testing of CC1.5 and HC2.5

Samples collected February 28, 2016

Final Report

Report date:
April 8, 2016

Submitted to:

Lorax Environmental
Vancouver, BC

8664 Commerce Court
Burnaby, BC
V5A 4N7

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SIGNATURE PAGE

Signature REDACTED

Emma Marus, B.Sc.
Laboratory Biologist

Signature REDACTED

Armando Tang, R. P. Bio.
Senior Reviewer

This report has been prepared by Nautilus Environmental Company Inc. based on data and/or samples provided by our client and the results of this study are for their sole benefit. Any reliance on the data by a third party is at the sole and exclusive risk of that party. The results presented here relate only to the samples tested.

1.0 INTRODUCTION

Nautilus Environmental conducted toxicity tests for Lorax Environmental on two samples identified as CC1.5 and HC2.5. Samples were collected on February 28, 2016 and delivered to the laboratory in Burnaby, BC on March 1, 2016. Each sample was transported in two 2-L plastic containers and was received at a temperature of 8.8°C. Samples were stored in the dark at 4 ± 2°C prior to testing.

This report describes the results of the toxicity tests conducted on these samples using *Ceriodaphnia dubia*. Copies of raw laboratory datasheets and printouts of statistical analyses are provided in Appendix A. The chain-of-custody form is provided in Appendix B.

2.0 METHODS

Methods for the toxicity tests using *C. dubia* are summarized in Table 1. Testing was conducted according to procedures described by Environment Canada (2007). Statistical analyses were performed using CETIS (Tidepool Scientific Software, 2013).

Table 1. Summary of test conditions: *Ceriodaphnia dubia* survival and reproduction test.

Test organism	*Ceriodaphnia dubia*
Test organism source	In-house culture
Test organism age	<24 hour old neonates within 12 hours of the same age
Test type	Static-renewal
Test duration	7 ± 1 day
Test vessel	20-mL glass test tube
Test volume	15 mL
Test solution depth	10 cm
Test concentrations	100% (v/v) undiluted sample plus laboratory control
Test replicates	10 test replicates per treatment
No. of organisms	1 per replicate
Control/dilution water	20% Perrier water and 80% deionized water (hardness 80-100 mg/L $CaCO_3$)
Test solution renewal	Daily (100% renewal)
Test temperature	25 ± 1°C
Feeding	Daily with *Pseudokirchneriella subcapitata* and YCT (3:1 ratio)
Light intensity	100 to 600 lux at water surface
Photoperiod	16 hours light/8 hours dark
Sample filtration	None
Aeration	None
pH adjustment	None
Test protocol	Environment Canada (2007), EPS 1/RM/21
Statistical software	CETIS (2013)
Test endpoints	Survival and reproduction
Test acceptability criteria for controls	≥80% survival; ≥15 young per surviving control producing three broods; ≥60% of controls producing three or more broods, no ephippia present
Reference toxicant	Sodium chloride

3.0 RESULTS

Results of the toxicity tests for samples CC1.5 and HC2.5 are provided in Tables 2 and 3. There were no adverse effects on survival or reproduction in either of the samples tested.

Table 2. Results: *Ceriodaphnia dubia* survival and reproduction test with sample CC1.5.

Sample ID	Survival (%)	Reproduction (Mean ± SD)
Control	100	20.5 ± 2.2
CC1.5	100	23.8 ± 2.3

SD = Standard Deviation.

Table 3. Results: *Ceriodaphnia dubia* survival and reproduction test with sample HC2.5.

Sample ID	Survival (%)	Reproduction (Mean ± SD)
Control	100	21.1 ± 2.2
HC2.5	100	23.6 ± 1.4

SD = Standard Deviation.

4.0 QA/QC

The health history of the test organisms used in the exposures was acceptable and met the requirements of the Environment Canada protocol. The tests met all control acceptability criteria and water quality parameters remained within ranges specified in the protocol throughout the tests. There were no deviations from the test methodology. Uncertainty associated with these tests is best described by the standard deviation around the mean and/or the confidence intervals around the point estimates.

Results of the reference toxicant test conducted during the testing program are summarized in Table 5. Results for this test fell within the range for organism performance of the mean and two standard deviations, based on historical results obtained by the laboratory with this test. Thus, the sensitivity of the organisms used in these tests was appropriate. The reference toxicant test was performed under the same conditions as those used for the samples.

Table 4. Reference toxicant test results.

Test Species	Endpoint	Historical Mean (2 SD Range)	CV (%)	Test Date
C. dubia	LC50 = 2.1 g/L NaCl	2.0 (1.9 - 2.2) g/L NaCl	4	February 17, 2016
	IC50 = 1.5 g/L NaCl	1.5 (1.2 – 1.9) g/L NaCl	12	

SD = Standard Deviation, CV = Coefficient of Variation, LC = Lethal Concentration, IC = Inhibition Concentration.

5.0 REFERENCES

Environment Canada. 2007. Biological test method: test of reproduction and survival using the cladoceran *Ceriodaphnia dubia*. Environmental Protection Series. Report EPS 1/RM/21, Second Edition, February 2007. Environment Canada, Method Development and Application Section, Environmental Science and Technology Centre, Science and Technology Branch, Ottawa, ON. 74 pp.

Tidepool Scientific Software. 2013. CETIS comprehensive environmental toxicity information system, version 1.8.7.16 Tidepool Scientific Software, McKinleyville, CA. 222 pp.

6.0 END OF REPORT

This is the end of the report.

APPENDIX A – Toxicity Test Data

Ceriodaphnia dubia Summary Sheet

Client: Lorax
Work Order No.: 16271

Start Date/Time: March 2/16 @ 1340h
Set up by: EMM/MCT

Sample Information:

Sample ID: CC1.5
Sample Date: Feb 28/16
Date Received: Mar 1/16
Sample Volume: 2x2L

Test Validity Criteria:

1) Mean survival of first generation controls is ≥80 %
2) At least 60% of controls have produced three broods within 8 days
3) An average of ≥15 live young produced per surviving female in the control solutions during the first three broods.
4) Invalid if ephippia observed in any control solution at any time.

WQ Ranges:

T (°C) = 25 ± 1; DO (mg/L) = 3.3 to 8.4 ; pH = 6.0 to 8.5

Test Organism Information:

Broodstock No.: 021816B
Age of young (Day 0): <24-h (within 12-h)
Avg No. young in first 3 broods of previous 7 d: 36
Mortality (%) in previous 7 d: Ø
Individual female # used ≥8 young on test day: 21→37

NaCl Reference Toxicant Results:

Reference Toxicant ID: Cd140
Stock Solution ID: 15Na03
Date Initiated: Feb17/16.

7-d LC50 (95% CL): 2.1 (1.5 - 3.0) g/L NaCL
7-d IC50 (95% CL): 1.5 (1.1 - 1.7) g/L NaCL

7-d LC50 Reference Toxicant Mean and Historical Range: 2.0 (1.9 - 2.2) g/L NaCL CV (%): 4
7-d IC50 Reference Toxicant Mean and Historical Range: 1.5 (1.2 - 1.9) g/L NaCL CV (%): 12

Test Results:

	Survival (%)	Reproduction (Mean ± SD)
Negative Control	100	20.5 ± 2.2
100% (v/v)	100	23.8 ± 2.3
		±
		±
		±
		±
		±
		±
		±

Reviewed by: JCu

Date reviewed: March 21/16

Chronic Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client: Lorax
Sample ID: CC1.5
Work Order #: 16271

Start Date & Time: March 2/16 @ 1340h
Stop Date & Time: March 9/16 @ 1130h
Test Species: *Ceriodaphnia dubia*

Concentration	Days													
	0	1		2		3		4		5		6		7
Control	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)	24.0	25.0	24.0	24.0	24.0	25.0	24.0	25.0	24.0	25.0	24.0	25.0	24.0	25.0
DO (mg/L)	8.0	7.9	8.0	7.7	8.1	7.4	8.2	7.3	8.0	7.4	8.0	7.3	8.0	7.7
pH	8.0	7.9	8.0	7.5	8.0	7.7	7.9	7.9	8.0	7.4	8.0	7.5	8.0	7.7
Cond. (µS/cm)	219	218		226		228		228		227		226		221
Initials	MLT	EMM		EMM		A		A		EMM		EMM		EMM

Concentration	Days													
	0	1		2		3		4		5		6		7
100% (v/v)	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)	26.0	25.0	25.0	24.0	24.0	25.0	24.0	25.0	24.0	25.0	24.0	25.0	24.0	25.0
DO (mg/L)	7.4	7.9	7.6	7.5	7.5	7.5	7.8	7.4	7.9	7.2	7.8	7.2	7.7	7.4
pH	7.9	8.1	7.8	7.9	7.5	8.1	7.5	8.2	7.6	8.1	7.6	7.9	7.6	7.5
Cond. (µS/cm)	762	755		771		764		770		769		760		770
Initials	MLT	EMM		EMM		A		A		EMM		EMM		EMM

Concentration	Days													
	0	1		2		3		4		5		6		7
	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)														
DO (mg/L)														
pH														
Cond. (µS/cm)														
Initials														

Concentration	Days													
	0	1		2		3		4		5		6		7
	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)														
DO (mg/L)														
pH														
Cond. (µS/cm)														
Initials														

Thermometer: 4 **DO meter:** 2 **pH meter:** 4 **Conductivity meter:** 4

	Control	100% (v/v)		
Hardness*	100	414		
Alkalinity*	98	208		

* mg/L as CaCO3

Analysts: MLT, EMM, AWD, JS, KL
Reviewed by: JGL
Date reviewed: March 21/16

Sample Description: clear, colourless, odourless, no particulates or precipitate

Comments: **Broodboard Used:** 021816B (21-37)

Chronic Freshwater Toxicity Test
C. dubia Reproduction Data

Client: Lorax
Sample ID: CC 1.5
Work Order: 16271

Start Date & Time: March 2/16 @ 1340h
Stop Date & Time: March 9/16 @ 1130h
Set up by: MLT/EMM

Days	Concentration: control											Concentration: 100% (v/v)											Concentration:										
	A	B	C	D	E	F	G	H	I	J	Init	A	B	C	D	E	F	G	H	I	J	Init	A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MG	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MG											
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	EMM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	EMM											
3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	A	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	A											
4	2	2	3	3	2	2	2	2	2	✓	~	3	2	3	2	3	3	3	3	2	3	~											
5	7	8	7	8	9	9	7	7	7	8	KL	11	10	9	9	9	8	✓	7	10	7	KL											
6	13	11	✓	11	✓	✓	✓	✓	✓	✓	JS	✓	14	✓	✓	✓	✓	8	✓	✓	✓	JS											
7	✓	✓	14	✓	10	11	10	9	10	9	EMM	14	✓	11	13	13	12	12	11	13	10	EMM											
8																																	
Total	22	21	24	22	21	22	19	18	19	17	EMM	28	26	28	24	25	23	23	21	25	20	EMM											

Days	Concentration:											Concentration:											Concentration:										
	A	B	C	D	E	F	G	H	I	J	Init	A	B	C	D	E	F	G	H	I	J	Init	A	B	C	D	E	F	G	H	I	J	Init
1																																	
2																																	
3																																	
4																																	
5																																	
6																																	
7																																	
8																																	
Total																																	

Days	Concentration:											Concentration:											Concentration:										
	A	B	C	D	E	F	G	H	I	J	Init	A	B	C	D	E	F	G	H	I	J	Init	A	B	C	D	E	F	G	H	I	J	Init
1																																	
2																																	
3																																	
4																																	
5																																	
6																																	
7																																	
8																																	
Total																																	

Notes: X = mortality.

Sample Description: clear, colourless, odourless, no particulates or precipitate

Comments: **Total # Young only based on the first 3 Broods. Fourth and subsequent broods not included in total count.**

Reviewed by: JGu

Date reviewed: March 21/16

CETIS Summary Report

Report Date: 17 Mar-16 12:47 (p 1 of 1)
Test Code: 16271a | 03-6708-8590

Ceriodaphnia 7-d Survival and Reproduction Test — **Nautilus Environmental**

Batch ID:	20-3865-6495	**Test Type:**	Reproduction-Survival (7d)	**Analyst:**	Emma Marus
Start Date:	02 Mar-16 13:40	**Protocol:**	EC/EPS 1/RM/21	**Diluent:**	20% Perrier Water
Ending Date:	09 Mar-16 11:30	**Species:**	Ceriodaphnia dubia	**Brine:**	
Duration:	6d 22h	**Source:**	In-House Culture	**Age:**	<24h

Sample ID:	01-4832-4587	**Code:**	8D740EB	**Client:**	Lorax
Sample Date:	28 Feb-16 23:30	**Material:**	Water Sample	**Project:**	
Receive Date:	01 Mar-16 17:30	**Source:**	Lorax		
Sample Age:	62h (8.8 °C)	**Station:**	CC1.5		

Comparison Summary

Analysis ID	Endpoint	NOEL	LOEL	TOEL	PMSD	TU	Method
07-2433-6389	7d Survival Rate	100	>100	NA	NA	1	Fisher Exact Test
07-0113-2088	Reproduction	<100	100	NA	8.56%	>1	Equal Variance t Two-Sample Test

7d Survival Rate Summary

C-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Negative Control	10	1	1	1	1	1	0	0	0.0%	0.0%
100		10	1	1	1	1	1	0	0	0.0%	0.0%

Reproduction Summary

C-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Negative Control	10	20.5	18.95	22.05	17	24	0.6872	2.173	10.6%	0.0%
100		10	23.8	22.12	25.48	20	28	0.7424	2.348	9.86%	-16.1%

7d Survival Rate Detail

C-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0	Negative Control	1	1	1	1	1	1	1	1	1	1
100		1	1	1	1	1	1	1	1	1	1

Reproduction Detail

C-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0	Negative Control	22	21	24	22	21	22	19	18	19	17
100		28	26	23	24	25	23	23	21	25	20

7d Survival Rate Binomials

C-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0	Negative Control	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
100		1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1

CETIS Analytical Report

Report Date:	17 Mar-16 12:46 (p 1 of 1)	**Test Code:**	16271a | 03-6708-8590

Ceriodaphnia 7-d Survival and Reproduction Test — **Nautilus Environmental**

Analysis ID:	07-2433-6389	**Endpoint:**	7d Survival Rate	**CETIS Version:**	CETISv1.8.7
Analyzed:	17 Mar-16 12:46	**Analysis:**	Single 2x2 Contingency Table	**Official Results:**	Yes
Batch ID:	20-3865-6495	**Test Type:**	Reproduction-Survival (7d)	**Analyst:**	Emma Marus
Start Date:	02 Mar-16 13:40	**Protocol:**	EC/EPS 1/RM/21	**Diluent:**	20% Perrier Water
Ending Date:	09 Mar-16 11:30	**Species:**	Ceriodaphnia dubia	**Brine:**	
Duration:	6d 22h	**Source:**	In-House Culture	**Age:**	<24h
Sample ID:	01-4832-4587	**Code:**	8D740EB	**Client:**	Lorax
Sample Date:	28 Feb-16 23:30	**Material:**	Water Sample	**Project:**	
Receive Date:	01 Mar-16 17:30	**Source:**	Lorax		
Sample Age:	62h (8.8 °C)	**Station:**	CC1.5		

Data Transform	Zeta	Alt Hyp	Trials	Seed	Test Result
Untransformed		C > T	NA	NA	Passes 7d survival rate

Fisher Exact Test

Control	vs	C-%	Test Stat	P-Value	P-Type	Decision(α:5%)
Negative Control		100	1	1.0000	Exact	Non-Significant Effect

Data Summary

C-%	Control Type	NR	R	NR + R	Prop NR	Prop R	%Effect
0	Negative Contr	10	0	10	1	0	0.0%
100		10	0	10	1	0	0.0%

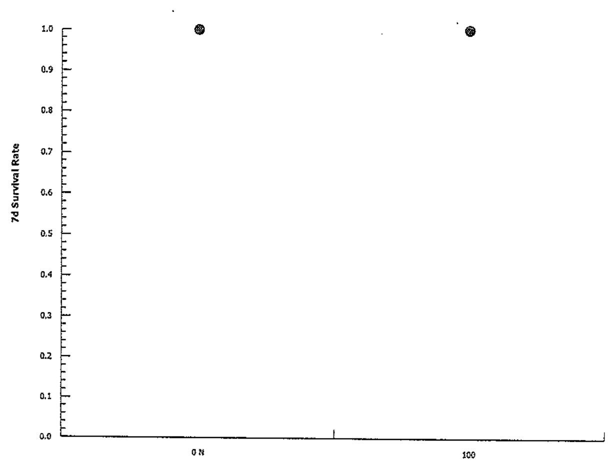
7d Survival Rate Detail

C-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0	Negative Control	1	1	1	1	1	1	1	1	1	1
100		1	1	1	1	1	1	1	1	1	1

7d Survival Rate Binomials

C-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0	Negative Control	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
100		1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1

Graphics



CETIS Analytical Report

Report Date:	17 Mar-16 12:46 (p 1 of 1)
Test Code:	16271a | 03-6708-8590

Ceriodaphnia 7-d Survival and Reproduction Test — **Nautilus Environmental**

Analysis ID:	07-0113-2088	**Endpoint:**	Reproduction	**CETIS Version:**	CETISv1.8.7
Analyzed:	17 Mar-16 12:46	**Analysis:**	Parametric-Two Sample	**Official Results:**	Yes
Batch ID:	20-3865-6495	**Test Type:**	Reproduction-Survival (7d)	**Analyst:**	Emma Marus
Start Date:	02 Mar-16 13:40	**Protocol:**	EC/EPS 1/RM/21	**Diluent:**	20% Perrier Water
Ending Date:	09 Mar-16 11:30	**Species:**	Ceriodaphnia dubia	**Brine:**	
Duration:	6d 22h	**Source:**	In-House Culture	**Age:**	<24h
Sample ID:	01-4832-4587	**Code:**	8D740EB	**Client:**	Lorax
Sample Date:	28 Feb-16 23:30	**Material:**	Water Sample	**Project:**	
Receive Date:	01 Mar-16 17:30	**Source:**	Lorax		
Sample Age:	62h (8.8 °C)	**Station:**	CC1.5		

Data Transform	Zeta	Alt Hyp	Trials	Seed	PMSD	Test Result
Untransformed	NA	C < T	NA	NA	8.56%	Fails ~~reproduction~~

Equal Variance t Two-Sample Test

Control vs	C-%	Test Stat	Critical	MSD	DF	P-Value	P-Type	Decision(α:5%)
Negative Control	100*	3.262	1.734	1.754	18	0.0022	CDF	Significant Effect

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	54.45	54.45	1	10.64	0.0043	Significant Effect
Error	92.1	5.116667	18			
Total	146.55		19			

Distributional Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variances	Variance Ratio F	1.167	6.541	0.8218	Equal Variances
Distribution	Shapiro-Wilk W Normality	0.9721	0.866	0.7986	Normal Distribution

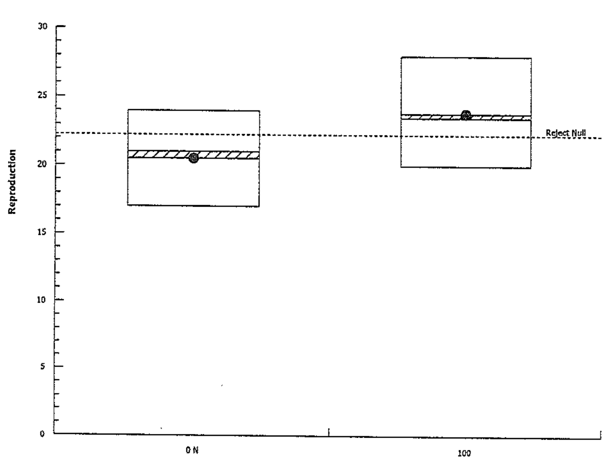
Reproduction Summary

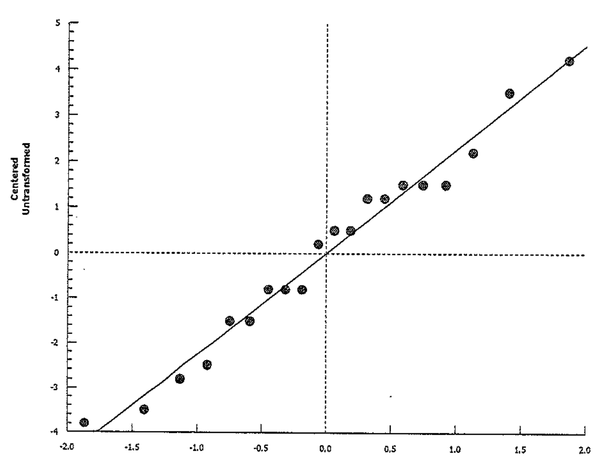
C-%	Control Type	Count	Mean	95% LCL	95% UCL	Median	Min	Max	Std Err	CV%	%Effect
0	Negative Control	10	20.5	18.95	22.05	21	17	24	0.6872	10.6%	0.0%
100		10	23.8	22.12	25.48	23.5	20	28	0.7424	9.86%	-16.1%

Reproduction Detail

C-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0	Negative Control	22	21	24	22	21	22	19	18	19	17
100		28	26	23	24	25	23	23	21	25	20

Graphics





Ceriodaphnia dubia Summary Sheet

Client: Lorax
Work Order No.: 16271

Start Date/Time: March 2/16 @ 1140h
Set up by: EMM/MCT

Sample Information:

Sample ID: HC25
Sample Date: Feb 28/16
Date Received: Mar 1/16
Sample Volume: 2x2L

Test Validity Criteria:

1) Mean survival of first generation controls is ≥80 %
2) At least 60% of controls have produced three broods within 8 days
3) An average of ≥15 live young produced per surviving female in the control solutions during the first three broods.
4) Invalid if ephippia observed in any control solution at any time.

WQ Ranges:

T (°C) = 25 ± 1; DO (mg/L) = 3.3 to 8.4 ; pH = 6.0 to 8.5

Test Organism Information:

Broodstock No.: 021816B
Age of young (Day 0): <24-h (within 12-h)
Avg No. young in first 3 broods of previous 7 d: 36
Mortality (%) in previous 7 d: Ø
Individual female # used ≥8 young on test day: 21→37

NaCl Reference Toxicant Results:

Reference Toxicant ID: Cd140
Stock Solution ID: 15Na03
Date Initiated: Feb17/16.

7-d LC50 (95% CL): 2.1 (1.5 - 3.0) g/L NaCL
7-d IC50 (95% CL): 1.5 (1.1 - 1.7) g/L NaCL

7-d LC50 Reference Toxicant Mean and Historical Range: 2.0 (1.9 - 2.2) g/L NaCL CV (%): 4
7-d IC50 Reference Toxicant Mean and Historical Range: 1.5 (1.2 - 1.9) g/L NaCL CV (%): 12

Test Results:

	Survival (%)	Reproduction (Mean ± SD)
Negative Control	100	21.1 ± 2.2
100% (v/v)	100	23.6 ± 1.4
		±
		±
		±
		±
		±
		±
		±

Reviewed by: JCh

Date reviewed: March 22/16

Jan 26, 2011; Ver. 2.0

Nautilus Environmental

Chronic Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client: Lorax
Sample ID: HC 2,5
Work Order #: 16271

Start Date & Time: March 2/16 @ ~~1340h~~ 1140 emm
Stop Date & Time: March 9/16 @ 1130h
Test Species: *Ceriodaphnia dubia*

Concentration	Days													
	0	1		2		3		4		5		6		7
Control	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)	24.0	25.0	24.0	24.0	24.0	25.0	24.0	25.0	24.0	25.0	24.0	25.0	24.0	25.0
DO (mg/L)	8.0	7.9	8.0	7.5	8.1	7.5	8.2	7.6	8.0	7.1	8.0	7.5	8.0	7.6
pH	8.0	7.9	8.0	7.9	8.0	7.8	7.9	7.9	8.0	7.5	8.0	7.5	8.0	7.7
Cond. (µS/cm)	219	218		226		228		228		227		226		229
Initials	MLT	EMM		EMM		[illegible]		A		EMM		EMM		EMM

Concentration	Days													
	0	1		2		3		4		5		6		7
100% (v/v)	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)	26.0	25.0	25.0	24.0	24.6	25.0	24.0	25.0	24.0	25.0	24.0	25.0	24.6	25.0
DO (mg/L)	7.3	7.4	7.7	7.6	7.8	7.4	7.8	7.5	7.9	7.1	7.8	7.3	7.9	7.4
pH	7.9	8.0	~~7.9~~ (1)	7.8	7.5	8.1	7.5	8.1	7.5	7.8	7.6	7.8	7.6	7.7
Cond. (µS/cm)	415	399		403		396		399		399		399		391
Initials	MLT	EMM		EMM		A		A		EMM		EMM		EMM

(1) 7.4 em

Concentration	Days													
	0	1		2		3		4		5		6		7
	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)														
DO (mg/L)														
pH														
Cond. (µS/cm)														
Initials														

Concentration	Days													
	0	1		2		3		4		5		6		7
	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)														
DO (mg/L)														
pH														
Cond. (µS/cm)														
Initials														

Thermometer: 4 **DO meter:** 2 **pH meter:** 4 **Conductivity meter:** 4

	Control	100% (v/v)		
Hardness*	100	214		
Alkalinity*	98	126		

* mg/L as CaCO3

Analysts: EMM, MLT, AWD, JS, KL
Reviewed by: [illegible]
Date reviewed: March 21/16

Sample Description: clear, colourless, odourless, no particulates or precipitate

Comments: **Broodboard Used:** 0218~~15B~~ 16B (21737)

Chronic Freshwater Toxicity Test
C. dubia Reproduction Data

Client: Lorax
Sample ID: HC 2.5
Work Order: 16271

Start Date & Time: March 2/16 @ ~~1340h~~ 1140 emm
Stop Date & Time: March 9/16 @ 1130h
Set up by: MG/EMM

Days	Concentration: Control A	B	C	D	E	F	G	H	I	J	Init	Concentration: 100% (v/v) A	B	C	D	E	F	G	H	I	J	Init	Concentration: A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MG	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MG											
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	EMM	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	EMM											
3	/	/	/	/	/	/	/	/	/	/	A	/	/	/	/	/	/	/	/	/	/	A											
4	2	2	2	2	2	3	4	2	3	3	AS	2	3	3	2	3	3	2	3	3	2	AS											
5	8	6	8	7	8	7	9	6	8	8	KL	8	9	8	11	9	8	9	9	9	9	KL											
6	✓	✓	✓	✓	✓	15	✓	✓	✓	✓	JS	15	✓	✓	✓	✓	✓	✓	✓	✓	✓	JS											
7	10	10	9	10	11	✓	10	11	12	11	EMM	✓	11	12	12	11	13	12	10	14	11	EMM											
8																																	
Total	20	18	19	19	21	25	23	21	23	22	EMM	25	23	23	25	23	24	23	22	26	22	[illegible]											

Days	Concentration: A	B	C	D	E	F	G	H	I	J	Init	Concentration: A	B	C	D	E	F	G	H	I	J	Init	Concentration: A	B	C	D	E	F	G	H	I	J	Init
1																																	
2																																	
3																																	
4																																	
5																																	
6																																	
7																																	
8																																	
Total																																	

Days	Concentration: A	B	C	D	E	F	G	H	I	J	Init	Concentration: A	B	C	D	E	F	G	H	I	J	Init	Concentration: A	B	C	D	E	F	G	H	I	J	Init
1																																	
2																																	
3																																	
4																																	
5																																	
6																																	
7																																	
8																																	
Total																																	

Notes: X = mortality.

Sample Description: clear, colourless, odourless, no particulates, no precipitate

Comments: Total # Young only based on the first 3 Broods. Fourth and subsequent broods not included in total count.

Reviewed by: JGu

Date reviewed: March 21/16

CETIS Summary Report

Report Date: 22 Mar-16 09:57 (p 1 of 1)
Test Code: 16271b | 16-8201-8927

Ceriodaphnia 7-d Survival and Reproduction Test — **Nautilus Environmental**

Batch ID:	02-0557-5746	**Test Type:**	Reproduction-Survival (7d)	**Analyst:**	Emma Marus
Start Date:	02 Mar-16 11:40	**Protocol:**	EC/EPS 1/RM/21	**Diluent:**	20% Perrier Water
Ending Date:	09 Mar-16 11:30	**Species:**	Ceriodaphnia dubia	**Brine:**	
Duration:	7d	**Source:**	In-House Culture	**Age:**	<24h

Sample ID:	09-8470-1488	**Code:**	3AB15A30	**Client:**	Lorax
Sample Date:	28 Feb-16 12:45	**Material:**	Water Sample	**Project:**	
Receive Date:	01 Mar-16 17:30	**Source:**	Lorax		
Sample Age:	71h (8.8 °C)	**Station:**	HC2.5		

Comparison Summary

Analysis ID	Endpoint	NOEL	LOEL	TOEL	PMSD	TU	Method
07-2543-6759	7d Survival Rate	100	>100	NA	NA	1	Fisher Exact Test
07-7822-8293	Reproduction	<100	100	NA	6.67%	>1	Equal Variance t Two-Sample Test

7d Survival Rate Summary

C-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Negative Control	10	1	1	1	1	1	0	0	0.0%	0.0%
100		10	1	1	1	1	1	0	0	0.0%	0.0%

Reproduction Summary

C-%	Control Type	Count	Mean	95% LCL	95% UCL	Min	Max	Std Err	Std Dev	CV%	%Effect
0	Negative Control	10	21.1	19.54	22.66	18	25	0.6904	2.183	10.35%	0.0%
100		10	23.6	22.63	24.57	22	26	0.4269	1.35	5.72%	-11.85%

7d Survival Rate Detail

C-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0	Negative Control	1	1	1	1	1	1	1	1	1	1
100		1	1	1	1	1	1	1	1	1	1

Reproduction Detail

C-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0	Negative Control	20	18	19	19	21	25	23	21	23	22
100		25	23	23	25	23	24	23	22	26	22

7d Survival Rate Binomials

C-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0	Negative Control	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
100		1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1

CETIS Analytical Report

Report Date:	17 Mar-16 12:56 (p 1 of 1)
Test Code:	16271b | 16-8201-8927

Ceriodaphnia 7-d Survival and Reproduction Test — **Nautilus Environmental**

Analysis ID:	07-2543-6759	**Endpoint:**	7d Survival Rate	**CETIS Version:**	CETISv1.8.7
Analyzed:	17 Mar-16 12:55	**Analysis:**	Single 2x2 Contingency Table	**Official Results:**	Yes

Batch ID:	02-0557-5746	**Test Type:**	Reproduction-Survival (7d)	**Analyst:**	Emma Marus
Start Date:	02 Mar-16 11:40	**Protocol:**	EC/EPS 1/RM/21	**Diluent:**	20% Perrier Water
Ending Date:	09 Mar-16 11:30	**Species:**	Ceriodaphnia dubia	**Brine:**	
Duration:	7d	**Source:**	In-House Culture	**Age:**	<24h

Sample ID:	09-8470-1488	**Code:**	3AB15A30	**Client:**	Lorax
Sample Date:	28 Feb-16 12:45	**Material:**	Water Sample	**Project:**	
Receive Date:	01 Mar-16 17:30	**Source:**	Lorax		
Sample Age:	71h (8.8 °C)	**Station:**	HC2.5		

Data Transform	Zeta	Alt Hyp	Trials	Seed	Test Result
Untransformed		C > T	NA	NA	Passes 7d survival rate

Fisher Exact Test

Control	vs	C-%	Test Stat	P-Value	P-Type	Decision(α:5%)
Negative Control		100	1	1.0000	Exact	Non-Significant Effect

Data Summary

C-%	Control Type	NR	R	NR + R	Prop NR	Prop R	%Effect
0	Negative Contr	10	0	10	1	0	0.0%
100		10	0	10	1	0	0.0%

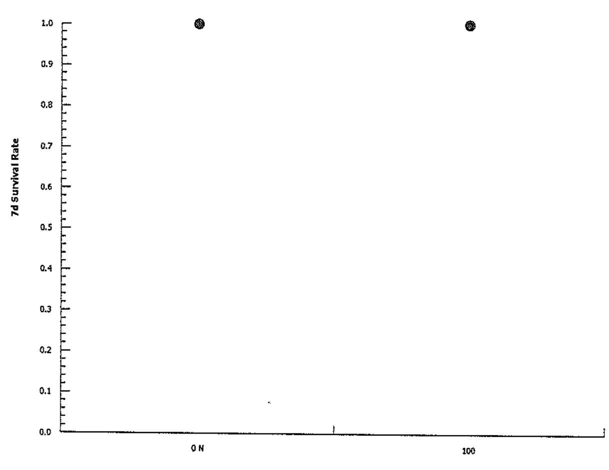
7d Survival Rate Detail

C-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0	Negative Control	1	1	1	1	1	1	1	1	1	1
100		1	1	1	1	1	1	1	1	1	1

7d Survival Rate Binomials

C-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0	Negative Control	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
100		1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1

Graphics



CETIS Analytical Report

Report Date:	17 Mar-16 12:56 (p 1 of 1)
Test Code:	16271b | 16-8201-8927

Ceriodaphnia 7-d Survival and Reproduction Test — **Nautilus Environmental**

Analysis ID:	07-7822-8293	**Endpoint:**	Reproduction	**CETIS Version:**	CETISv1.8.7
Analyzed:	17 Mar-16 12:55	**Analysis:**	Parametric-Two Sample	**Official Results:**	Yes
Batch ID:	02-0557-5746	**Test Type:**	Reproduction-Survival (7d)	**Analyst:**	Emma Marus
Start Date:	02 Mar-16 11:40	**Protocol:**	EC/EPS 1/RM/21	**Diluent:**	20% Perrier Water
Ending Date:	09 Mar-16 11:30	**Species:**	Ceriodaphnia dubia	**Brine:**	
Duration:	7d	**Source:**	In-House Culture	**Age:**	<24h
Sample ID:	09-8470-1488	**Code:**	3AB15A30	**Client:**	Lorax
Sample Date:	28 Feb-16 12:45	**Material:**	Water Sample	**Project:**	
Receive Date:	01 Mar-16 17:30	**Source:**	Lorax		
Sample Age:	71h (8.8 °C)	**Station:**	HC2.5		

Data Transform	Zeta	Alt Hyp	Trials	Seed	PMSD	Test Result
Untransformed	NA	C < T	NA	NA	6.67%	Fails reproduction

Equal Variance t Two-Sample Test

Control	vs	C-%	Test Stat	Critical	MSD	DF	P-Value	P-Type	Decision(α:5%)
Negative Control		100*	3.08	1.734	1.408	18	0.0032	CDF	Significant Effect

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	31.25	31.25	1	9.486	0.0065	Significant Effect
Error	59.3	3.294445	18			
Total	90.55		19			

Distributional Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variances	Variance Ratio F	2.616	6.541	0.1682	Equal Variances
Distribution	Shapiro-Wilk W Normality	0.9752	0.866	0.8590	Normal Distribution

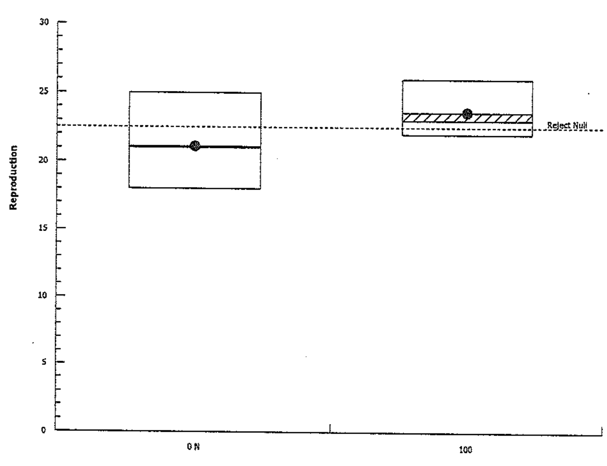
Reproduction Summary

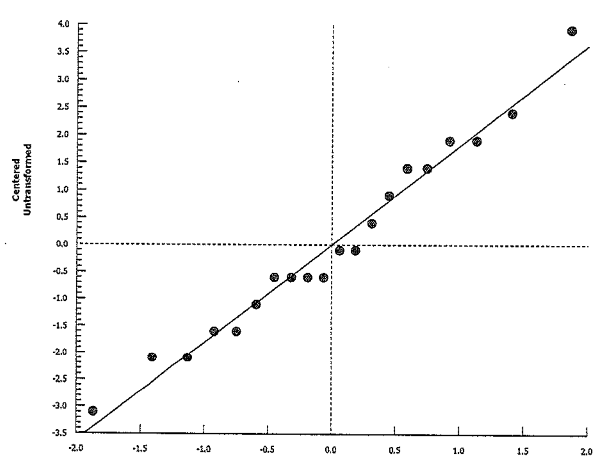
C-%	Control Type	Count	Mean	95% LCL	95% UCL	Median	Min	Max	Std Err	CV%	%Effect
0	Negative Control	10	21.1	19.54	22.66	21	18	25	0.6904	10.35%	0.0%
100		10	23.6	22.63	24.57	23	22	26	0.4269	5.72%	-11.85%

Reproduction Detail

C-%	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0	Negative Control	20	18	19	19	21	25	23	21	23	22
100		25	23	23	25	23	24	23	22	26	22

Graphics





Client: Lorax Environmental

W.O.#: 1627

Hardness and Alkalinity Datasheet

Sample ID	Alkalinity: Sample Date	Alkalinity: Sample Volume (mL)	Alkalinity: (mL) 0.02N HCL/H_2SO_4 used to pH 4.5	Alkalinity: (mL) of 0.02N HCL/H_2SO_4 used to pH 4.2	Alkalinity: Total Alkalinity (mg/L$CaCO_3$)		Hardness: Sample Volume (mL)	Hardness: Volume of 0.01M EDTA Used (mL)	Hardness: Total Hardness (mg/L $CaCO_3$)	Technician
HC25	March 21/16	50	6.5	6.7	126		50	10.7	214	KL
CCl.5	March 21/16	↓	10.5	10.6	208		↓	20.7	414	↓
20% pemer	March 21/16	50	5.0	5.1	98		50	5.0	100	fmh

Notes:

Reviewed by: ______________________ Signature

Date Reviewed: March 21/16

APPENDIX B – Chain-of-Custody Form

Nautilus Environmental

TESTING LOCATION (Please Circle)

Burnaby
8664 Commerce Court
Burnaby, British Columbia, Canada
V5A 4N7
Phone 604.420.8773

Calgary
#4 6125 12th St S.E.
Calgary, Alberta, Canada
T2H 2K1
Phone 403.253.7121

Chain of Custody

Date 3/3/16 Page 1 of 1

Sample Collection By:

Report to:		**Invoice To:**	
Company	Lorax Environmtal	**Company**	same as report
Address	2289 Burrard St.	**Address**	
City/State/Zip	Vancouver, BC V6J 3H9	**City/State/Zip**	
Contact	Robert Goldblatt	**Contact**	
Phone		**Phone**	
Email		**Email**	

	SAMPLE ID	DATE	① TIME	MATRIX	CONTAINER TYPE	NO. OF CONTAINERS	COMMENTS	ANALYSES REQUIRED: Ceriodaphnia - 100%										Receipt Temperature (°C)
1	CC1.5	28-Feb-2016	23:30	stream water	2x2L			X										8.8
2	HC2.5	28-Feb-2016	12:45	stream water	2x2L			X										8.8
3																		
4																		
5								WO# 16271										
6																		
7																		
8																		
9																		
10																		

PROJECT INFORMATION		SAMPLE RECEIPT	
Client:		**Total No. of Containers**	4
PO No.:		**Received Good Condition?**	Y
Shipped Via:		**Matches Test Schedule?**	Y

RELINQUISHED BY (CLIENT)
(Signature) (Time)
(Printed Name) (Date)
(Company)

RELINQUISHED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (LABORATORY)
(Signature) NA (Time) 17:30
(Printed Name) (Date) Mar 01/16
(Company) Nautilus

SPECIAL INSTRUCTIONS/COMMENTS:

Please include Project # 362-4 (Coffee Gold) on invoice

① sample times sent by email

Additional costs may be required for sample disposal or storage. Payment net 30 unless otherwise contracted.

2 x 2x1L

APPENDIX C2
TOXICITY TEST REPORT – JUNE 2016

Nautilus Environmental

Toxicity testing on Lab, CC1.5 and HC2.5

Samples collected June 25, 2016

Final Report

Report date:
August 5, 2016

Submitted to:

Lorax Environmental
Vancouver, BC

8664 Commerce Court
Burnaby, BC
V5A 4N7

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LIST OF TABLES

LIST OF APPENDICES

SIGNATURE PAGE

Signature REDACTED
Signature REDACTED

Emma Marus, B.Sc.
Laboratory Biologist

Signature REDACTED

Armando Tang, R. P. Bio.
Senior Reviewer

This report has been prepared by Nautilus Environmental Company Inc. based on data and/or samples provided by our client and the results of this study are for their sole benefit. Any reliance on the data by a third party is at the sole and exclusive risk of that party. The results presented here relate only to the samples tested.

1.0 INTRODUCTION

Nautilus Environmental conducted toxicity tests for Lorax Environmental to evaluate the chronic effects of uranium on survival and reproduction of *Ceriodaphnia dubia*. Tests were conducted on three samples identified as Lab, CC1.5 and HC2.5. Samples were collected on June 25, 2016 and transported in 2-L plastic containers to the Nautilus Environmental laboratory in Burnaby, BC on June 27, 2016. Samples were received at temperatures of 11.5 and 13.0°C, and were stored in the dark at 4 ± 2ºC prior to testing.

This report describes the results of these toxicity tests. Copies of raw laboratory datasheets and printouts of statistical analyses are provided in Appendix A. The chain-of-custody form is provided in Appendix B.

2.0 METHODS

Methods for the toxicity tests using *C. dubia* are summarized in Table 1. Testing was conducted according to procedures described by Environment Canada (2007). All test solutions were prepared by Lorax Environmental prior to sample receipt at the Nautilus Environmental laboratory. Uranium was measured in all concentrations by the client prior to testing and statistical analyses were conducted on the basis of these measurements using CETIS (Tidepool Scientific Software, 2013).

Table 1. Summary of test conditions: *Ceriodaphnia dubia* survival and reproduction test.

Test organism	*Ceriodaphnia dubia*
Test organism source	In-house culture
Test organism age	<24 hour old neonates within 12 hours of the same age
Test type	Static-renewal
Test duration	7 ± 1 day
Test vessel	20-mL glass test tube
Test volume	15 mL
Nominal concentrations (µg/L U)	320, 160, 80, 40, 20, 10, 0 and laboratory control
Test replicates	10 test replicates per treatment
No. of organisms	1 per replicate
Laboratory control water	20% Perrier water and 80% deionized water (hardness 80-100 mg/L $CaCO_3$)
Test solution renewal	Daily
Test temperature	25 ± 1°C
Feeding	Daily with *Pseudokirchneriella subcapitata* and YCT (3:1 ratio)
Light intensity	100 to 600 lux at water surface
Photoperiod	16 hours light/8 hours dark
Sample filtration	None
Aeration	None
pH adjustment	None
Test protocol	Environment Canada (2007), EPS 1/RM/21
Statistical software	CETIS (2013)
Test endpoints	Survival and reproduction
Test acceptability criteria for controls	≥80% survival; ≥15 young per surviving control producing three broods; ≥60% of controls producing three or more broods, no ephippia present
Reference toxicant	Sodium chloride

3.0 RESULTS

Results of the toxicity tests for samples Lab, CC1.5 and HC2.5 are provided in Tables 2 to 4. Nominal and measured concentrations of uranium were provided by the client and results are based on measured concentrations. There were no adverse effects on survival in any of the samples tested; the resulting LC values were therefore greater than the highest concentration tested. For sample Lab, there were adverse effects on reproduction; the resulting IC25 and IC50 values were 106.2 and 141.6 µg/L U. There were no adverse effects on reproduction in samples CC1.5 or HC2.5.

Table 2. Results: *Ceriodaphnia dubia* survival and reproduction test on Lab (amended with U).

Concentrations (µg/L U)		**Survival (%)**	**Reproduction (mean ± SD)**
U (nominal)	U (measured)		
lab control	0.7	90	20.1 ± 9.0
10	11.1	100	24.8 ± 3.3 †
20	21.0	100	23.0 ± 2.3 †
40	41.7	100	22.9 ± 3.5 †
80	79.6	100	23.2 ± 3.9 †
160	162.0	60	7.7 ± 7.7
320	322.0	60	7.1 ± 6.4
Endpoints as µg/L U (based on measured)	LC50	>322	--
	IC25 (95% CL)	--	106.2 (28.2 – 117.2)
	IC50 (95% CL)	--	141.6 (113.9 – 227.2)

SD = Standard Deviation, LC = Lethal Concentration, IC = Inhibition Concentration, CL = Confidence Limits.
† = The data did not fit the hormesis regression model; therefore the reproduction was adjusted to that of the control value and analyzed using linear interpolation.

Table 3. Results: *Ceriodaphnia dubia* survival and reproduction test on CC1.5 (amended with U).

Concentrations (µg/L U)		**Survival (%)**	**Reproduction (mean ± SD)**
U (nominal)	U (measured)		
lab control	0.7	100	21.5 ± 5.5
0 (site control)	7.4	80	7.7 ± 4.6
10	17.5	70	10.7 ± 9.8
20	28.1	100	17.3 ± 4.9
40	48.8	100	20.8 ± 4.7
80	88.4	90	16.5 ± 9.2
160	171.0	100	20.8 ± 4.1
320	331.0	100	19.8 ± 5.3
Endpoints as µg/L U (based on measured)	LC50	>331*	--
	IC25	--	>331*
	IC50	--	>331*

SD = Standard Deviation, LC = Lethal Concentration, IC = Inhibition Concentration.
* = statistical analyses were conducted against the site control.

Table 4. Results: *Ceriodaphnia dubia* survival and reproduction test on HC2.5 (amended with U).

Concentrations (µg/L U)		Survival (%)	Reproduction (mean ± SD)
U (nominal)	U (measured)		
lab control	0.7	100	19.5 ± 5.3
0 (site control)	23.9	100	21.3 ± 4.9
10	34.3	90	16.1 ± 7.6
20	44.4	100	18.9 ± 6.9
40	64.2	100	17.1 ± 5.1
80	105.0	100	19.6 ± 5.9
160	188.0	90	15.0 ± 9.7
320	351.0	100	18.4 ± 5.9
Endpoints as µg/L U (based on measured)	LC50	>351*	--
	IC25	--	>351*
	IC50	--	>351*

SD = Standard Deviation, LC = Lethal Concentration, IC = Inhibition Concentration.
* = statistical analyses were conducted against the site control.

4.0 QA/QC

The health history of the test organisms used in the exposures was acceptable and met the requirements of the Environment Canada protocol. The tests met all control acceptability criteria and water quality parameters remained within ranges specified in the protocol throughout the tests. There were no deviations from the test methodology. Uncertainty associated with these tests is best described by the standard deviation around the mean and/or the confidence intervals around the point estimates.

Results of the reference toxicant test conducted during the testing program are summarized in Table 5. Results for this test fell within the range for organism performance of the mean and two standard deviations, based on historical results obtained by the laboratory with this test. Thus, the sensitivity of the organisms used in these tests was appropriate. The reference toxicant test was performed under the same conditions as those used for the samples.

Table 5. Reference toxicant test results.

Test Species	Endpoint	Historical Mean (2 SD Range)	CV (%)	Test Date
C. dubia	LC50 = 2.1 g/L NaCl	2.0 (1.8 - 2.2) g/L NaCl	5	June 29, 2016
	IC50 = 1.6 g/L NaCl	1.6 (1.2 – 2.0) g/L NaCl	13	

SD = Standard Deviation, CV = Coefficient of Variation, LC = Lethal Concentration, IC = Inhibition Concentration.

5.0 REFERENCES

Environment Canada. 2007. Biological test method: test of reproduction and survival using the cladoceran *Ceriodaphnia dubia*. Environmental Protection Series. Report EPS 1/RM/21, Second Edition, February 2007. Environment Canada, Method Development and Application Section, Environmental Science and Technology Centre, Science and Technology Branch, Ottawa, ON. 74 pp.

Tidepool Scientific Software. 2013. CETIS comprehensive environmental toxicity information system, version 1.8.7.16 Tidepool Scientific Software, McKinleyville, CA. 222 pp.

6.0 END OF REPORT

This is the end of the report.

APPENDIX A – Toxicity Test Data

Ceriodaphnia dubia Summary Sheet

Client: Lorax Environmental
Work Order No.: 16703

Start Date/Time: June 28/16 @ 1000h
Set up by: EMM

Sample Information:

Sample ID: LAB Water ("LAB")
Sample Date: JW ~~July~~ June ~~25/16~~ n/a EM
Date Received: June 27/16
Sample Volume: 7 x 2L

Test Validity Criteria:
1) Mean survival of first generation controls is ≥80 %
2) At least 60% of controls have produced three broods within 8 days
3) An average of ≥15 live young produced per surviving female in the control solutions during the first three broods.
4) Invalid if ephippia observed in any control solution at any time.

WQ Ranges:
T (°C) = 25 ± 1; DO (mg/L) = 3.3 to 8.4 ; pH = 6.0 to 8.5

Test Organism Information:

Broodstock No.: 061616 B
Age of young (Day 0): <24-h (within 12-h)
Avg No. young in first 3 broods of previous 7 d: 34
Mortality (%) in previous 7 d: 0
Individual female # used ≥8 young on test day: 1, 2, 6 - 10

NaCl Reference Toxicant Results:

Reference Toxicant ID: Cd 146
Stock Solution ID: 16 Na 01
Date Initiated: June 29/16

7-d LC50 (95% CL): 2.1 (1.5 - 3.0) g/L NaCL
7-d IC50 (95% CL): 1.6 (1.4 - 1.7) g/L NaCL

7-d LC50 Reference Toxicant Mean and Historical Range: 2.0 (1.8 - 2.2) g/L NaCL CV (%): 5
7-d IC50 Reference Toxicant Mean and Historical Range: 1.6 (1.2 - 2.0) g/L NaCL CV (%): 13

Test Results:

µg/L U	Survival	Reproduction
LC50 ~~%~~ (v/v) (95% CL)	> 322	
IC25 % (v/v) (95% CL)		106.2 (28.2 - 117.2)
IC50 % (v/v) (95% CL)		141.6 (113.9 - 227.2)

JW

Signature REDACTED

Reviewed by: ______

Date reviewed: July 27/16

Chronic Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client: Lorax Environmental Services Ltd
Sample ID: Uranium in lab water (1)
Work Order #: 16703
Start Date & Time: June 28/16 @ 1000h
Stop Date & Time: July 5/16 @ 1125h
Test Species: *Ceriodaphnia dubia*

(1) sample ID: "LAB-0,10,20,40,80,160,320" on CoC

~~Site~~ mg Concentration Control	0	1		2		3		4		5		6		7
	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)	24.0	25.0	24.0	25.0	25.0	25.0	24.0	25.0	24.0	25.0	24.0	25.0	24.0	25.0
DO (mg/L)	8.1	7.8	8.2	7.8	8.0	7.8	8.3	7.6	8.1	7.5	8.0	7.2	8.0	7.5
pH	8.0	7.6	7.9	7.6	7.9	7.6	7.7	7.6	8.0	7.8	8.0	7.6	8.0	7.5
Cond. (µS/cm)	214	216		217		215		216		221		220		218
Initials	MLT	MLT		MLT		JW		FMM		MLT		FMM		MLT

Concentration 10 ~~mg~~ µg/L U	0	1		2		3		4		5		6		7
	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)	24.0	25.0	24.0	~~24.5~~ 25.0	25.0	25.0	24.0	25.0	24.0	25.0	25.0	25.0	24.0	25.0
DO (mg/L)	8.1	7.8	8.2	7.8	7.8	7.8	8.3	7.6	8.1	7.5	8.1	7.2	8.1	7.5
pH	8.0	7.6	7.9	7.7	7.9	7.6	7.8	7.6	7.9	7.8	7.9	7.6	8.0	7.5
Cond. (µS/cm)	217	217		217		216		217		219		219		218
Initials	MLT	MLT		MLT		JW		FMM		MLT		FMM		MLT

Concentration 20 ~~mg~~ µg/L U	0	1		2		3		4		5		6		7
	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)	24.0	25.0	24.0	25.0	25.0	25.0	24.0	25.0	24.0	25.0	25.0	25.0	24.0	25.0
DO (mg/L)	8.1	7.8	8.2	7.9	7.8	7.9	8.3	7.6	8.1	7.5	8.1	7.2	8.1	7.5
pH	8.0	7.6	7.9	7.7	7.9	7.6	7.8	7.6	7.9	7.8	8.0	7.6	8.0	7.5
Cond. (µS/cm)	217	217		217		217		217		220		220		~~216~~ 218
Initials	MLT	MLT		MLT		JW		FMM		MLT		FMM		MLT

40 Concentration ~~37.5~~ µg/L U	0	1		2		3		4		5		6		7
	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)	24.0	25.0	24.0	25.0	25.0	25.0	24.0	25.0	24.0	25.0	25.0	25.0	24.0	25.0
DO (mg/L)	8.1	7.8	8.2	7.9	7.8	7.8	8.3	7.7	8.1	7.5	8.1	7.2	8.1	7.4
pH	7.9	7.6	7.9	7.6	7.9	7.6	7.7	7.6	7.9	7.8	8.0	7.6	8.0	7.4
Cond. (µS/cm)	218	218		218		218		218		220		220		217
Initials	MLT	MLT		MLT		JW		FMM		MLT		FMM		MLT

Thermometer: 4 **DO meter:** 2 **pH meter:** 2 **Conductivity meter:** 2

	Control	100% (v/v) lab	
Hardness*	100	100	
Alkalinity*	98	98	

* mg/L as CaCO3

Analysts: FMM, AWD, MLT, JW
Reviewed by: JGL
Date reviewed: July 26/16

Sample Description: uranium spiked in lab water; clear, colourless, odourless, no particulates

Comments: **Broodboard Used:** 061616B (ct# 1,2,6,7,8,9,10)

Chronic Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client: Lorax Environmental Services Ltd
Sample ID: Uranium in lab water
Work Order #: 16703
Start Date & Time: June 28/16 @ 1000h
Stop Date & Time: July 5/16 @ 1125h
Test Species: *Ceriodaphnia dubia*

Concentration 80 (~~75~~) µg/L U	Day 0 init.	Day 1 old	Day 1 new	Day 2 old	Day 2 new	Day 3 old	Day 3 new	Day 4 old	Day 4 new	Day 5 old	Day 5 new	Day 6 old	Day 6 new	Day 7 final
Temperature (°C)	24.0	25.0	24.0	25.0	25.0	25.0	24.0	25.0	24.0	25.0	25.0	25.0	24.0	25.0
DO (mg/L)	8.1	7.7	8.2	7.8	7.7	7.7	8.3	7.6	8.1	7.5	8.1	7.2	8.1	7.4
pH	7.9	7.5	7.8	7.6	7.9	7.5	7.7	7.5	7.9	7.6	8.0	7.4	8.0	7.4
Cond. (µS/cm)	218	218		218		219		219		220		220		~~218~~ MLT 216
Initials	MLT	MLT		MLT		JW		EMM		MLT		EMM		MLT

Concentration 160 (~~150~~) µg/L U	Day 0 init.	Day 1 old	Day 1 new	Day 2 old	Day 2 new	Day 3 old	Day 3 new	Day 4 old	Day 4 new	Day 5 old	Day 5 new	Day 6 old	Day 6 new	Day 7 final
Temperature (°C)	24.0	25.0	24.0	25.0	25.0	25.0	24.0	25.0	24.0	25.0	25.0	25.0	24.0	25.0
DO (mg/L)	8.1	7.7	8.1	7.9	~~7.8~~ 8.0	7.7	8.3	7.6	8.1	7.6	8.1	7.2	8.1	7.6
pH	5.8	6.7	5.8	6.6	6.0	7.2	5.8	7.0	6.0	6.7	6.1	7.1	6.1	6.9
Cond. (µS/cm)	190	190		190		190		190		190		190		189
Initials	MLT	MLT		MLT		JW		EMM		MLT		EMM		MLT

Concentration 320 (~~300~~) µg/L U	Day 0 init.	Day 1 old	Day 1 new	Day 2 old	Day 2 new	Day 3 old	Day 3 new	Day 4 old	Day 4 new	Day 5 old	Day 5 new	Day 6 old	Day 6 new	Day 7 final
Temperature (°C)	24.0	25.0	24.0	25.0	25.0	25.0	24.0	25.0	24.0	25.0	25.0	25.0	24.0	25.0
DO (mg/L)	8.1	7.7	8.1	7.8	7.8	7.7	8.3	7.6	8.1	7.6	8.1	7.2	8.1	7.6
pH	5.9	6.8	5.8	7.0	6.2	7.1	5.9	7.6	6.0	6.7	6.1	7.1	6.1	7.0
Cond. (µS/cm)	192	191		192		192		191		192		192		191
Initials	MLT	MLT		MLT		JW		EMM		MLT		EMM		MLT

Concentration ~~Lab~~ ~~control~~ MLT	Day 0 init.	Day 1 old	Day 1 new	Day 2 old	Day 2 new	Day 3 old	Day 3 new	Day 4 old	Day 4 new	Day 5 old	Day 5 new	Day 6 old	Day 6 new	Day 7 final
Temperature (°C)														
DO (mg/L)														
pH														
Cond. (µS/cm)														
Initials														

Thermometer: 4 **DO meter:** 2 **pH meter:** 2 **Conductivity meter:** 2

	Control	Lab 100% (W)		
Hardness*	100	100		
Alkalinity*	98	98		

* mg/L as CaCO3

Analysts: EMM, ALW, MLT, JW
Reviewed by: JGL
Date reviewed: July 26/16

Sample Description: Uranium spiked in lab water; clear, colourless, no particulates, odourless

Comments: **Broodboard Used:** 061616B (H# 1,2,6,7,8,9,10)

Chronic Freshwater Toxicity Test
C. dubia Reproduction Data

Client: Lorax Environmental Services Ltd.
Sample ID: Uranium in lab water
Work Order: 16703

Start Date & Time: June 28/16 @ 1000h
Stop Date & Time: ~~June~~ MT July 5/16 @ 1125h
Set up by: EMM

(µg/L) Uranium

Concentration: lab control

Days	A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MT
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	KL
3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	YML
4	✓	✓	4	4	✓	4	3	X	✓	3	MM
5	4	4	6	✓	6	✓	3	|	3	6	MT
6	6	11	✓	6	14	7	✓	|	✓	12	MT
7	13	12	10	13	14	11	12	|	10	✓	MT
8											
Total	23	27	20	23	34	22	18	0X	13	21	MT

Concentration: 10 ~~9~~ MT

Days	A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MT
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	KL
3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	YML
4	4	✓	3	✓	3	✓	3	2	3	3	MM
5	✓	5	8	4	7	4	8	8	9	8	MT
6	9	12	✓	11	✓	11	✓	✓	✓	✓	MT
7	12	15	14	12	13	12	13	11	11	10	MT
8											
Total	25	32	25	27	23	27	24	19	23	21	MT

Concentration: 20 ~~19~~ MT

Days	A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MT
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	KL
3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	YML
4	3	3	4	3	2	✓	3	3	2	2	MM
5	7	9	7	7	8	5	9	8	9	6	MT
6	13	16	14	✓	✓	10	10	✓	✓	14	MT
7	✓	✓	✓	11	12	10	✓	10	10	✓	MT
8											
Total	23	28	25	21	22	25	22	21	21	22	MT

Concentration: MT ~~37.5~~ 40

Days	A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MT
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	KL
3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	YML
4	3	3	✓	3	2	2	3	✓	4	3	MM
5	✓	6	4	9	9	8	7	5	10	9	MT
6	10	✓	10	12	✓	✓	✓	11	✓	✓	MT
7	14	10	14	✓	12	12	14	✓	10	10	MT
8											
Total	27	19	28	24	23	22	24	16	24	22	MT

Concentration: MT ~~75~~ 80

Days	A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MT
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	KL
3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	YML
4	3	4	3	✓	3	2	2	2	3	2	MM
5	7	✓	7	4	10	5	9	8	8	7	MT
6	13	11	✓	12	14	12	✓	✓	✓	12	MT
7	✓	13	6	12	✓	✓	13	14	11	✓	MT
8											
Total	23	28	16	28	27	19	24	24	22	21	MT

Concentration: MT ~~150~~ 160

Days	A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MT
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	KL
3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	YML
4	3	✓	X	✓	X	X	✓	3	2	2	MM
5	5	✓	|	X	|	|	3	6	6	7	MT
6	✓	4	|	|	|	|	6	✓	✓	✓	MT
7	2	✓	|	|	|	|	9	7	4	8	MT
8											
Total	10	4	0X	0X	0X	0X	18	16	12	17	MT

Concentration: MT ~~300~~ 320

Days	A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MT
2	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	KL
3	✓	✓	✓	|	✓	✓	✓	X	✓	✓	YML
4	2	X	✓	|	✓	3	✓	|	2	2	MM
5	✓	|	3	|	4	4	2	|	3	4	MT
6	2	|	5	|	6	6	✓	|	✓	8	MT
7	X	|	✓	|	8	✓	5	|	2	✓	MT
8	|	|		|				|			
Total	4X	0X	8	0X	18	13	7	0X	7	14	MT

Concentration:

Days	A	B	C	D	E	F	G	H	I	J	Init
1											
2											
3											
4											
5											
6											
7											
8											
Total											

Concentration:

Days	A	B	C	D	E	F	G	H	I	J	Init
1											
2											
3											
4											
5											
6											
7											
8											
Total											

Notes: X = mortality.

Sample Description: Uranium spiked into lab water
Comments: Total # Young only based on the first 3 Broods. Fourth and subsequent broods not included in total count.

Reviewed by: [signature]
Date reviewed: July 26/16

Version 2.1 Issued July 29, 2009

Nautilus Environmental

CETIS Analytical Report

Report Date: 27 Jul-16 11:37 (p 1 of 4)
Test Code: 16703a | 11-0872-9963

Ceriodaphnia 7-d Survival and Reproduction Test — **Nautilus Environmental**

Analysis ID:	16-0646-1932	**Endpoint:**	7d Survival Rate	**CETIS Version:**	CETISv1.8.7
Analyzed:	08 Jul-16 16:05	**Analysis:**	Linear Interpolation (ICPIN)	**Official Results:**	Yes

Batch ID:	05-2343-1164	**Test Type:**	Reproduction-Survival (7d)	**Analyst:**	Krysta Pearcy
Start Date:	28 Jun-16 10:00	**Protocol:**	EC/EPS 1/RM/21	**Diluent:**	20% Perrier Water
Ending Date:	05 Jul-16 11:25	**Species:**	Ceriodaphnia dubia	**Brine:**	
Duration:	7d 1h	**Source:**	In-House Culture	**Age:**	<24h

Sample ID:	07-4311-8196	**Code:**	2C4B1574	**Client:**	Lorax Environmental
Sample Date:	27 Jun-16 n/a	**Material:**	Uranium	**Project:**	
Receive Date:	27 Jun-16 14:15	**Source:**	Lab Water (20% Perrier)		
Sample Age:	34h (11.5 °C)	**Station:**	Lab Water (20% Perrier)		

Linear Interpolation Options

X Transform	Y Transform	Seed	Resamples	Exp 95% CL	Method
Log(X+1)	Linear	285816	200	Yes	Two-Point Interpolation

Point Estimates

Level	µg/L	95% LCL	95% UCL
EC5	87.26	84.54	98.56
EC10	95.65	89.78	122
EC15	104.8	95.35	150.9
EC20	114.9	101.3	241.4
EC25	125.9	107.5	N/A
EC40	>322	N/A	N/A
EC50	>322	N/A	N/A

7d Survival Rate Summary

			Calculated Variate(A/B)								
C-µg/L	Control Type	Count	Mean	Min	Max	Std Err	Std Dev	CV%	%Effect	A	B
0.7	Negative Control	10	0.9	0	1	0.1	0.3162	35.14%	0.0%	9	10
11.1		10	1	1	1	0	0	0.0%	-11.11%	10	10
21		10	1	1	1	0	0	0.0%	-11.11%	10	10
41.7		10	1	1	1	0	0	0.0%	-11.11%	10	10
79.6		10	1	1	1	0	0	0.0%	-11.11%	10	10
162		10	0.6	0	1	0.1633	0.5164	86.07%	33.33%	6	10
322		10	0.6	0	1	0.1633	0.5164	86.07%	33.33%	6	10

7d Survival Rate Detail

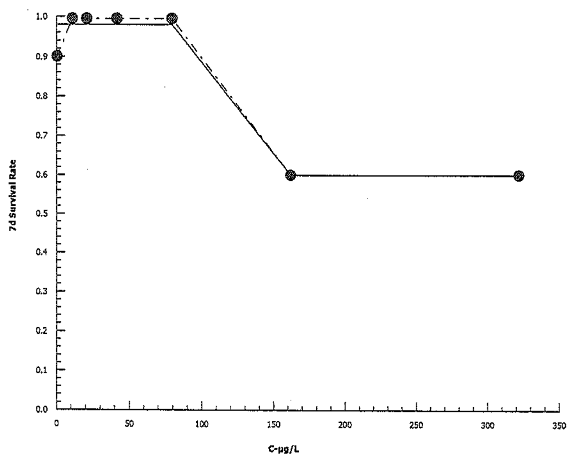
C-µg/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0.7	Negative Control	1	1	1	1	1	1	1	0	1	1
11.1		1	1	1	1	1	1	1	1	1	1
21		1	1	1	1	1	1	1	1	1	1
41.7		1	1	1	1	1	1	1	1	1	1
79.6		1	1	1	1	1	1	1	1	1	1
162		1	1	0	0	0	0	1	1	1	1
322		0	0	1	0	1	1	1	0	1	1

7d Survival Rate Binomials

C-µg/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0.7	Negative Control	1/1	1/1	1/1	1/1	1/1	1/1	1/1	0/1	1/1	1/1
11.1		1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
21		1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
41.7		1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
79.6		1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
162		1/1	1/1	0/1	0/1	0/1	0/1	1/1	1/1	1/1	1/1
322		0/1	0/1	1/1	0/1	1/1	1/1	1/1	0/1	1/1	1/1

Analysis ID:	16-0646-1932	**Endpoint:**	7d Survival Rate	**CETIS Version:**	CETISv1.8.7
Analyzed:	08 Jul-16 16:05	**Analysis:**	Linear Interpolation (ICPIN)	**Official Results:**	Yes

Graphics



Ceriodaphnia 7-d Survival and Reproduction Test — **Nautilus Environmental**

Analysis ID:	20-1017-0021	**Endpoint:**	Reproduction	**CETIS Version:**	CETISv1.8.7
Analyzed:	08 Jul-16 16:06	**Analysis:**	Linear Interpolation (ICPIN)	**Official Results:**	Yes

Batch ID:	05-2343-1164	**Test Type:**	Reproduction-Survival (7d)	**Analyst:**	Krysta Pearcy
Start Date:	28 Jun-16 10:00	**Protocol:**	EC/EPS 1/RM/21	**Diluent:**	20% Perrier Water
Ending Date:	05 Jul-16 11:25	**Species:**	Ceriodaphnia dubia	**Brine:**	
Duration:	7d 1h	**Source:**	In-House Culture	**Age:**	<24h

Sample ID:	07-4311-8196	**Code:**	2C4B1574	**Client:**	Lorax Environmental
Sample Date:	27 Jun-16 n/a	**Material:**	Uranium	**Project:**	
Receive Date:	27 Jun-16 14:15	**Source:**	Lab Water (20% Perrier)		
Sample Age:	34h (11.5 °C)	**Station:**	Lab Water (20% Perrier)		

Linear Interpolation Options

X Transform	Y Transform	Seed	Resamples	Exp 95% CL	Method
Log(X+1)	Linear	393173	200	Yes	Two-Point Interpolation

Point Estimates

Level	µg/L	95% LCL	95% UCL
IC5	84	16.71	85.7
IC10	88.64	54.05	92.27
IC15	93.54	81.3	99.33
IC20	98.7	87.91	107.4
IC25	104.1	93.54	115.7
IC40	122.3	109.4	147.1
IC50	136.2	122.3	181.8

Reproduction Summary

			Calculated Variate						
C-µg/L	Control Type	Count	Mean	Min	Max	Std Err	Std Dev	CV%	%Effect
0.7	Negative Control	10	20.1	0	34	2.83	8.95	44.53%	0.0%
11.1		10	24.8	21	32	1.041	3.293	13.28%	-23.38%
21		10	23	21	28	0.7303	2.309	10.04%	-14.43%
41.7		10	22.9	16	28	1.11	3.51	15.33%	-13.93%
79.6		10	23.2	16	28	1.236	3.91	16.85%	-15.42%
162		10	7.7	0	18	2.441	7.718	100.2%	61.69%
322		10	7.1	0	18	2.008	6.35	89.44%	64.68%

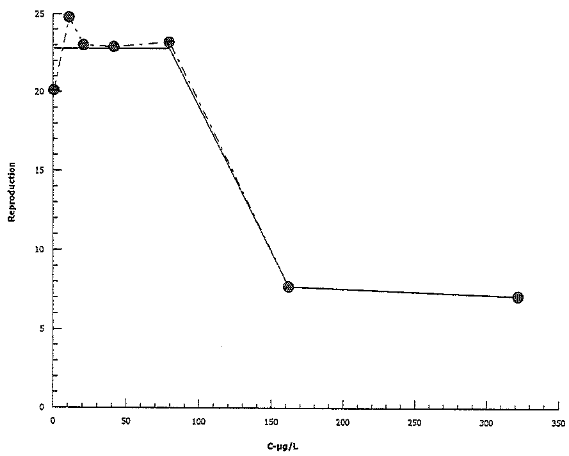
Reproduction Detail

C-µg/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0.7	Negative Control	23	27	20	23	34	22	18	0	13	21
11.1		25	32	25	27	23	27	24	21	23	21
21		23	28	25	21	22	25	22	21	21	22
41.7		27	19	28	24	23	22	24	16	24	22
79.6		23	28	16	28	27	19	24	24	22	21
162		10	4	0	0	0	0	18	16	12	17
322		4	0	8	0	18	13	7	0	7	14

Ceriodaphnia 7-d Survival and Reproduction Test | **Nautilus Environmental**

Analysis ID:	20-1017-0021	**Endpoint:**	Reproduction	**CETIS Version:**	CETISv1.8.7
Analyzed:	08 Jul-16 16:06	**Analysis:**	Linear Interpolation (ICPIN)	**Official Results:**	Yes

Graphics



CETIS Analytical Report

Ceriodaphnia 7-d Survival and Reproduction Test — **Nautilus Environmental**

Analysis ID:	08-5168-3730	**Endpoint:**	Reproduction	**CETIS Version:**	CETISv1.8.7
Analyzed:	08 Jul-16 16:07	**Analysis:**	Linear Interpolation (ICPIN)	**Official Results:**	Yes

Batch ID:	18-6912-5017	**Test Type:**	Reproduction-Survival (7d)	**Analyst:**	Krysta Pearcy
Start Date:	28 Jun-16 10:00	**Protocol:**	EC/EPS 1/RM/21	**Diluent:**	20% Perrier Water
Ending Date:	05 Jul-16 11:25	**Species:**	Ceriodaphnia dubia	**Brine:**	
Duration:	7d 1h	**Source:**	In-House Culture	**Age:**	<24h

Sample ID:	07-4311-8196	**Code:**	2C4B1574	**Client:**	Lorax Environmental
Sample Date:	27 Jun-16 n/a	**Material:**	Uranium	**Project:**	
Receive Date:	27 Jun-16 14:15	**Source:**	Lab Water (20% Perrier)		
Sample Age:	34h (11.5 °C)	**Station:**	Lab Water (20% Perrier)		

Linear Interpolation Options

X Transform	Y Transform	Seed	Resamples	Exp 95% CL	Method
Log(X+1)	Linear	670656	200	Yes	Two-Point Interpolation

Point Estimates

Level	µg/L	95% LCL	95% UCL
IC5	84.33	1.755	85.78
IC10	89.35	3.465	92.69
IC15	94.65	6.236	100.1
IC20	100.3	10.73	108.3
IC25	106.2	28.18	117.2
IC40	126.2	92.16	166.5
IC50	141.6	113.9	227.2

Reproduction Summary

			Calculated Variate						
C-µg/L	Control Type	Count	Mean	Min	Max	Std Err	Std Dev	CV%	%Effect
0.7	Negative Control	10	20.1	0	34	2.83	8.95	44.53%	0.0%
11.1		10	20.1	0	34	2.83	8.95	44.53%	0.0%
21		10	20.1	0	34	2.83	8.95	44.53%	0.0%
41.7		10	20.1	0	34	2.83	8.95	44.53%	0.0%
79.6		10	20.1	0	34	2.83	8.95	44.53%	0.0%
162		10	7.7	0	18	2.441	7.718	100.2%	61.69%
322		10	7.1	0	18	2.008	6.35	89.44%	64.68%

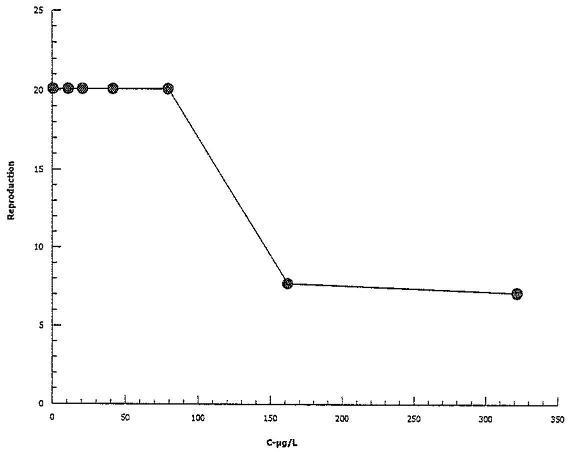
Reproduction Detail

C-µg/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0.7	Negative Control	23	27	20	23	34	22	18	0	13	21
11.1		23	27	20	23	34	22	18	0	13	21
21		23	27	20	23	34	22	18	0	13	21
41.7		23	27	20	23	34	22	18	0	13	21
79.6		23	27	20	23	34	22	18	0	13	21
162		10	4	0	0	0	0	18	16	12	17
322		4	0	8	0	18	13	7	0	7	14

Ceriodaphnia 7-d Survival and Reproduction Test | **Nautilus Environmental**

Analysis ID:	08-5168-3730	**Endpoint:**	Reproduction	**CETIS Version:**	CETISv1.8.7
Analyzed:	08 Jul-16 16:07	**Analysis:**	Linear Interpolation (ICPIN)	**Official Results:**	Yes

Graphics



Ceriodaphnia dubia Summary Sheet

Client: Lorax Environmental
Work Order No.: 16703

Start Date/Time: June 28 /16 @ 1000h
Set up by: EMM

Sample Information:

Sample ID: CC 1.5
Sample Date: JW ~~July~~ June 25/16
Date Received: June 27 /16
Sample Volume: 7 x 2L

Test Validity Criteria:
1) Mean survival of first generation controls is ≥80 %
2) At least 60% of controls have produced three broods within 8 days
3) An average of ≥15 live young produced per surviving female in the control solutions during the first three broods.
4) Invalid if ephippia observed in any control solution at any time.

WQ Ranges:
T (°C) = 25 ± 1; DO (mg/L) = 3.3 to 8.4 ; pH = 6.0 to 8.5

Test Organism Information:

Broodstock No.: 061616
Age of young (Day 0): <24-h (within 12-h)
Avg No. young in first 3 broods of previous 7 d: 33
Mortality (%) in previous 7 d: 0
Individual female # used ≥8 young on test day: 1 - 12

NaCl Reference Toxicant Results:

Reference Toxicant ID: Cd 146
Stock Solution ID: 16 Na 01
Date Initiated: June 29 /16

7-d LC50 (95% CL): 2.1 (1.5 - 3.0) g/L NaCL
7-d IC50 (95% CL): 1.6 (1.4 - 1.7) g/L NaCL

7-d LC50 Reference Toxicant Mean and Historical Range: 2.0 (1.8 - 2.2) g/L NaCL CV (%): 5
7-d IC50 Reference Toxicant Mean and Historical Range: 1.6 (1.2 - 2.0) g/L NaCL CV (%): 13

Test Results:

µg/L U	Survival	Reproduction
LC50 ~~%~~ (v/v) (95% CL)	> 331	
IC25 ~~%~~ (v/v) (95% CL)		> 331
IC50 ~~%~~ (v/v) (95% CL)		> 331

JW

Signature REDACTED

Reviewed by: ______

Date reviewed: July 27/16

Jan 26, 2011; Ver. 2.0

Nautilus Environmental

Chronic Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client: Lorax Environmental Services Ltd
Sample ID: Uranium in Stream CC1.5 ①
Work Order #: 16703

Start Date & Time: June 28/16 @ 1000h
Stop Date & Time: July 4/16 @ 1530
Test Species: *Ceriodaphnia dubia*

① "CC1.5 - 0, 10, 20, 40, 80, 160, 320" on Col"

Concentration: 0 mg/L U Site control	Day 0 init.	Day 1 old	Day 1 new	Day 2 old	Day 2 new	Day 3 old	Day 3 new	Day 4 old	Day 4 new	Day 5 old	Day 5 new	Day 6 old	Day 6 new	Day 7 final
Temperature (°C)	24.0	25.0	24.0	25.0	25.0	25.0	24.0	25.0	24.0	25.0	25.0	24.5		
DO (mg/L)	8.1	7.7	8.1	7.7	8.2	7.7	8.3	7.6	8.1	7.6	8.0	7.2		
pH	7.5	7.5	7.4	7.4	7.5	7.4	7.5	7.4	7.4	7.5	7.6	7.5		
Cond. (µS/cm)	296	292		294		294		294		297		298		
Initials	MLT	MLT		MLT		JW		EMM		MLT		EMM		

Concentration: 10 µg/L U	Day 0 init.	Day 1 old	Day 1 new	Day 2 old	Day 2 new	Day 3 old	Day 3 new	Day 4 old	Day 4 new	Day 5 old	Day 5 new	Day 6 old	Day 6 new	Day 7 final
Temperature (°C)	24.0	25.0	24.0	25.0	25.0	25.0	24.0	25.0	24.0	25.0	25.0	24.5		
DO (mg/L)	8.1	7.7	8.1	7.6	8.1	7.7	8.3	7.6	8.1	7.6	8.0	7.0		
pH	7.5	7.5	7.4	7.3	7.5	7.4	7.4	7.4	7.4	7.5	7.6	7.4		
Cond. (µS/cm)	299	293		298		296		294		298		298		
Initials	MLT	MLT		MLT		JW		EMM		MLT		EMM		

Concentration: 20 µg/L U	Day 0 init.	Day 1 old	Day 1 new	Day 2 old	Day 2 new	Day 3 old	Day 3 new	Day 4 old	Day 4 new	Day 5 old	Day 5 new	Day 6 old	Day 6 new	Day 7 final
Temperature (°C)	24.0	25.0	24.0	25.0	25.0	25.0	24.0	25.0	24.0	25.0	25.0	24.5		
DO (mg/L)	8.1	7.7	8.1	7.6	8.1	7.8	8.3	7.6	8.1	7.5	8.0	7.0		
pH	7.5	7.5	7.4	7.3	7.4	7.4	7.4	7.4	7.4	7.5	7.6	7.4		
Cond. (µS/cm)	300	298		298		297		298		298		300		
Initials	MLT	MLT		MLT		JW		EMM		MLT		EMM		

Concentration: 40 (~~37.5~~) µg/L U	Day 0 init.	Day 1 old	Day 1 new	Day 2 old	Day 2 new	Day 3 old	Day 3 new	Day 4 old	Day 4 new	Day 5 old	Day 5 new	Day 6 old	Day 6 new	Day 7 final
Temperature (°C)	24.0	25.0	24.0	25.0	25.0	25.0	24.0	25.0	24.0	25.0	25.0	24.5		
DO (mg/L)	8.1	7.7	8.1	7.6	8.1	7.7	8.3	7.7	8.1	7.5	8.0	7.0		
pH	7.5	7.5	7.4	7.3	7.4	7.4	7.4	7.4	7.4	7.4	7.6	7.4		
Cond. (µS/cm)	300	298		298		297		298		298		300		
Initials	MLT	MLT		MLT		JW		EMM		MLT		EMM		

Thermometer: 4 DO meter: 2 pH meter: 2 Conductivity meter: 2

	Control	100% (N) CC1.5	
Hardness*	100	138	
Alkalinity*	98	70	

* mg/L as CaCO3

Analysts: EMM, MLT, AWD, JW, VVL
Reviewed by: [initials]
Date reviewed: July 26/16

Sample Description: Uranium spiked in stream water; clear, colourless, odourless, no particulates

Comments: **Broodboard Used:** 061616 (1-12)

Chronic Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client: Lorax Environmental Services Ltd
Sample ID: Uranium in Stream CC1.5
Work Order #: 16703

Start Date & Time: June 28/16 @ 1000h
Stop Date & Time: July 4/16 @ 1530h
Test Species: *Ceriodaphnia dubia*

Concentration 80 (~~75~~) µg/L U	0	1		2		3		4		5		6		7
	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)	24.0	25.0	24.0	25.0	25.0	25.0	24.0	25.0	24.0	25.0	25.0	24.5		
DO (mg/L)	8.1	7.7	8.1	7.6	8.2	7.7	8.3	7.6	8.1	7.6	8.0	7.1		
pH	7.4	7.4	7.3	7.1	7.4	7.5	7.3	7.5	7.3	7.4	7.5	7.5		
Cond. (µS/cm)	300	301		299		299		298		300		301		
Initials	MLT	MLT		MLT		JW		EMM		MLT		EMM		

Concentration 160 (~~150~~) µg/L U	0	1		2		3		4		5		6		7
	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)	24.0	25.0	24.0	25.0	25.0	25.0	24.0	25.0	24.0	25.0	25.0	24.5		
DO (mg/L)	8.1	7.7	8.1	7.6	8.1	7.6	8.3	7.6	8.1	7.6	8.0	7.1		
pH	7.2	7.4	7.1	7.2	7.2	7.5	7.2	7.5	7.2	7.4	7.3	7.4		
Cond. (µS/cm)	302	301		301		300		301		301		302		
Initials	MLT	MLT		MLT		JW		EMM		MLT		EMM		

Concentration 320 (~~300~~) µg/L U	0	1		2		3		4		5		6		7
	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)	24.0	25.0	24.0	25.0	25.0	25.0	24.0	25.0	24.0	25.0	25.0	24.5		
DO (mg/L)	8.1	7.7	8.2	7.6	8.0	7.7	8.2	7.6	8.1	7.6	8.0	7.2		
pH	6.9	7.4	6.9	7.2	6.9	7.4	7.0	7.4	7.0	7.4	7.2	7.4		
Cond. (µS/cm)	304	304		304		302		304		304		308		
Initials	MLT	MLT		MLT		JW		EMM		MLT		EMM		

Concentration Lab Control	0	1		2		3		4		5		6		7
	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)	24.0	25.0	24.0	25.0	25.0	25.0	24.0	25.0	24.0	25.0	24.0	24.5		
DO (mg/L)	8.1	7.7	8.1	7.7	8.0	7.6	8.3	7.6	8.1	7.6	8.0	7.2		
pH	8.0	7.6	7.9	7.7	7.9	7.4	7.6	7.4	8.0	7.8	8.0	7.5		
Cond. (µS/cm)	214	216		217		214		216		221		222		
Initials	MLT	MLT		MLT		JW		EMM		MLT		EMM		

Thermometer: 4 **DO meter:** 2 **pH meter:** 2 **Conductivity meter:** 2

	Control	100% (v/v) CC1.5	
Hardness*	100	138	
Alkalinity*	98	70	

* mg/L as CaCO3

Analysts: EMM, MLT, AWD, JW, MK
Reviewed by: JGN
Date reviewed: July 27/16

Sample Description: Uranium spiked in Stream water; clear, colourless, odourless, no particulates

Comments: **Broodboard Used:** 061616 (1→12)

Chronic Freshwater Toxicity Test
C. dubia Reproduction Data

Client: Lorax Environmental Services Ltd.
Sample ID: uranium in stream CCL5
Work Order: 16703

(µg/L) uranium

Start Date & Time: June 28 /16 @ 1000h
Stop Date & Time: July 4/16 @ 1530h
Set up by: EMM

Days	Concentration: site control (1) A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MD
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MD
3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	KJL
4	2	3	X	3	3	3	2	2	2	2	EMM
5	✓	✓		7	✓	✓	✓	4	✓	X	YWL
6	10	6		✓	9	9	✓	4	6		EMM
7											
8											
Total	12	9	0X	10	12	12	2	10	8	0X	EMM

Days	Concentration: 10 MD A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MD
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MD
3	4	✓	✓	✓	3	✓	✓	✓	X	✓	KJL
4	✓	3	2	✓	✓	X	X	3		4	EMM
5	7	5	✓	✓	9			9		8	YWL
6	6	7	9	✓	10			10		8	EMM
7											
8											
Total	17	15	11	0	22	0X	0X	22	0X	20	EMM

Days	Concentration: 20 MD A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MD
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MD
3	✓	✓	✓	3	✓	✓	✓	✓	✓	4	YJC
4	4	3	3	✓	3	3	4	2	3	✓	EMM
5	9	7	8	9	8	7	4	10	9	9	YWC
6	✓	11	✓	10	10	12	8	✓	✓	10	EMM
7											
8											
Total	13	21	11	22	21	22	16	12	12	23	EMM

Days	Concentration: MD ~~37.5~~ 40 A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MD
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MD
3	✓	4	✓	4	✓	4	✓	✓	✓	4	JW
4	4	✓	3	✓	3	✓	5	3	3	✓	EMM
5	6	8	9	8	7	9	9	7	6	8	YWL
6	8	10	13	9	✓	12	10	8	11	13	EMM
7											
8											
Total	18	22	25	21	10	25	24	18	20	25	EMM

Days	Concentration: MD ~~75~~ 80 A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MD
2	✓	✓	✓	✓	X	✓	✓	✓	✓	✓	MD
3	✓	✓	4	✓		✓	✓	✓	4	4	JW
4	4	3	✓	3		3	2	3	✓	✓	EMM
5	9	10	8	8		9	5	6	9	9	YWL
6	✓	12	11	3		10	✓	✓	13	13	EMM
7											
8											
Total	13	25	23	14	0X	22	7	9	26	26	EMM

Days	Concentration: MD ~~150~~ 160 A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MD
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MD
3	✓	✓	✓	4	✓	2	4	✓	✓	4	JW
4	3	3	4	✓	3	✓	✓	2	3	✓	EMM
5	5	6	7	10	7	8	10	10	9	10	MD
6	14	13	12	12	6	10	9	✓	8	10	EMM
7											
8											
Total	22	22	23	26	16	20	23	12	20	24	EMM

Days	Concentration: MD ~~300~~ 320 A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MD
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MD
3	✓	✓	✓	3	4	✓	✓	✓	4	✓	JW
4	4	3	3	✓	✓	2	2	3	✓	3	EMM
5	9	7	8	10	6	4	10	9	8	10	MD
6	13	12	✓	10	10	9	✓	9	12	11	EMM
7											
8											
Total	26	22	11	23	20	15	12	21	24	24	EMM

Days	Concentration: Lab control A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MD
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MD
3	2	4	2	3	2	✓	4	✓	2	✓	KJL
4	✓	✓	✓	✓	✓	4	✓	3	✓	3	EMM
5	10	8	9	10	8	8	10	✓	7	9	YWL
6	10	✓	13	14	12	12	14	9	12	11	EMM
7											
8											
Total	22	12	24	27	22	24	28	12	21	23	EMM

Days	Concentration: A	B	C	D	E	F	G	H	I	J	Init
1											
2											
3											
4											
5											
6											
7											
8											
Total											

Notes: X = mortality.

Sample Description: uranium spiked into CCL5 water ; (1) Site water control did not meet passing criteria
Comments: Total # Young only based on the first 3 Broods. Fourth and subsequent broods not included in total count.

Reviewed by: JGh
Date reviewed: July 26/16

Version 2.1 Issued July 29, 2009

CETIS Analytical Report

Report Date: 08 Jul-16 16:03 (p 1 of 2)
Test Code: 16703b | 13-5043-2357

Ceriodaphnia 7-d Survival and Reproduction Test — **Nautilus Environmental**

Analysis ID:	11-7679-0636	**Endpoint:**	6d Survival Rate	**CETIS Version:**	CETISv1.8.7
Analyzed:	08 Jul-16 16:02	**Analysis:**	Linear Interpolation (ICPIN)	**Official Results:**	Yes

Batch ID:	21-3838-6892	**Test Type:**	Reproduction-Survival (7d)	**Analyst:**	Krysta Pearcy
Start Date:	28 Jun-16 10:00	**Protocol:**	EC/EPS 1/RM/21	**Diluent:**	Stream water (CC1.5)
Ending Date:	04 Jul-16 15:30	**Species:**	Ceriodaphnia dubia	**Brine:**	
Duration:	6d 6h	**Source:**	In-House Culture	**Age:**	<24h

Sample ID:	04-9047-0523	**Code:**	1D3BFC7B	**Client:**	Lorax Environmental
Sample Date:	25 Jun-16 08:00	**Material:**	Uranium	**Project:**	
Receive Date:	27 Jul-16 14:15	**Source:**	CC1.5		
Sample Age:	74h (11.5 °C)	**Station:**	CC1.5		

Linear Interpolation Options

X Transform	Y Transform	Seed	Resamples	Exp 95% CL	Method
Log(X+1)	Linear	1021649	200	Yes	Two-Point Interpolation

Point Estimates

Level	ug/L	95% LCL	95% UCL
EC5	>331	N/A	N/A
EC10	>331	N/A	N/A
EC15	>331	N/A	N/A
EC20	>331	N/A	N/A
EC25	>331	N/A	N/A
EC40	>331	N/A	N/A
EC50	>331	N/A	N/A

6d Survival Rate Summary

			Calculated Variate(A/B)								
C-ug/L	Control Type	Count	Mean	Min	Max	Std Err	Std Dev	CV%	%Effect	A	B
7.4	(1) Negative Control	10	0.8	0	1	0.1333	0.4216	52.7%	0.0%	8	10
17.5		10	0.7	0	1	0.1528	0.483	69.01%	12.5%	7	10
28.1		10	1	1	1	0	0	0.0%	-25.0%	10	10
48.8		10	1	1	1	0	0	0.0%	-25.0%	10	10
88.4		10	0.9	0	1	0.1	0.3162	35.14%	-12.5%	9	10
171		10	1	1	1	0	0	0.0%	-25.0%	10	10
331		10	1	1	1	0	0	0.0%	-25.0%	10	10

6d Survival Rate Detail

C-ug/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
7.4 ✓	(1) Negative Control	1	1	0	1	1	1	1	1	1	0
17.5 ✓		1	1	1	1	1	0	0	1	0	1
28.1 ✓		1	1	1	1	1	1	1	1	1	1
48.8 ✓		1	1	1	1	1	1	1	1	1	1
88.4 ✓		1	1	1	1	0	1	1	1	1	1
171 ✓		1	1	1	1	1	1	1	1	1	1
331 ✓		1	1	1	1	1	1	1	1	1	1

6d Survival Rate Binomials

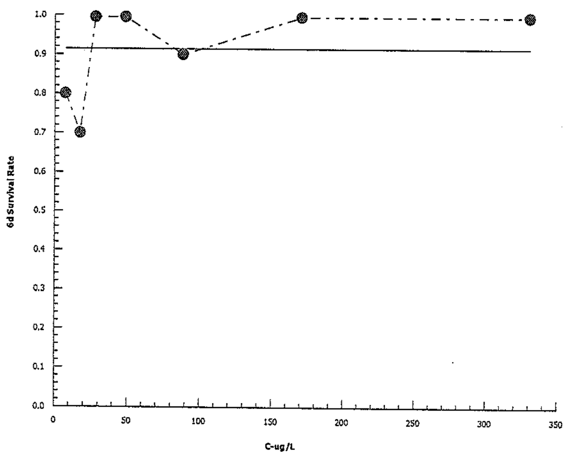
C-ug/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
7.4	(1) Negative Control	1/1	1/1	0/1	1/1	1/1	1/1	1/1	1/1	1/1	0/1
17.5		1/1	1/1	1/1	1/1	1/1	0/1	0/1	1/1	0/1	1/1
28.1		1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
48.8		1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
88.4		1/1	1/1	1/1	1/1	0/1	1/1	1/1	1/1	1/1	1/1
171		1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
331		1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1

(1) negative = site water CC1.5 control control

Ceriodaphnia 7-d Survival and Reproduction Test — **Nautilus Environmental**

Analysis ID:	11-7679-0636	**Endpoint:**	6d Survival Rate	**CETIS Version:**	CETISv1.8.7
Analyzed:	08 Jul-16 16:02	**Analysis:**	Linear Interpolation (ICPIN)	**Official Results:**	Yes

Graphics



CETIS Analytical Report

Report Date:	08 Jul-16 16:03 (p 1 of 1)
Test Code:	16703b | 13-5043-2357

Ceriodaphnia 7-d Survival and Reproduction Test — **Nautilus Environmental**

Analysis ID:	02-5487-0727	**Endpoint:**	6d Survival Rate	**CETIS Version:**	CETISv1.8.7
Analyzed:	08 Jul-16 16:02	**Analysis:**	Single 2x2 Contingency Table	**Official Results:**	Yes
Batch ID:	21-3838-6892	**Test Type:**	Reproduction-Survival (7d)	**Analyst:**	Krysta Pearcy
Start Date:	28 Jun-16 10:00	**Protocol:**	EC/EPS 1/RM/21	**Diluent:**	Stream water (CC1.5)
Ending Date:	04 Jul-16 15:30	**Species:**	Ceriodaphnia dubia	**Brine:**	
Duration:	6d 6h	**Source:**	In-House Culture	**Age:**	<24h
Sample ID:	04-9047-0523	**Code:**	1D3BFC7B	**Client:**	Lorax Environmental
Sample Date:	25 Jun-16 08:00	**Material:**	Uranium	**Project:**	
Receive Date:	27 Jul-16 14:15	**Source:**	CC1.5		
Sample Age:	74h (11.5 °C)	**Station:**	CC1.5		

Data Transform	Zeta	Alt Hyp	Trials	Seed	Test Result
Untransformed		C > T	NA	NA	Passes 6d survival rate

Fisher Exact Test

Sample	vs	Sample	Test Stat	P-Value	P-Type	Decision(α:5%)
0.7		7.4	0.2368	0.2368	Exact	Non-Significant Effect

Data Summary

C-ug/L	Control Type	NR	R	NR + R	Prop NR	Prop R	%Effect
0.7	Lab Water	10	0	10	1	0	0.0%
7.4	Negative Contr	8	2	10	0.8	0.2	20.0%

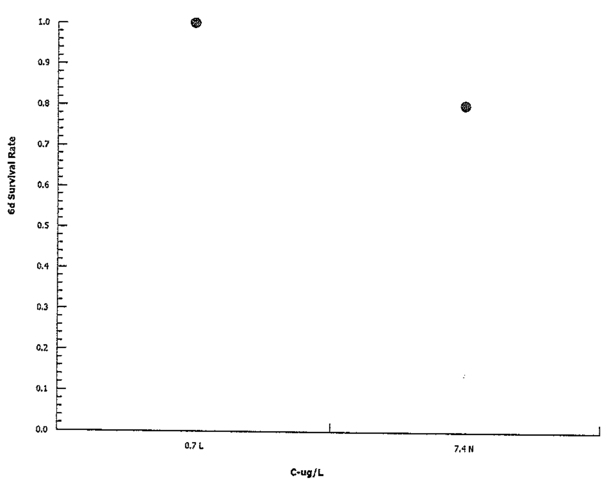
6d Survival Rate Detail

C-ug/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0.7	Lab Water	1	1	1	1	1	1	1	1	1	1
7.4	Negative Control	1	1	0	1	1	1	1	1	1	0

6d Survival Rate Binomials

C-ug/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0.7	Lab Water	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
7.4	Negative Control	1/1	1/1	0/1	1/1	1/1	1/1	1/1	1/1	1/1	0/1

Graphics



CETIS Analytical Report

Report Date: 08 Jul-16 16:03 (p 1 of 2)
Test Code: 16703b | 13-5043-2357

Ceriodaphnia 7-d Survival and Reproduction Test — **Nautilus Environmental**

Analysis ID:	17-5347-0632	**Endpoint:**	Reproduction	**CETIS Version:**	CETISv1.8.7
Analyzed:	08 Jul-16 16:02	**Analysis:**	Linear Interpolation (ICPIN)	**Official Results:**	Yes

Batch ID:	21-3838-6892	**Test Type:**	Reproduction-Survival (7d)	**Analyst:**	Krysta Pearcy
Start Date:	28 Jun-16 10:00	**Protocol:**	EC/EPS 1/RM/21	**Diluent:**	Stream water (CC1.5)
Ending Date:	04 Jul-16 15:30	**Species:**	Ceriodaphnia dubia	**Brine:**	
Duration:	6d 6h	**Source:**	In-House Culture	**Age:**	<24h

Sample ID:	04-9047-0523	**Code:**	1D3BFC7B	**Client:**	Lorax Environmental
Sample Date:	25 Jun-16 08:00	**Material:**	Uranium	**Project:**	
Receive Date:	27 Jul-16 14:15	**Source:**	CC1.5		
Sample Age:	74h (11.5 °C)	**Station:**	CC1.5		

Linear Interpolation Options

X Transform	Y Transform	Seed	Resamples	Exp 95% CL	Method
Log(X+1)	Linear	1107491	200	Yes	Two-Point Interpolation

Point Estimates

Level	ug/L	95% LCL	95% UCL
IC5	>331	N/A	N/A
IC10	>331	N/A	N/A
IC15	>331	N/A	N/A
IC20	>331	N/A	N/A
IC25	>331	N/A	N/A
IC40	>331	N/A	N/A
IC50	>331	N/A	N/A

Reproduction Summary

			Calculated Variate						
C-ug/L	Control Type	Count	Mean	Min	Max	Std Err	Std Dev	CV%	%Effect
7.4	(1) Negative Control	10	7.7	0	12	1.461	4.62	60.0%	0.0%
17.5		10	10.7	0	22	3.088	9.764	91.26%	-38.96%
28.1		10	17.3	11	23	1.564	4.945	28.59%	-124.7%
48.8		10	20.8	10	25	1.482	4.686	22.53%	-170.1%
88.4		10	16.5	0	26	2.911	9.204	55.78%	-114.3%
171		10	20.8	12	26	1.298	4.104	19.73%	-170.1%
331		10	19.8	11	26	1.672	5.287	26.7%	-157.1%

Reproduction Detail

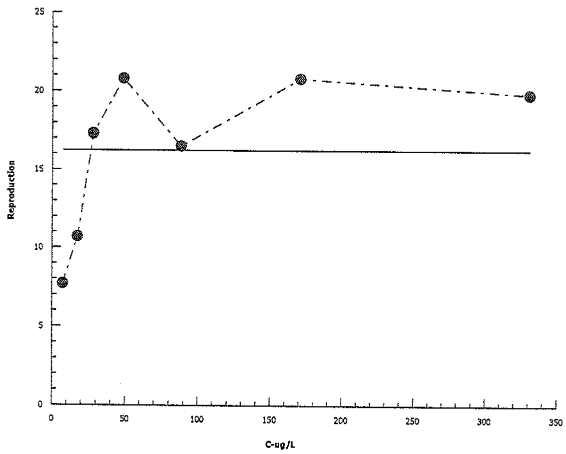
C-ug/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
7.4	(1) Negative Control	12	9	0	10	12	12	2	10	8	2
17.5		17	15	11	0	22	0	0	22	0	20
28.1		13	21	11	22	21	22	16	12	12	23
48.8		18	22	25	21	10	25	24	18	20	25
88.4		13	25	23	14	0	22	7	9	26	26
171		22	22	23	26	16	20	23	12	20	24
331		26	22	11	23	20	15	12	21	24	24

(1) negative control = site water control CC1.5

Ceriodaphnia 7-d Survival and Reproduction Test | **Nautilus Environmental**

Analysis ID:	17-5347-0632	**Endpoint:**	Reproduction	**CETIS Version:**	CETISv1.8.7
Analyzed:	08 Jul-16 16:02	**Analysis:**	Linear Interpolation (ICPIN)	**Official Results:**	Yes

Graphics



CETIS Analytical Report

Report Date:	08 Jul-16 16:03 (p 1 of 1)
Test Code:	16703b | 13-5043-2357

Ceriodaphnia 7-d Survival and Reproduction Test — **Nautilus Environmental**

Analysis ID:	05-2870-9378	**Endpoint:**	Reproduction	**CETIS Version:**	CETISv1.8.7
Analyzed:	08 Jul-16 16:02	**Analysis:**	Parametric-Two Sample	**Official Results:**	Yes
Batch ID:	21-3838-6892	**Test Type:**	Reproduction-Survival (7d)	**Analyst:**	Krysta Pearcy
Start Date:	28 Jun-16 10:00	**Protocol:**	EC/EPS 1/RM/21	**Diluent:**	Stream water (CC1.5)
Ending Date:	04 Jul-16 15:30	**Species:**	Ceriodaphnia dubia	**Brine:**	
Duration:	6d 6h	**Source:**	In-House Culture	**Age:**	<24h
Sample ID:	04-9047-0523	**Code:**	1D3BFC7B	**Client:**	Lorax Environmental
Sample Date:	25 Jun-16 08:00	**Material:**	Uranium	**Project:**	
Receive Date:	27 Jul-16 14:15	**Source:**	CC1.5		
Sample Age:	74h (11.5 °C)	**Station:**	CC1.5		

Data Transform	Zeta	Alt Hyp	Trials	Seed	PMSD	Test Result
Untransformed	NA	C > T	NA	NA	18.2%	Fails reproduction

Equal Variance t Two-Sample Test

Control	vs	Control	Test Stat	Critical	MSD	DF	P-Value	P-Type	Decision(α:5%)
0.7		7.4*	6.1	1.734	3.923	18	<0.0001	CDF	Significant Effect

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	952.2	952.2	1	37.21	<0.0001	Significant Effect
Error	460.6	25.58889	18			
Total	1412.8		19			

Distributional Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variances	Variance Ratio F	1.398	6.541	0.6260	Equal Variances
Distribution	Shapiro-Wilk W Normality	0.8744	0.866	0.0141	Normal Distribution

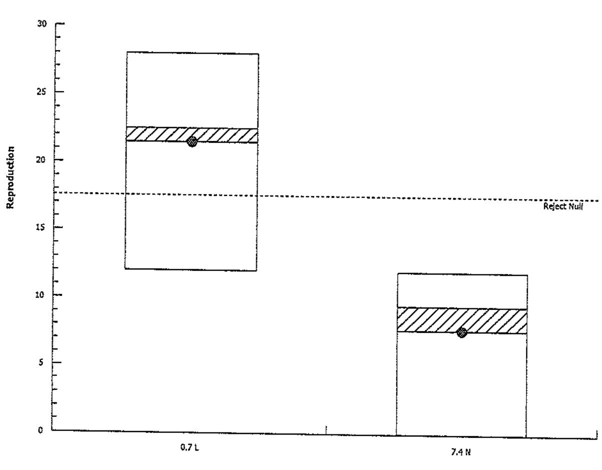
Reproduction Summary

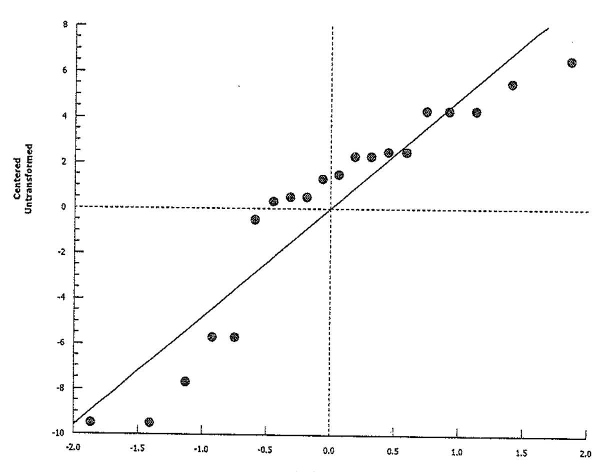
C-ug/L	Control Type	Count	Mean	95% LCL	95% UCL	Median	Min	Max	Std Err	CV%	%Effect
0.7	Lab Water	10	21.5	17.59	25.41	22.5	12	28	1.727	25.4%	0.0%
7.4	Negative Control	10	7.7	4.395	11	9.5	0	12	1.461	60.0%	64.19%

Reproduction Detail

C-ug/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0.7	Lab Water	22	12	24	27	22	24	28	12	21	23
7.4	Negative Control	12	9	0	10	12	12	2	10	8	2

Graphics





CETIS Analytical Report

Report Date:	19 Jul-16 10:07 (p 1 of 2)
Test Code:	16703b | 13-5043-2357

Ceriodaphnia 7-d Survival and Reproduction Test — **Nautilus Environmental**

Analysis ID:	05-4536-0245	**Endpoint:**	Reproduction	**CETIS Version:**	CETISv1.8.7
Analyzed:	19 Jul-16 10:07	**Analysis:**	Linear Interpolation (ICPIN)	**Official Results:**	Yes

Batch ID:	21-3838-6892	**Test Type:**	Reproduction-Survival (7d)	**Analyst:**	Krysta Pearcy
Start Date:	28 Jun-16 10:00	**Protocol:**	EC/EPS 1/RM/21	**Diluent:**	Stream water (CC1.5)
Ending Date:	04 Jul-16 15:30	**Species:**	Ceriodaphnia dubia	**Brine:**	
Duration:	6d 6h	**Source:**	In-House Culture	**Age:**	<24h

Sample ID:	04-9047-0523	**Code:**	1D3BFC7B	**Client:**	Lorax Environmental
Sample Date:	25 Jun-16 08:00	**Material:**	Uranium	**Project:**	
Receive Date:	27 Jul-16 14:15	**Source:**	CC1.5		
Sample Age:	74h (11.5 °C)	**Station:**	CC1.5		

Linear Interpolation Options

X Transform	Y Transform	Seed	Resamples	Exp 95% CL	Method
Log(X+1)	Linear	915298	200	Yes	Two-Point Interpolation

Point Estimates

Level	ug/L	95% LCL	95% UCL
IC5	2.311	1.535	N/A
IC10	5.448	2.779	N/A
IC15	11.56	4.634	N/A
IC20	>331	N/A	N/A
IC25	>331	N/A	N/A
IC40	>331	N/A	N/A
IC50	>331	N/A	N/A

Reproduction Summary

			Calculated Variate						
C-ug/L	Control Type	Count	Mean	Min	Max	Std Err	Std Dev	CV%	%Effect
0.7	Lab Water	10	21.5	12	28	1.727	5.462	25.4%	0.0%
17.5		10	10.7	0	22	3.088	9.764	91.26%	50.23%
28.1		10	17.3	11	23	1.564	4.945	28.59%	19.53%
48.8		10	20.8	10	25	1.482	4.686	22.53%	3.26%
88.4		10	16.5	0	26	2.911	9.204	55.78%	23.26%
171		10	20.8	12	26	1.298	4.104	19.73%	3.26%
331		10	19.8	11	26	1.672	5.287	26.7%	7.91%

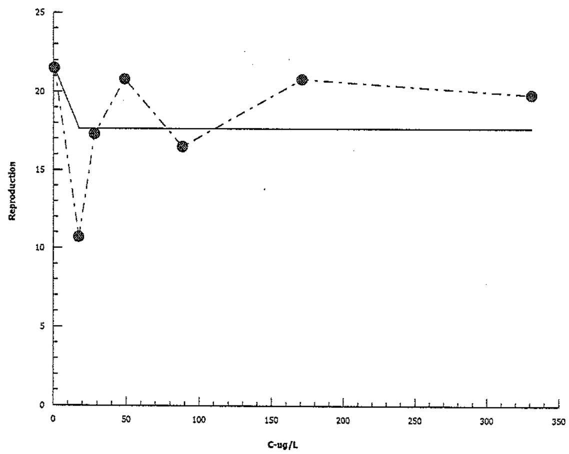
Reproduction Detail

C-ug/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0.7	Lab Water	22	12	24	27	22	24	28	12	21	23
17.5		17	15	11	0	22	0	0	22	0	20
28.1		13	21	11	22	21	22	16	12	12	23
48.8		18	22	25	21	10	25	24	18	20	25
88.4		13	25	23	14	0	22	7	9	26	26
171		22	22	23	26	16	20	23	12	20	24
331		26	22	11	23	20	15	12	21	24	24

Ceriodaphnia 7-d Survival and Reproduction Test | **Nautilus Environmental**

Analysis ID:	05-4536-0245	**Endpoint:**	Reproduction	**CETIS Version:**	CETISv1.8.7
Analyzed:	19 Jul-16 10:07	**Analysis:**	Linear Interpolation (ICPIN)	**Official Results:**	Yes

Graphics



Ceriodaphnia dubia Summary Sheet

Client:	Lorax Environmental	Start Date/Time:	June 28/16 @ 1000h
Work Order No.:	16703	Set up by:	EMM

Sample Information:

Sample ID:	HC 2.5
Sample Date:	JW ~~July~~ June 25/16
Date Received:	June 27/16
Sample Volume:	7 x 2L

Test Validity Criteria:

1) Mean survival of first generation controls is ≥80 %
2) At least 60% of controls have produced three broods within 8 days
3) An average of ≥15 live young produced per surviving female in the control solutions during the first three broods.
4) Invalid if ephippia observed in any control solution at any time.

WQ Ranges:

T (°C) = 25 ± 1; DO (mg/L) = 3.3 to 8.4 ; pH = 6.0 to 8.5

Test Organism Information:

Broodstock No.:	061616
Age of young (Day 0):	<24-h (within 12-h)
Avg No. young in first 3 broods of previous 7 d:	33
Mortality (%) in previous 7 d:	Ø
Individual female # used ≥8 young on test day	1 - 12

NaCl Reference Toxicant Results:

Reference Toxicant ID:	Cd 146
Stock Solution ID:	16 Na 01
Date Initiated:	June 29/16

7-d LC50 (95% CL):	2.1 (1.5 - 3.0) g/L NaCL
7-d IC50 (95% CL):	1.6 (1.4 - 1.7) g/L NaCL

7-d LC50 Reference Toxicant Mean and Historical Range:	2.0 (1.8 - 2.2) g/L NaCL	CV (%): 5
7-d IC50 Reference Toxicant Mean and Historical Range:	1.6 (1.2 - 2.0) g/L NaCL	CV (%): 13

Test Results:

µg/L U	Survival	Reproduction
LC50 ~~%~~ (v/v) (95% CL)	> 351	
IC25 % (v/v) (95% CL)		> 351
IC50 % (v/v) (95% CL)		> 351

JW

Reviewed by: JW Date reviewed: July 27/16

Jan 26, 2011; Ver. 2.0

Nautilus Environmental

Chronic Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client: Lorax Environmental Services Ltd
Sample ID: Uranium in Stream HC2.5 (1)
Work Order #: 16703
Start Date & Time: June 28/16 @ 1000h
Stop Date & Time: July 4/16 @ 1600h
Test Species: *Ceriodaphnia dubia*

(1) ID: "HC25-0,10,20,40,80,160,320" on CoC

Concentration: HC2.5 Site control (9 µg/L U)	Day 0	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7
	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)	24.0	25.0	24.0	24.0	24.5	25.0	24.0	25.0	24.0	25.0	25.0	25.0	24.0	24.0
DO (mg/L)	8.2	7.7	8.1	7.7	8.4	7.9	8.3	7.8	8.1	7.6	7.9	7.3	8.0	7.2
pH	7.6	7.4	7.5	7.7	7.6	7.4	7.4	7.4	7.6	7.5	7.7	7.4	7.7	
Cond. (µS/cm)	202	197		199		201		199		205		205		
Initials	MLT	MLT		MLT		JW		EMM		MLT		EMM		

Concentration: 10 µg/L U	Day 0	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7
	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)	24.0	25.0	24.0	24.0	24.5	25.0	24.0	25.0	24.0	25.0	25.0	25.0	24.0	
DO (mg/L)	8.1	7.7	8.1	7.7	8.4	7.9	8.3	7.7	8.1	7.6	7.9	6.8	8.0	7.0
pH	7.6	7.4	7.5	7.2	7.6	7.4	7.4	7.4	7.6	7.5	7.7	7.4	7.7	
Cond. (µS/cm)	204	203		201		201		202		204		~~204~~ 203		
Initials	MLT	MLT		MLT		JW		EMM		MLT		EMM		

Concentration: 20 (19 µg/L U)	Day 0	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7
	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)	24.0	25.0	24.0	24.0	25.0	25.0	24.0	25.0	24.0	25.0	25.0	25.0	24.0	
DO (mg/L)	8.1	7.7	8.1	7.7	8.4	7.9	8.3	7.7	8.1	7.6	7.9	6.8	8.0	
pH	7.6	7.4	7.5	7.2	7.6	7.4	7.4	7.4	7.6	7.5	7.7	7.4	7.7	
Cond. (µS/cm)	204	203		203		203		203		204		204		
Initials	MLT	MLT		MLT		JW		EMM		MLT		EMM		

Concentration: 40 (~~38~~ 37 µg/L U)	Day 0	Day 1		Day 2		Day 3		Day 4		Day 5		Day 6		Day 7
	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)	24.0	25.0	24.0	24.0	24.5	25.0	24.0	25.0	24.0	25.0	25.0	25.0	24.0	
DO (mg/L)	8.1	7.8	8.0	7.6	8.4	7.9	8.3	7.7	8.1	7.6	7.9	7.1	8.0	
pH	7.6	7.4	7.5	7.3	7.6	7.4	7.4	7.4	7.6	7.5	7.7	7.5	7.7	
Cond. (µS/cm)	204	203		204		202		203		204		204		
Initials	MLT	MLT		MLT		JW		EMM		MLT		EMM		

Thermometer: 4 **DO meter:** 2 **pH meter:** 2 **Conductivity meter:** 2

	Control	100% (vv) HC2.5		
Hardness*	100	96		
Alkalinity*	98	66		

* mg/L as CaCO3

Analysts: MLT, EMM, AWD, YYL, JW
Reviewed by: JOL
Date reviewed: July 26/16

Sample Description: Uranium in Stream water HC2.5; clear, colourless, odourless, no particulates

Comments: **Broodboard Used:** 061616 (1-12)

Chronic Freshwater Toxicity Test
Initial and Final Water Quality Measurements

Client: Lorax Environmental Services Ltd
Sample ID: Uranium in Stream HC2.5
Work Order #: 16703
Start Date & Time: June 28/16 @ 1000h
Stop Date & Time: July 4/16 @ 1600h
Test Species: Ceriodaphnia dubia

Concentration 80 (MLT ~~75~~) µg/L U	Days 0	1		2		3		4		5		6		7
	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)	24.0	25.0	24.0	24.0	24.5	25.0	24.0	25.0	24.0	25.0	25.0	25.0	24.0	24.0
DO (mg/L)	8.1	7.7	8.0	7.6	8.4	8.0	8.3	7.7	8.1	7.6	7.9	7.3	8.0	7.1
pH	7.5	7.4	7.4	7.3	7.6	7.4	7.4	7.4	7.4	7.4	7.6	7.3	7.6	
Cond. (µS/cm)	205	204		205		204		204		204		208		
Initials	MLT	MLT		MLT		JW		EMM		MLT		EMM		EMM

Concentration 160 (MLT ~~150~~) µg/L U	Days 0	1		2		3		4		5		6		7
	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)	24.0	25.0	24.0	24.0	24.5	25.0	24.0	25.0	24.0	25.0	25.0	25.0	24.0	24.0
DO (mg/L)	8.1	7.7	8.0	7.6	8.4	7.9	8.3	7.7	8.1	7.6	7.9	7.0	8.0	7.1
pH	7.4	7.4	7.3	7.3	7.5	7.4	7.3	7.4	7.4	7.4	7.6	7.3	7.6	
Cond. (µS/cm)	206	206		206		206		206		207		~~208~~ 209		
Initials	MLT	MLT		MLT		JW		EMM		MLT		EMM		EMM

Concentration 320 (MLT ~~300~~) µg/L U	Days 0	1		2		3		4		5		6		7
	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)	24.0	25.0	24.0	24.0	24.5	25.0	24.0	25.0	24.0	25.0	25.0	25.0	24.0	24.0
DO (mg/L)	8.1	7.8	8.0	7.6	8.4	7.9	8.3	7.8	8.1	7.6	7.9	7.1	8.0	7.2
pH	7.2	7.4	7.1	7.3	7.2	7.3	7.1	7.3	7.2	7.3	7.4	7.3	7.5	
Cond. (µS/cm)	209	209		209		208		209		209		209		
Initials	MLT	MLT		MLT		JW		EMM		MLT		EMM		EMM

Concentration Lab control	Days 0	1		2		3		4		5		6		7
	init.	old	new	old	new	old	new	old	new	old	new	old	new	final
Temperature (°C)	24.0	25.0	24.0	24.0	25.0	25.0	24.0	25.0	24.0	25.0	24.0	25.0	24.0	24.0
DO (mg/L)	8.1	7.7	8.2	7.7	8.0	8.0	8.3	7.7	8.1	7.6	8.0	7.3	8.0	7.2
pH	8.0	7.7	7.9	7.3	7.9	7.4	7.7	7.3	8.0	7.8	8.0	7.2	8.0	
Cond. (µS/cm)	214	216		217		216		216		221		220		
Initials	MLT	MLT		MLT		JW		EMM		MLT		EMM		EMM

Thermometer: 4 DO meter: 2 pH meter: 2 Conductivity meter: 2

	Control	100% (v/v) HC2.5		
Hardness*	100	96		
Alkalinity*	98	66		

* mg/L as CaCO3

Analysts: MLT, EMM, AWD, JW, ML
Reviewed by: JOL
Date reviewed: July 27/16

Sample Description: Uranium in Stream HC2.5 water; clear, colourless, odourless, no particulates

Comments: **Broodboard Used:** 061616 (1-12)

Chronic Freshwater Toxicity Test
C. dubia Reproduction Data

Client: Lorax Environmental Services Ltd.
Sample ID: uranium in stream HC2.5
Work Order: 16703

Start Date & Time: June 28/16 @ 1000h
Stop Date & Time: July 4/16 @ 1600h
Set up by: EMM

(µg/L) uranium

Concentration: site control HC25

Days	A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MLJ
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	KM
3	~~4~~	~~2~~	~~3~~	✓	✓	~~3~~4	3	✓	✓	~~4x~~	YM
4	4	4	✓	4	4	✓	✓	3	3	✓	MM
5	6	8	8	5	9	9	7	10	5	8	MLJ
6	12	12	11	✓	12	13	11	12	10	9	MM
7											
8											
Total	22	24	22	9	25	26	21	25	18	21	MM

Concentration: 10 ~~9~~ MLJ

Days	A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MLJ
2	–	–	–	–	–	–	–	–	–	–	KM
3	✓	✓	✓	4	✓	3	✓	✓	✓	✓	YM
4	2	3	3	✓	3	✓	2	3	3	4	MM
5	X	5	✓	7	8	7	8	10	6	✓	MLJ
6	|	10	9	13	✓	14	12	11	✓	11	MM
7											
8											
Total	2X	18	12	24	11	24	22	24	9	15	MM

Concentration: MLJ ~~19~~ 20

Days	A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MLJ
2	–	–	–	–	–	–	–	–	–	–	KM
3	3	✓	4	✓	4	3	✓	3	✓	✓	YM
4	✓	4	✓	3	✓	✓	3	✓	2	3	MM
5	7	9	8	6	7	9	9	10	8	8	MLJ
6	14	✓	13	✓	14	12	✓	12	✓	11	MM
7											
8											
Total	24	13	25	9	25	24	12	25	10	22	MM

Concentration: MLJ ~~37.5~~ 40

Days	A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MLJ
2	–	–	–	–	–	–	–	–	–	–	KM
3	✓	2	2	✓	✓	✓	3	4	✓	3	YM
4	3	✓	✓	2	2	4	✓	✓	4	✓	MM
5	4	8	6	6	4	5	8	6	9	6	MLJ
6	4	13	13	14	10	✓	12	8	✓	6	MM
7											
8											
Total	11	23	21	22	16	9	23	18	13	~~14~~ 15 yg.	MM

Concentration: MLJ ~~75~~ 80

Days	A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MLJ
2	–	–	–	–	–	–	–	–	–	–	KM
3	4	3	4	✓	2	✓	4	✓	4	3	YM
4	✓	✓	✓	3	✓	3	✓	4	✓	✓	MM
5	8	8	6	10	8	5	6	10	7	6	MLJ
6	14	11	12	✓	12	✓	14	✓	13	12	MM
7											
8											
Total	26	22	22	13	22	8	24	14	24	21	MM

Concentration: MLJ ~~150~~ 160

Days	A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MLJ
2	–	–	–	–	–	–	–	–	–	–	KM
3	✓	✓	✓	✓	✓	X	3	2	✓	✓	YM
4	✓	4	4	5	3	|	✓	✓	3	4	MM
5	✓	7	4	8	9	|	10	7	9	10	MLJ
6	✓	✓	10	12	✓		14	12	✓	10	MM
7											
8											
Total	0	11	18	25	12	0X	27	21	12	24	MM

Concentration: MLJ ~~300~~ 320

Days	A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MLJ
2	–	–	–	–	–	–	–	–	–	–	KM
3	3	✓	4	4	2	3	3	✓	✓	✓	YM
4	✓	5	✓	✓	✓	✓	✓	6	5	4	MM
5	7	7	8	7	3	6	8	8	8	7	MLJ
6	11	12	10	11	✓	11	10	✓	✓	11	MM
7											
8											
Total	21	24	22	22	5	20	21	14	13	22	MM

Concentration: Lab control

Days	A	B	C	D	E	F	G	H	I	J	Init
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	MLJ
2	–	–	–	–	–	–	–	–	–	–	KM
3	4	2	✓	✓	✓	3	3	✓	✓	✓	YM
4	✓	✓	4	5	4	✓	✓	3	3	3	MM
5	7	8	✓	8	9	9	8	8	7	9	MLJ
6	13	11	10	10	9	12	11	12	✓	✓	MM
7											
8											
Total	24	21	14	23	22	24	22	23	10	12	MM

Concentration:

Days	A	B	C	D	E	F	G	H	I	J	Init
1											
2											
3											
4											
5											
6											
7											
8											
Total											

Notes: X = mortality.

Sample Description: uranium spiked into HC2.5 water

Comments: Total # Young only based on the first 3 Broods. Fourth and subsequent broods not included in total count.

Reviewed by: JGh

Date reviewed: July 28/16

Client: Lorax Environmental Services

W.O.#: 16703

Hardness and Alkalinity Datasheet

Sample ID	Alkalinity: Sample Date	Alkalinity: Sample Volume (mL)	Alkalinity: (mL) 0.02N HCL/H_2SO_4 used to pH 4.5	Alkalinity: (mL) of 0.02N HCL/H_2SO_4 used to pH 4.2	Alkalinity: Total Alkalinity (mg/L$CaCO_3$)	Hardness: Sample Volume (mL)	Hardness: Volume of 0.01M EDTA Used (mL)	Hardness: Total Hardness (mg/L $CaCO_3$)	Technician
HC25	June 28/16	50	3.4	3.5	66	50	4.8	96	KL
CC15	↓	↓	3.7	3.9	70	↓	6.9	138	↓
LAB	↓	↓	~~4.9~~ 5.0	5.1	98	↓	5.0	100	↓
20% Perrier Ctrl	↓	↓	5.0	5.1	98	↓	5.0	100	↓

Notes:

Reviewed by: Jon

Date Reviewed: July 26/16

CETIS Analytical Report

Report Date: 08 Jul-16 15:58 (p 1 of 2)
Test Code: 16703c | 14-7178-3006

Ceriodaphnia 7-d Survival and Reproduction Test — Nautilus Environmental

Analysis ID:	19-5670-5645	**Endpoint:**	6d Survival Rate	**CETIS Version:**	CETISv1.8.7
Analyzed:	08 Jul-16 15:57	**Analysis:**	Linear Interpolation (ICPIN)	**Official Results:**	Yes

Batch ID:	05-2140-8020	**Test Type:**	Reproduction-Survival (7d)	**Analyst:**	Krysta Pearcy
Start Date:	28 Jun-16 10:00	**Protocol:**	EC/EPS 1/RM/21	**Diluent:**	Stream water (HC2.5)
Ending Date:	04 Jul-16 16:00	**Species:**	Ceriodaphnia dubia	**Brine:**	
Duration:	6d 6h	**Source:**	In-House Culture	**Age:**	<24h

Sample ID:	01-8607-2632	**Code:**	B173E38	**Client:**	Lorax Environmental
Sample Date:	25 Jun-16 08:30	**Material:**	Uranium	**Project:**	
Receive Date:	27 Jun-16 14:15	**Source:**	HC2.5		
Sample Age:	74h (13 °C)	**Station:**	HC2.5		

Linear Interpolation Options

X Transform	Y Transform	Seed	Resamples	Exp 95% CL	Method
Log(X+1)	Linear	1437852	200	Yes	Two-Point Interpolation

Point Estimates

Level	ug/L	95% LCL	95% UCL
EC5	351	30.42	N/A
EC10	>351	N/A	N/A
EC15	>351	N/A	N/A
EC20	>351	N/A	N/A
EC25	>351	N/A	N/A
EC40	>351	N/A	N/A
EC50	>351	N/A	N/A

6d Survival Rate Summary

			Calculated Variate(A/B)								
C-ug/L	Control Type	Count	Mean	Min	Max	Std Err	Std Dev	CV%	%Effect	A	B
23.9 ✓	(1) Negative Control	10	1	1	1	0	0	0.0%	0.0%	10	10
34.3 ✓		10	0.9	0	1	0.1	0.3162	35.14%	10.0%	9	10
44.4 ✓		10	1	1	1	0	0	0.0%	0.0%	10	10
64.2 ✓		10	1	1	1	0	0	0.0%	0.0%	10	10
105 ✓		10	1	1	1	0	0	0.0%	0.0%	10	10
188 ✓		10	0.9	0	1	0.1	0.3162	35.14%	10.0%	9	10
351 ✓		10	1	1	1	0	0	0.0%	0.0%	10	10

6d Survival Rate Detail

C-ug/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
23.9	(1) Negative Control	1	1	1	1	1	1	1	1	1	1
34.3		0	1	1	1	1	1	1	1	1	1
44.4		1	1	1	1	1	1	1	1	1	1
64.2		1	1	1	1	1	1	1	1	1	1
105		1	1	1	1	1	1	1	1	1	1
188		1	1	1	1	1	0	1	1	1	1
351		1	1	1	1	1	1	1	1	1	1

6d Survival Rate Binomials

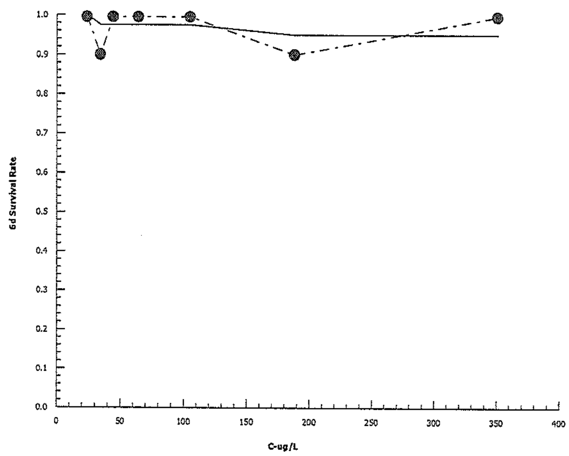
C-ug/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
23.9	(1) Negative Control	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
34.3		0/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
44.4		1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
64.2		1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
105		1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
188		1/1	1/1	1/1	1/1	1/1	0/1	1/1	1/1	1/1	1/1
351		1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1

(1) negative control = site water HC2.5 control

Ceriodaphnia 7-d Survival and Reproduction Test — **Nautilus Environmental**

Analysis ID:	19-5670-5645	**Endpoint:**	6d Survival Rate	**CETIS Version:**	CETISv1.8.7
Analyzed:	08 Jul-16 15:57	**Analysis:**	Linear Interpolation (ICPIN)	**Official Results:**	Yes

Graphics



CETIS Analytical Report

Report Date: 08 Jul-16 15:58 (p 1 of 1)
Test Code: 16703c | 14-7178-3006

Ceriodaphnia 7-d Survival and Reproduction Test — **Nautilus Environmental**

Analysis ID:	16-4297-4168	**Endpoint:**	6d Survival Rate	**CETIS Version:**	CETISv1.8.7
Analyzed:	08 Jul-16 15:58	**Analysis:**	Single 2x2 Contingency Table	**Official Results:**	Yes
Batch ID:	05-2140-8020	**Test Type:**	Reproduction-Survival (7d)	**Analyst:**	Krysta Pearcy
Start Date:	28 Jun-16 10:00	**Protocol:**	EC/EPS 1/RM/21	**Diluent:**	Stream water (HC2.5)
Ending Date:	04 Jul-16 16:00	**Species:**	Ceriodaphnia dubia	**Brine:**	
Duration:	6d 6h	**Source:**	In-House Culture	**Age:**	<24h
Sample ID:	01-8607-2632	**Code:**	B173E38	**Client:**	Lorax Environmental
Sample Date:	25 Jun-16 08:30	**Material:**	Uranium	**Project:**	
Receive Date:	27 Jun-16 14:15	**Source:**	HC2.5		
Sample Age:	74h (13 °C)	**Station:**	HC2.5		

Data Transform	Zeta	Alt Hyp	Trials	Seed	Test Result
Untransformed		C > T	NA	NA	Passes 6d survival rate

Fisher Exact Test

Sample	vs	Sample	Test Stat	P-Value	P-Type	Decision(α:5%)
0.7		23.9	1	1.0000	Exact	Non-Significant Effect

Data Summary

C-ug/L	Control Type	NR	R	NR + R	Prop NR	Prop R	%Effect
0.7	Lab Water	10	0	10	1	0	0.0%
23.9	(1) Negative Contr	10	0	10	1	0	0.0%

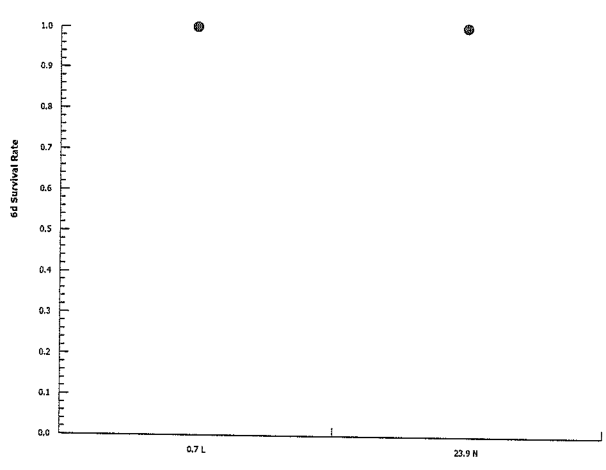
6d Survival Rate Detail

C-ug/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0.7	Lab Water	1	1	1	1	1	1	1	1	1	1
23.9	(1) Negative Control	1	1	1	1	1	1	1	1	1	1

6d Survival Rate Binomials

C-ug/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0.7	Lab Water	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1
23.9	(1) Negative Control	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1	1/1

Graphics



(1) negative control = site water HC2.5 control

CETIS Analytical Report

Report Date:	08 Jul-16 15:58 (p 1 of 2)
Test Code:	16703c | 14-7178-3006

Ceriodaphnia 7-d Survival and Reproduction Test — **Nautilus Environmental**

Analysis ID:	16-7609-5466	**Endpoint:**	Reproduction	**CETIS Version:**	CETISv1.8.7
Analyzed:	08 Jul-16 15:58	**Analysis:**	Linear Interpolation (ICPIN)	**Official Results:**	Yes

Batch ID:	05-2140-8020	**Test Type:**	Reproduction-Survival (7d)	**Analyst:**	Krysta Pearcy
Start Date:	28 Jun-16 10:00	**Protocol:**	EC/EPS 1/RM/21	**Diluent:**	Stream water (HC2.5)
Ending Date:	04 Jul-16 16:00	**Species:**	Ceriodaphnia dubia	**Brine:**	
Duration:	6d 6h	**Source:**	In-House Culture	**Age:**	<24h

Sample ID:	01-8607-2632	**Code:**	B173E38	**Client:**	Lorax Environmental
Sample Date:	25 Jun-16 08:30	**Material:**	Uranium	**Project:**	
Receive Date:	27 Jun-16 14:15	**Source:**	HC2.5		
Sample Age:	74h (13 °C)	**Station:**	HC2.5		

Linear Interpolation Options

X Transform	Y Transform	Seed	Resamples	Exp 95% CL	Method
Log(X+1)	Linear	274753	200	Yes	Two-Point Interpolation

Point Estimates

Level	ug/L	95% LCL	95% UCL
IC5	26.8	25.43	117.4
IC10	30.04	27.06	N/A
IC15	33.65	28.79	N/A
IC20	160	30.62	N/A
IC25	>351	N/A	N/A
IC40	>351	N/A	N/A
IC50	>351	N/A	N/A

Reproduction Summary

			Calculated Variate						
C-ug/L	Control Type	Count	Mean	Min	Max	Std Err	Std Dev	CV%	%Effect
23.9	(1) Negative Control	10	21.3	9	26	1.564	4.945	23.22%	0.0%
34.3		10	16.1	2	24	2.401	7.593	47.16%	24.41%
44.4		10	18.9	9	25	2.193	6.935	36.7%	11.27%
64.2		10	17.1	9	23	1.616	5.109	29.88%	19.72%
105		10	19.6	8	26	1.851	5.854	29.87%	7.98%
188		10	15	0	27	3.08	9.741	64.94%	29.58%
351		10	18.4	5	24	1.869	5.91	32.12%	13.62%

Reproduction Detail

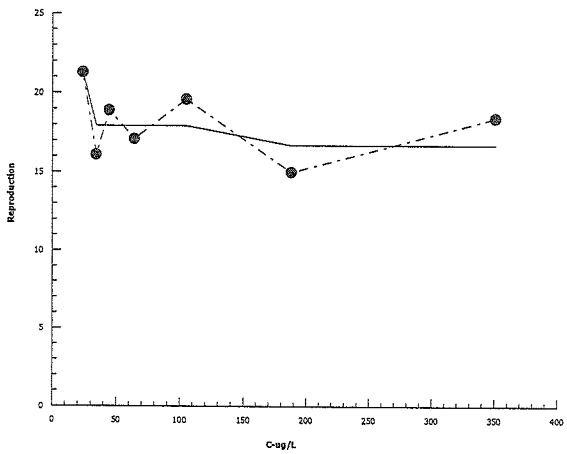
C-ug/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
23.9	(1) Negative Control	22	24	22	9	25	26	21	25	18	21
34.3		2	18	12	24	11	24	22	24	9	15
44.4		24	13	25	9	25	24	12	25	10	22
64.2		11	23	21	22	16	9	23	18	13	15
105		26	22	22	13	22	8	24	14	24	21
188		0	11	18	25	12	0	27	21	12	24
351		21	24	22	22	5	20	21	14	13	22

(1) negative control = site water HC2.5 control

Ceriodaphnia 7-d Survival and Reproduction Test | **Nautilus Environmental**

Analysis ID:	16-7609-5466	**Endpoint:**	Reproduction	**CETIS Version:**	CETISv1.8.7
Analyzed:	08 Jul-16 15:58	**Analysis:**	Linear Interpolation (ICPIN)	**Official Results:**	Yes

Graphics



CETIS Analytical Report

Report Date:	08 Jul-16 15:58 (p 1 of 1)
Test Code:	16703c | 14-7178-3006

Ceriodaphnia 7-d Survival and Reproduction Test — **Nautilus Environmental**

Analysis ID:	14-2383-4989	Endpoint:	Reproduction	CETIS Version:	CETISv1.8.7
Analyzed:	08 Jul-16 15:58	Analysis:	Nonparametric-Two Sample	Official Results:	Yes
Batch ID:	05-2140-8020	Test Type:	Reproduction-Survival (7d)	Analyst:	Krysta Pearcy
Start Date:	28 Jun-16 10:00	Protocol:	EC/EPS 1/RM/21	Diluent:	Stream water (HC2.5)
Ending Date:	04 Jul-16 16:00	Species:	Ceriodaphnia dubia	Brine:	
Duration:	6d 6h	Source:	In-House Culture	Age:	<24h
Sample ID:	01-8607-2632	Code:	B173E38	Client:	Lorax Environmental
Sample Date:	25 Jun-16 08:30	Material:	Uranium	Project:	
Receive Date:	27 Jun-16 14:15	Source:	HC2.5		
Sample Age:	74h (13 °C)	Station:	HC2.5		

Data Transform	Zeta	Alt Hyp	Trials	Seed	PMSD	Test Result
Untransformed	NA	C > T	NA	NA	20.5%	Passes reproduction

Wilcoxon Rank Sum Two-Sample Test

Control	vs	Control	Test Stat	Critical	Ties	DF	P-Value	P-Type	Decision(α:5%)
0.7		23.9	114	NA	4	18	0.7548	Exact	Non-Significant Effect

ANOVA Table

Source	Sum Squares	Mean Square	DF	F Stat	P-Value	Decision(α:5%)
Between	16.2	16.2	1	0.6118	0.4443	Non-Significant Effect
Error	476.6	26.47778	18			
Total	492.8		19			

Distributional Tests

Attribute	Test	Test Stat	Critical	P-Value	Decision(α:1%)
Variances	Variance Ratio F	1.165	6.541	0.8234	Equal Variances
Distribution	Shapiro-Wilk W Normality	0.8261	0.866	0.0022	Non-normal Distribution

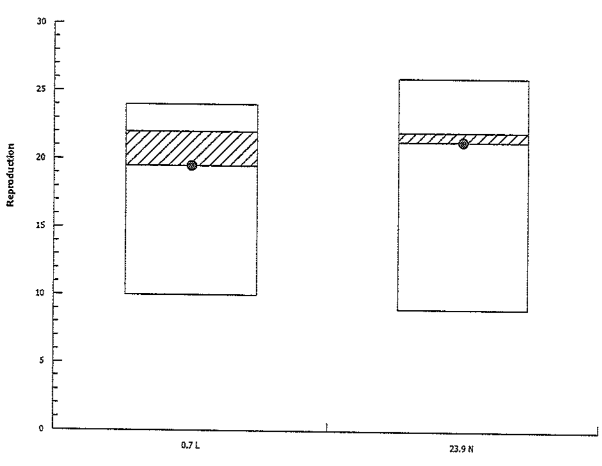
Reproduction Summary

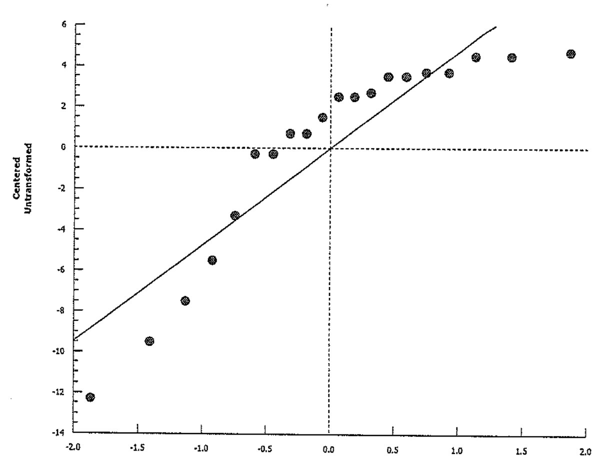
C-ug/L	Control Type	Count	Mean	95% LCL	95% UCL	Median	Min	Max	Std Err	CV%	%Effect
0.7	Lab Water	10	19.5	15.68	23.32	22	10	24	1.688	27.38%	0.0%
23.9	(1) Negative Control	10	21.3	17.76	24.84	22	9	26	1.564	23.22%	-9.23%

Reproduction Detail

C-ug/L	Control Type	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6	Rep 7	Rep 8	Rep 9	Rep 10
0.7	Lab Water	24	21	14	23	22	24	22	23	10	12
23.9	(1) Negative Control	22	24	22	9	25	26	21	25	18	21

Graphics





(1) negative control = site water HC2.5 control

APPENDIX B – Chain-of-Custody Form

Nautilus Environmental

BRITISH COLUMBIA
8664 Commerce Court
Burnaby British Columbia Canada V5A 4N7
Phone 604.420.8773
Fax 604.357.1361

WO# 16703

Chain of Custody
1737

Date 27 JUN 2016 Page 1 of 1

Sample Collection by: LABERGE ENVIRONMENTAL

Report to:
Company LORAX ENVIRONMENTAL
Address 2289 BURRARD ST.
City VANCOUVER Prov. BC PC
Contact ROBERT GOLDBLATT
Phone No. Phone Number REDACTED

Invoice to:
Company Same
Address
City Prov. PC
Contact
Phone No.

ANALYSIS REQUIRED

SAMPLE ID	DATE	TIME	MATRIX	CONTAINER TYPE	NUMBER OF CONTAINERS	COMMENTS	Ceriodaphnia	Survival + repro	IC25 Tests								RECEIPT TEMPERATURE (°C)
CC1.5-0,10,20,40	23/6/2016	08:00	Fresh water	2L plastic		• Stream H_2O spiked w/ U	✓										11.5
-80,160,320					7	up to 320 ppb.											
HC2.5-0,10,20,40						• Stream H_2O spiked w/ U	✓										13.0
-80,160,320	25/6	08:30	Fresh H_2O		7	• up to 320 ppb											
LAB-0,10,20,40						• Cerio lab H_2O spiked	✓										11.5
-80,160,320						w/ U up to 320 ppb.											

PROJECT INFORMATION	SAMPLE RECEIPT	
CLIENT LORAX	TOTAL NO. OF CONTAINERS	21
P.O. NO. A362-2 (COFFEE)	REC'D GOOD CONDITION	Y
SHIPPED VIA:		

SPECIAL INSTRUCTIONS/COMMENTS:
sample description: all samples appear clear, colourless, no particulates and odourless

RELINQUISHED BY (CLIENT)
R. Goldblatt
(Signature) (Time)
ROBERT GOLDBLATT
(Printed Name) (Date)
LORAX
(Company)
27-JUN-2016 11:30

RELINQUISHED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

RECEIVED BY (COURIER)
(Signature) (Time)
(Printed Name) (Date)
(Company)

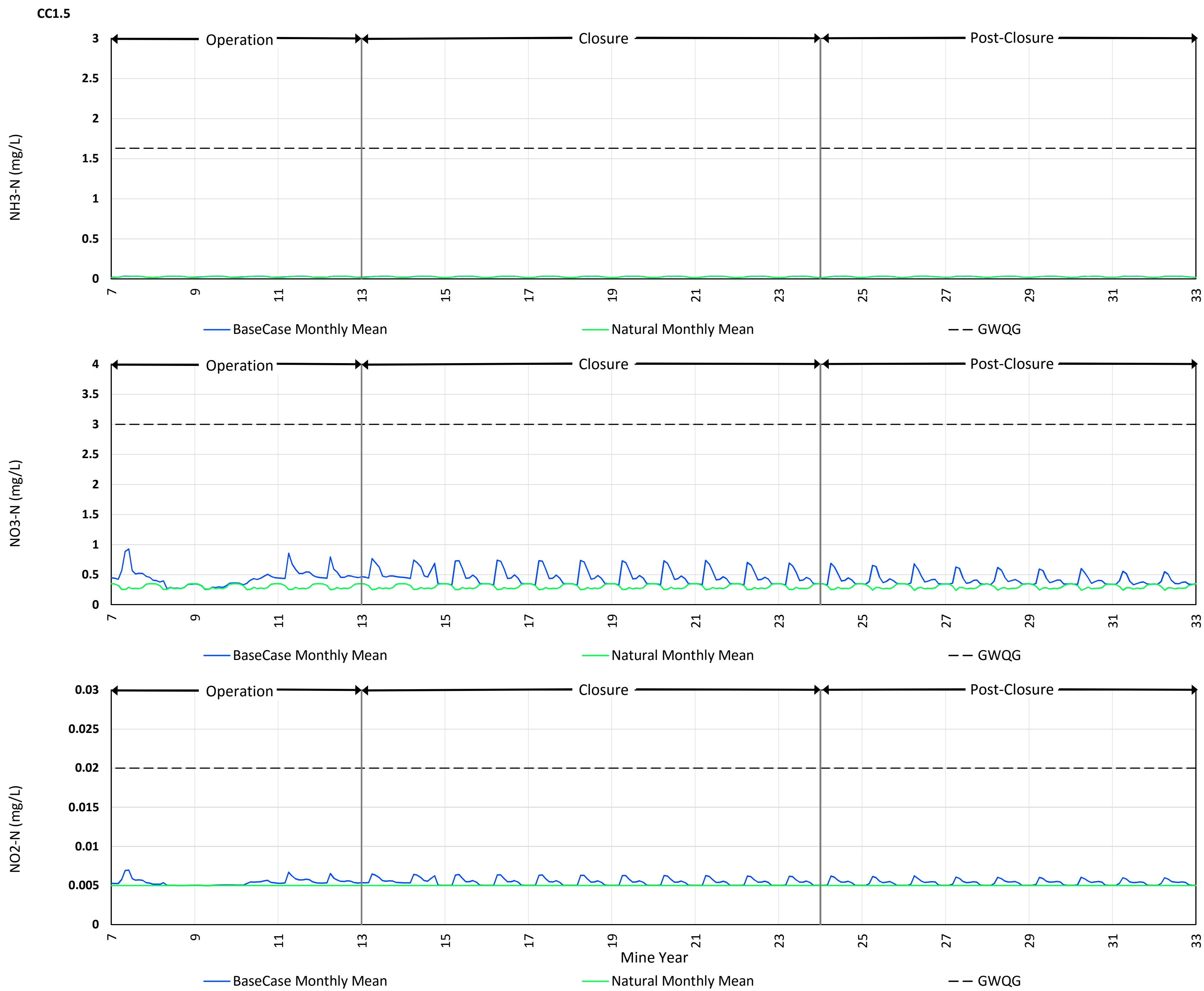
RECEIVED BY (LABORATORY)
Nautilus
(Signature) NY (Time) 14:15
Signature REDACTED
(Date) Jun 27/16

Additional costs may be required for sample disposal or storage. Net 30 unless otherwise contracted.

DISTRIBUTION: WHITE - Nautilus Environmental, COLOR - Originator

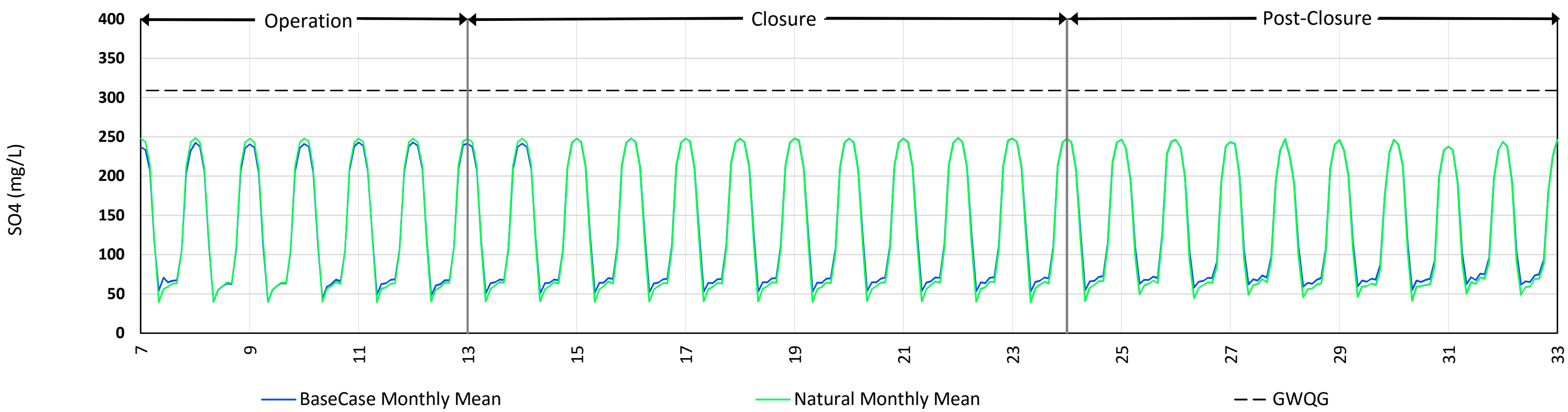
Appendix 12-C-5: Base Case Water Quality Model Results

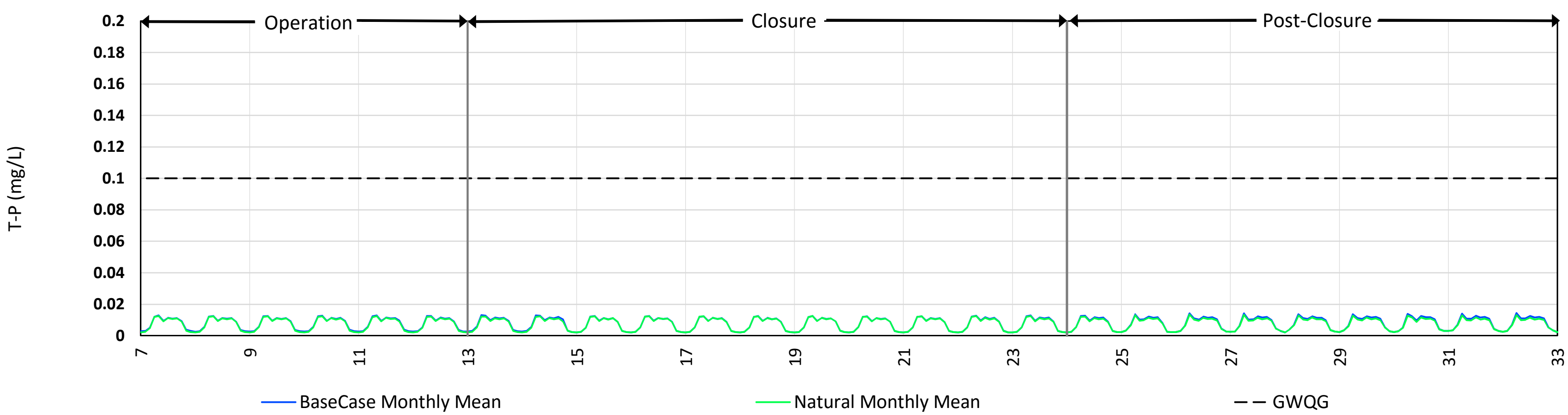
GOLDCORP

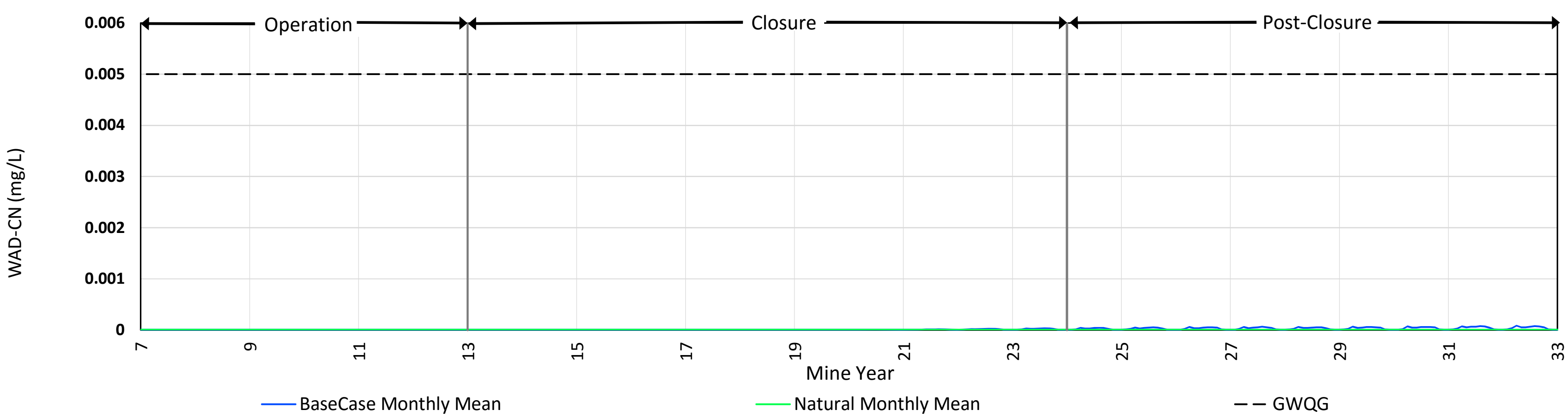


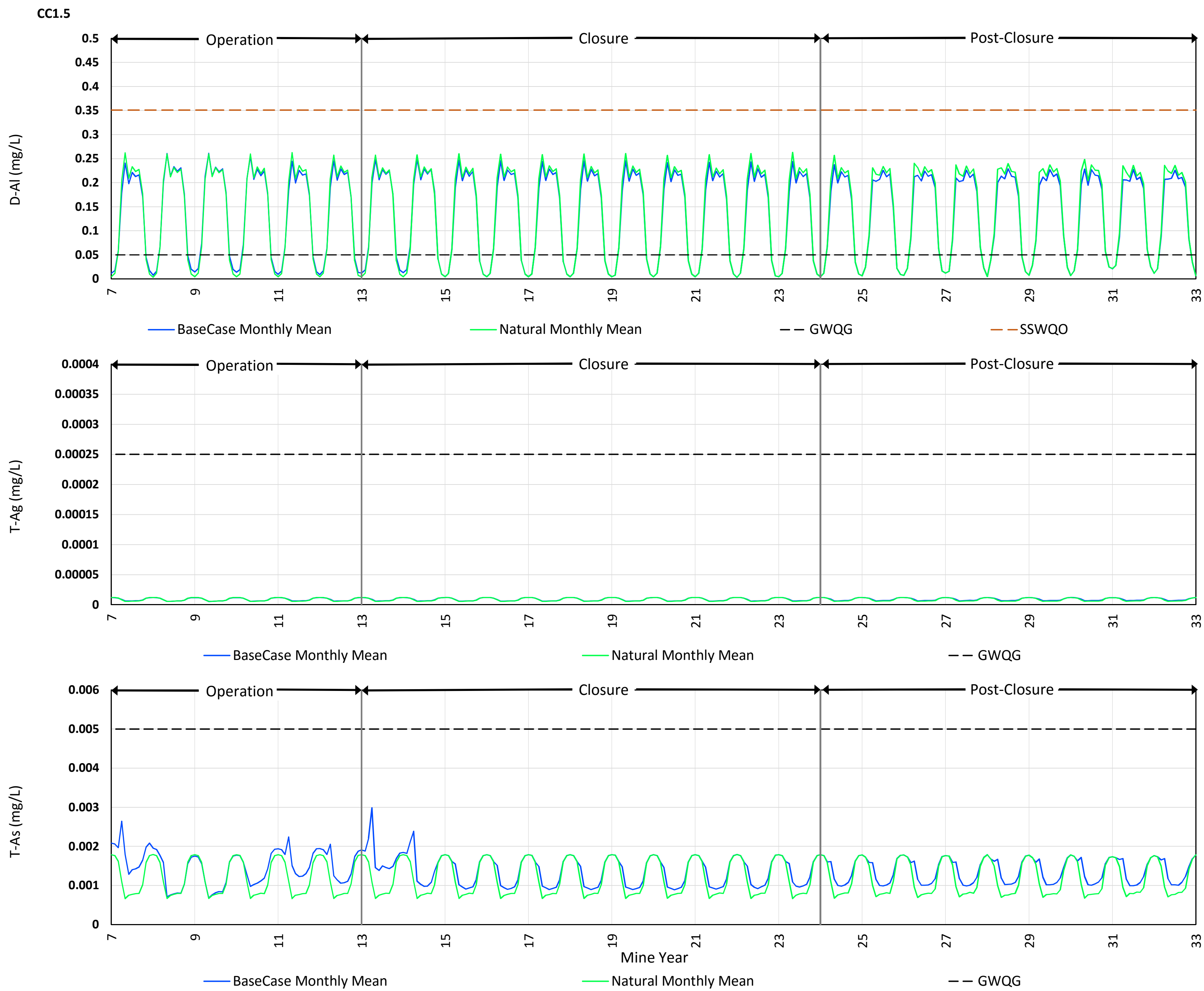
CC1.5
Operation
Closure
Post-Closure
NH3-N (mg/L)
3
2.5
2
1.5
1
0.5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
NO3-N (mg/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
NO2-N (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
Mine Year

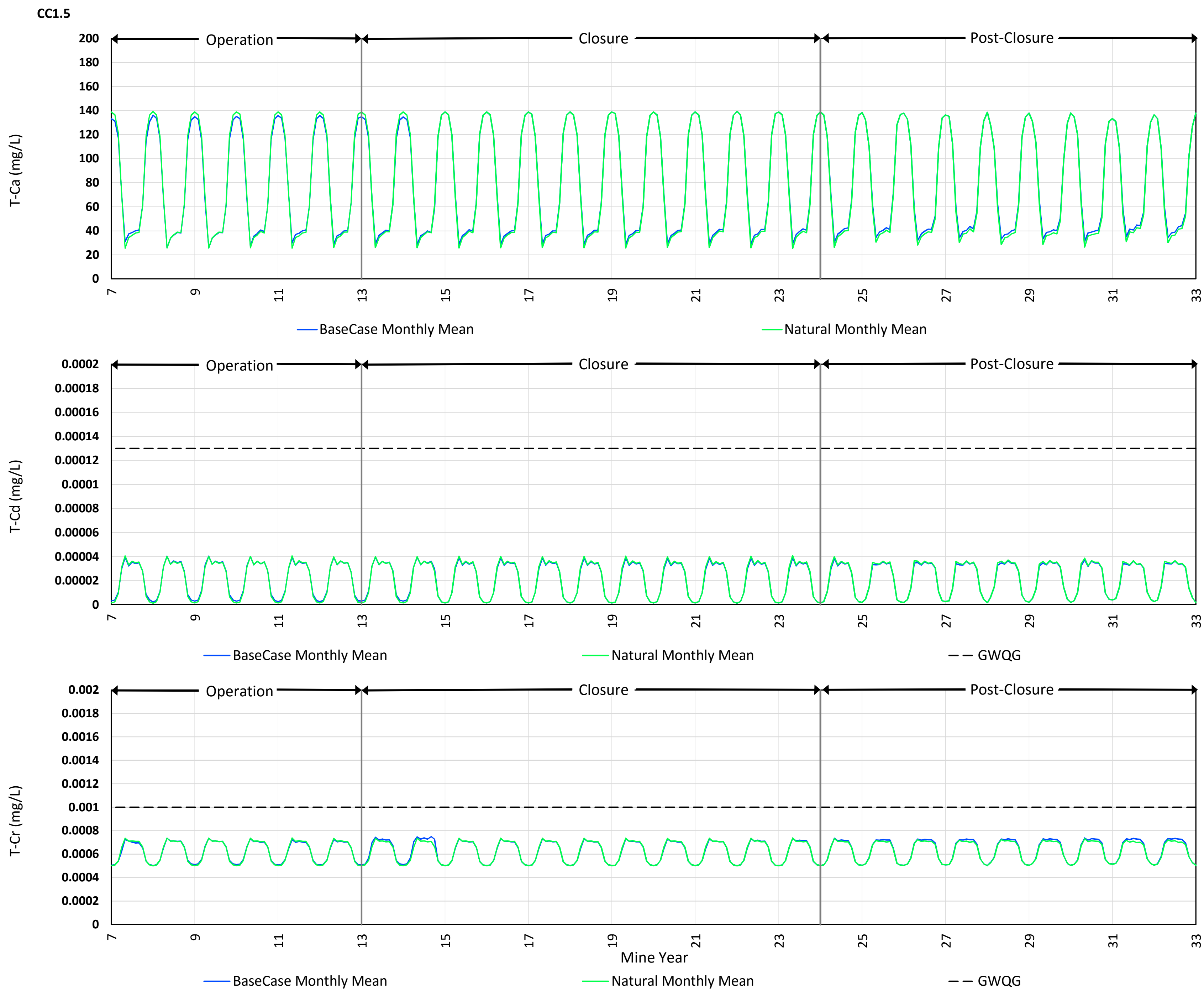
CC1.5

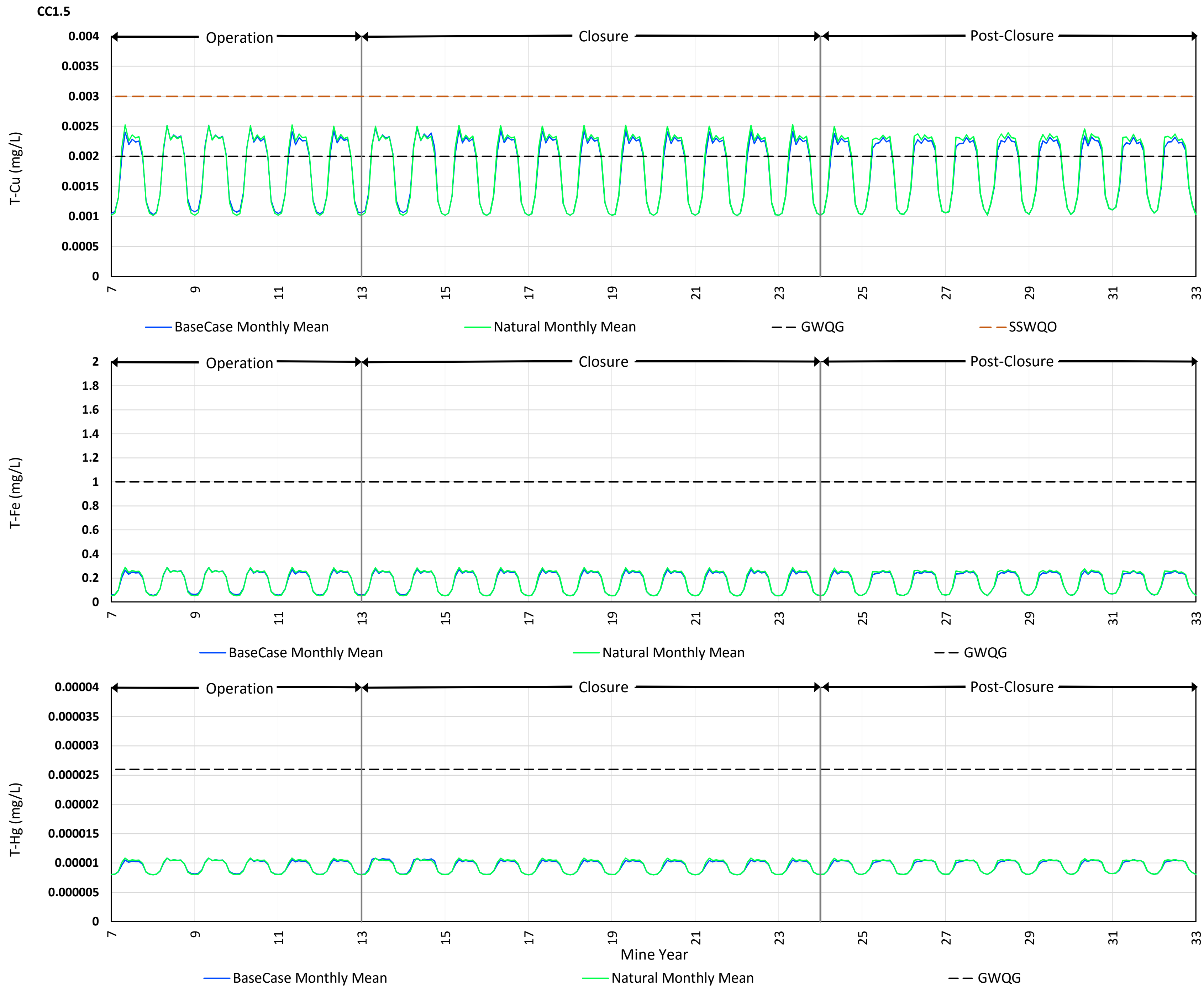

Operation
Closure
Post-Closure
SO4 (mg/L)
400
350
300
250
200
150
100
50
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG


Operation
Closure
Post-Closure
T-P (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

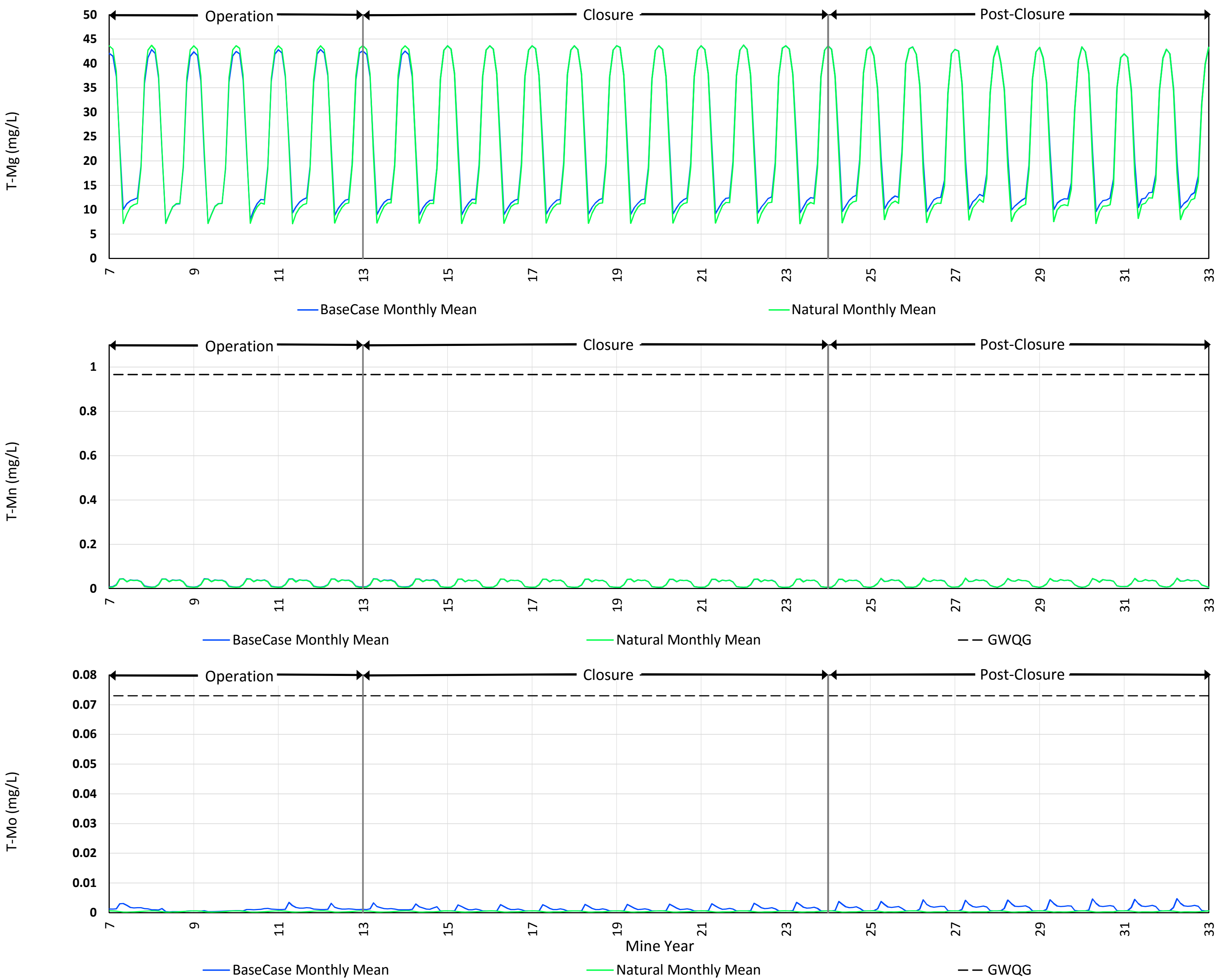

Operation
Closure
Post-Closure
WAD-CN (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG


CC1.5
Operation
Closure
Post-Closure
D-Al (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Ag (mg/L)
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
T-As (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
Mine Year

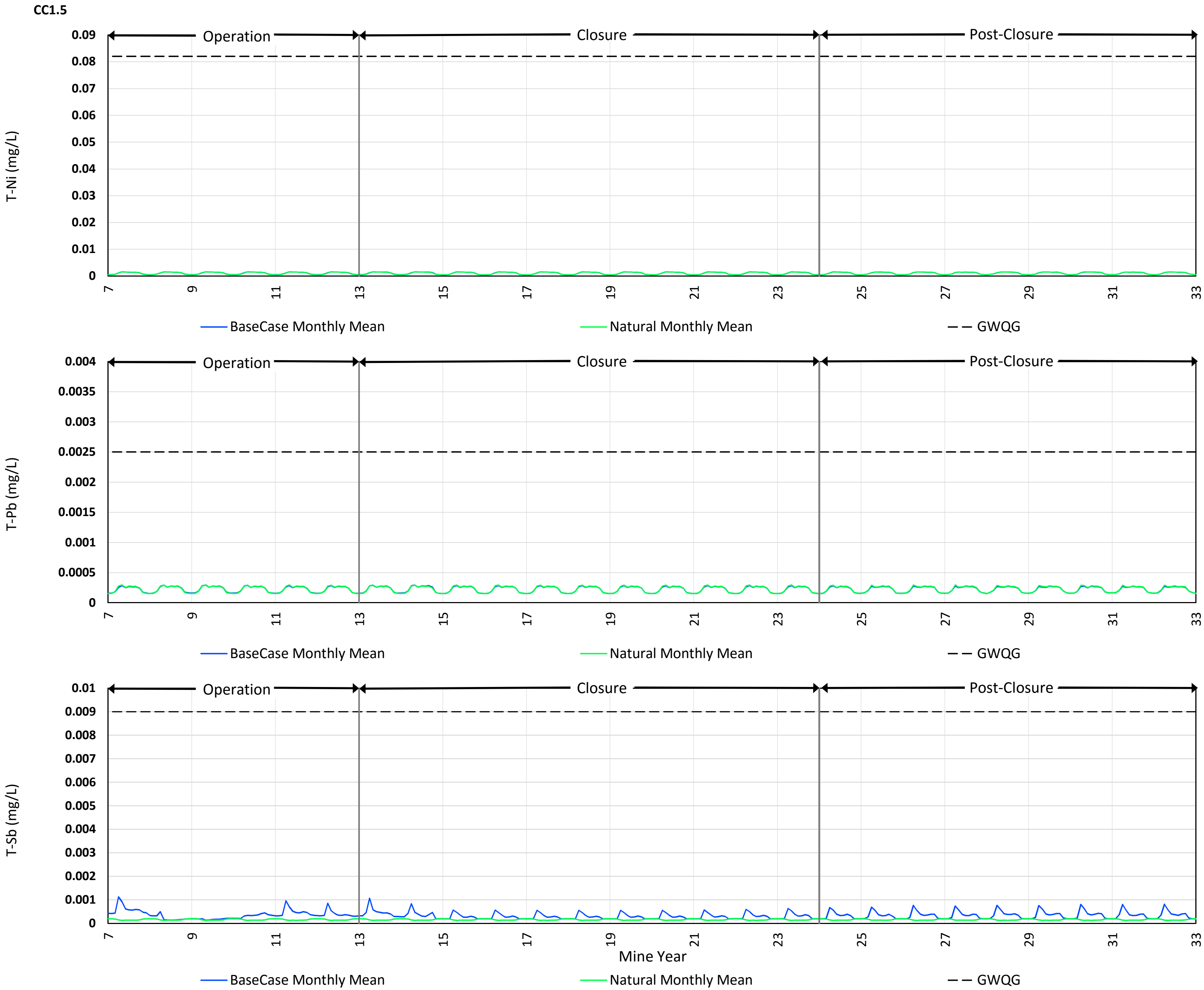

CC1.5
Operation
Closure
Post-Closure
T-Ca (mg/L)
BaseCase Monthly Mean
Natural Monthly Mean
T-Cd (mg/L)
GWQG
T-Cr (mg/L)
Mine Year


CC1.5
Operation
Closure
Post-Closure
T-Cu (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Fe (mg/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
T-Hg (mg/L)
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
Mine Year

CC1.5

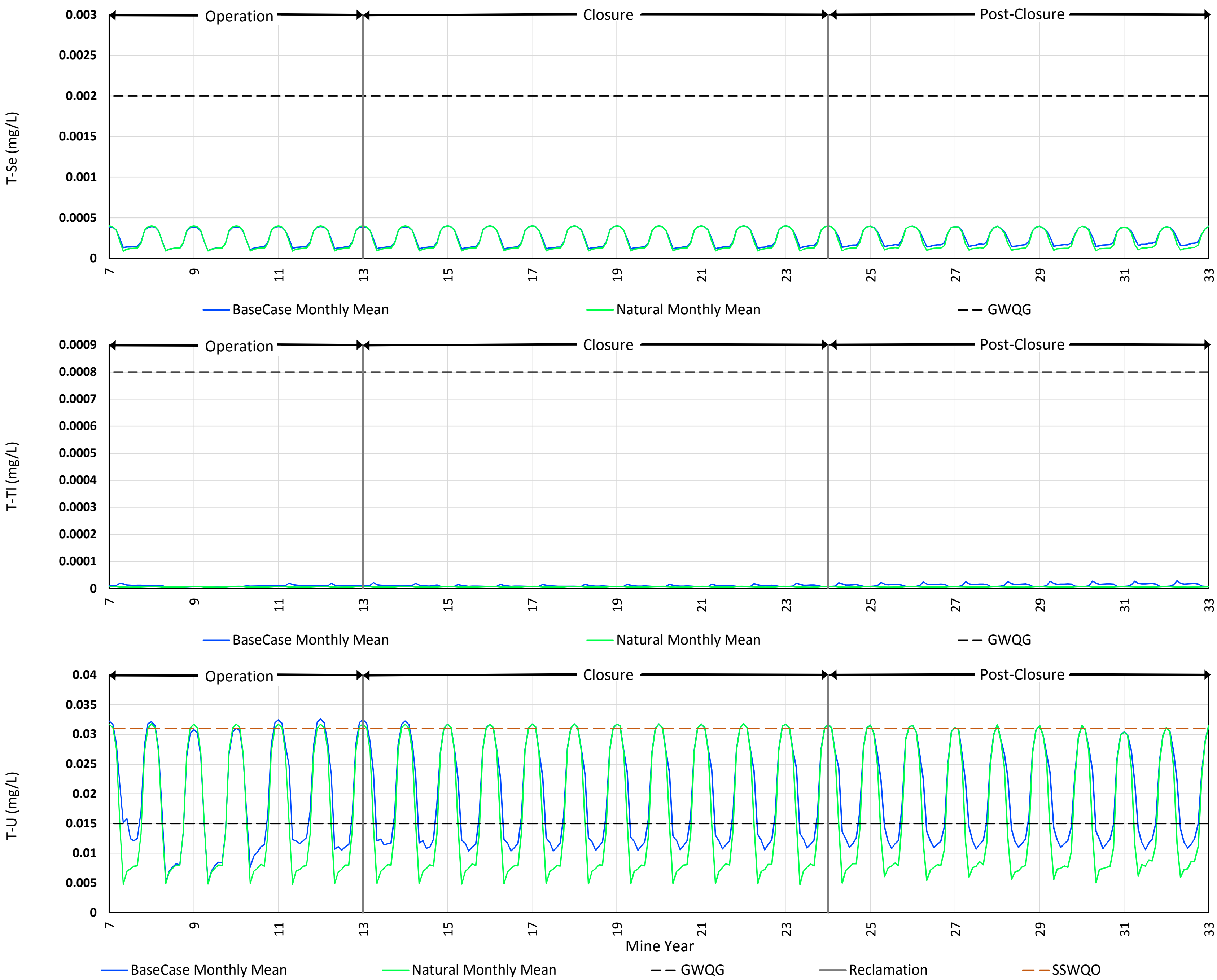


Operation
Closure
Post-Closure
T-Mg (mg/L)
50
45
40
35
30
25
20
15
10
5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Mn (mg/L)
1
0.8
0.6
0.4
0.2
0
GWQG
T-Mo (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Mine Year

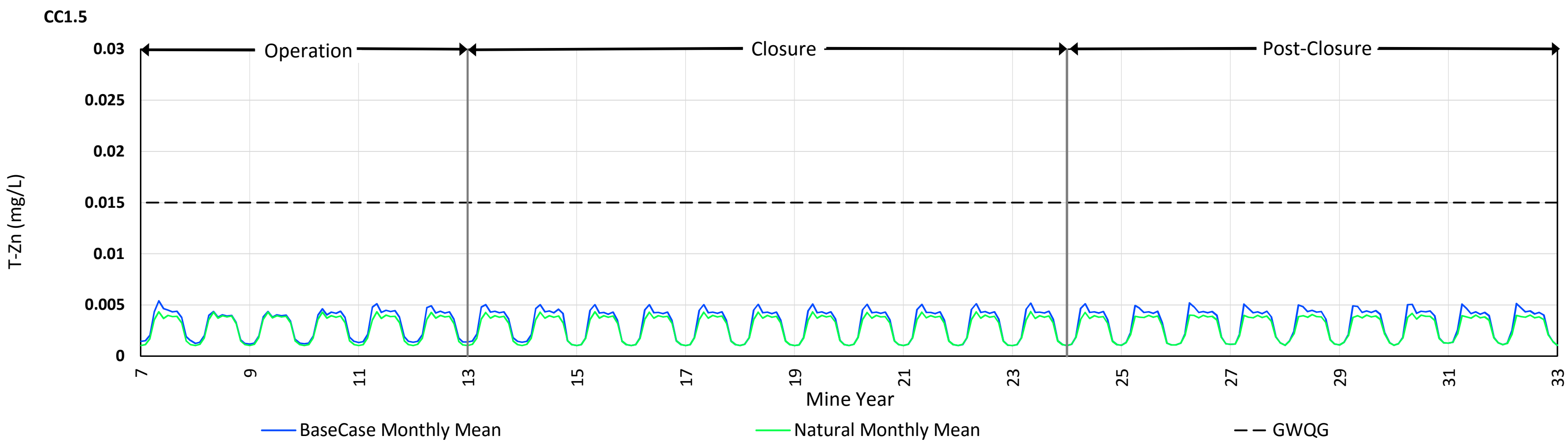


CC1.5
Operation
Closure
Post-Closure
T-Ni (mg/L)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
7 9 11 13 15 17 19 21 23 25 27 29 31 33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
T-Pb (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7 9 11 13 15 17 19 21 23 25 27 29 31 33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
T-Sb (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
7 9 11 13 15 17 19 21 23 25 27 29 31 33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

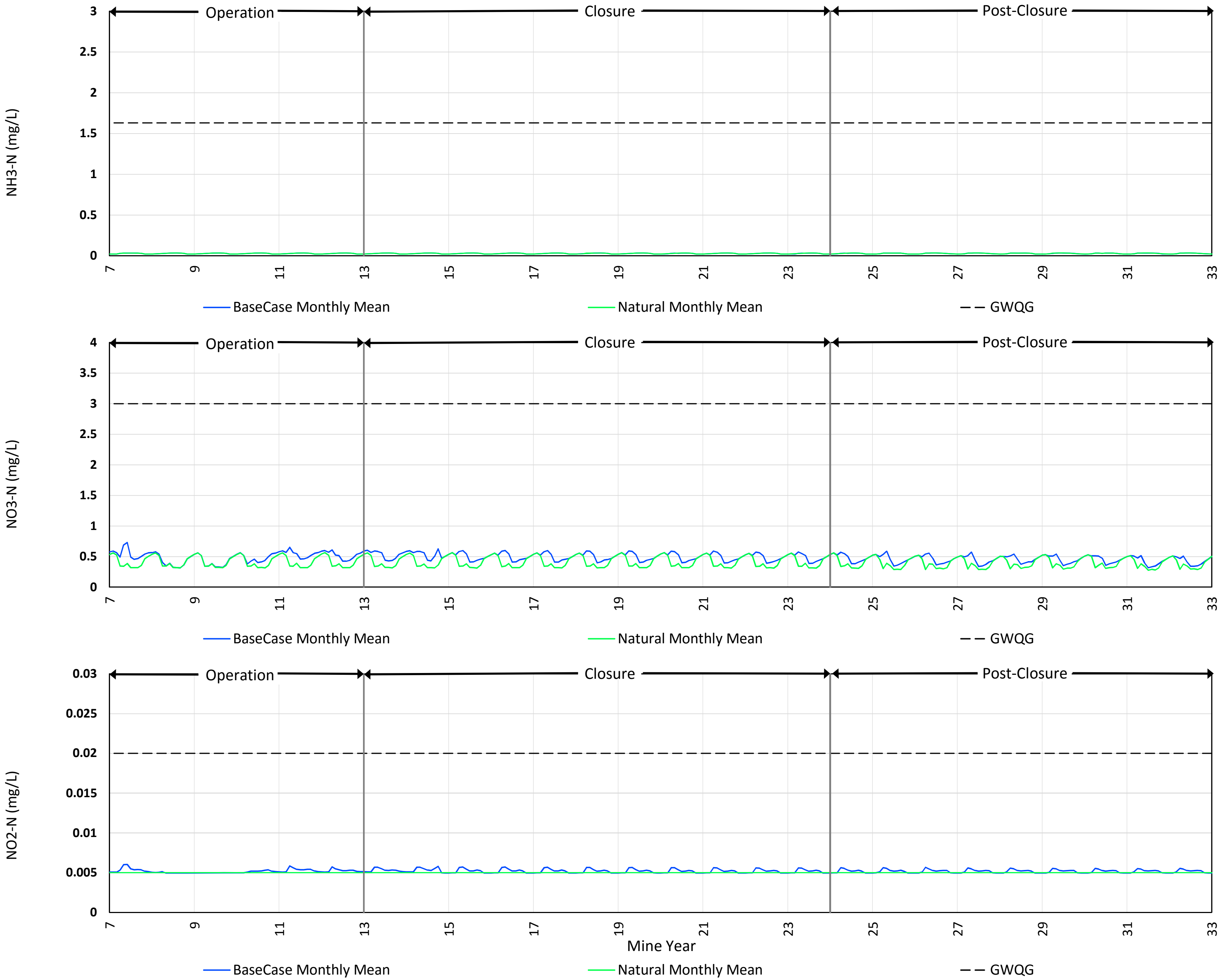
CC1.5



Operation
Closure
Post-Closure
T-Se (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
T-Tl (mg/L)
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
T-U (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
Mine Year
Reclamation
SSWQO

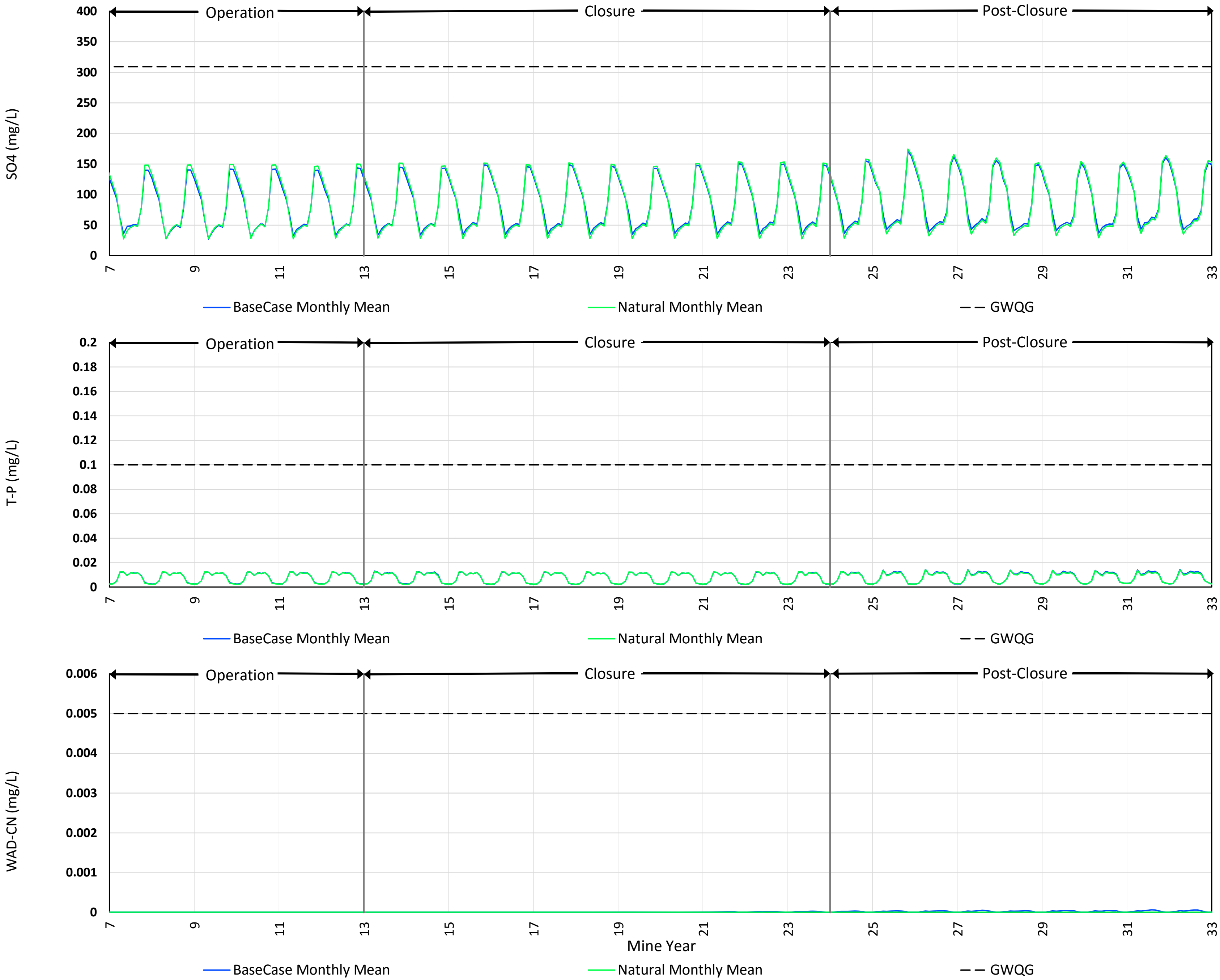

CC1.5
Operation
Closure
Post-Closure
T-Zn (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

CC3.5



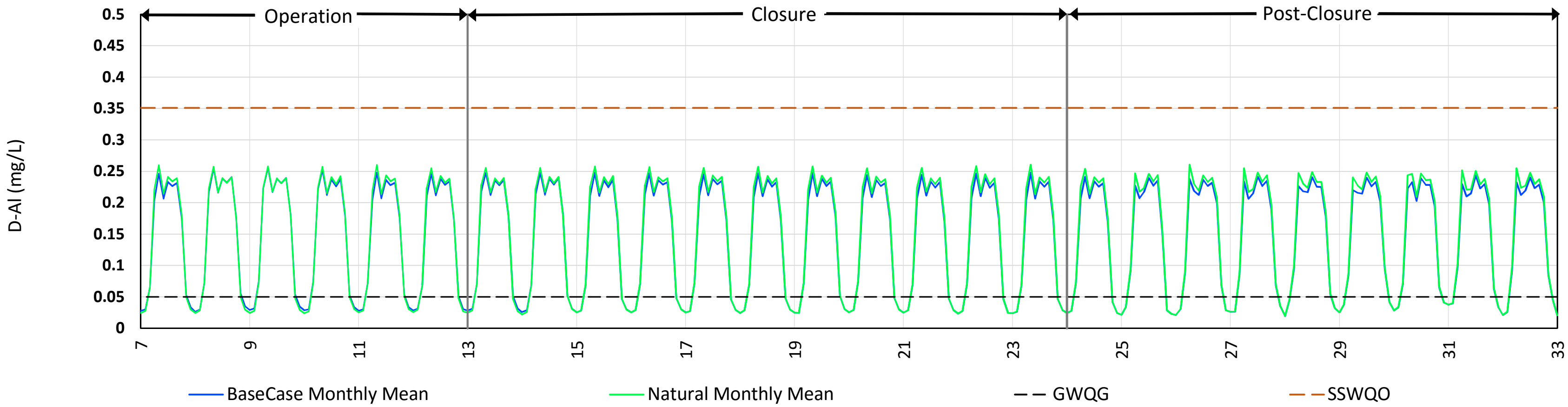
Operation
Closure
Post-Closure
NH3-N (mg/L)
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
NO3-N (mg/L)
NO2-N (mg/L)
Mine Year

CC3.5

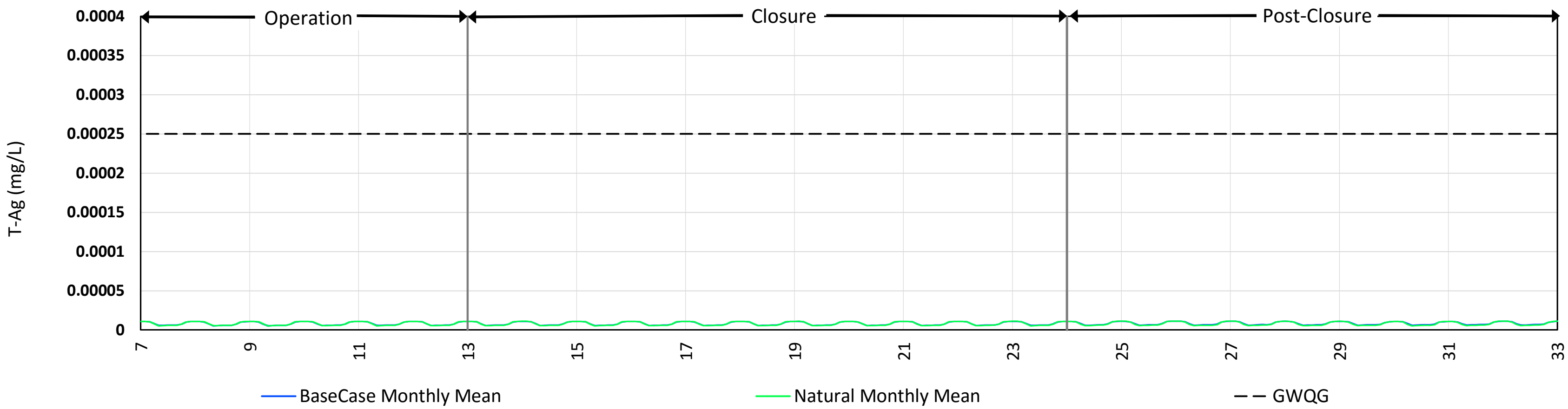


Operation
Closure
Post-Closure
SO4 (mg/L)
400
350
300
250
200
150
100
50
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
T-P (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
WAD-CN (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
Mine Year

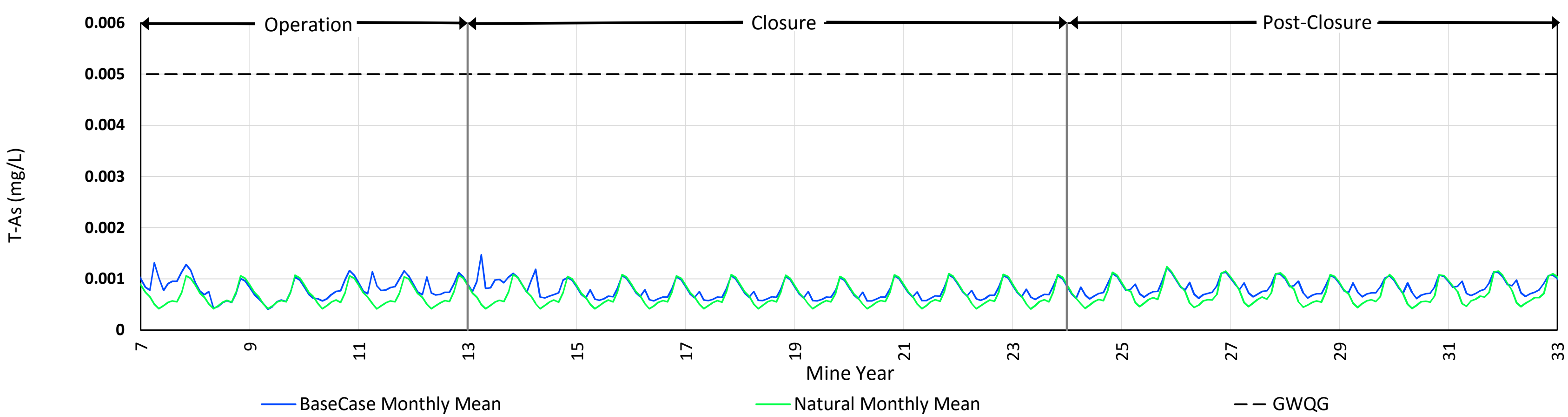
CC3.5



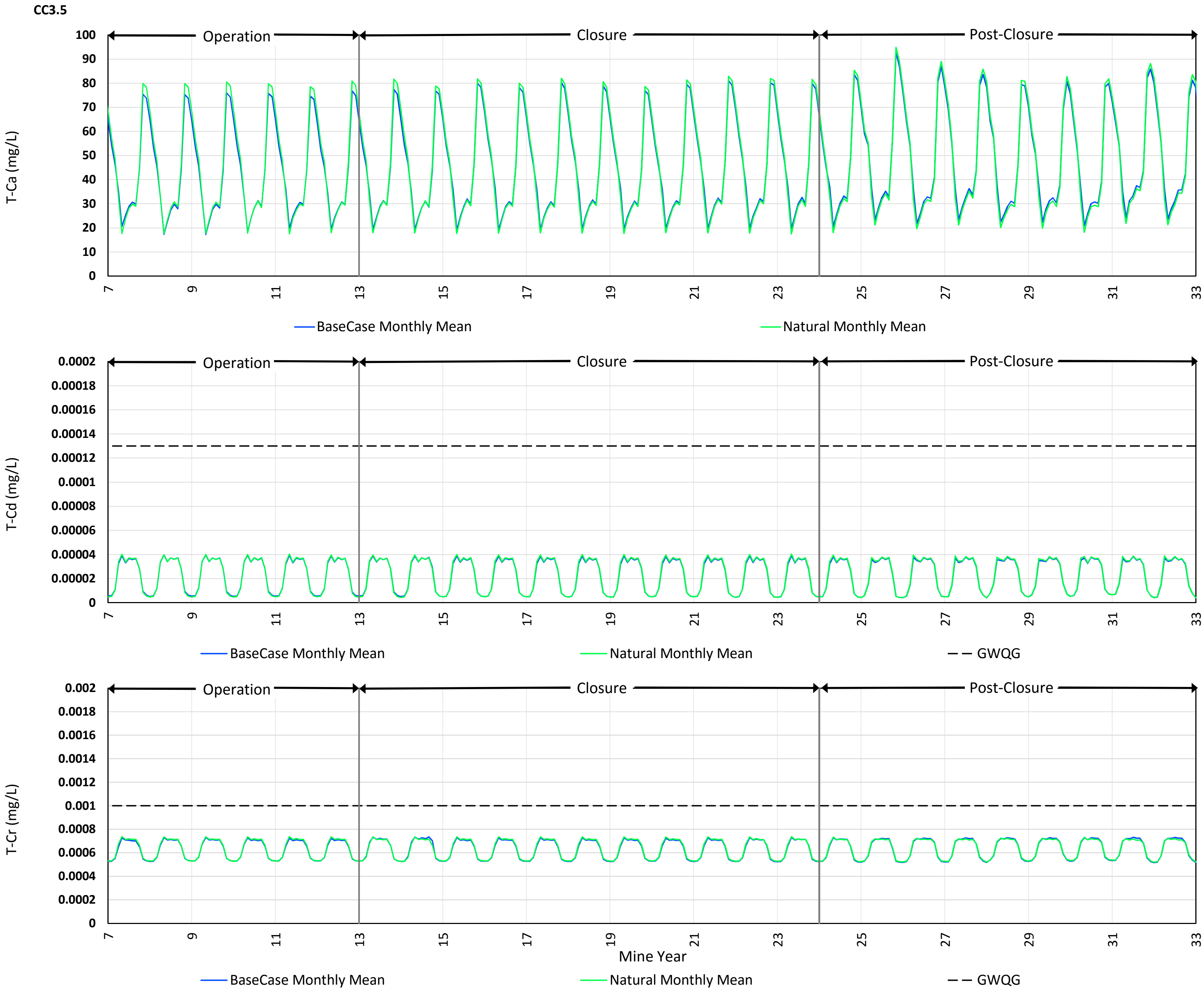
Operation
Closure
Post-Closure
D-Al (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
SSWQO



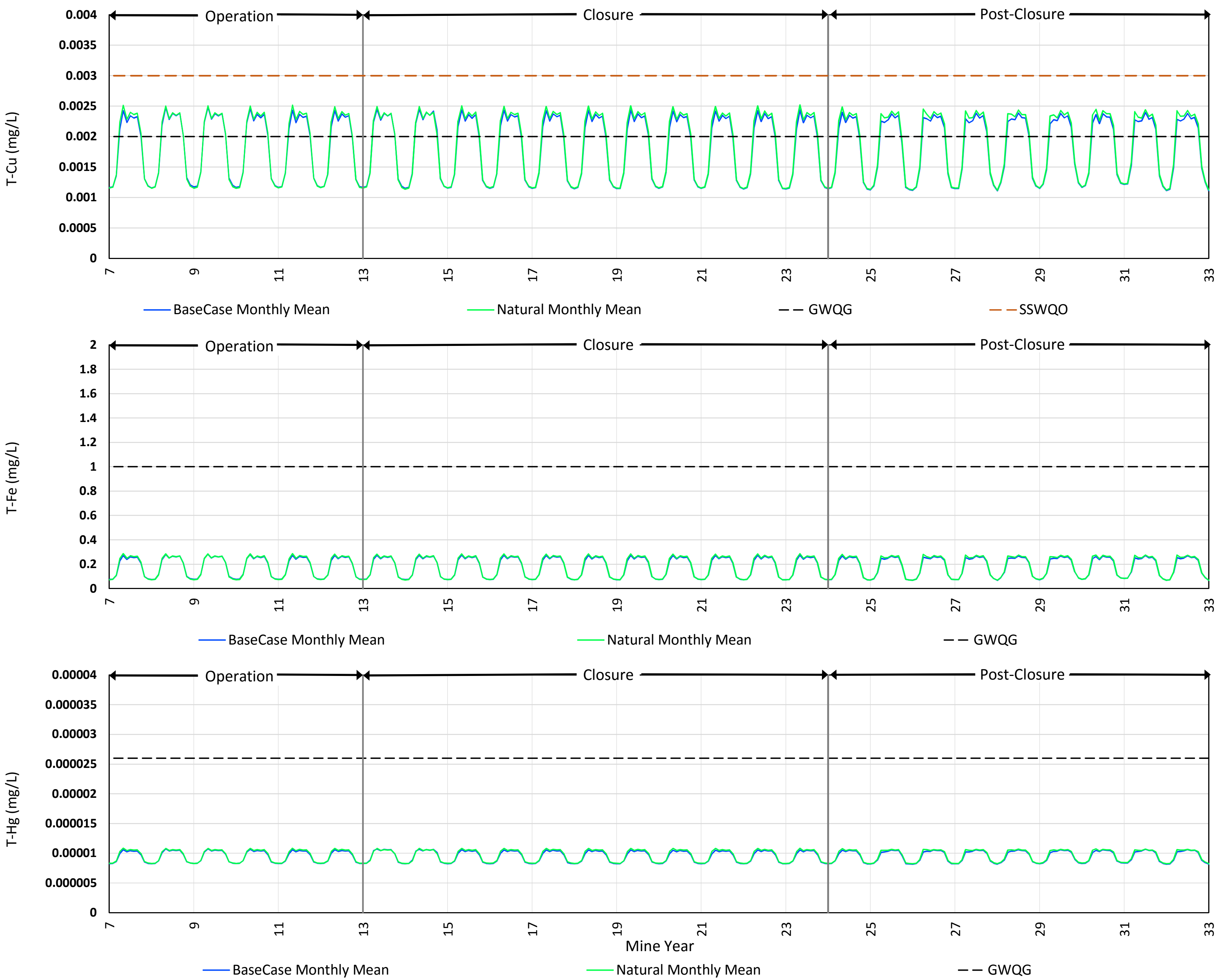
Operation
Closure
Post-Closure
T-Ag (mg/L)
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG



Operation
Closure
Post-Closure
T-As (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

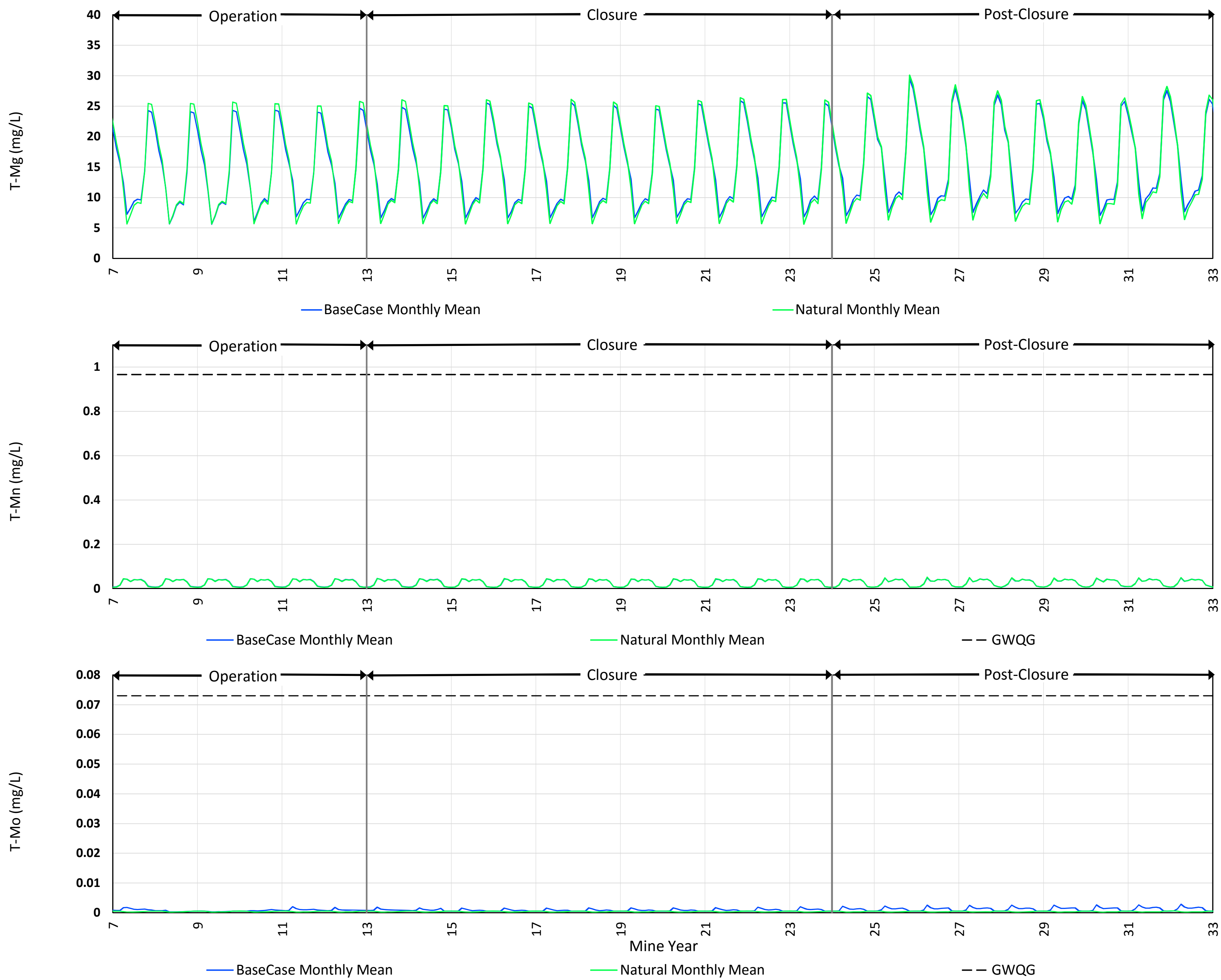

CC3.5
Operation
Closure
Post-Closure
T-Ca (mg/L)
BaseCase Monthly Mean
Natural Monthly Mean
T-Cd (mg/L)
GWQG
T-Cr (mg/L)
Mine Year

CC3.5



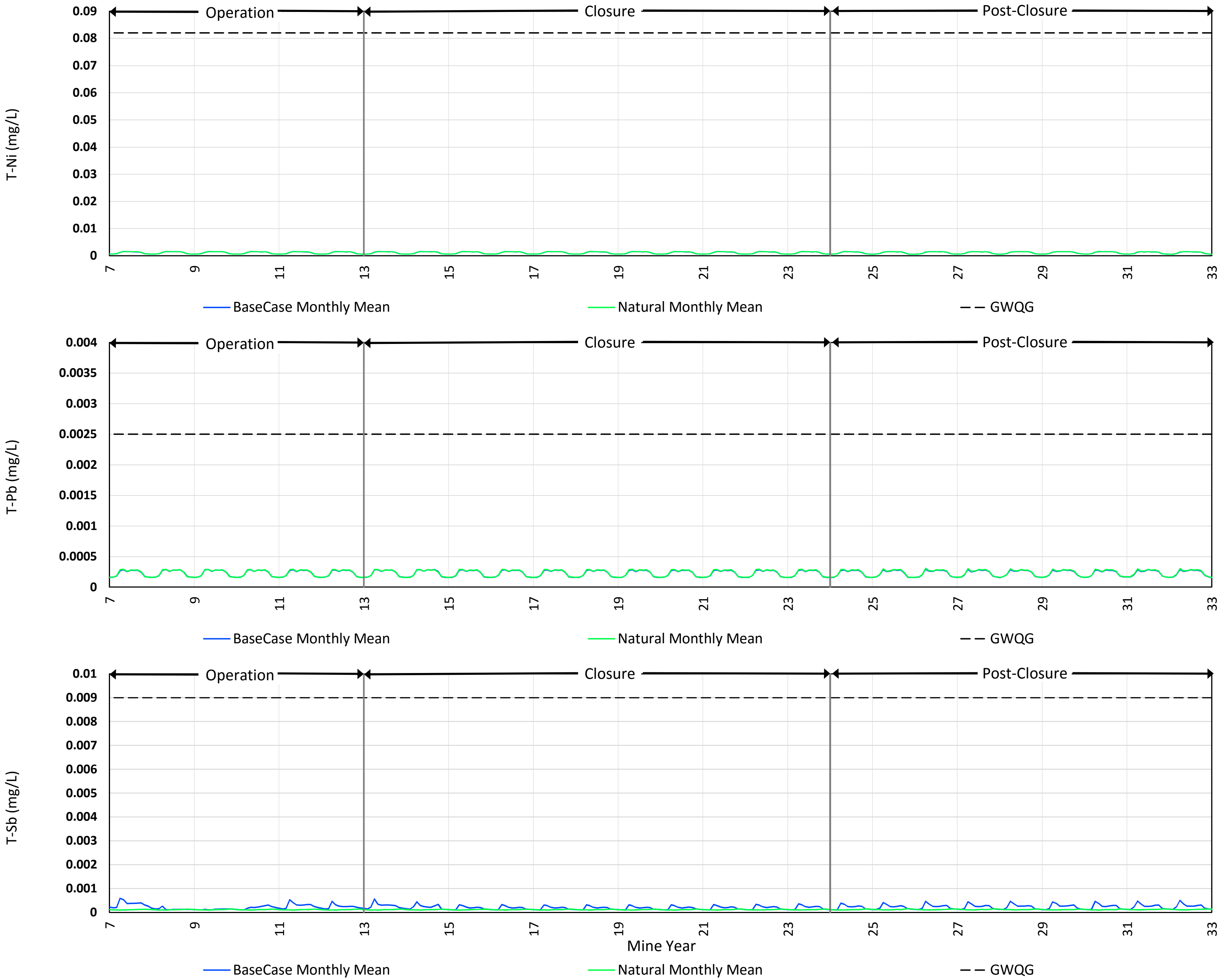
Operation
Closure
Post-Closure
T-Cu (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Fe (mg/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
T-Hg (mg/L)
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
Mine Year

CC3.5

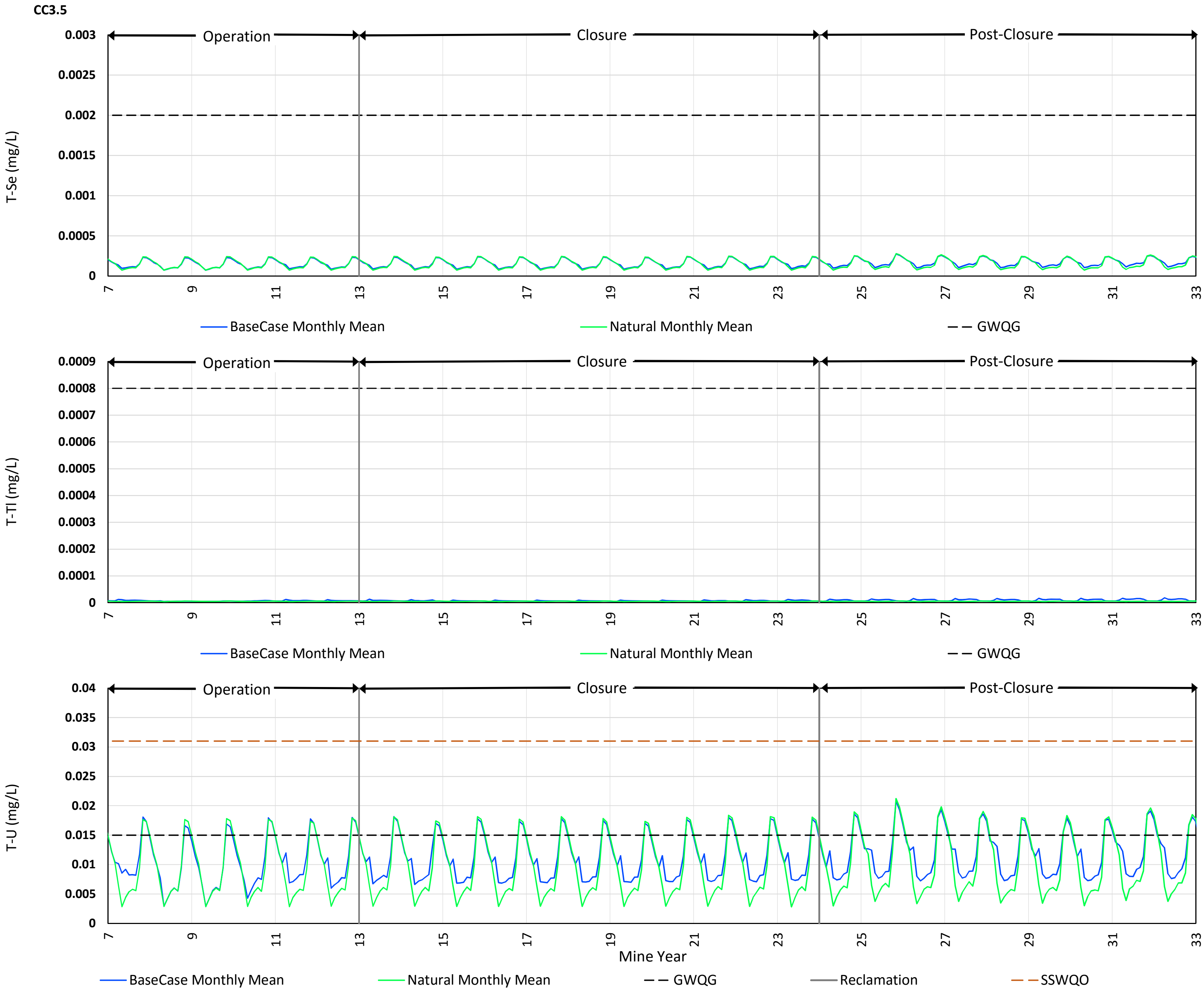


Operation
Closure
Post-Closure
T-Mg (mg/L)
BaseCase Monthly Mean
Natural Monthly Mean
T-Mn (mg/L)
GWQG
T-Mo (mg/L)
Mine Year

CC3.5

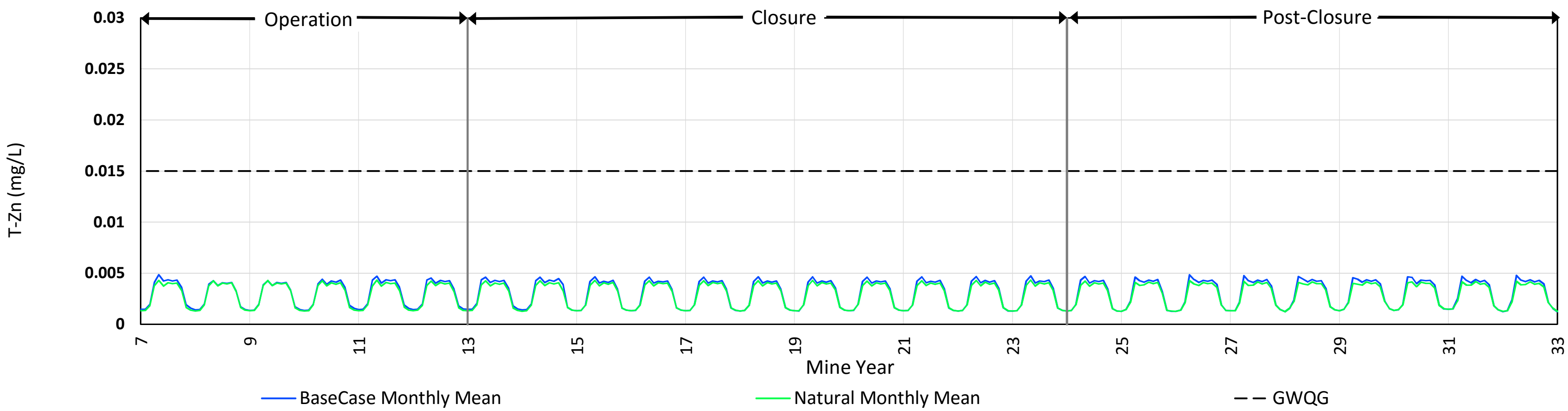


T-Ni (mg/L)
Operation
Closure
Post-Closure
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
T-Pb (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
T-Sb (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
Mine Year

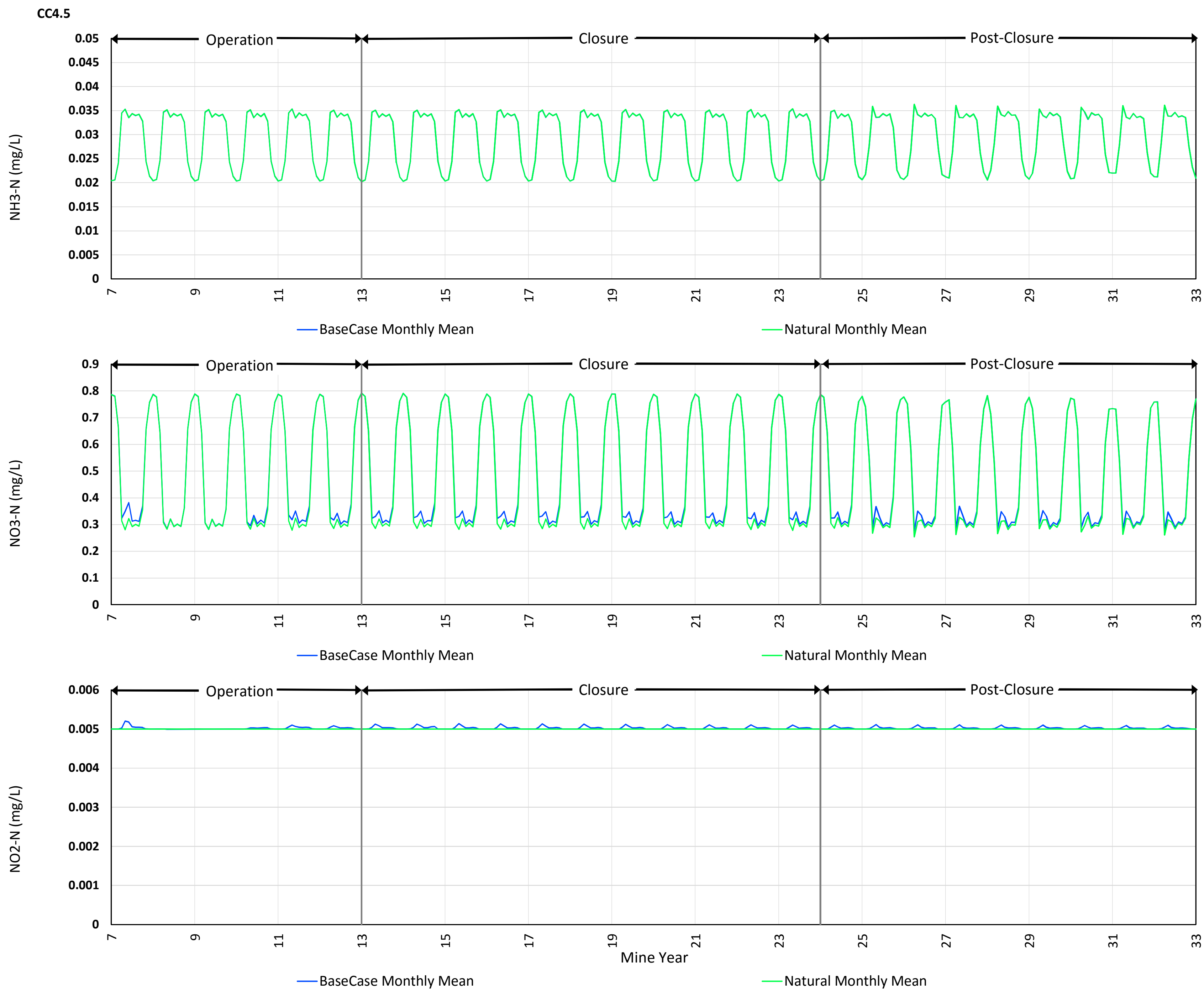


CC3.5
Operation
Closure
Post-Closure
T-Se (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
T-Tl (mg/L)
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
T-U (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Reclamation
SSWQO

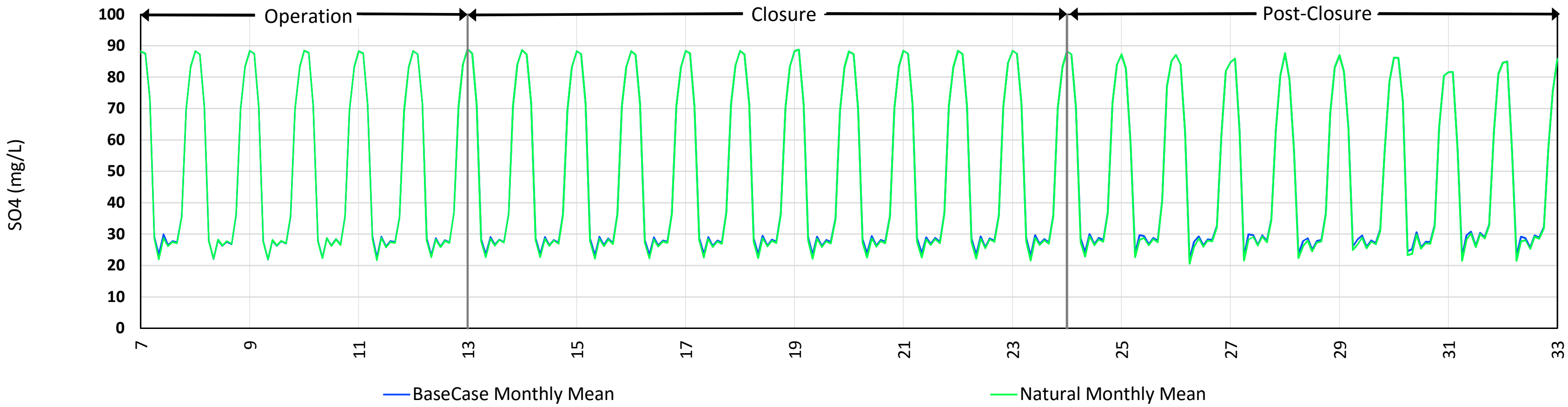
CC3.5



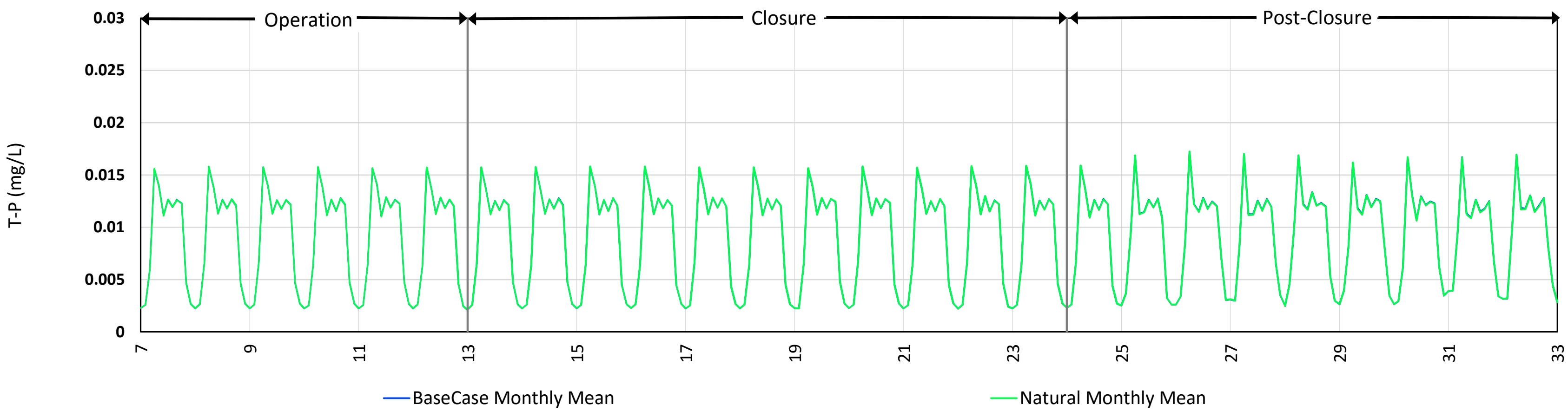
Operation
Closure
Post-Closure
0.03
0.025
0.02
0.015
0.01
0.005
0
T-Zn (mg/L)
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG


CC4.5
Operation
Closure
Post-Closure
NH3-N (mg/L)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
NO3-N (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
NO2-N (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
Mine Year

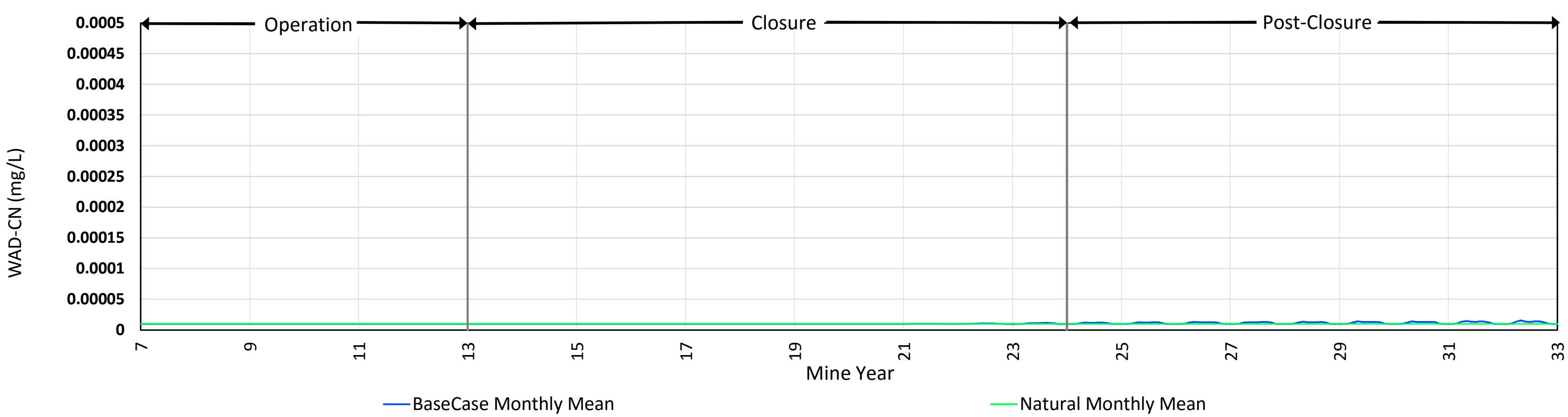
CC4.5



Operation
Closure
Post-Closure
SO4 (mg/L)
100
90
80
70
60
50
40
30
20
10
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean

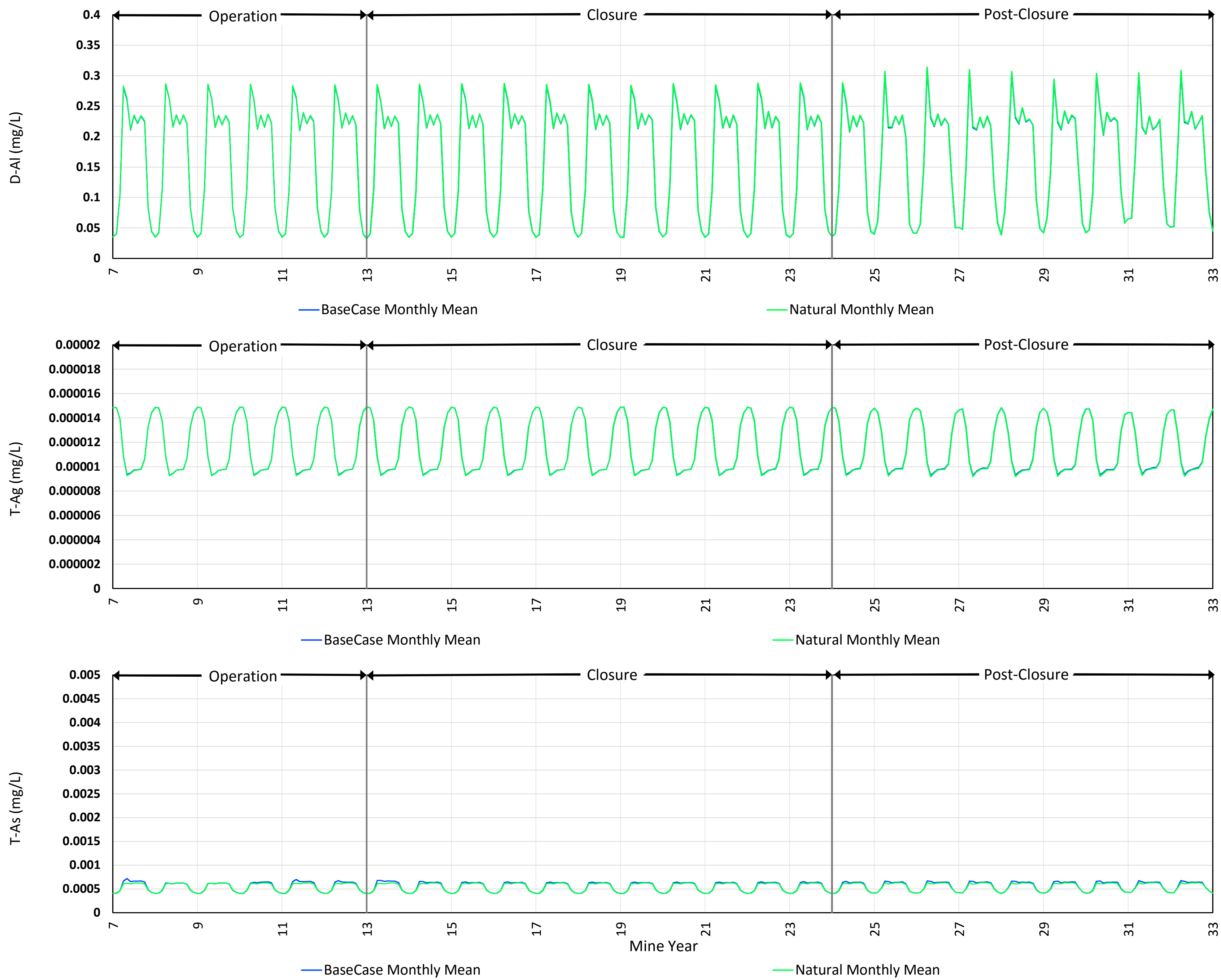


Operation
Closure
Post-Closure
T-P (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean

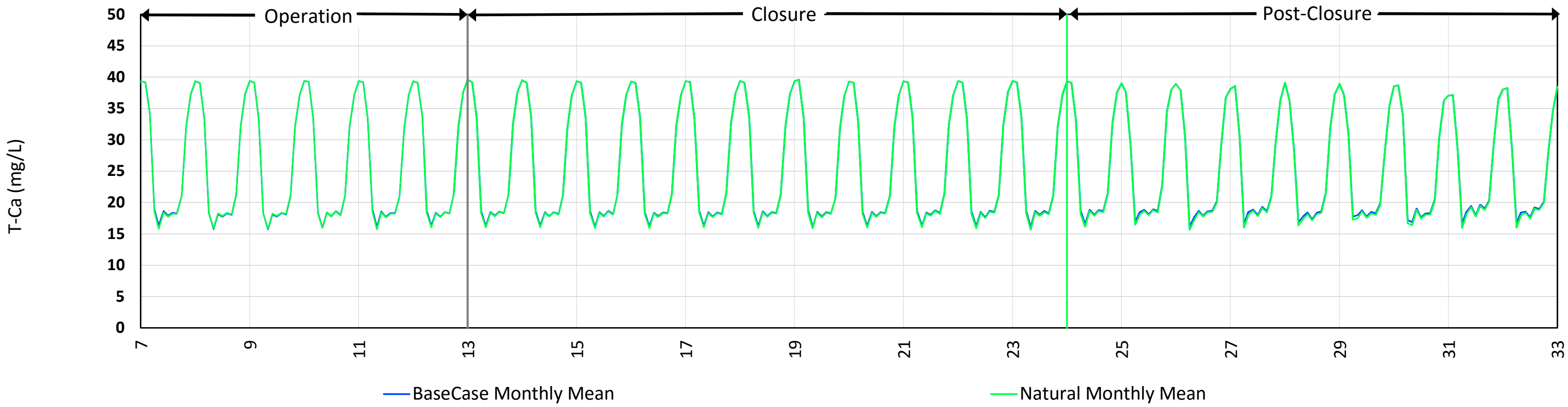


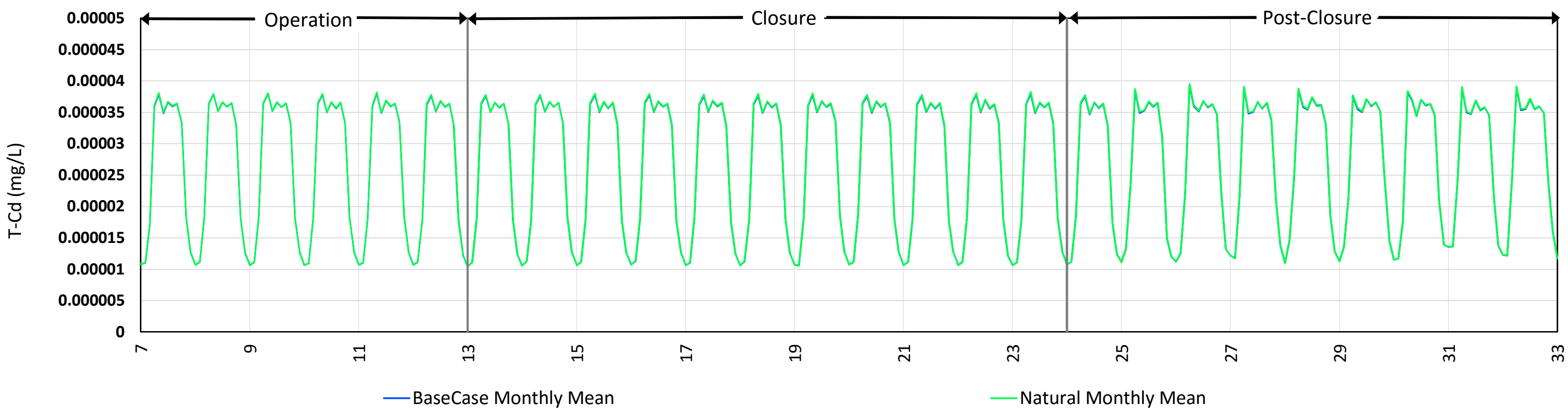
Operation
Closure
Post-Closure
WAD-CN (mg/L)
0.0005
0.00045
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

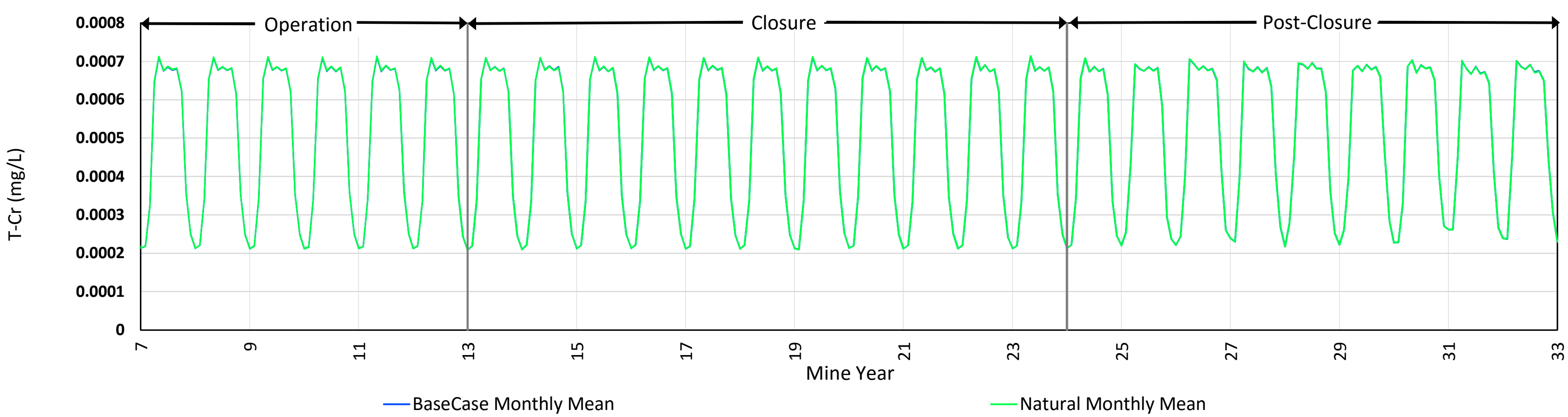
CC4.5

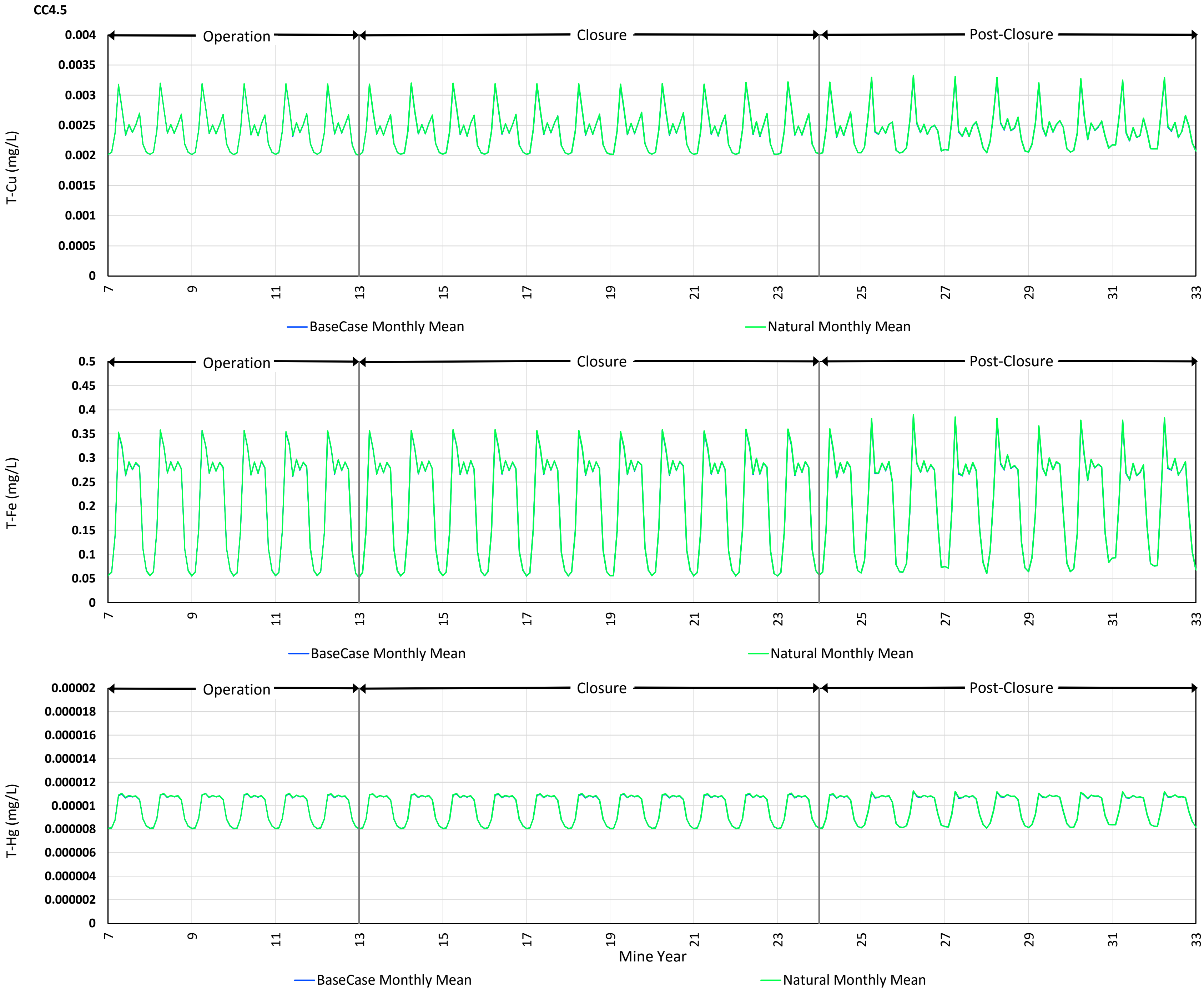

Operation
Closure
Post-Closure
D-Al (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Ag (mg/L)
0.00002
0.000018
0.000016
0.000014
0.000012
0.00001
0.000008
0.000006
0.000004
0.000002
T-As (mg/L)
0.005
0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
Mine Year

CC4.5


Operation
Closure
Post-Closure
T-Ca (mg/L)
50
45
40
35
30
25
20
15
10
5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean

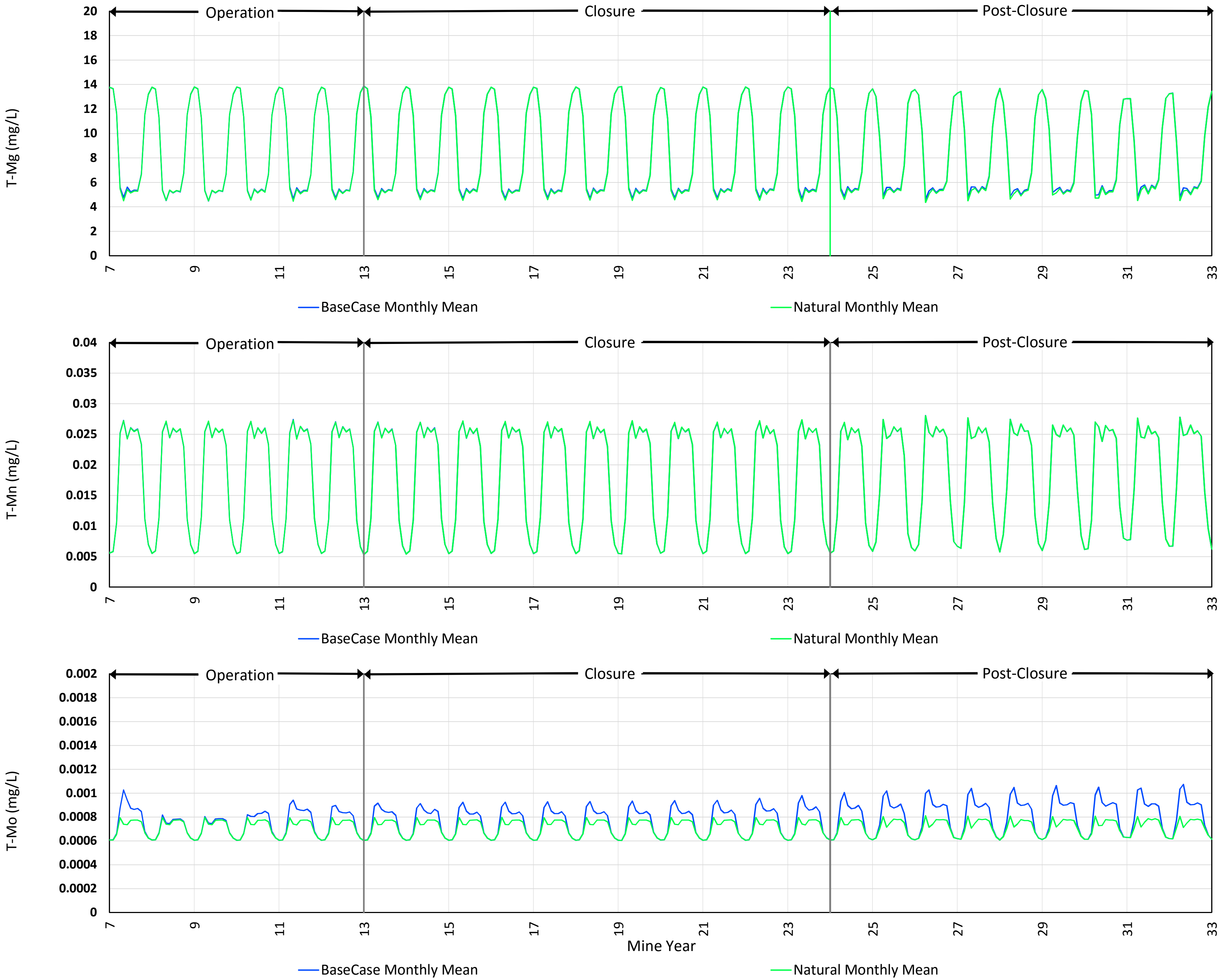

Operation
Closure
Post-Closure
T-Cd (mg/L)
0.00005
0.000045
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean


Operation
Closure
Post-Closure
T-Cr (mg/L)
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean



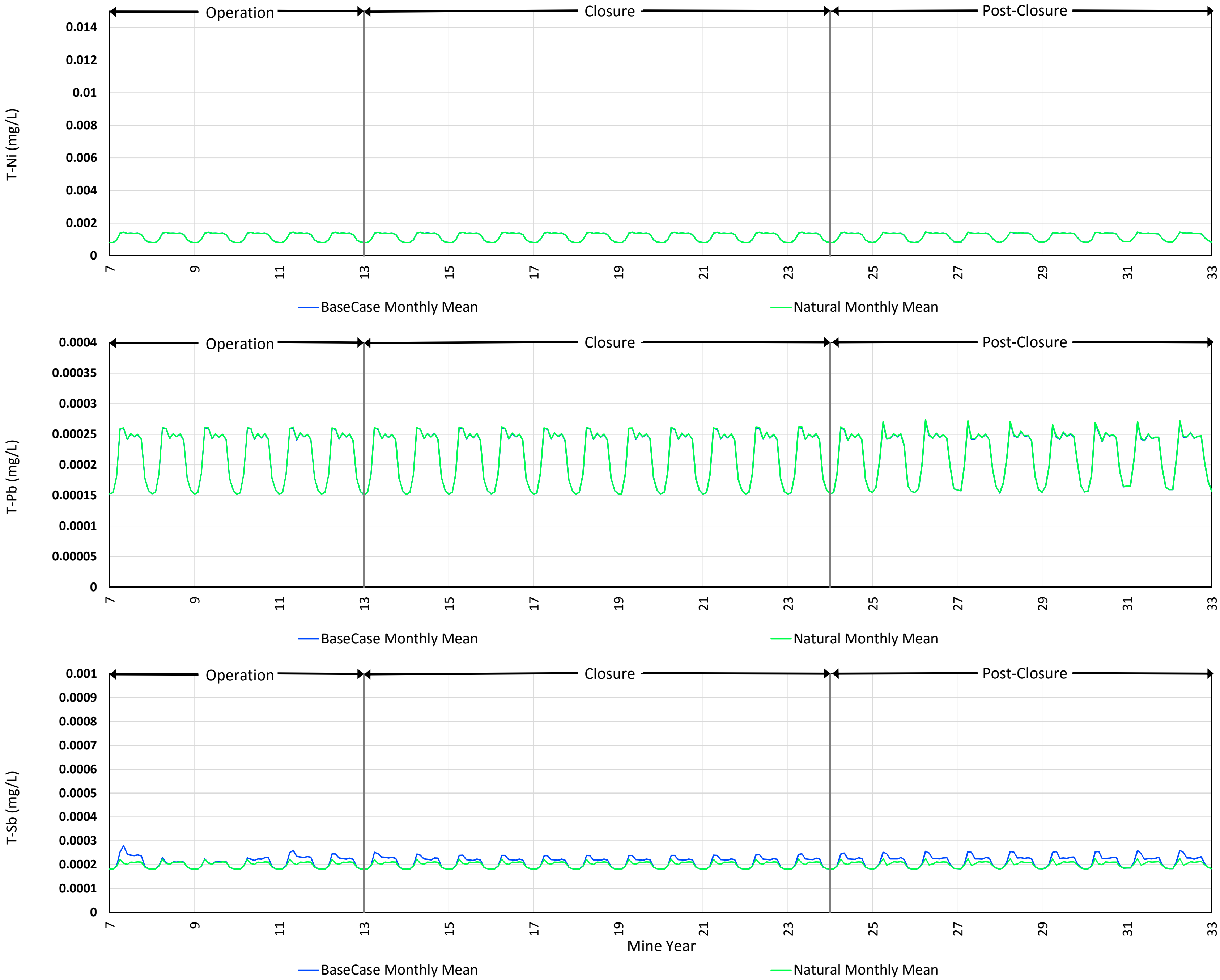
CC4.5
Operation
Closure
Post-Closure
T-Cu (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7 9 11 13 15 17 19 21 23 25 27 29 31 33
BaseCase Monthly Mean
Natural Monthly Mean
T-Fe (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
T-Hg (mg/L)
0.00002
0.000018
0.000016
0.000014
0.000012
0.00001
0.000008
0.000006
0.000004
0.000002
0
Mine Year

CC4.5



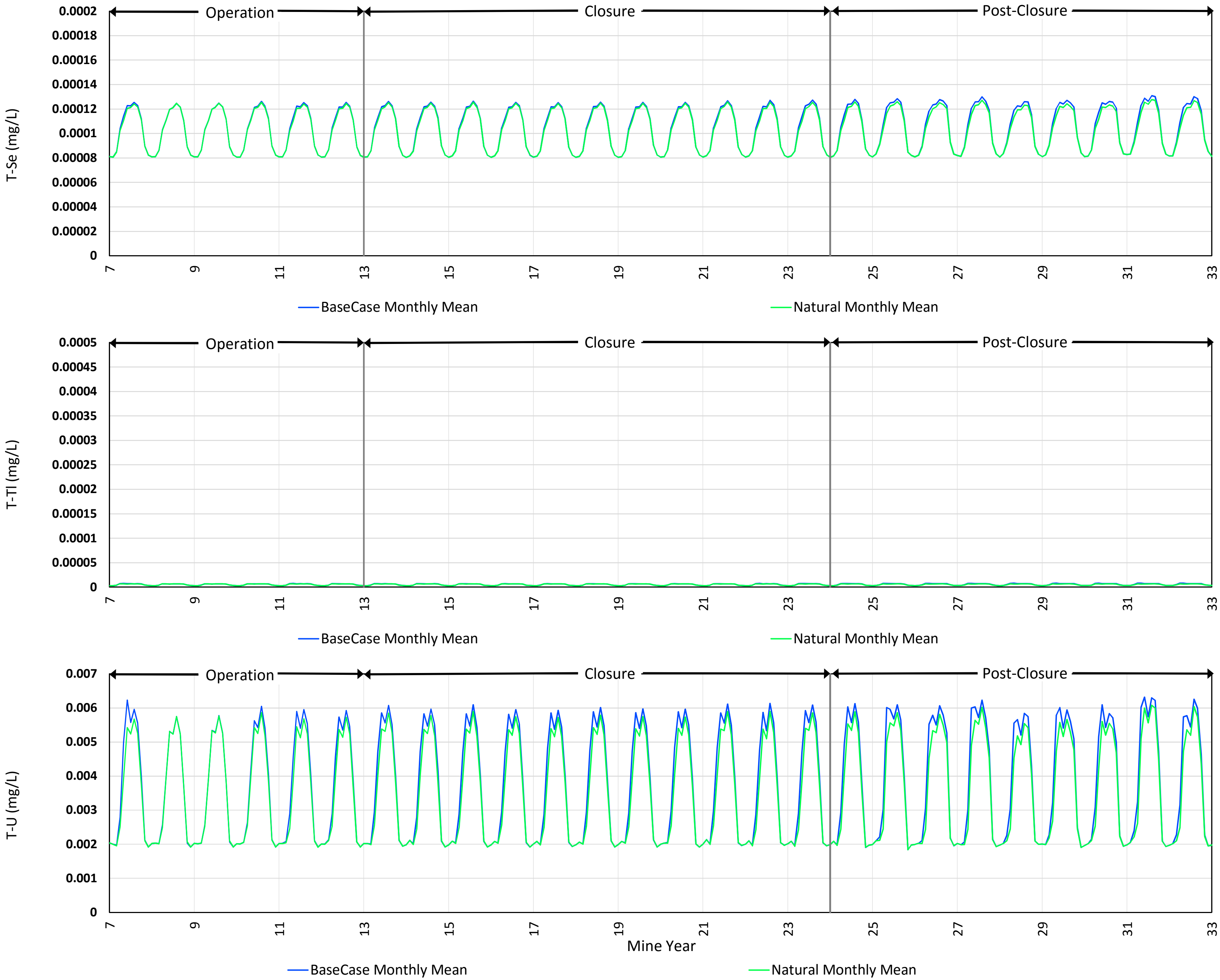
Operation
Closure
Post-Closure
T-Mg (mg/L)
20
18
16
14
12
10
8
6
4
2
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Mn (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
T-Mo (mg/L)
0.002
0.0018
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
Mine Year

CC4.5

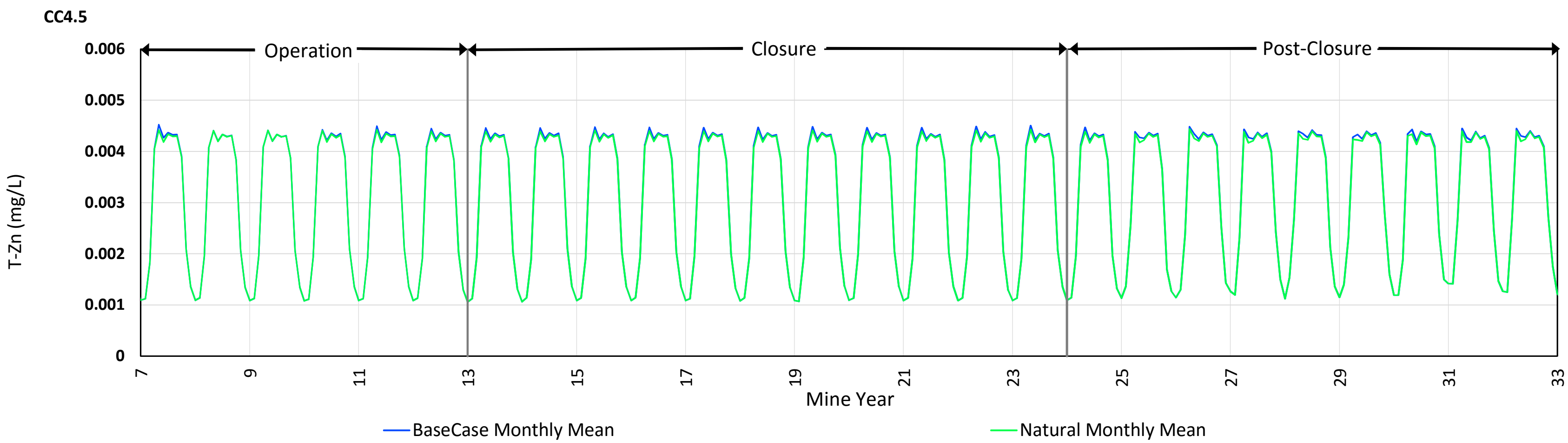


Operation
Closure
Post-Closure
T-Ni (mg/L)
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Pb (mg/L)
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
T-Sb (mg/L)
0.001
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
Mine Year

CC4.5

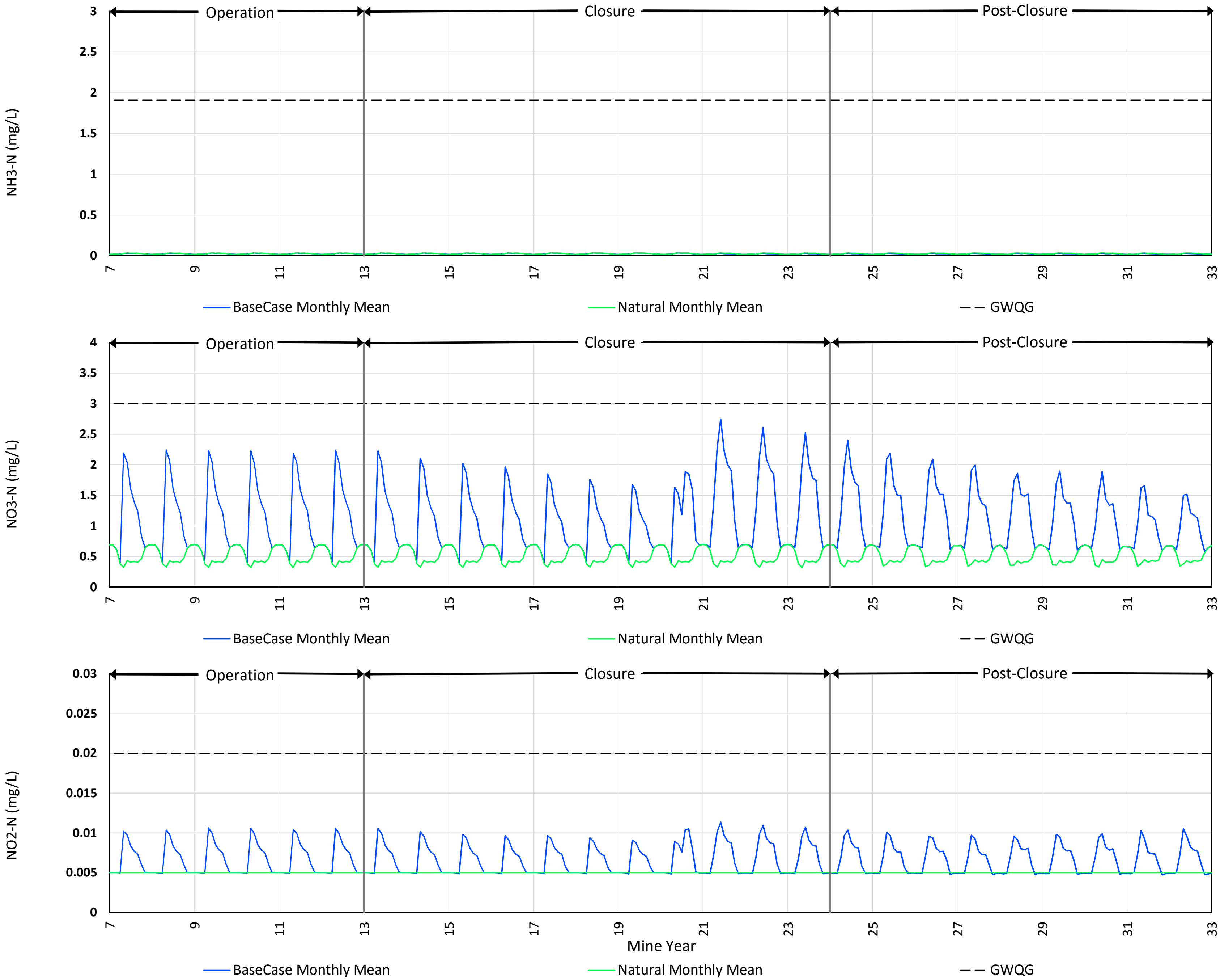


Operation
Closure
Post-Closure
T-Se (mg/L)
0.0002
0.00018
0.00016
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Tl (mg/L)
0.0005
0.00045
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
T-U (mg/L)
0.007
0.006
0.005
0.004
0.003
0.002
0.001
Mine Year



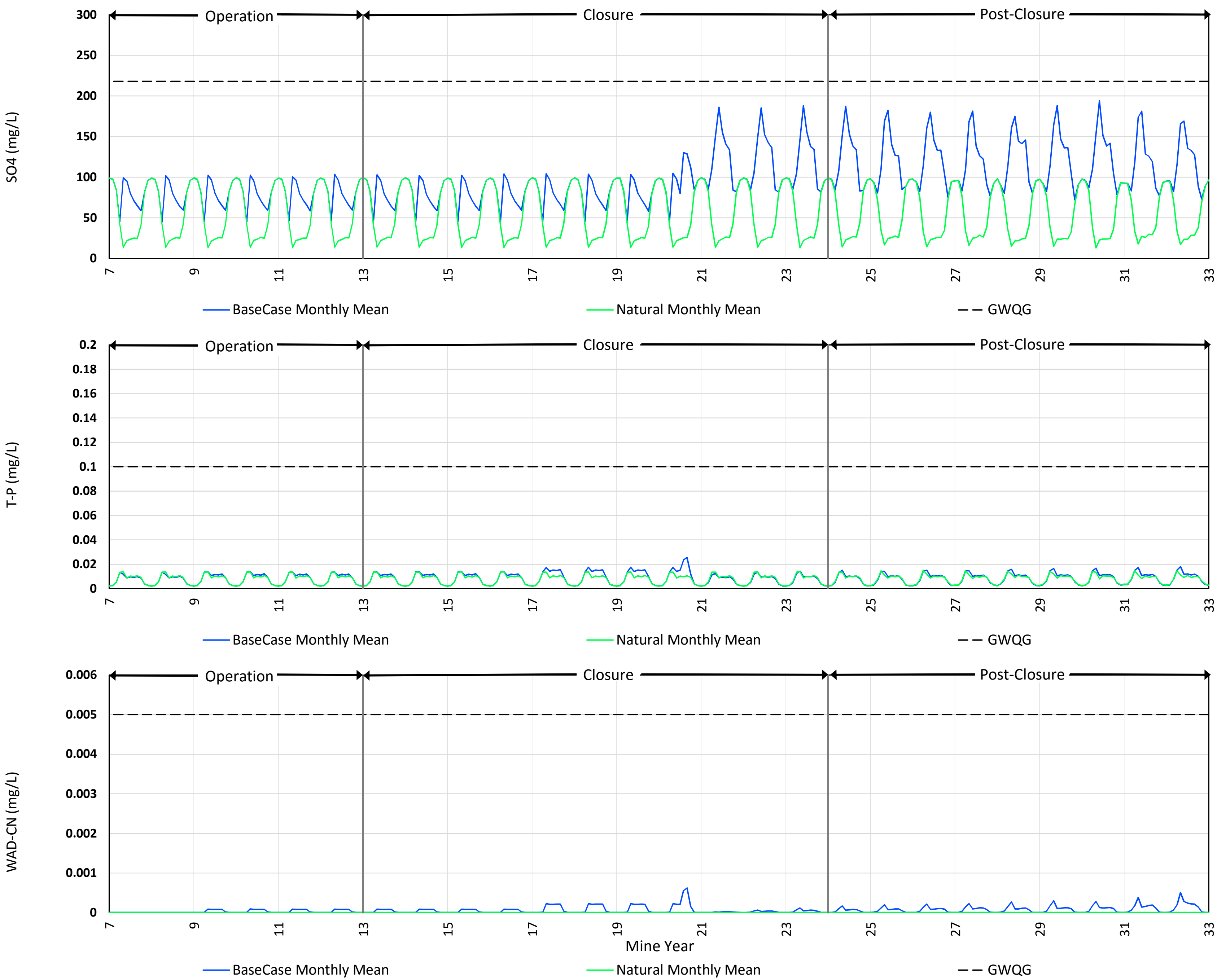
CC4.5
Operation
Closure
Post-Closure
0.006
0.005
0.004
0.003
0.002
0.001
0
T-Zn (mg/L)
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

HC2.5

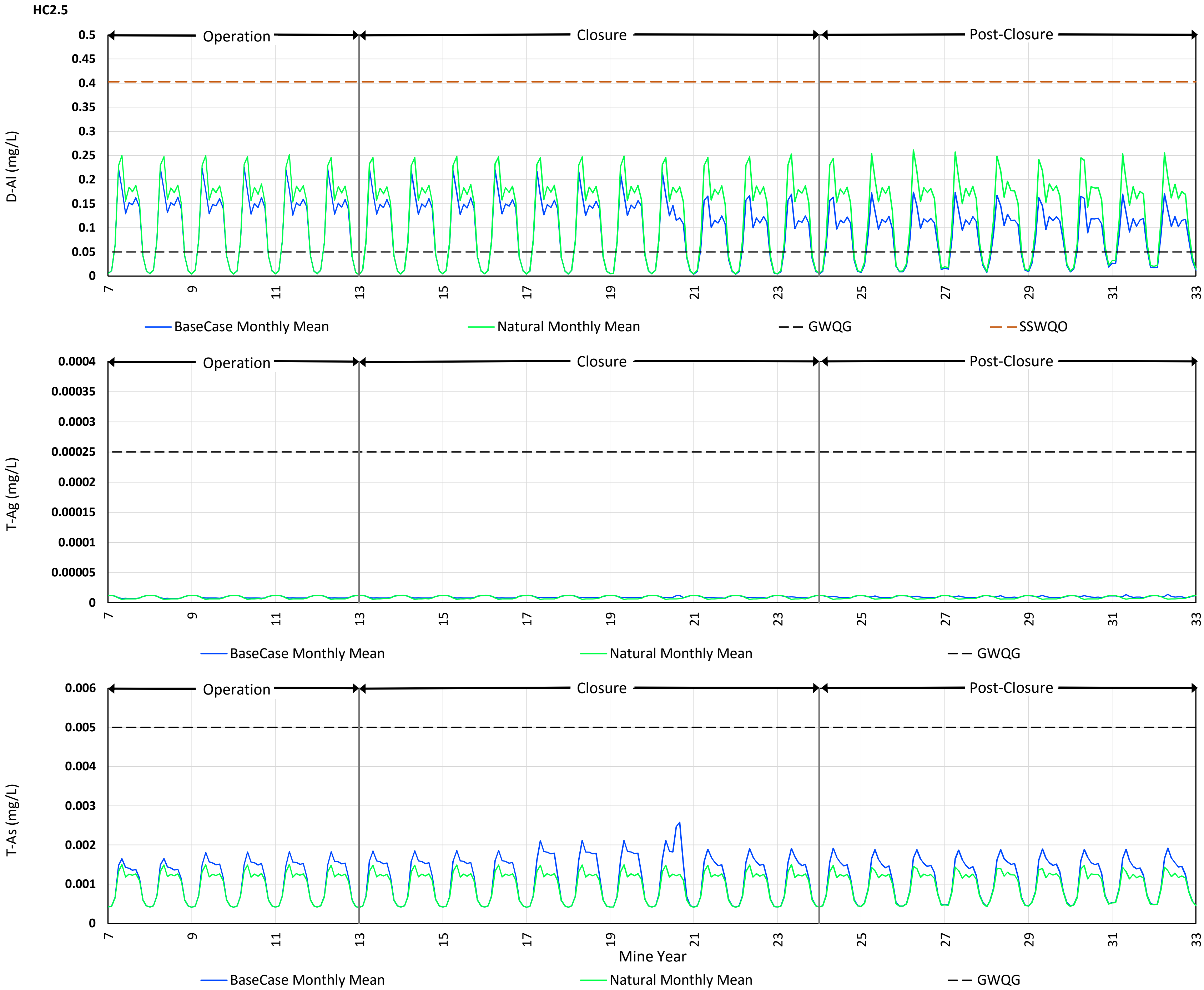


Operation
Closure
Post-Closure
NH3-N (mg/L)
0
0.5
1
1.5
2
2.5
3
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
NO3-N (mg/L)
0
0.5
1
1.5
2
2.5
3
3.5
4
NO2-N (mg/L)
0
0.005
0.01
0.015
0.02
0.025
0.03
Mine Year

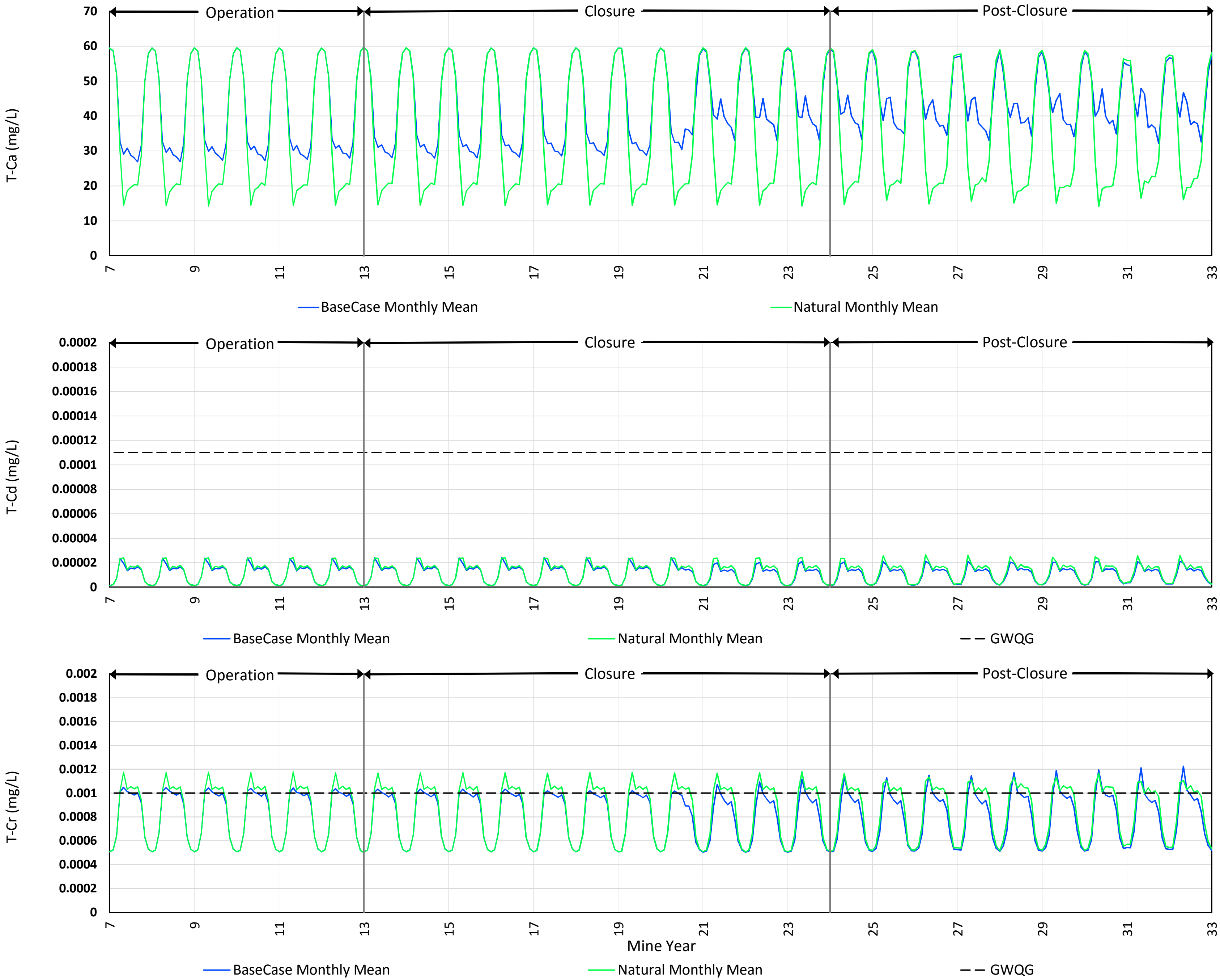
HC2.5



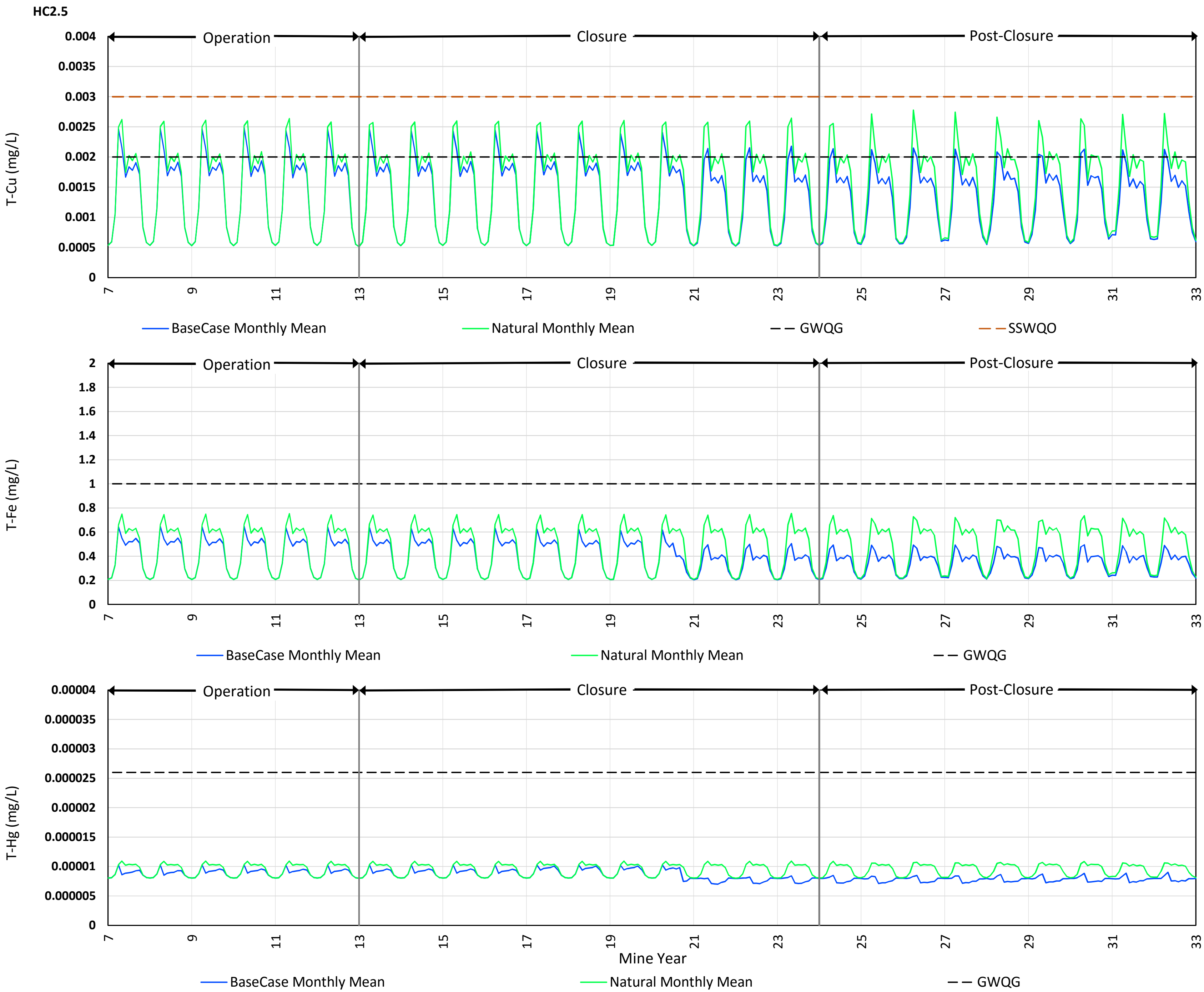
Operation
Closure
Post-Closure
SO4 (mg/L)
300
250
200
150
100
50
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
T-P (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
WAD-CN (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
Mine Year


HC2.5
Operation
Closure
Post-Closure
D-Al (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Ag (mg/L)
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
T-As (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
Mine Year

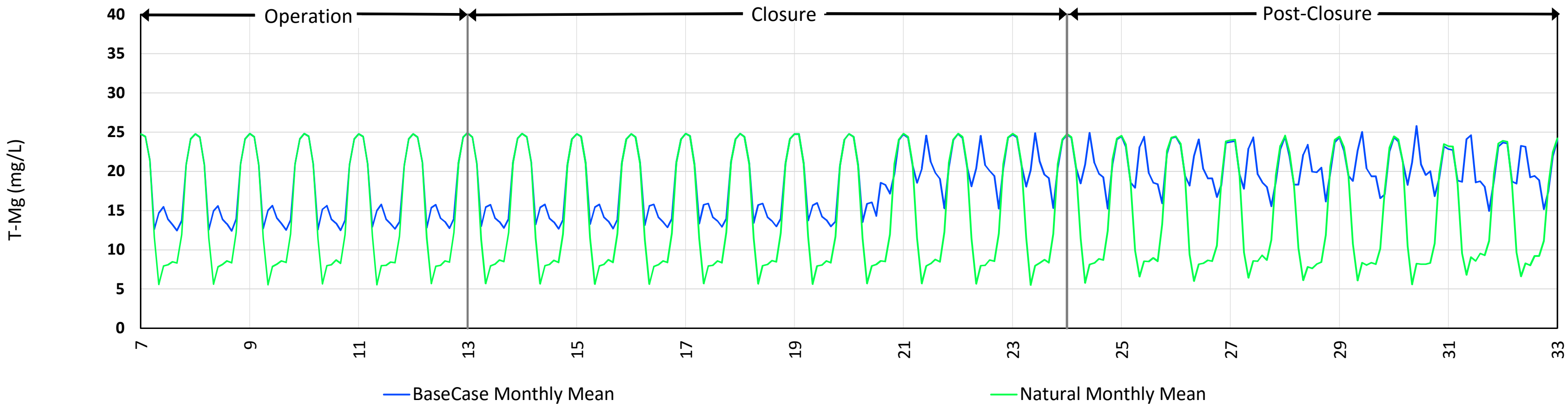
HC2.5

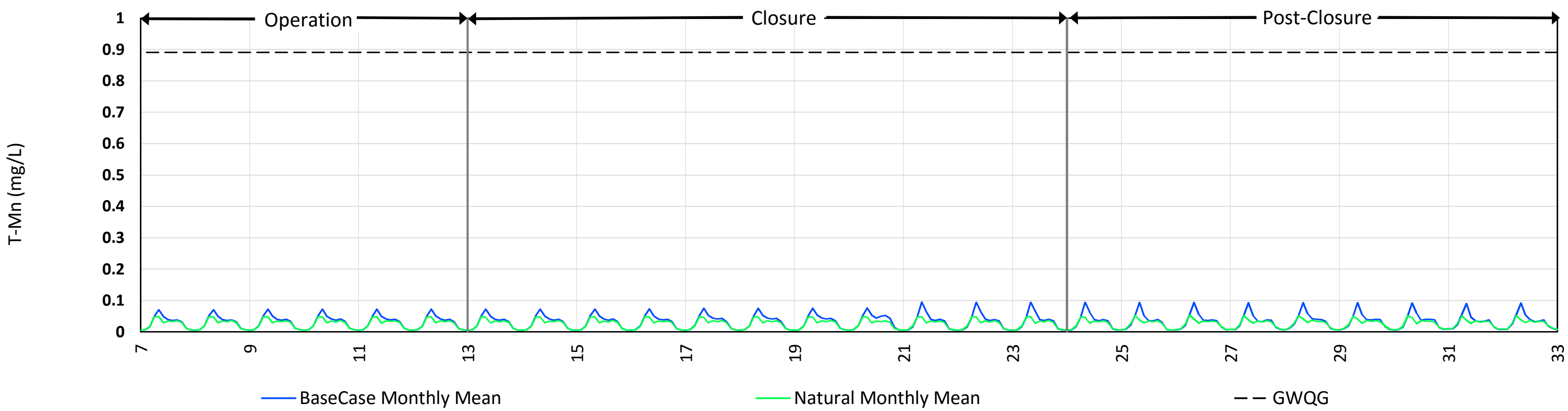


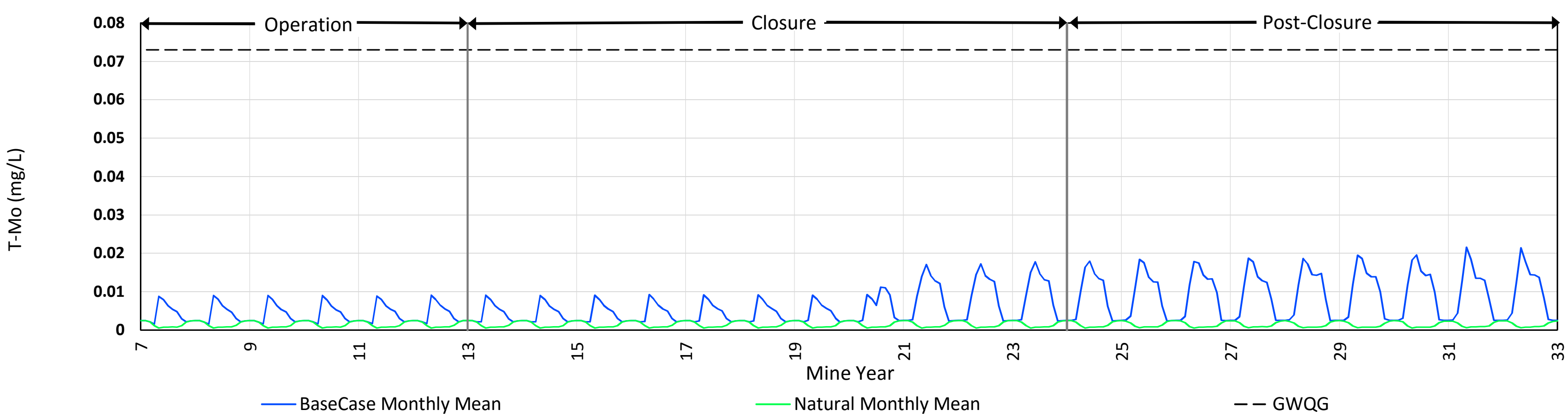
Operation
Closure
Post-Closure
T-Ca (mg/L)
0
10
20
30
40
50
60
70
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
Operation
Closure
Post-Closure
T-Cd (mg/L)
0
0.00002
0.00004
0.00006
0.00008
0.0001
0.00012
0.00014
0.00016
0.00018
0.0002
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
T-Cr (mg/L)
0
0.0002
0.0004
0.0006
0.0008
0.001
0.0012
0.0014
0.0016
0.0018
0.002
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG


HC2.5
Operation
Closure
Post-Closure
T-Cu (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Fe (mg/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
T-Hg (mg/L)
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
0
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

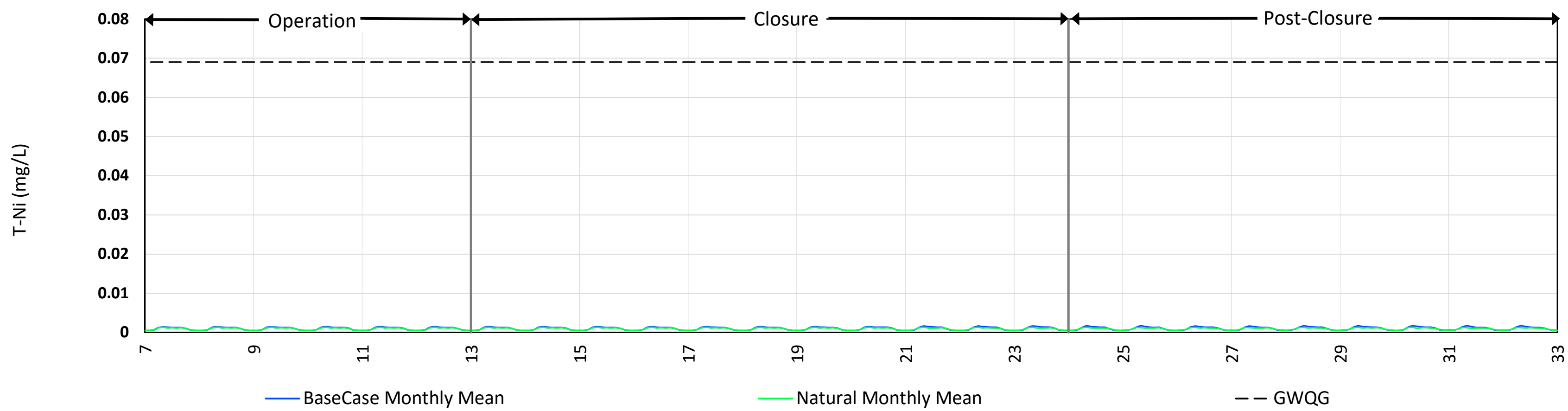
HC2.5

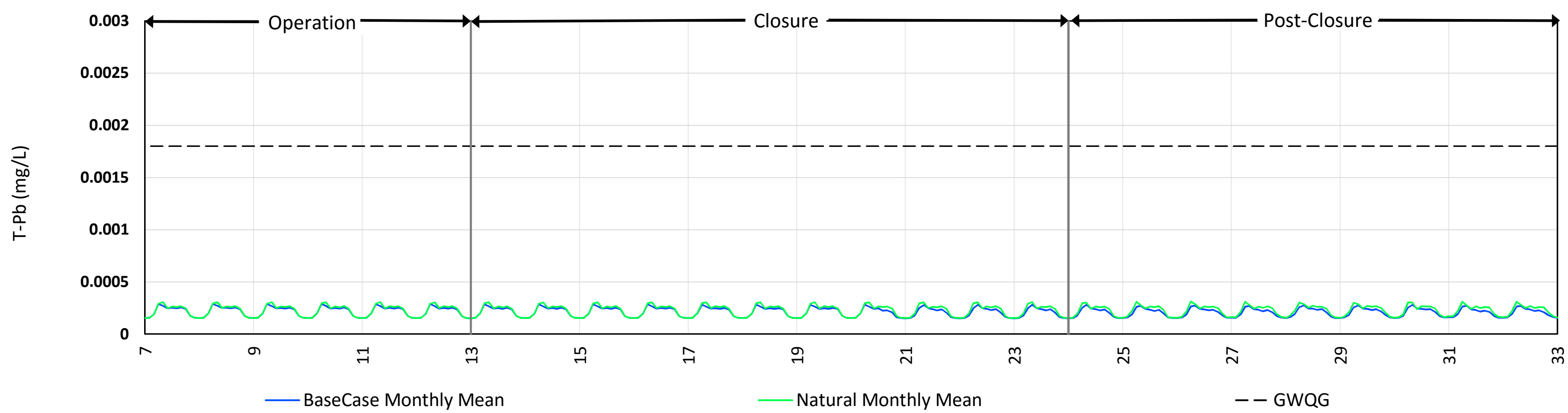

Operation
Closure
Post-Closure
T-Mg (mg/L)
40
35
30
25
20
15
10
5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean

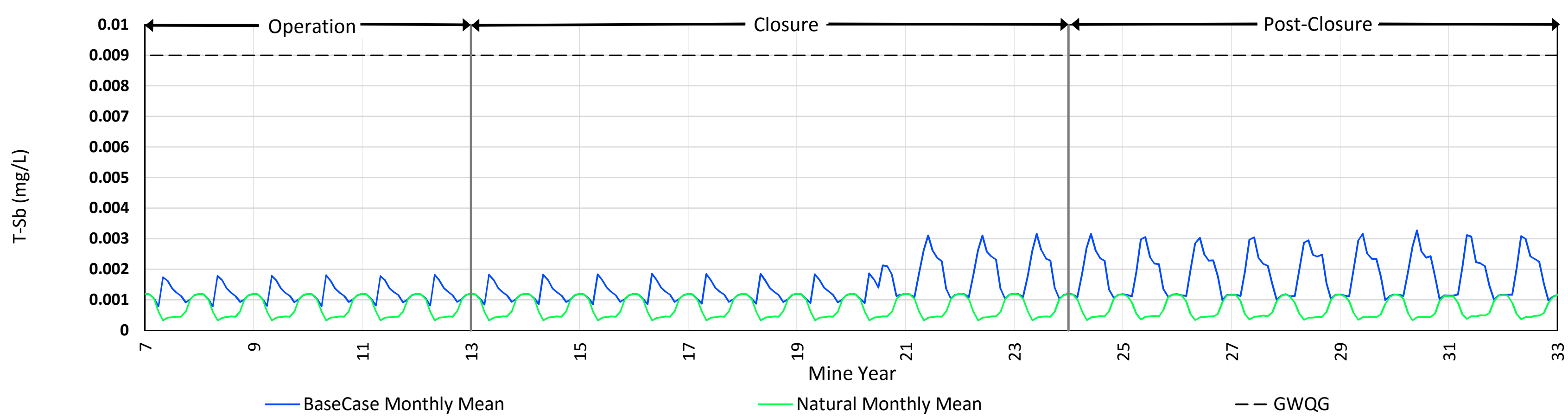

Operation
Closure
Post-Closure
T-Mn (mg/L)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG


Operation
Closure
Post-Closure
T-Mo (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

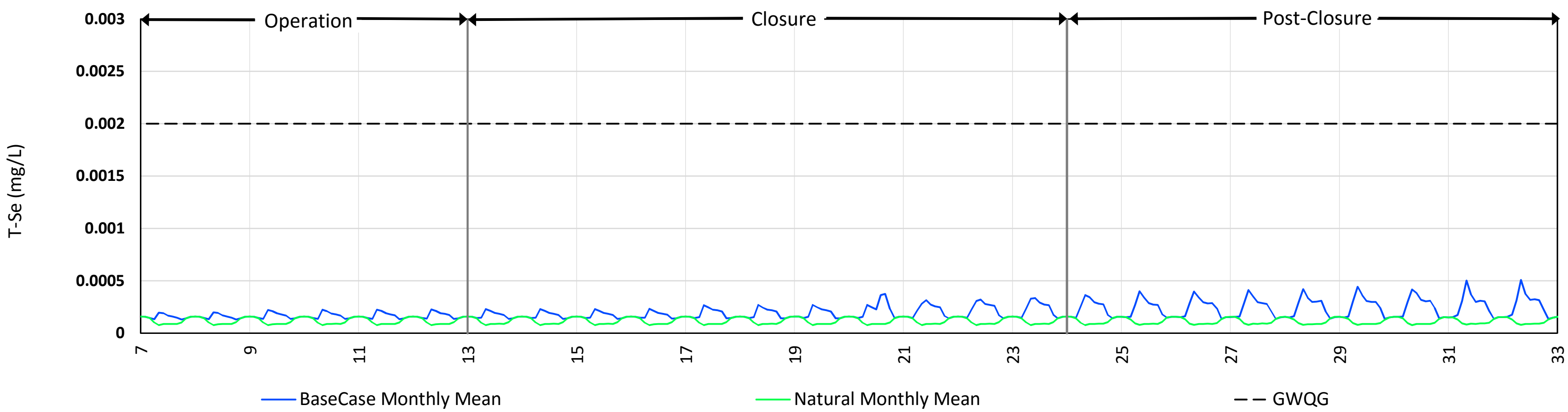
HC2.5


Operation
Closure
Post-Closure
T-Ni (mg/L)
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

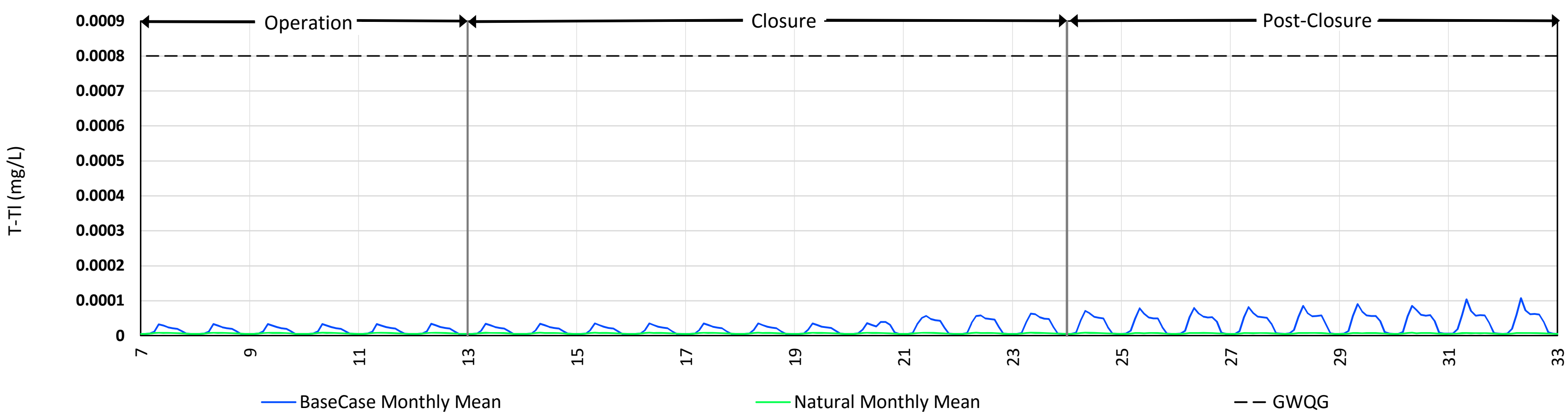

Operation
Closure
Post-Closure
T-Pb (mg/L)
BaseCase Monthly Mean
Natural Monthly Mean
GWQG


Operation
Closure
Post-Closure
T-Sb (mg/L)
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

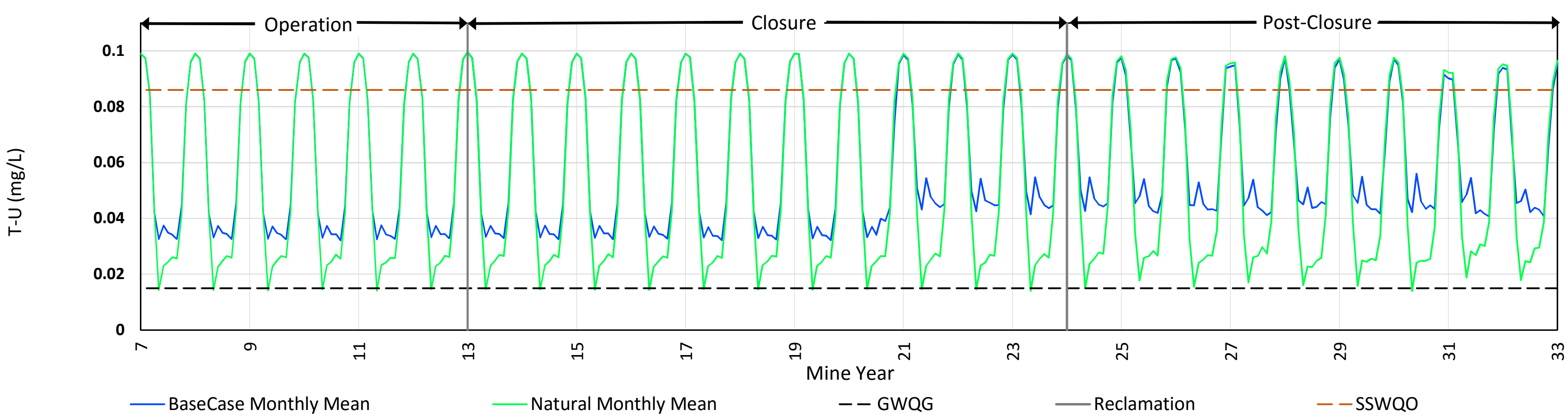
HC2.5



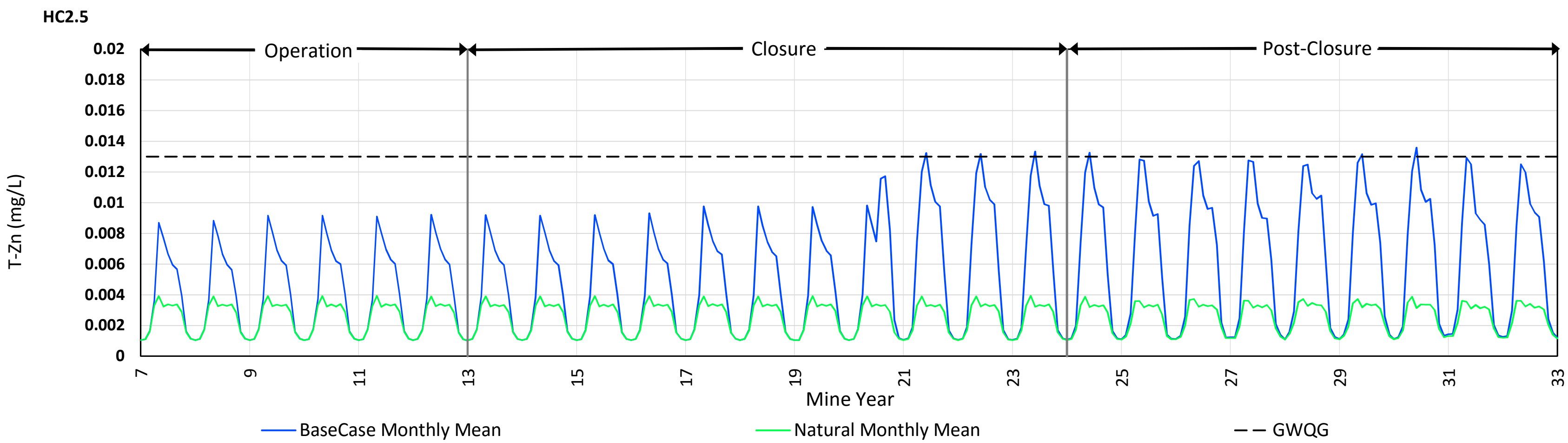
Operation
Closure
Post-Closure
T-Se (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG



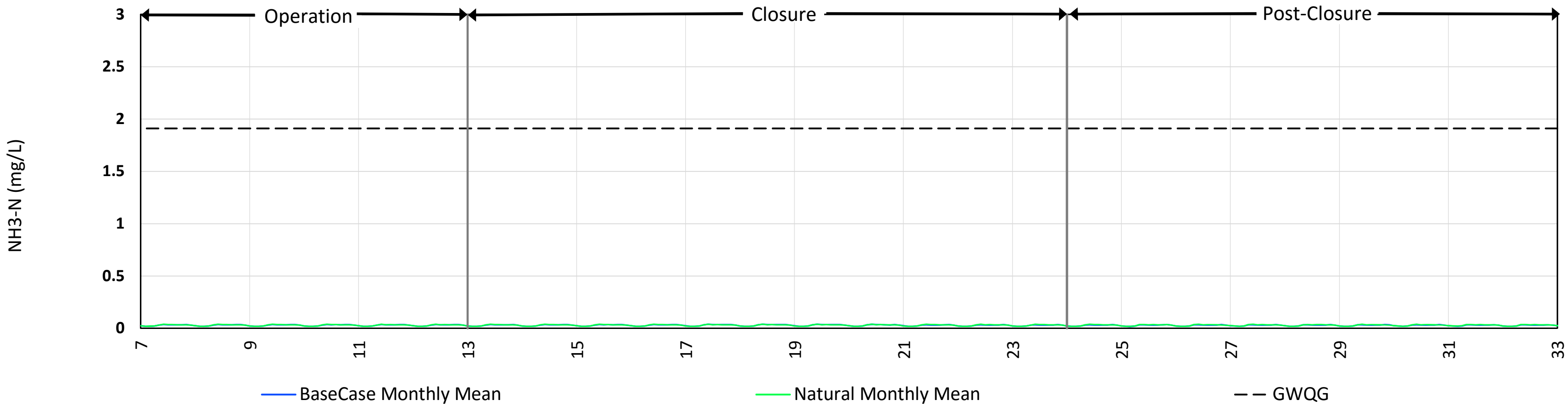
Operation
Closure
Post-Closure
T-Tl (mg/L)
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG



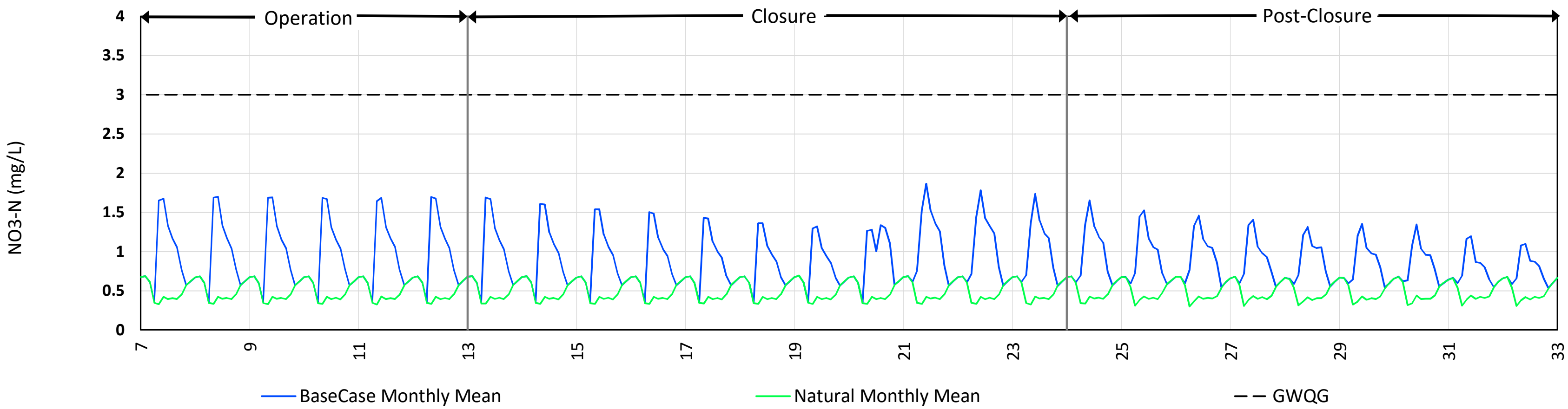
Operation
Closure
Post-Closure
T-U (mg/L)
0.1
0.08
0.06
0.04
0.02
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
Reclamation
SSWQO


HC2.5
Operation
Closure
Post-Closure
T-Zn (mg/L)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

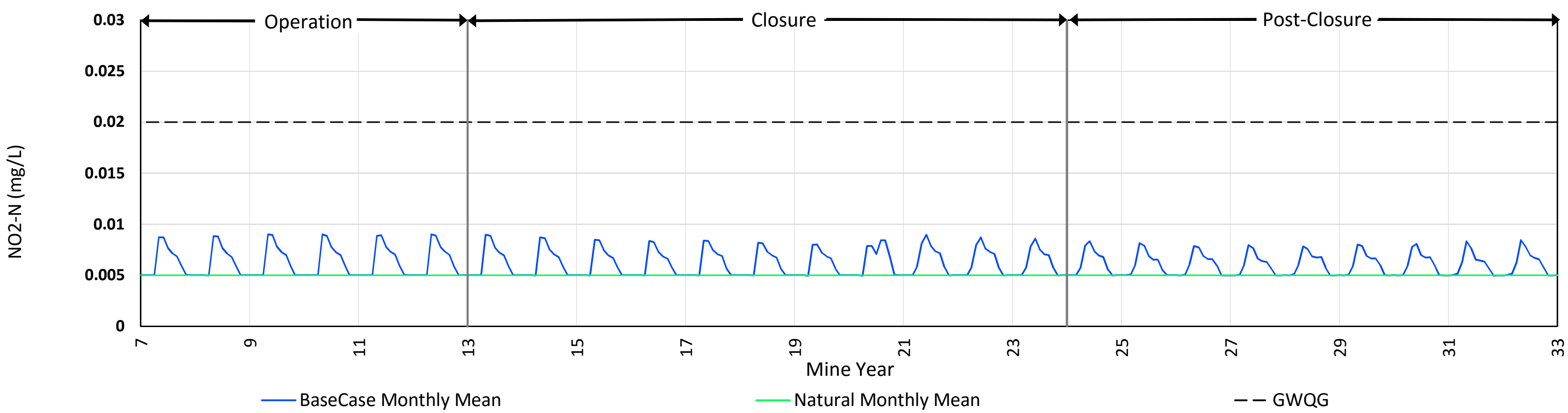
HC5.0



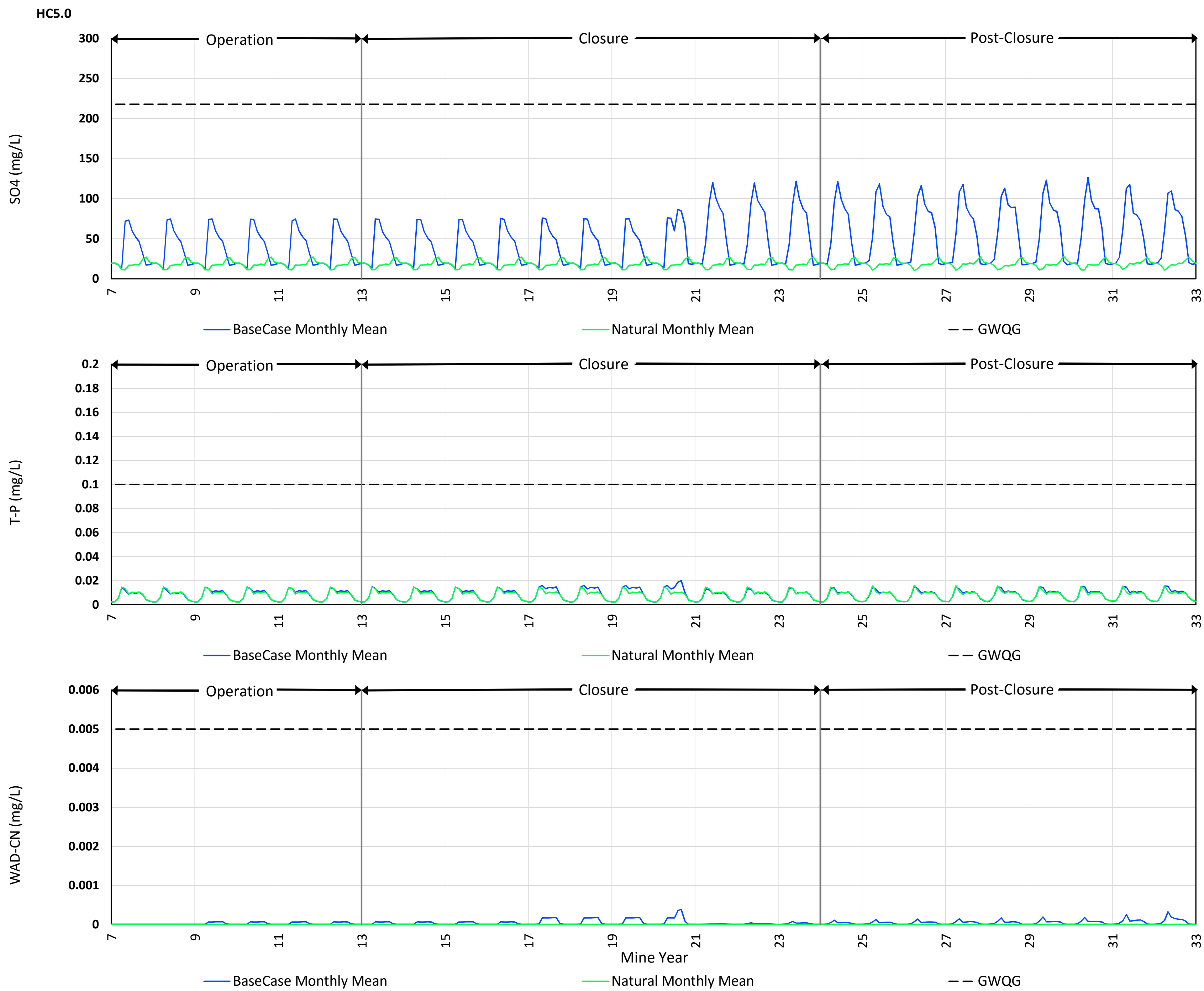
Operation
Closure
Post-Closure
NH3-N (mg/L)
3
2.5
2
1.5
1
0.5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG



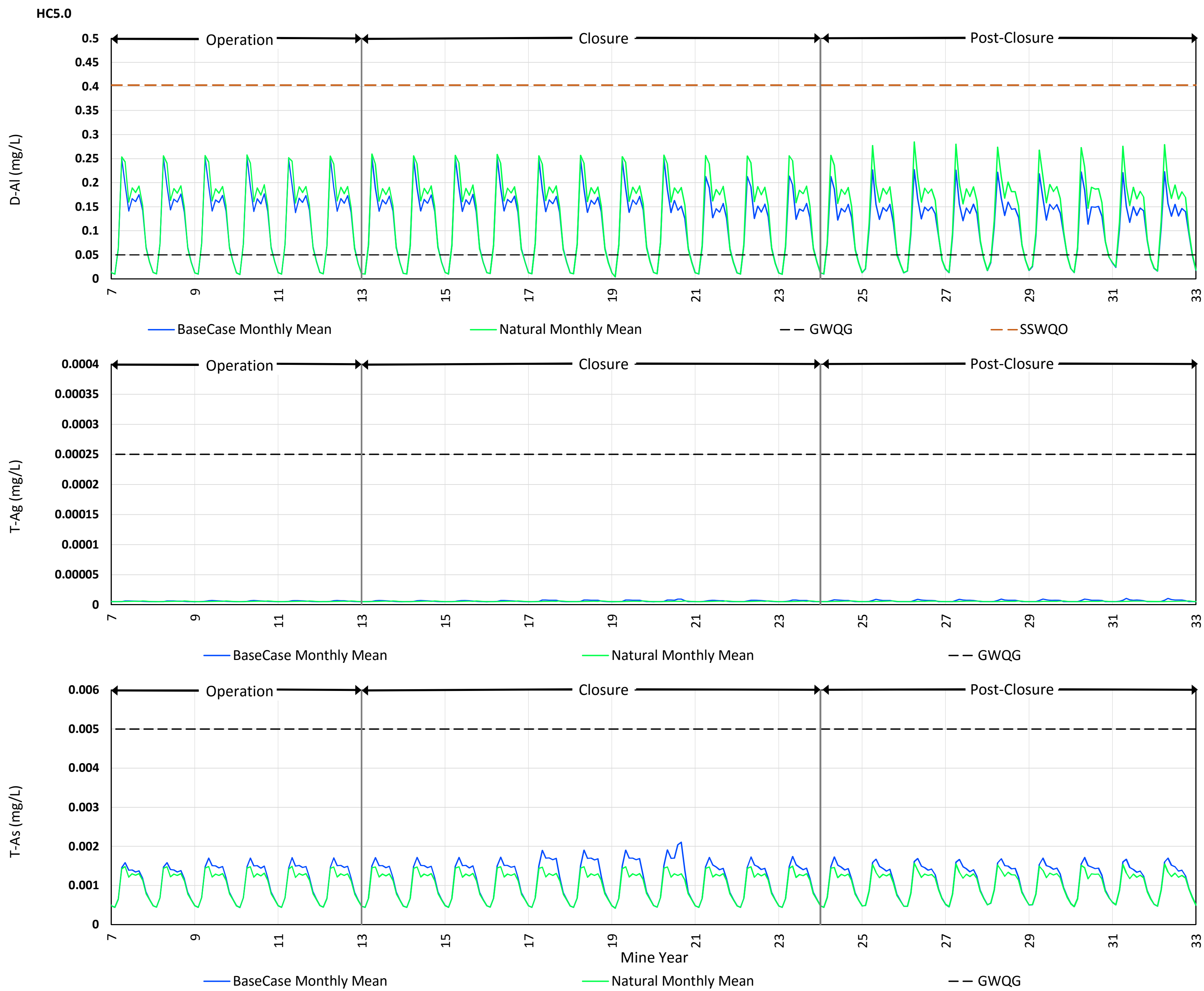
Operation
Closure
Post-Closure
NO3-N (mg/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG



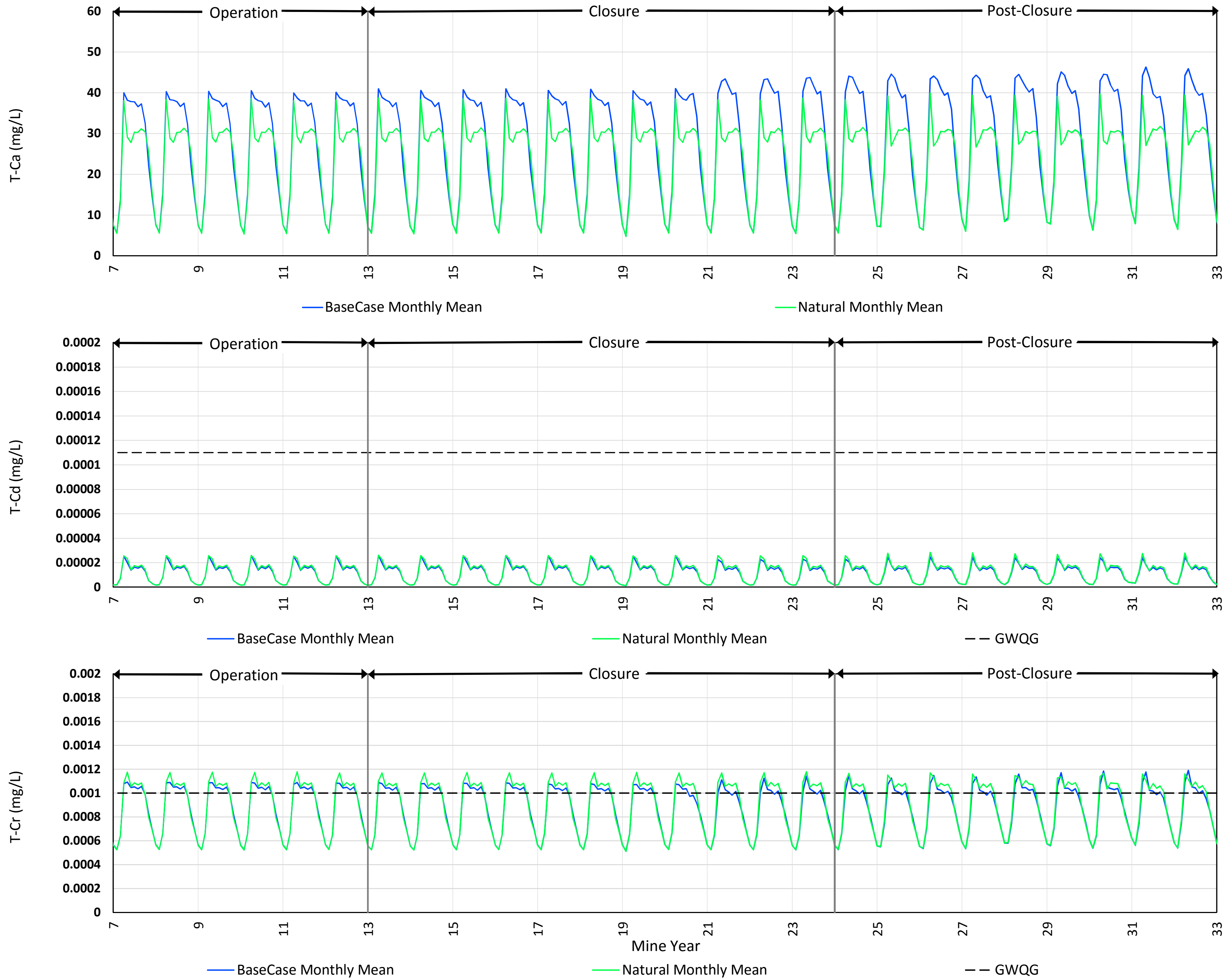
Operation
Closure
Post-Closure
NO2-N (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

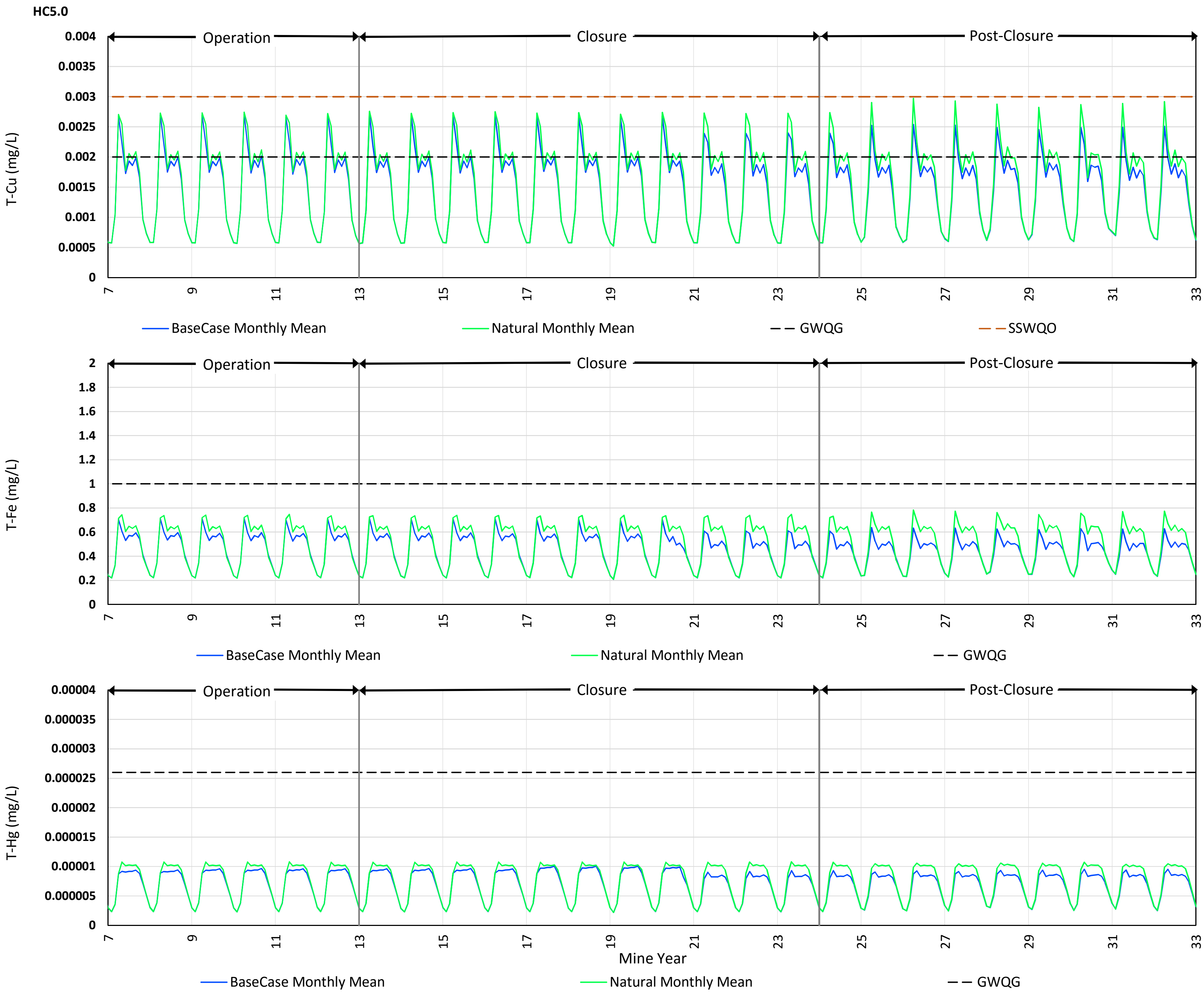


HC5.0
Operation
Closure
Post-Closure
SO4 (mg/L)
300
250
200
150
100
50
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
T-P (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
WAD-CN (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
Mine Year

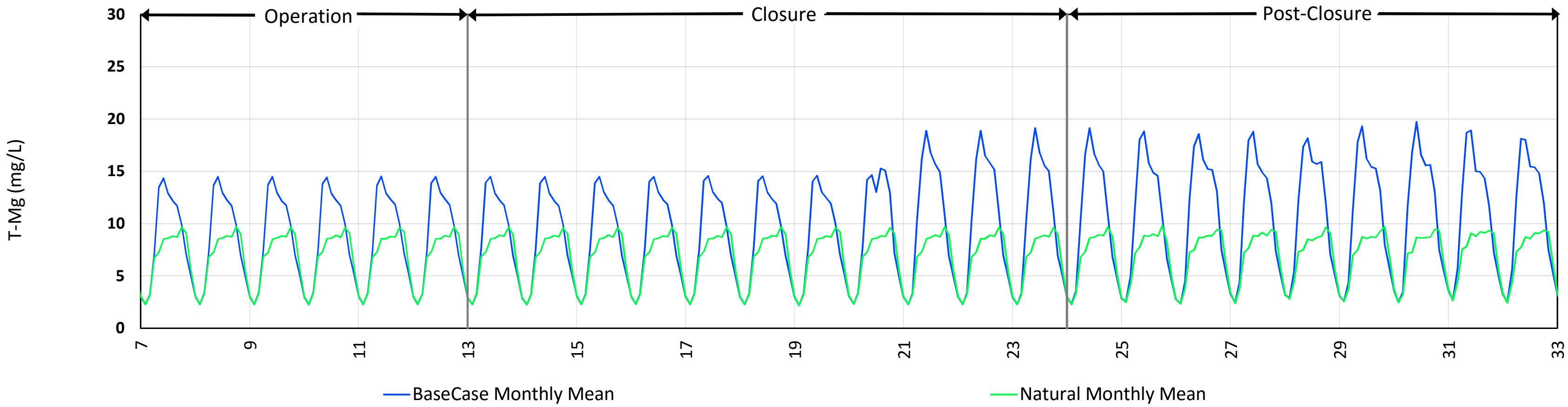

HC5.0
Operation
Closure
Post-Closure
D-Al (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Ag (mg/L)
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
T-As (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
Mine Year

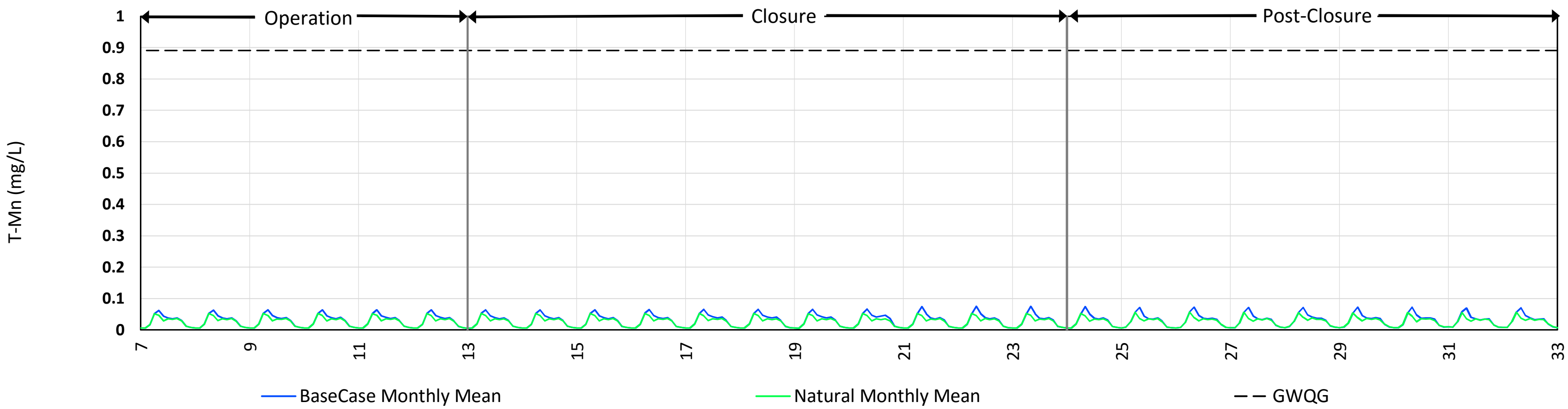
HC5.0

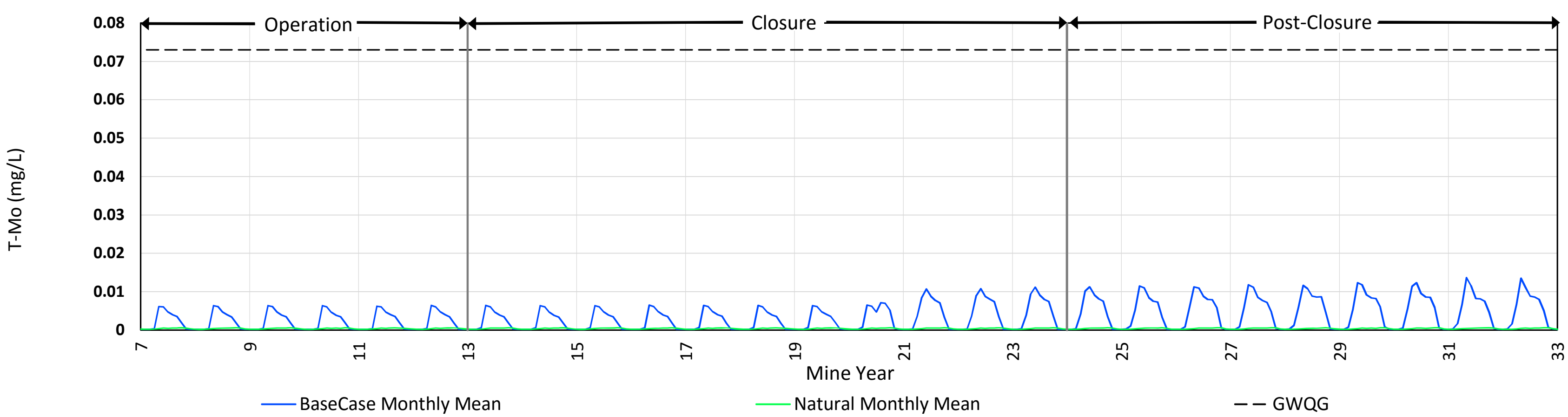

Operation
Closure
Post-Closure
T-Ca (mg/L)
60
50
40
30
20
10
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Cd (mg/L)
0.0002
0.00018
0.00016
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
GWQG
T-Cr (mg/L)
0.002
0.0018
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
Mine Year


HC5.0
Operation
Closure
Post-Closure
T-Cu (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Fe (mg/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
T-Hg (mg/L)
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
0
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

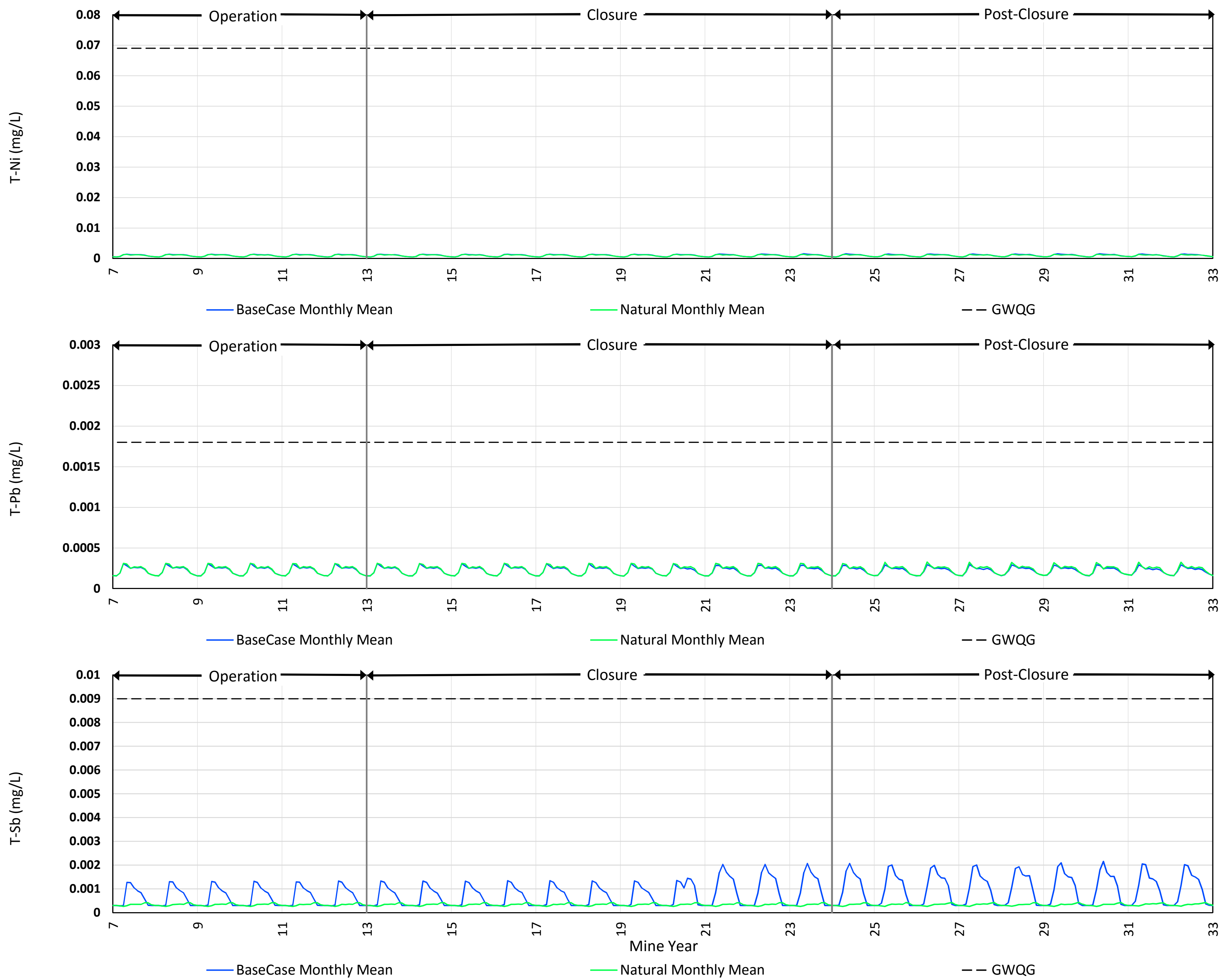
HC5.0


Operation
Closure
Post-Closure
T-Mg (mg/L)
30
25
20
15
10
5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean

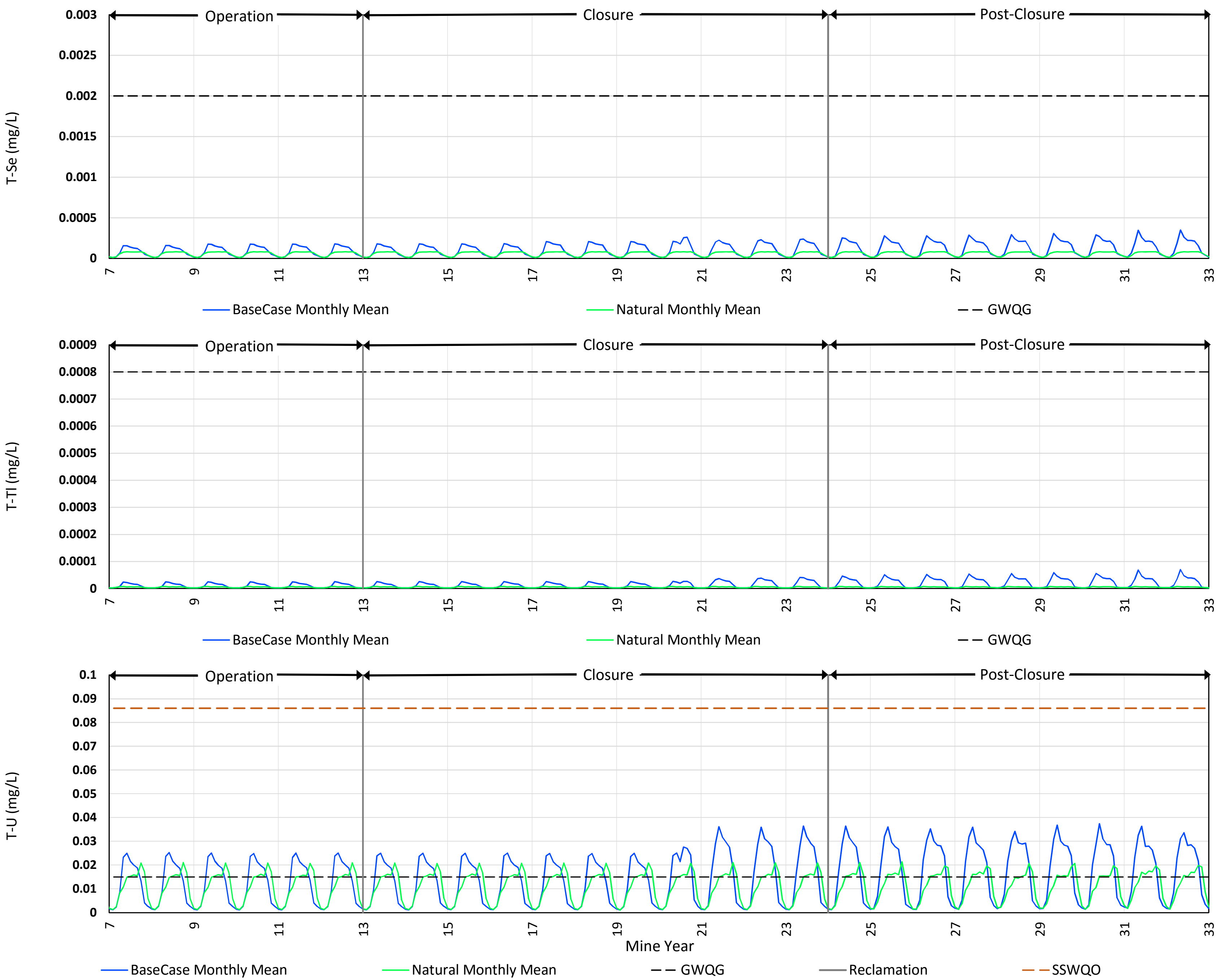

Operation
Closure
Post-Closure
T-Mn (mg/L)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG


Operation
Closure
Post-Closure
T-Mo (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

HC5.0

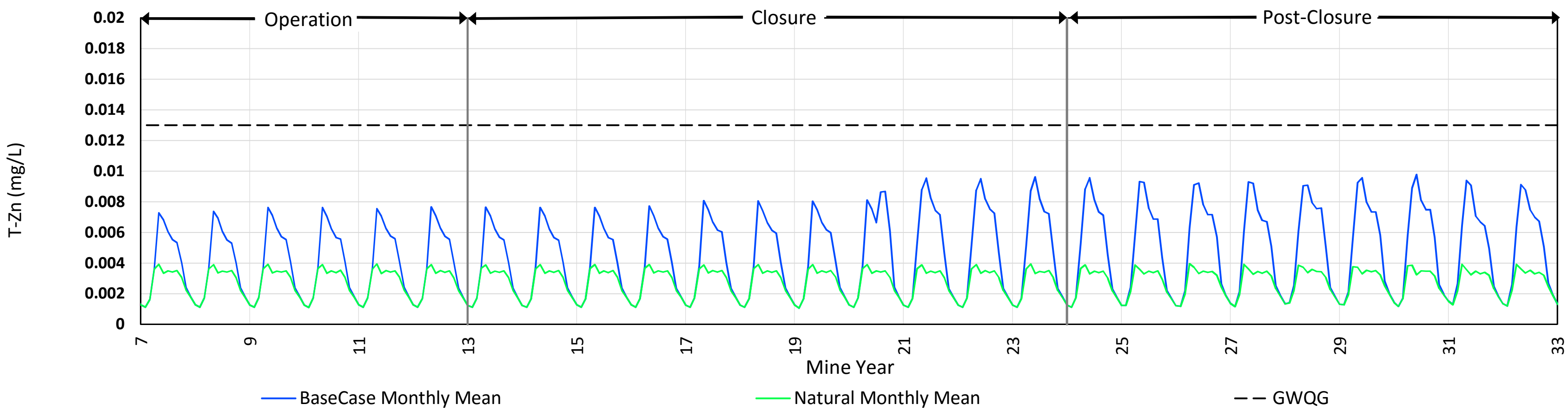

0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
T-Ni (mg/L)
Operation
Closure
Post-Closure
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
T-Pb (mg/L)
Operation
Closure
Post-Closure
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
T-Sb (mg/L)
Operation
Closure
Post-Closure
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

HC5.0

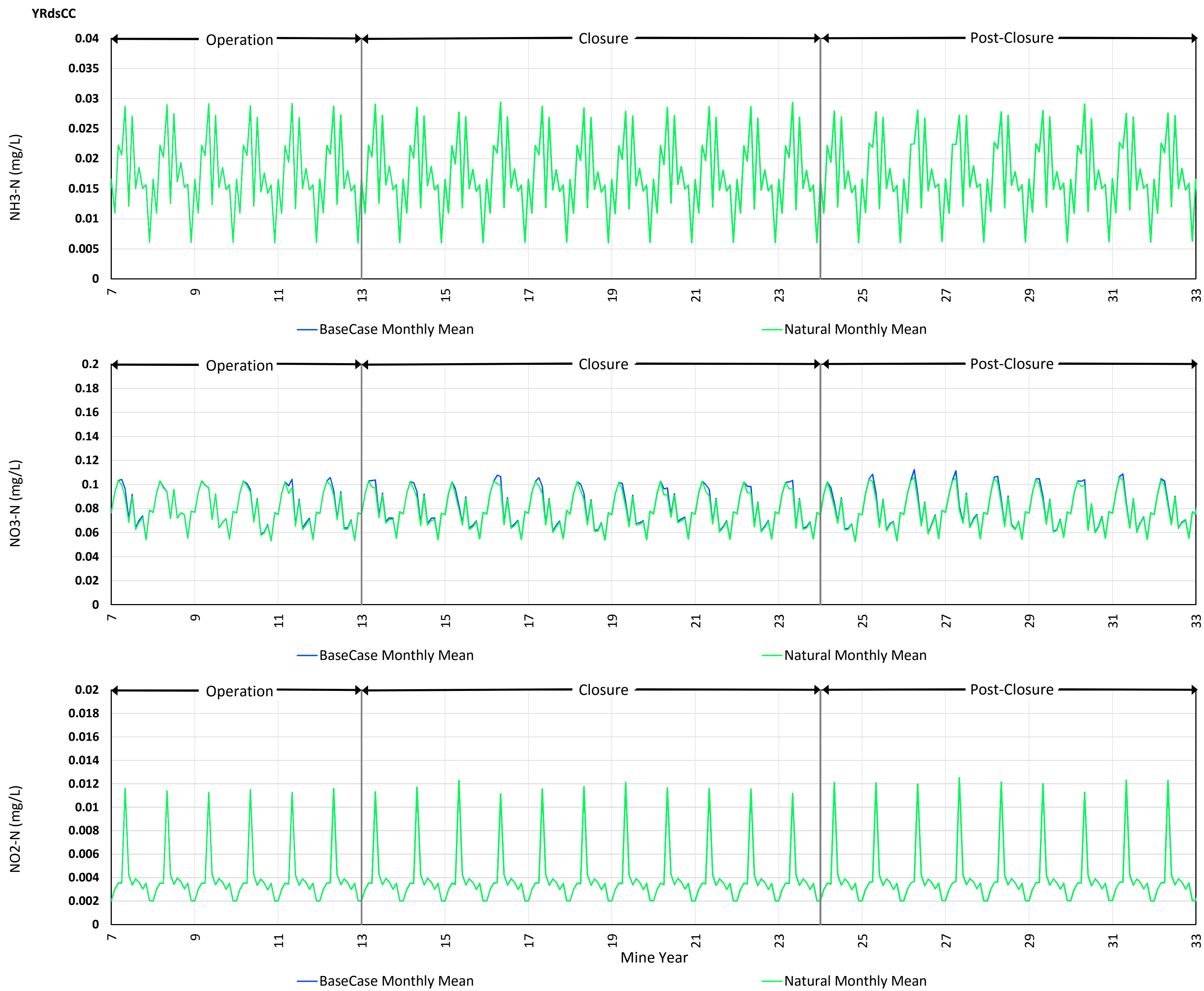


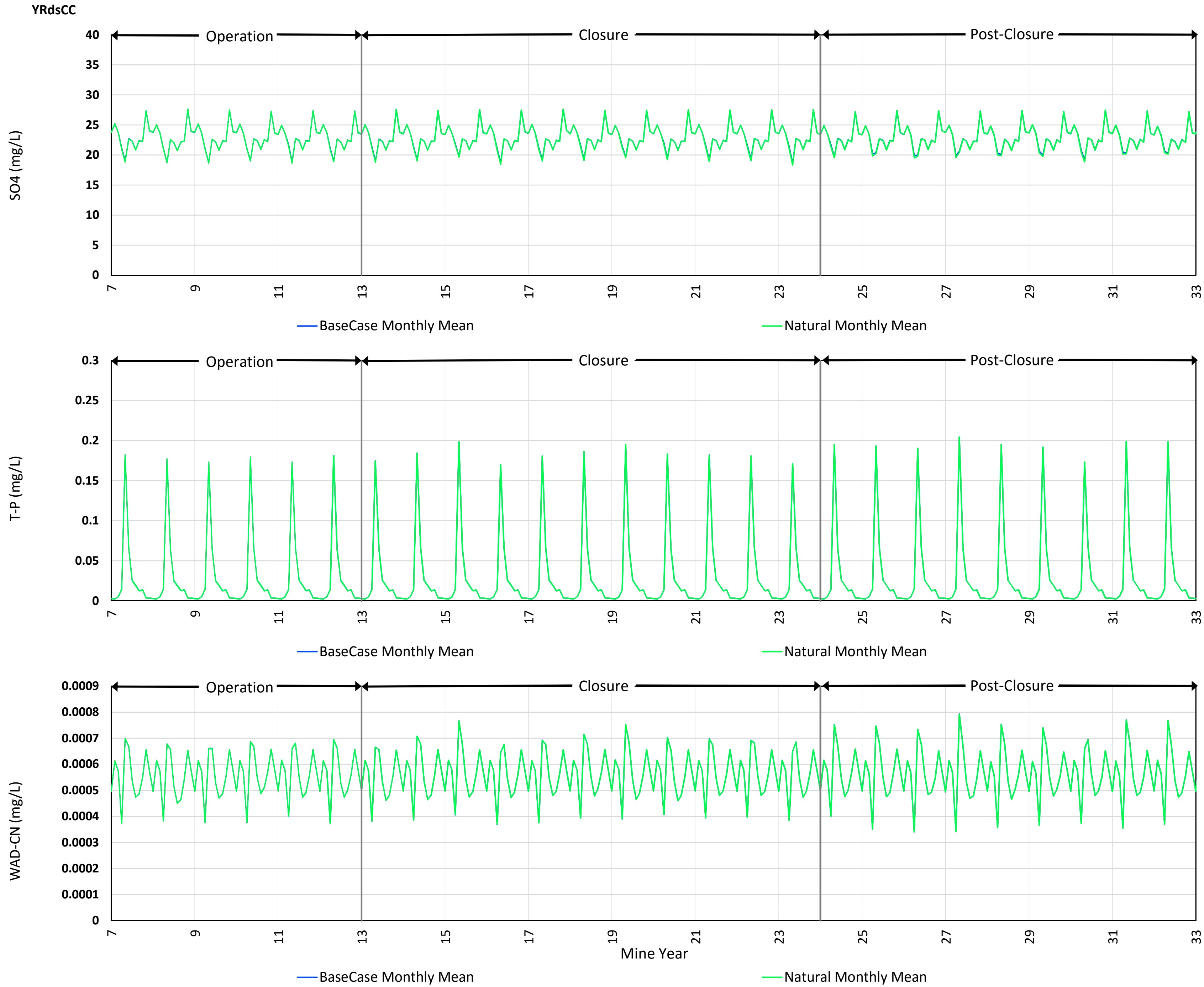
Operation
Closure
Post-Closure
T-Se (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
T-Tl (mg/L)
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
T-U (mg/L)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
Mine Year
Reclamation
SSWQO

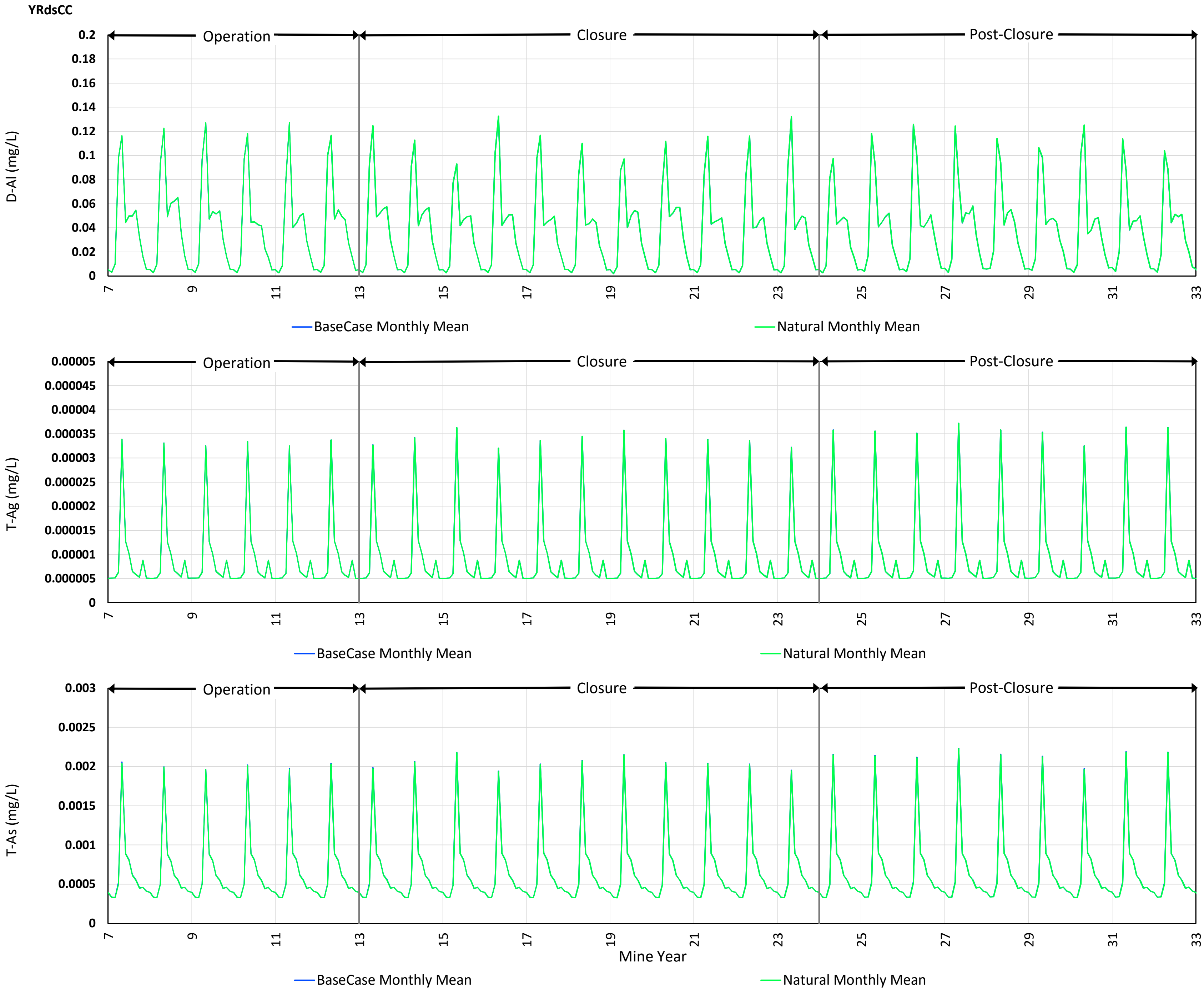
HC5.0

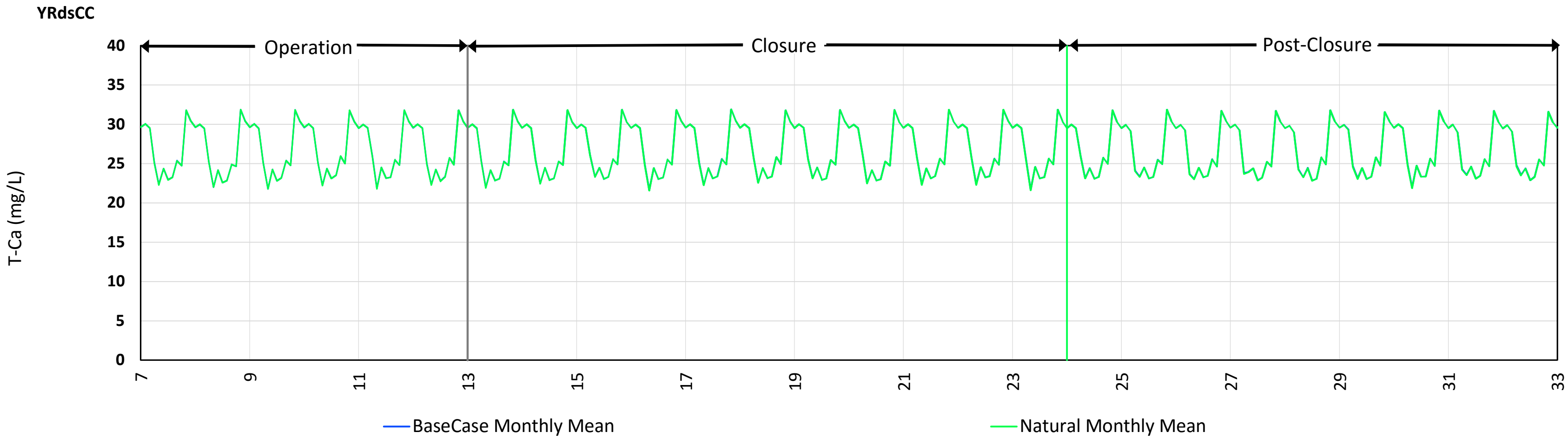


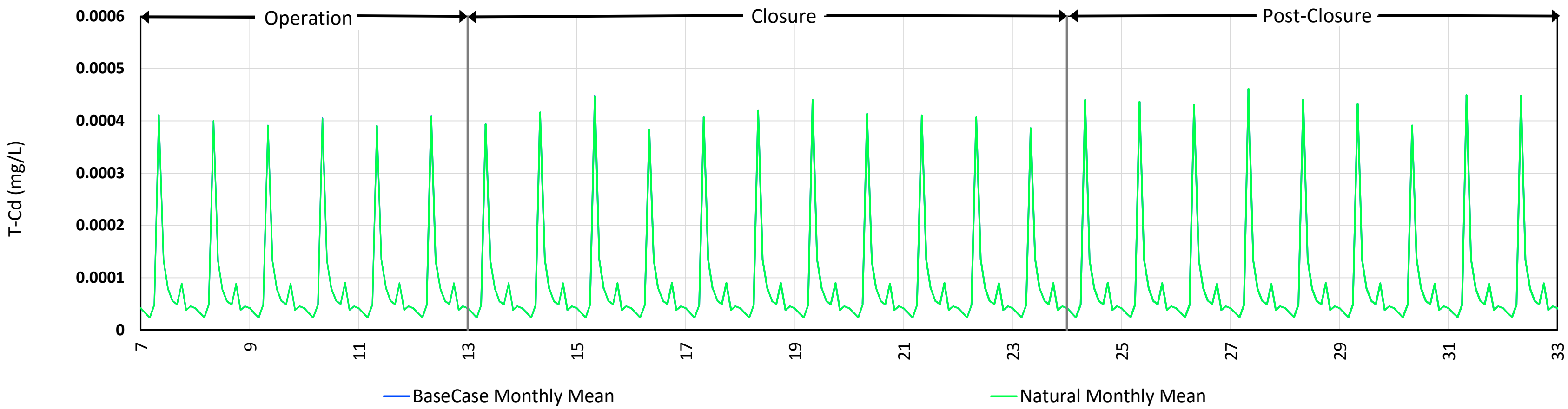
Operation
Closure
Post-Closure
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
T-Zn (mg/L)
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

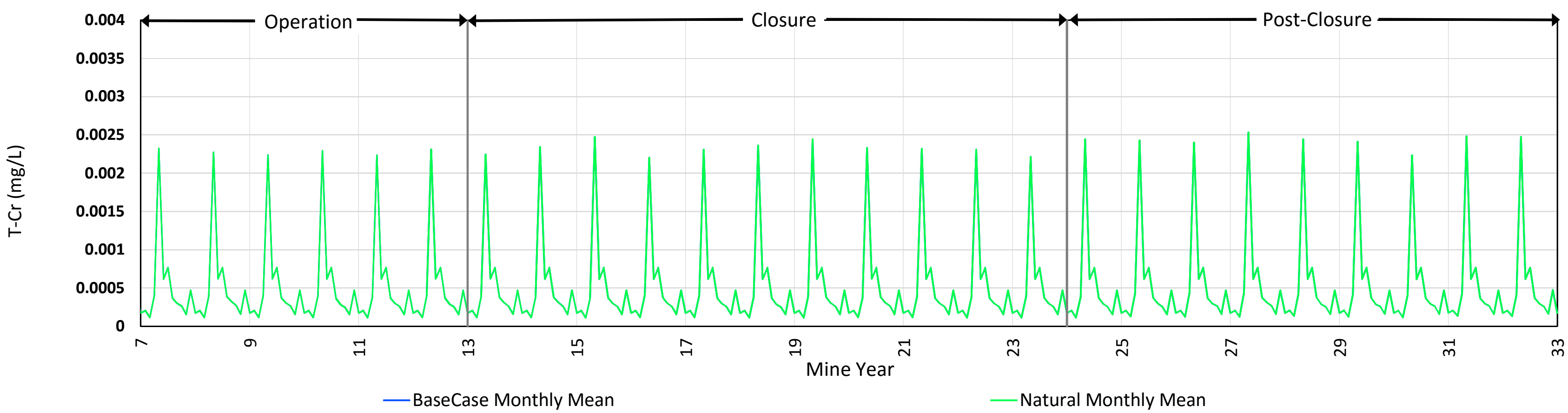

YRdsCC
Operation
Closure
Post-Closure
NH3-N (mg/L)
NO3-N (mg/L)
NO2-N (mg/L)
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

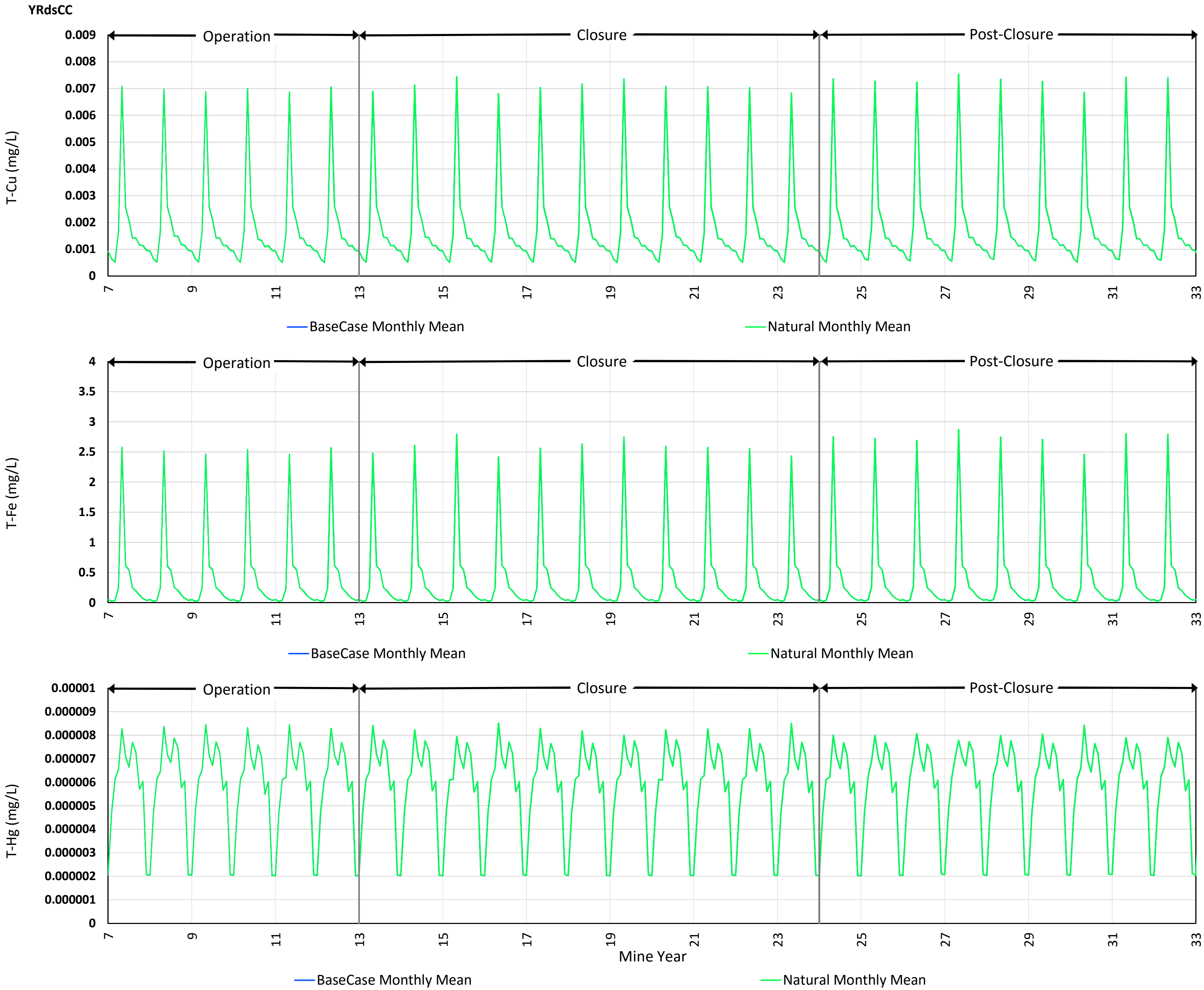

YRdsCC
Operation
Closure
Post-Closure
SO4 (mg/L)
BaseCase Monthly Mean
Natural Monthly Mean
T-P (mg/L)
WAD-CN (mg/L)
Mine Year


YRdsCC
Operation
Closure
Post-Closure
D-Al (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Ag (mg/L)
0.00005
0.000045
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
0
T-As (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
Mine Year

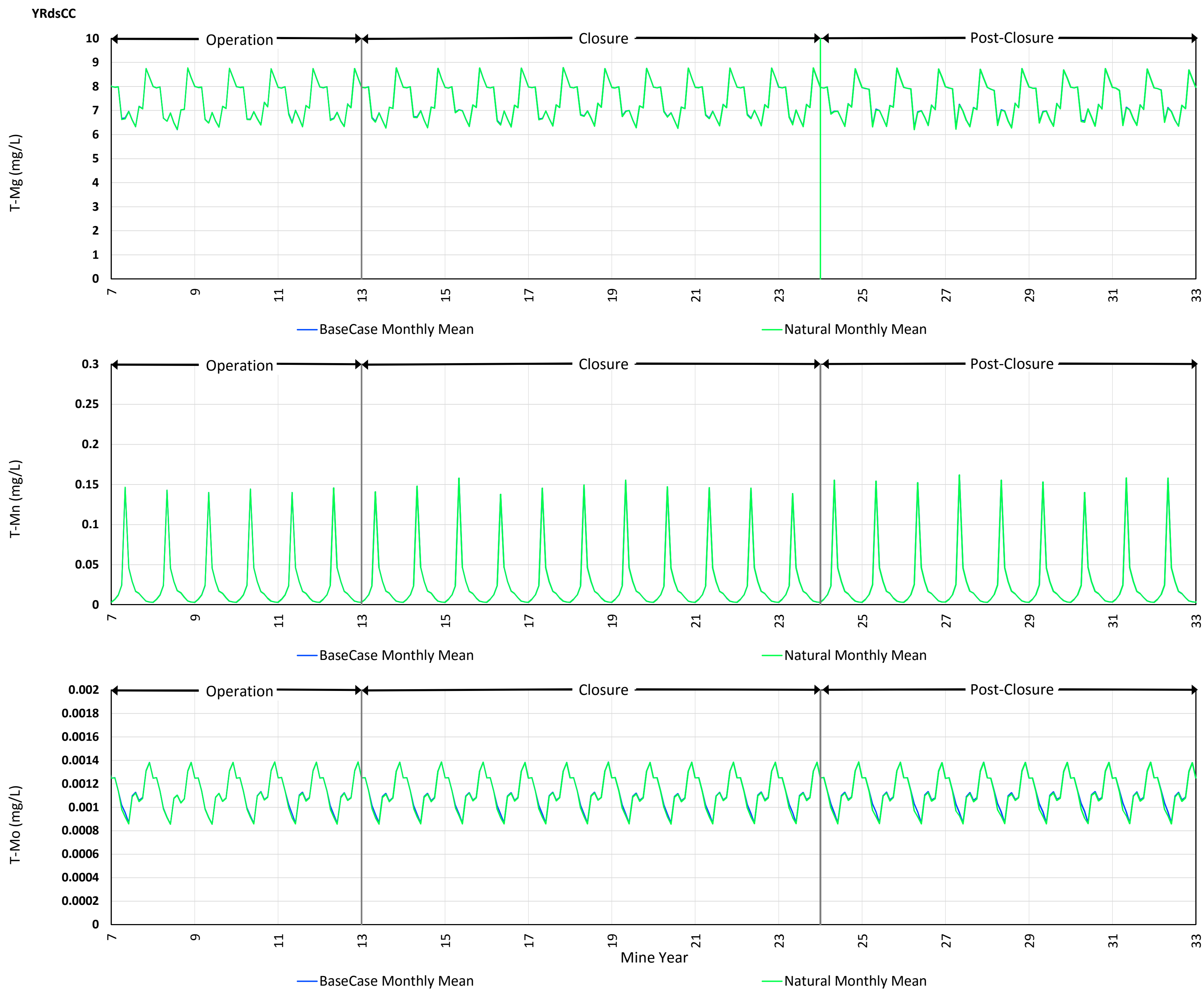

YRdsCC
Operation
Closure
Post-Closure
T-Ca (mg/L)
40
35
30
25
20
15
10
5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean

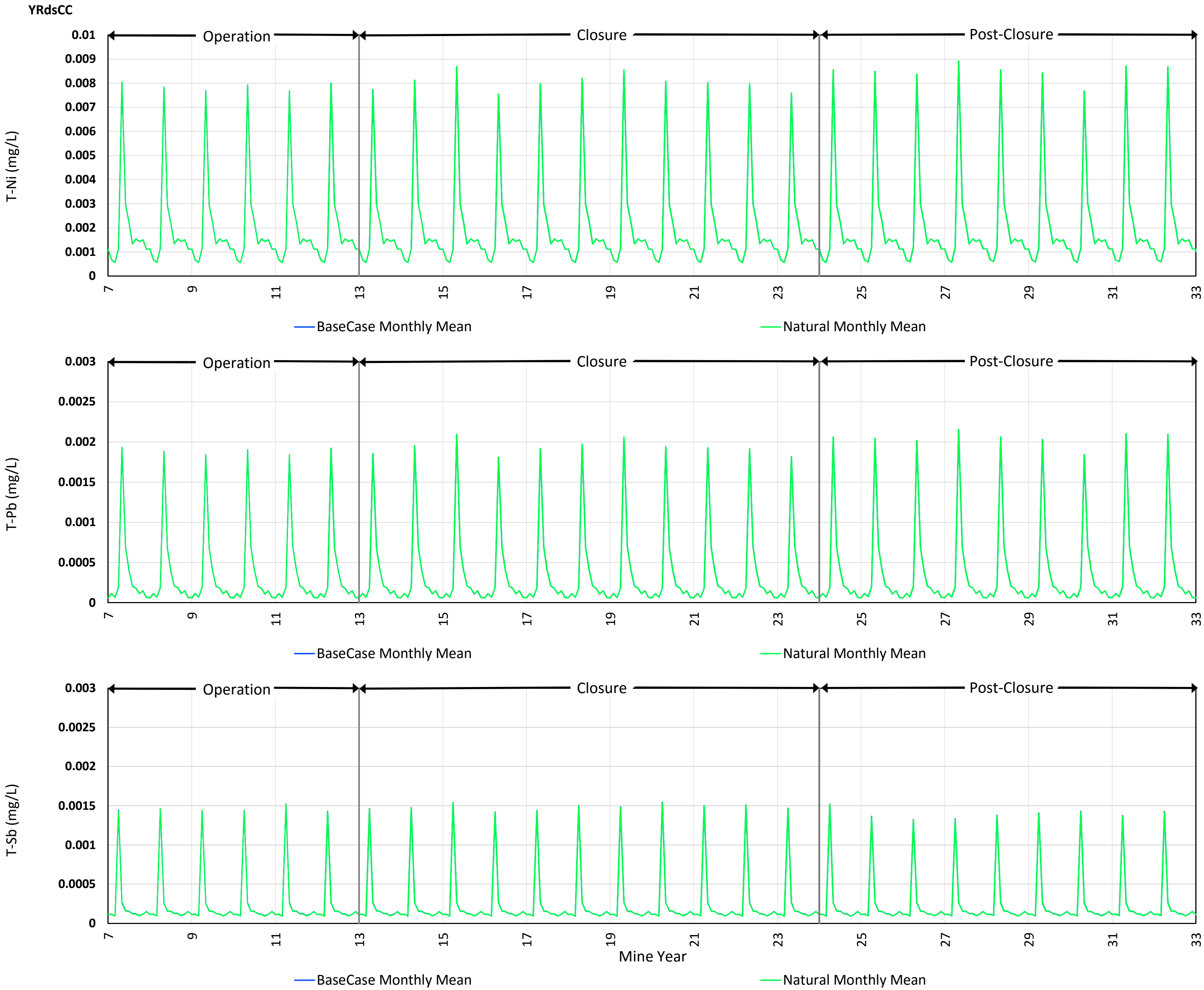

Operation
Closure
Post-Closure
T-Cd (mg/L)
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean


Operation
Closure
Post-Closure
T-Cr (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

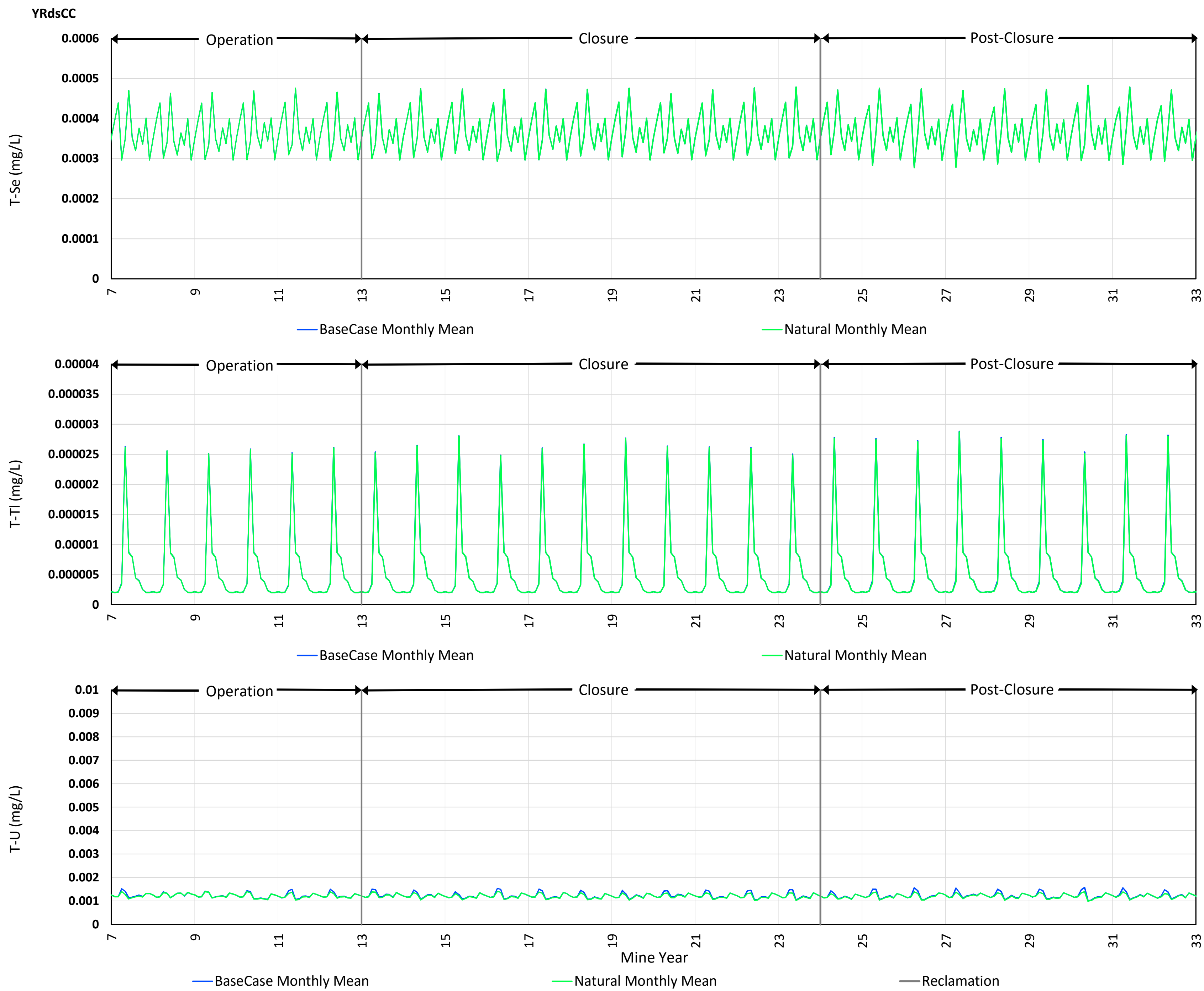


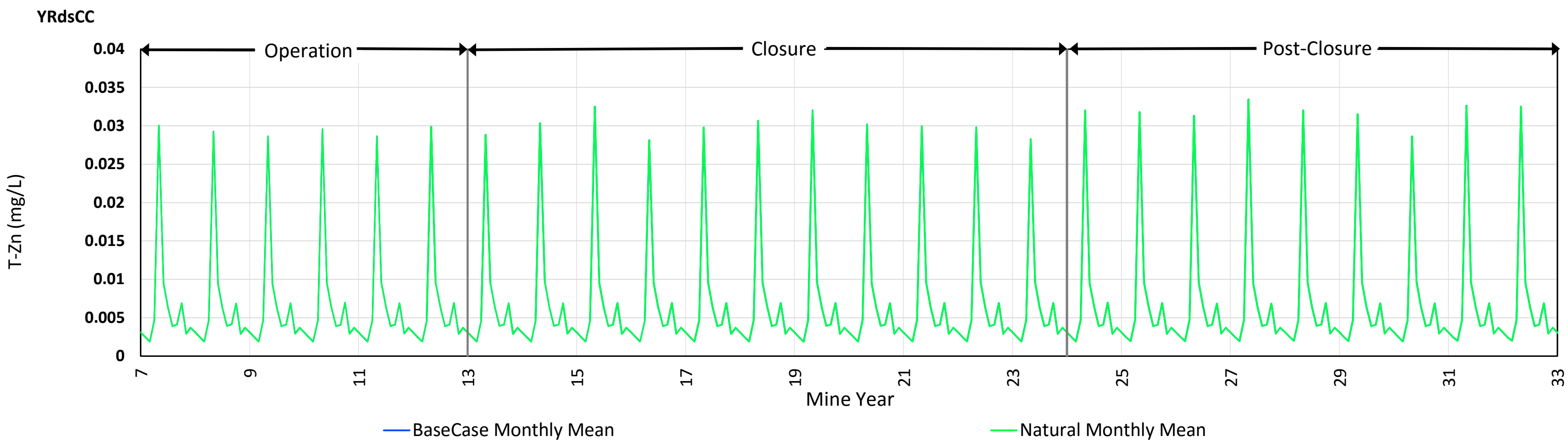
YRdsCC
Operation
Closure
Post-Closure
T-Cu (mg/L)
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Fe (mg/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
T-Hg (mg/L)
0.00001
0.000009
0.000008
0.000007
0.000006
0.000005
0.000004
0.000003
0.000002
0.000001
Mine Year


YRdsCC
Operation
Closure
Post-Closure
T-Mg (mg/L)
T-Mn (mg/L)
T-Mo (mg/L)
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

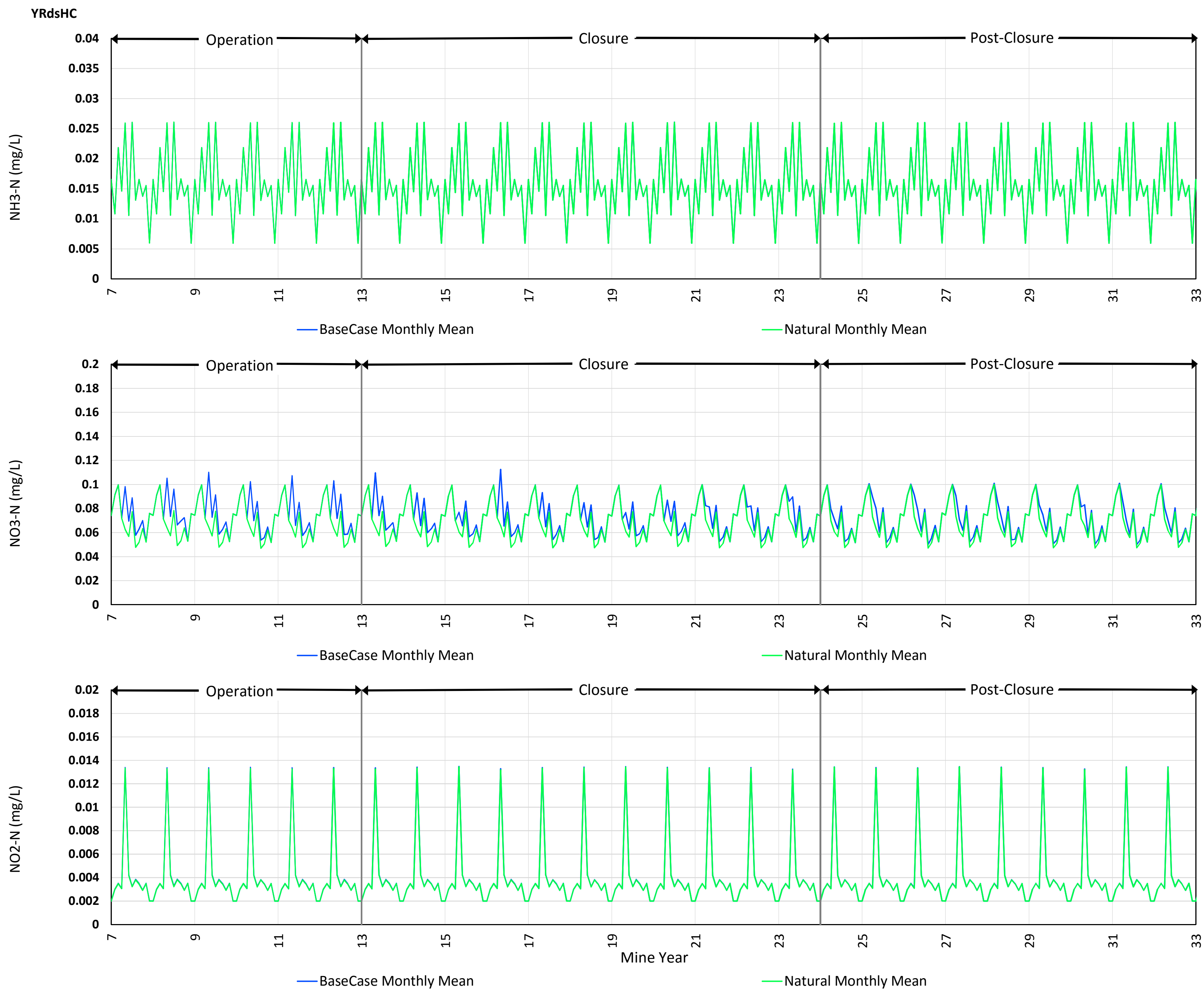


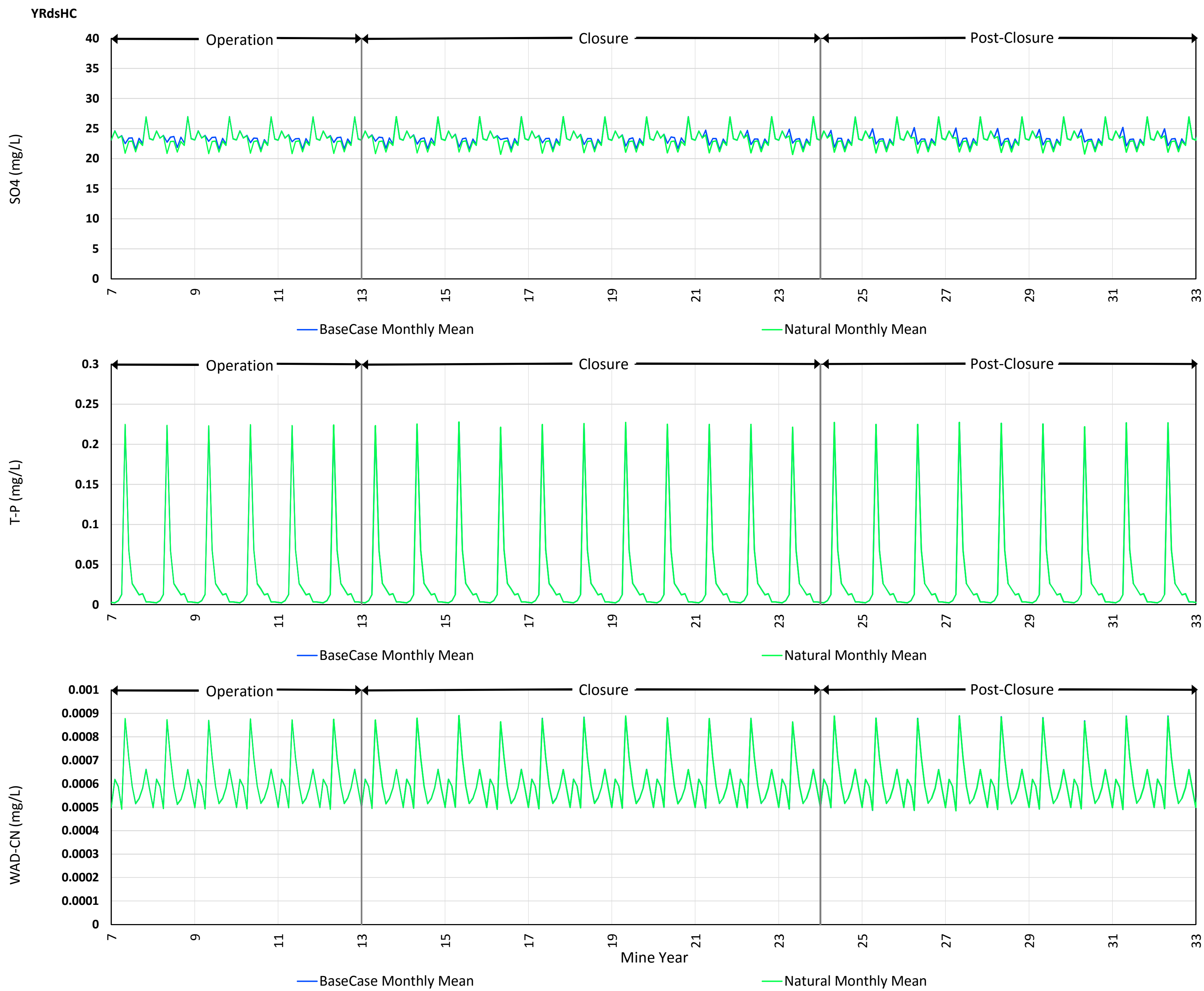
YRdsCC
Operation
Closure
Post-Closure
T-Ni (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Pb (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
T-Sb (mg/L)
Mine Year


YRdsCC
Operation
Closure
Post-Closure
T-Se (mg/L)
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Tl (mg/L)
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
0
T-U (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
Mine Year
Reclamation



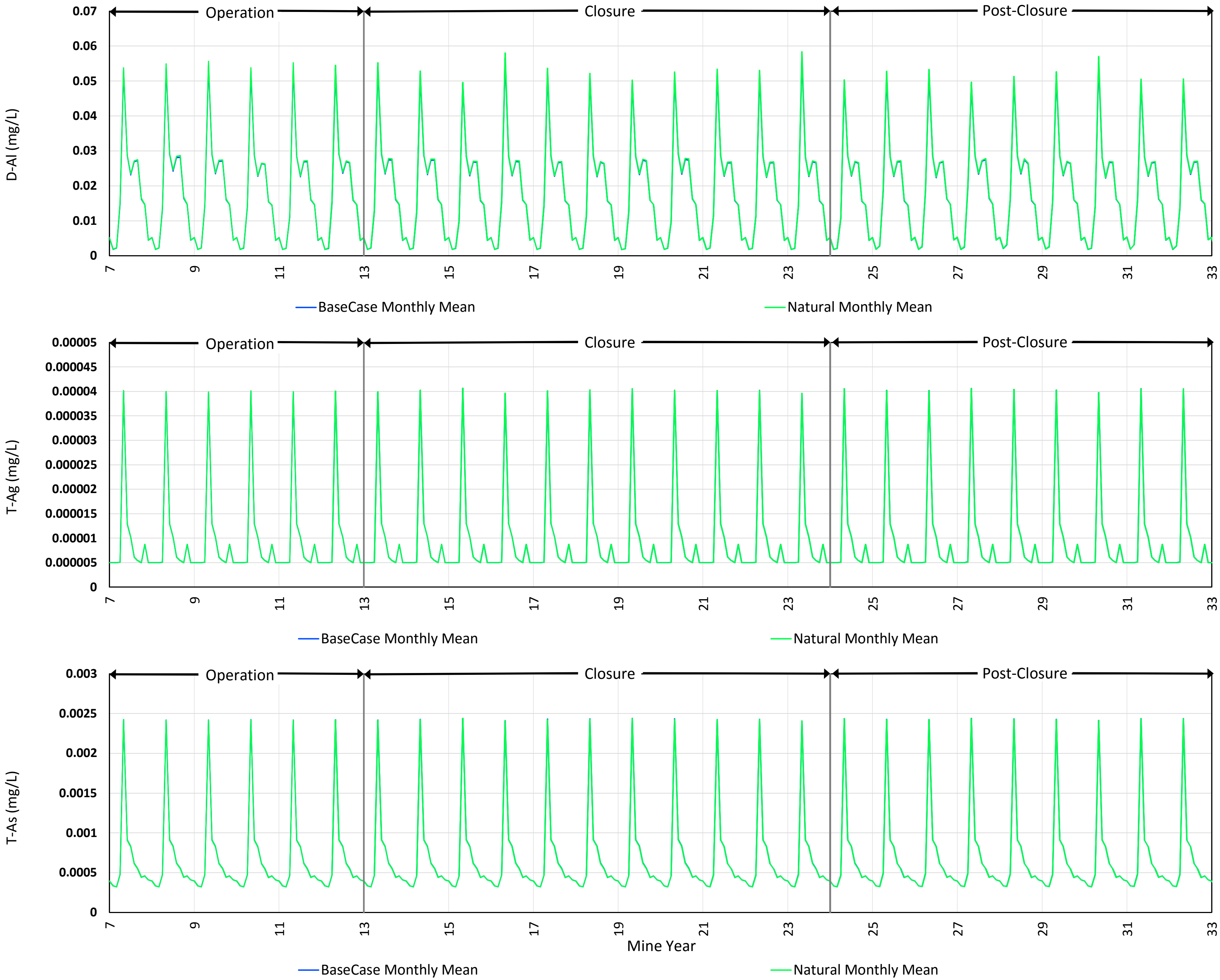
YRdsCC
Operation
Closure
Post-Closure
T-Zn (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean


YRdsHC
Operation
Closure
Post-Closure
NH3-N (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
NO3-N (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
NO2-N (mg/L)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Mine Year



YRdsHC
Operation
Closure
Post-Closure
SO4 (mg/L)
40
35
30
25
20
15
10
5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-P (mg/L)
0.3
0.25
0.2
0.15
0.1
0.05
0
WAD-CN (mg/L)
0.001
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
Mine Year

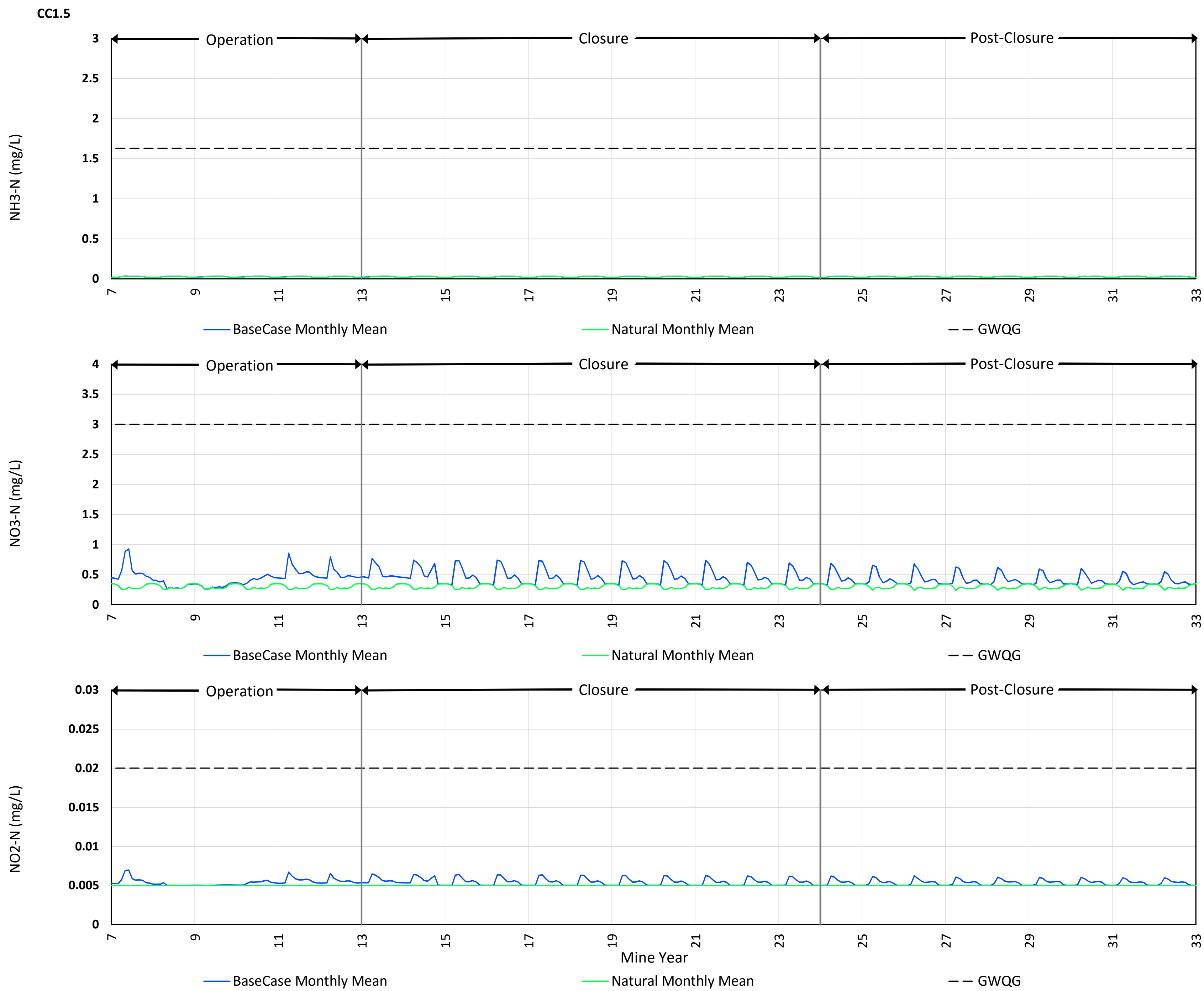
YRdsHC

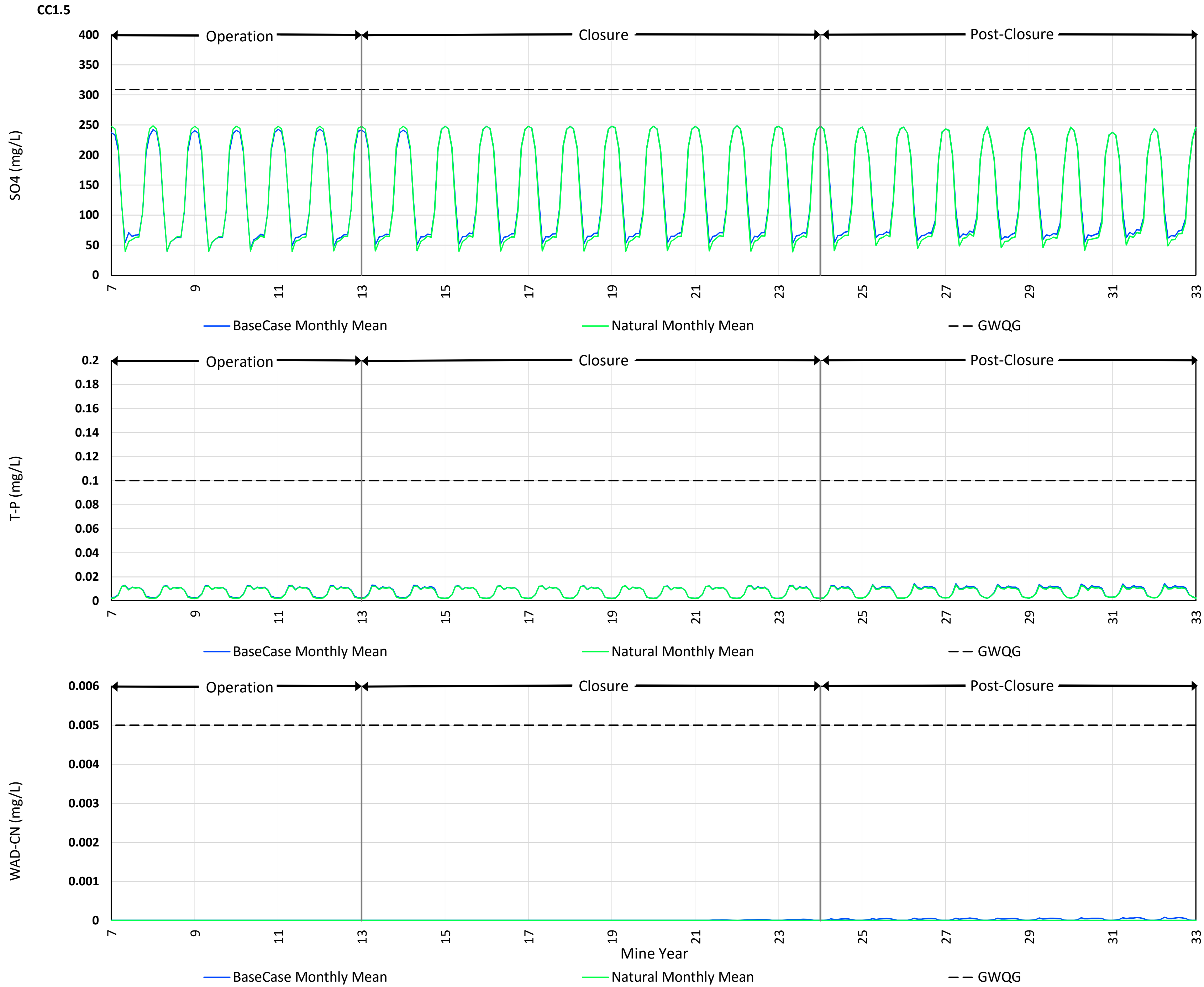


Operation
Closure
Post-Closure
D-Al (mg/L)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Ag (mg/L)
0.00005
0.000045
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
T-As (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
Mine Year

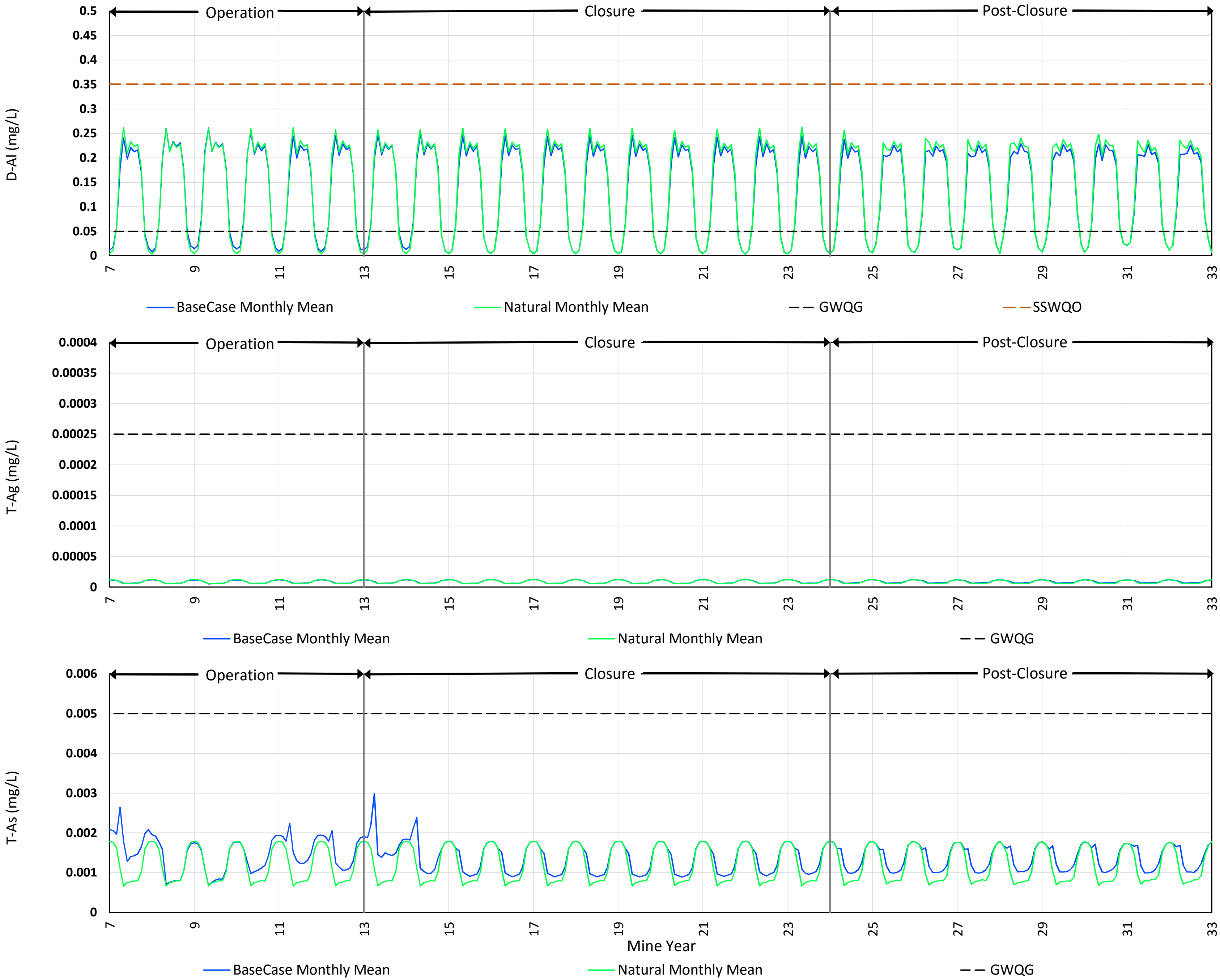
Appendix 12-C-5: Base Case Water Quality Model Results

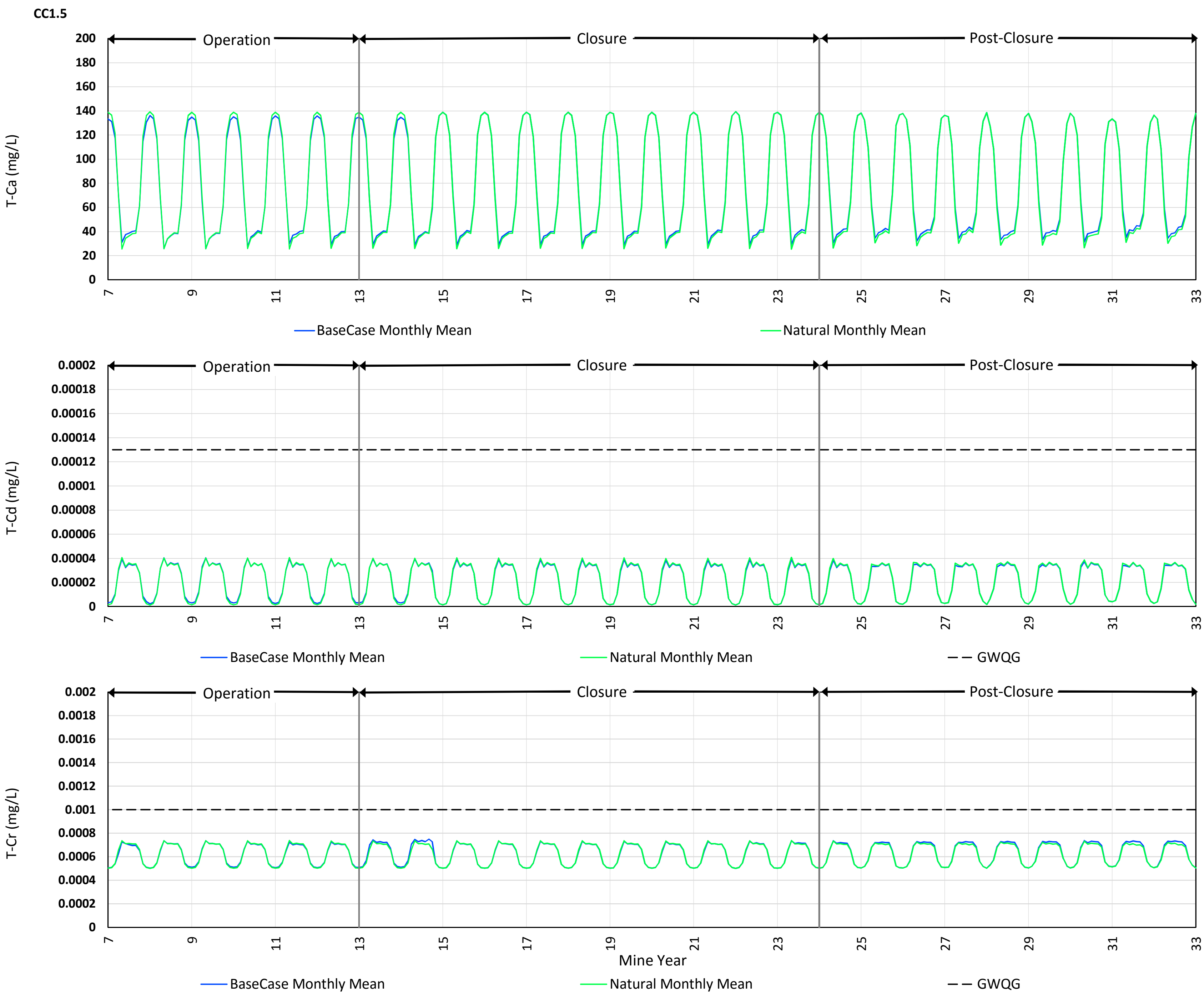
GOLDCORP

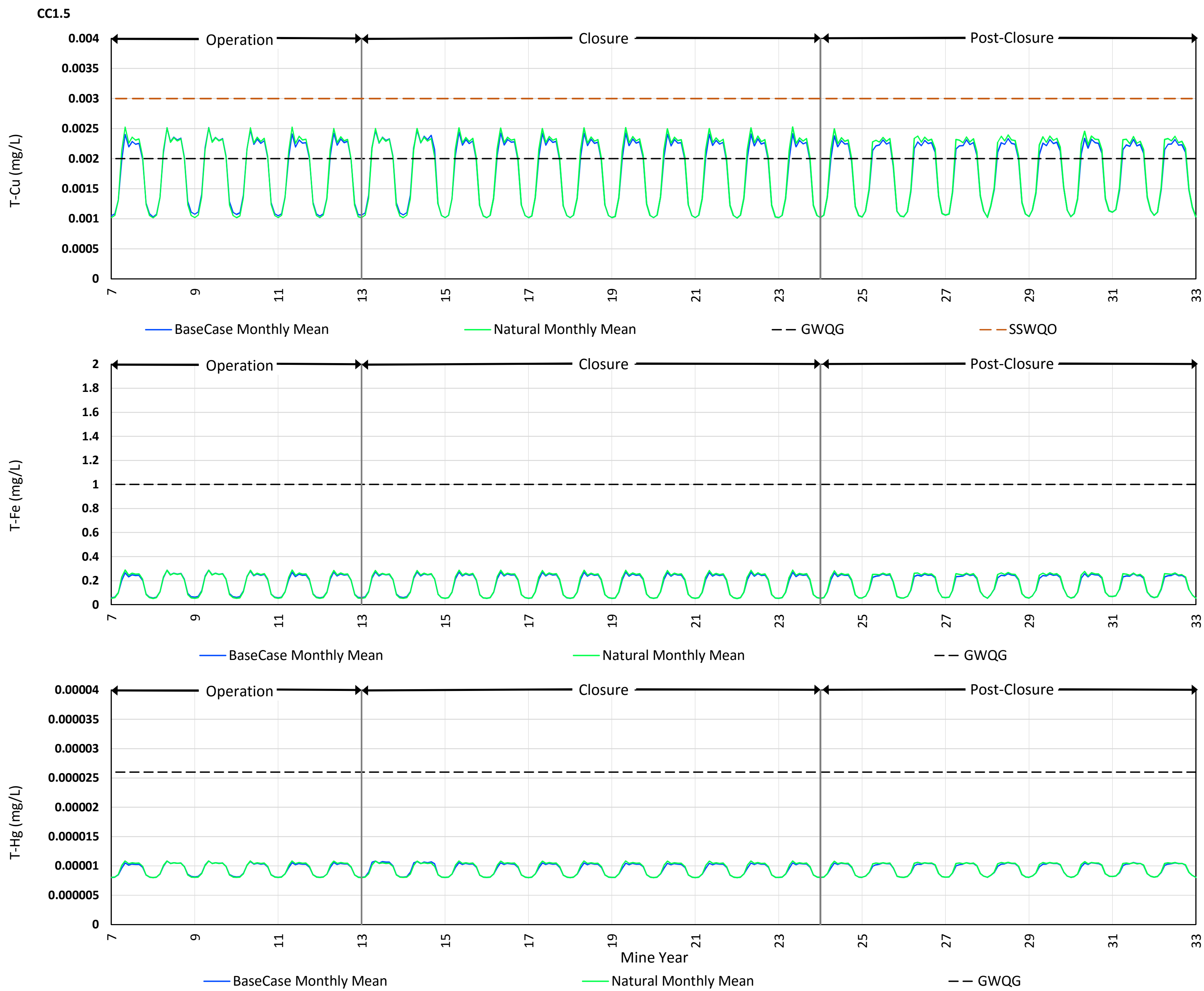

CC1.5
Operation
Closure
Post-Closure
NH3-N (mg/L)
NO3-N (mg/L)
NO2-N (mg/L)
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG


CC1.5
Operation
Closure
Post-Closure
SO4 (mg/L)
400
350
300
250
200
150
100
50
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
T-P (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
WAD-CN (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
Mine Year

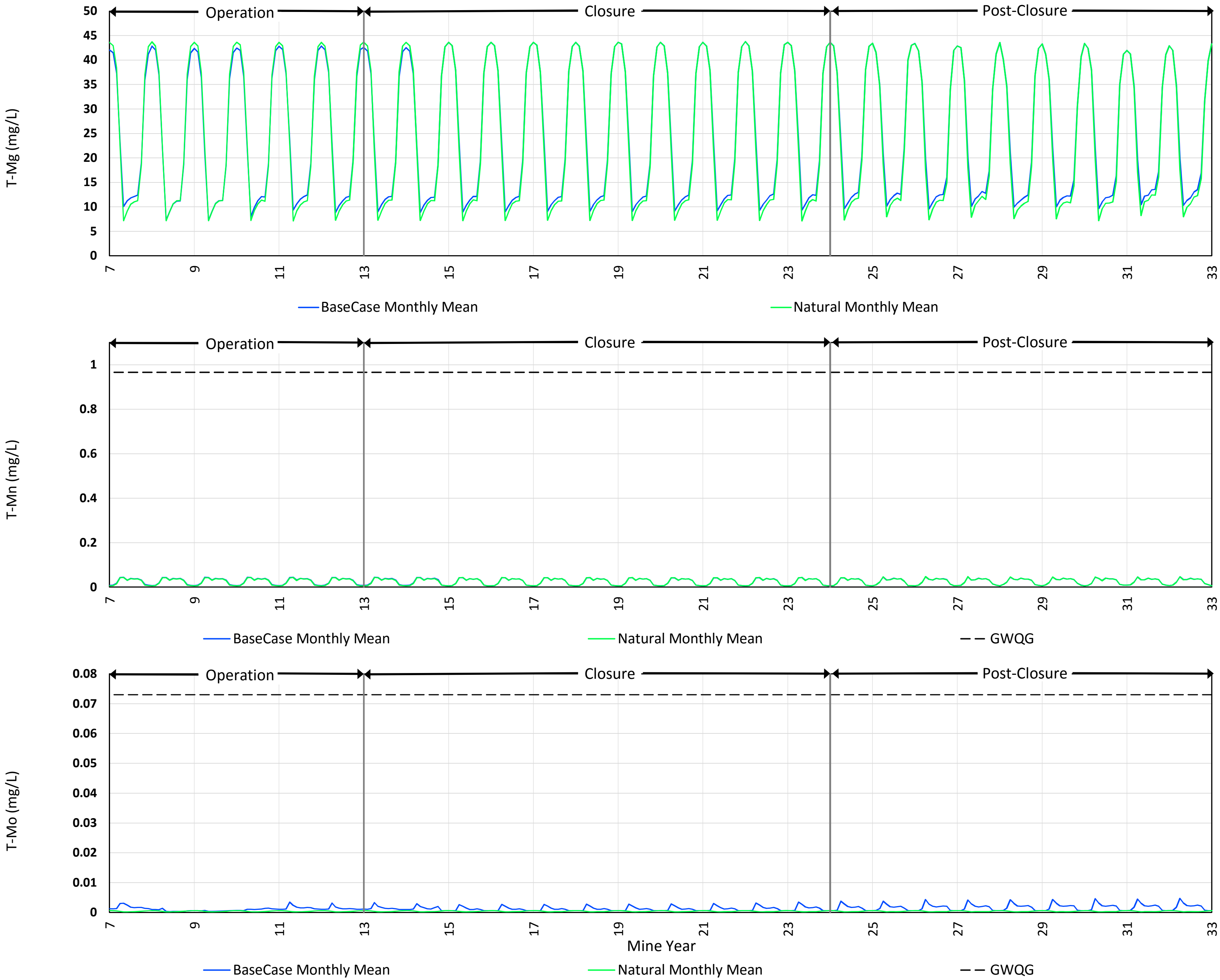
CC1.5


Operation
Closure
Post-Closure
D-Al (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
Operation
Closure
Post-Closure
T-Ag (mg/L)
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
T-As (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG


CC1.5
Operation
Closure
Post-Closure
T-Ca (mg/L)
BaseCase Monthly Mean
Natural Monthly Mean
T-Cd (mg/L)
GWQG
T-Cr (mg/L)
Mine Year

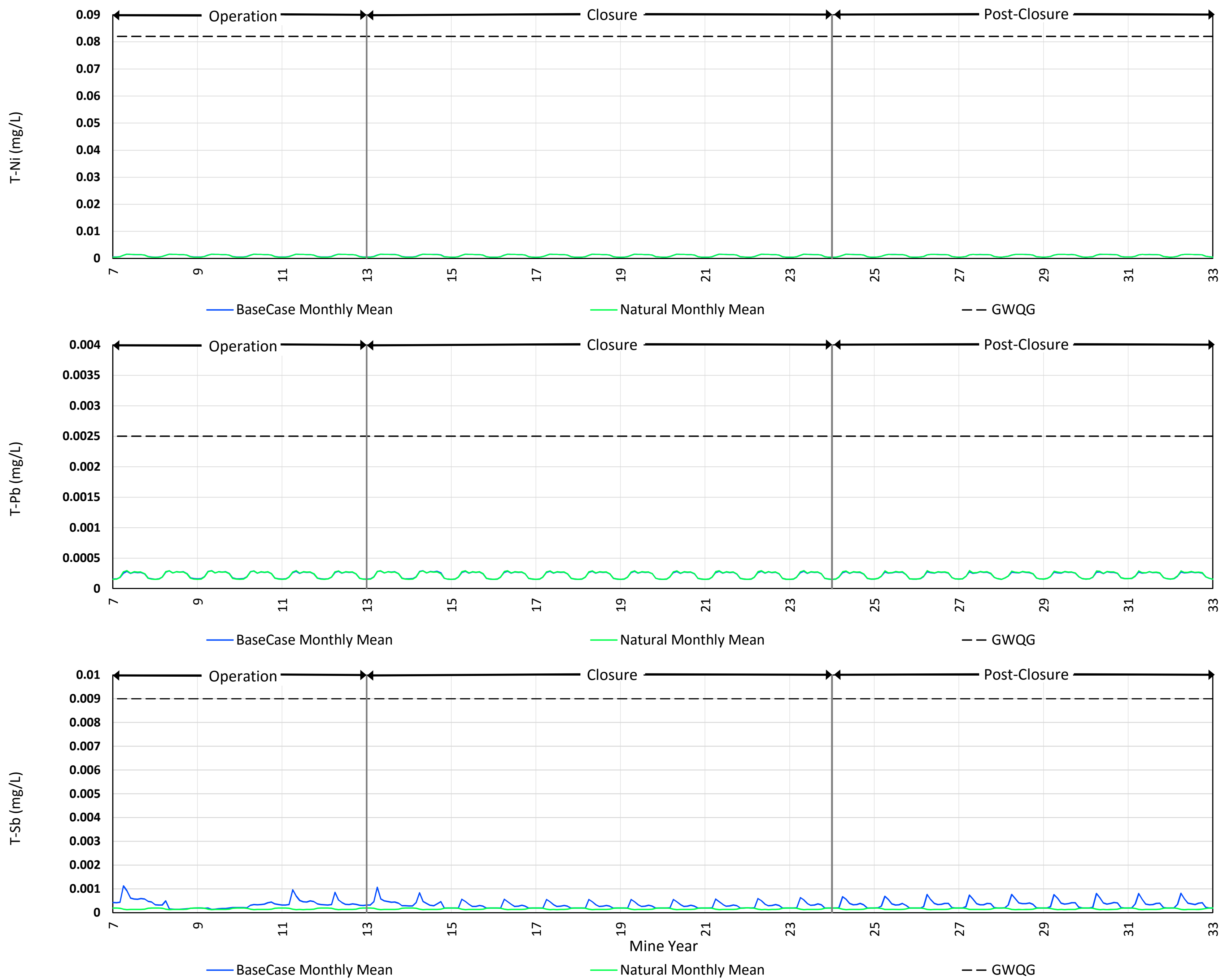

CC1.5
Operation
Closure
Post-Closure
T-Cu (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7 9 11 13 15 17 19 21 23 25 27 29 31 33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Fe (mg/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
T-Hg (mg/L)
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
0
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

CC1.5

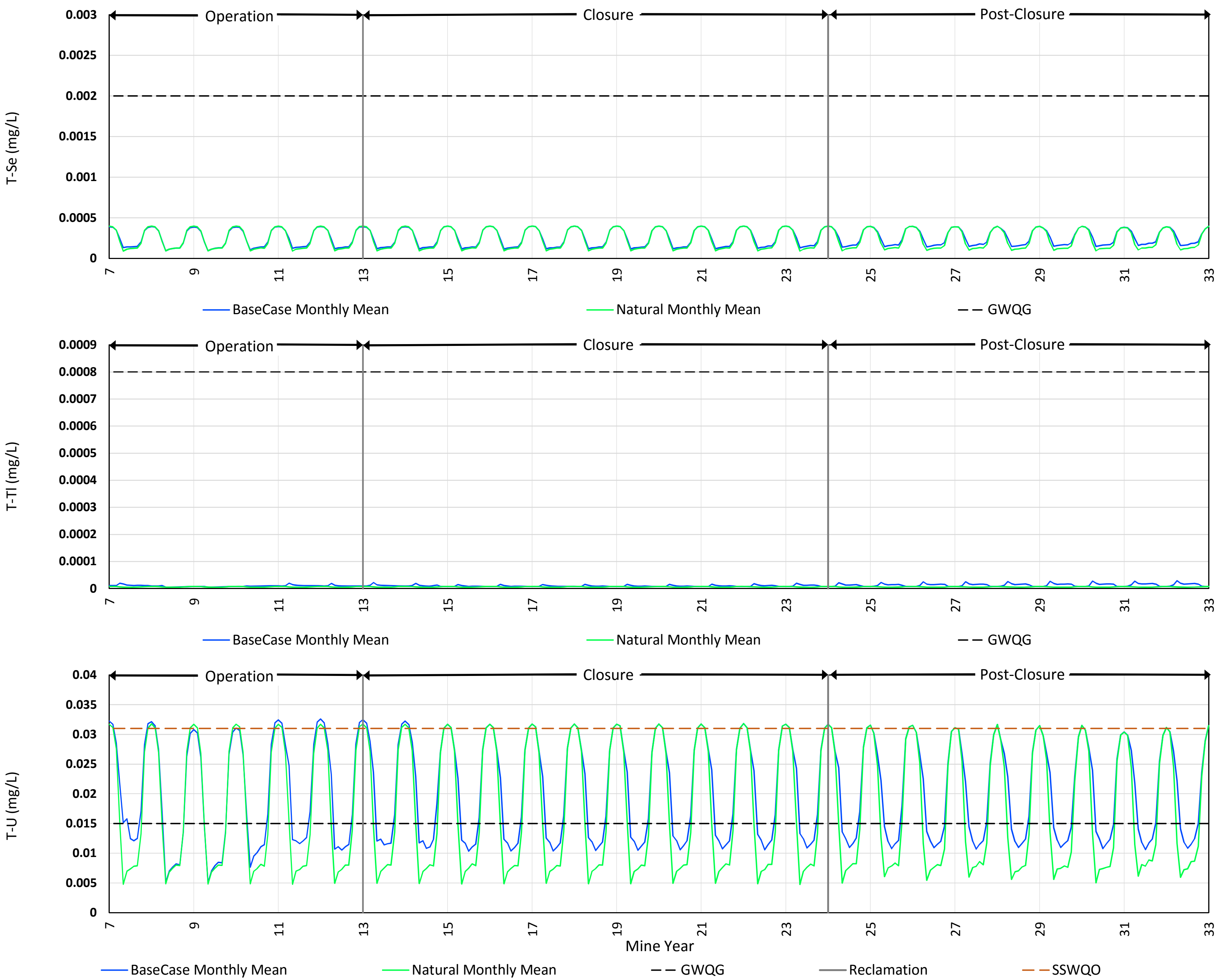


Operation
Closure
Post-Closure
T-Mg (mg/L)
BaseCase Monthly Mean
Natural Monthly Mean
T-Mn (mg/L)
GWQG
T-Mo (mg/L)
Mine Year

CC1.5

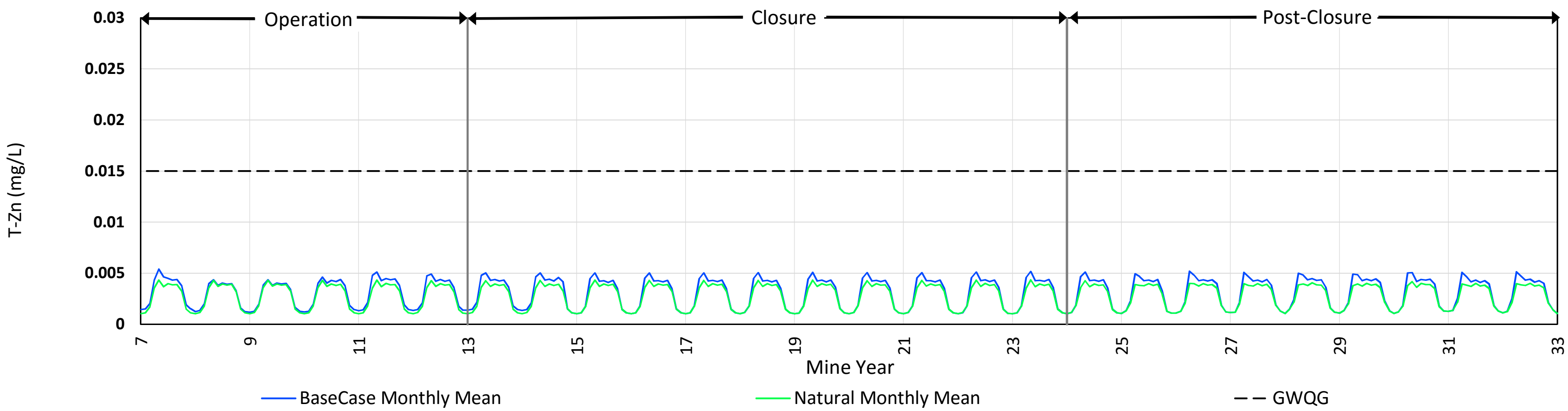

Operation
Closure
Post-Closure
T-Ni (mg/L)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
T-Pb (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
T-Sb (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
Mine Year

CC1.5

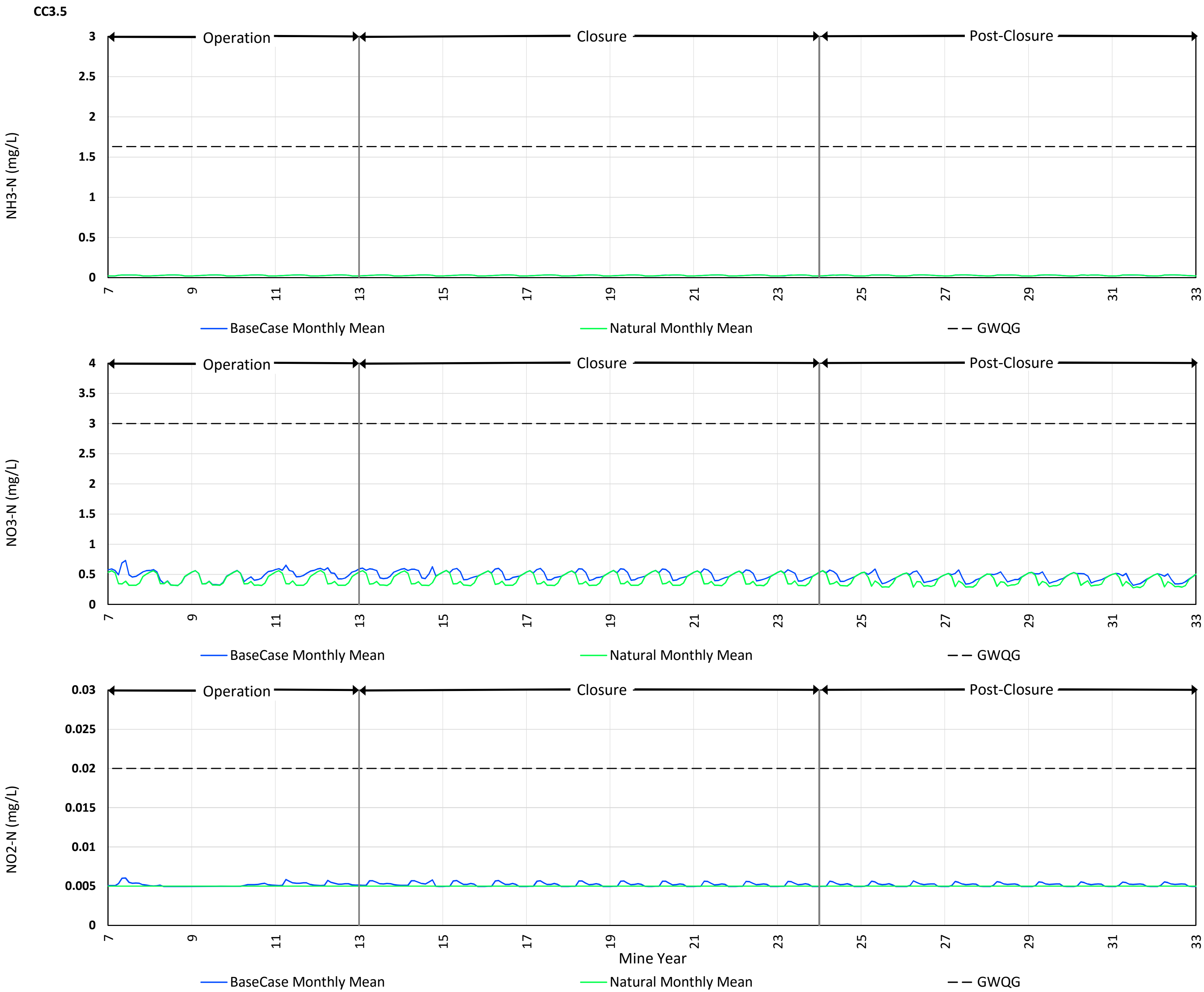


Operation
Closure
Post-Closure
T-Se (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7 9 11 13 15 17 19 21 23 25 27 29 31 33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
T-Tl (mg/L)
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
7 9 11 13 15 17 19 21 23 25 27 29 31 33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
T-U (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
7 9 11 13 15 17 19 21 23 25 27 29 31 33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
Reclamation
SSWQO

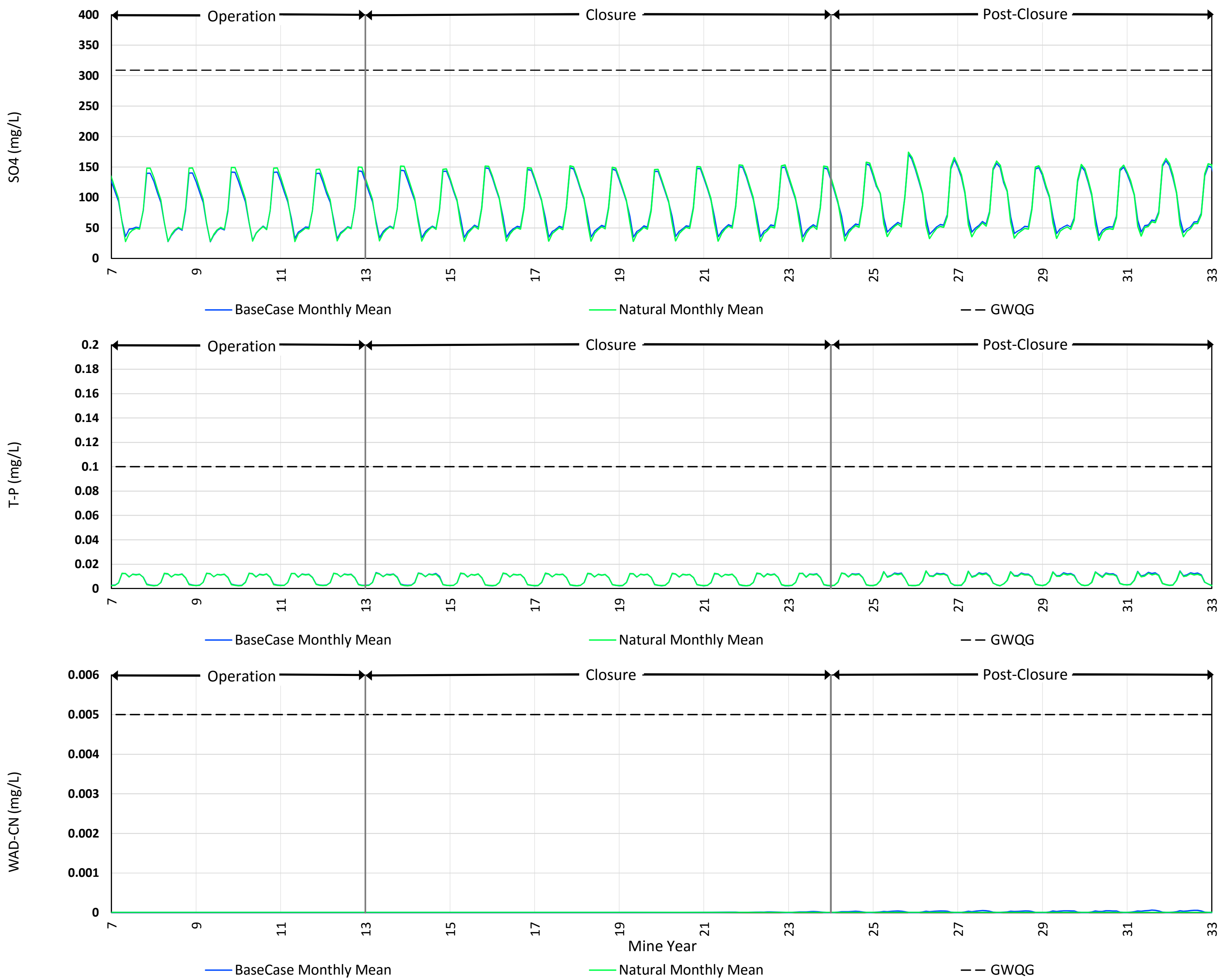
CC1.5



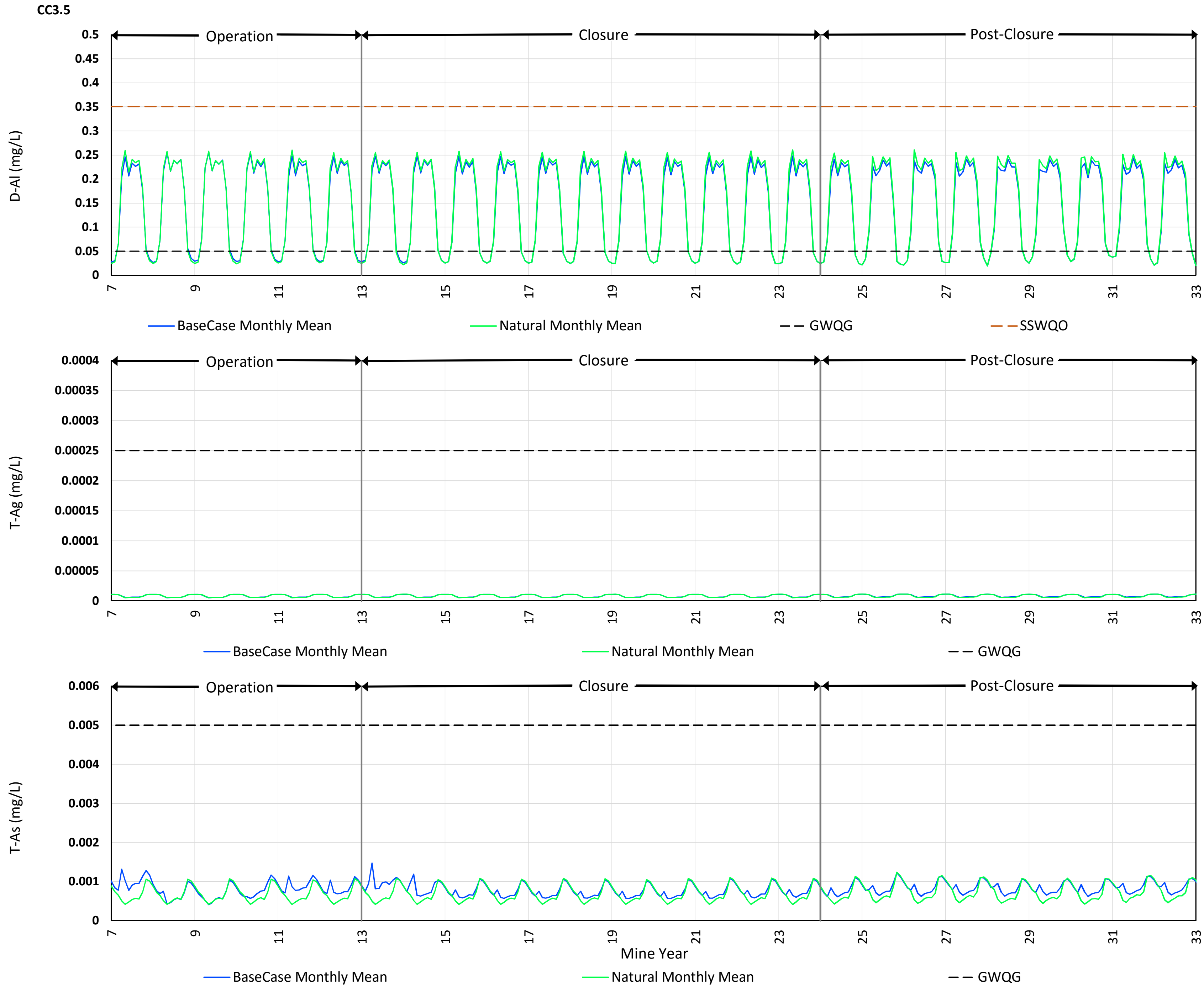
Operation
Closure
Post-Closure
0.03
0.025
0.02
0.015
0.01
0.005
0
T-Zn (mg/L)
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG


CC3.5
Operation
Closure
Post-Closure
NH3-N (mg/L)
3
2.5
2
1.5
1
0.5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
NO3-N (mg/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
NO2-N (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

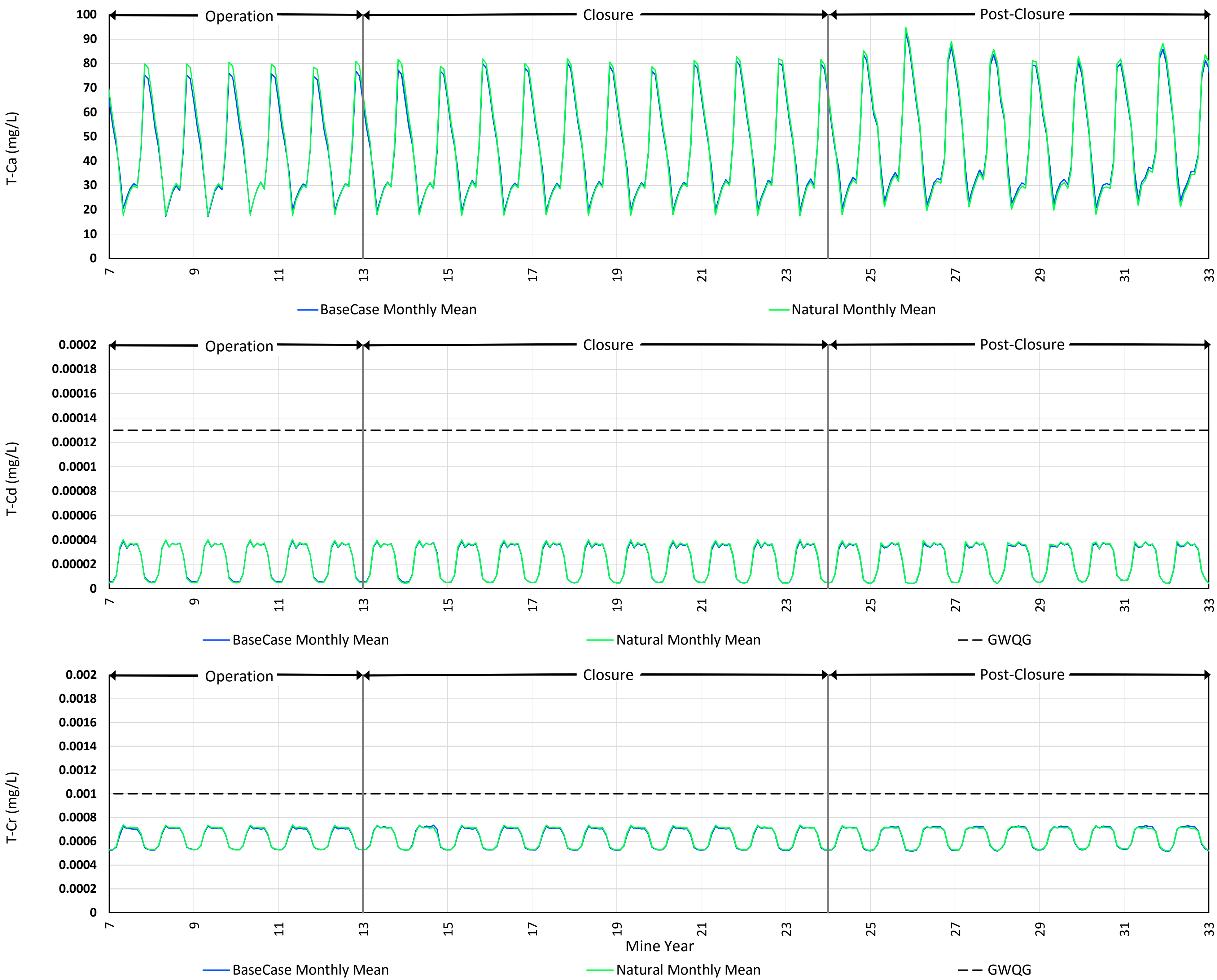
CC3.5



Operation
Closure
Post-Closure
SO4 (mg/L)
400
350
300
250
200
150
100
50
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
T-P (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
WAD-CN (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
Mine Year

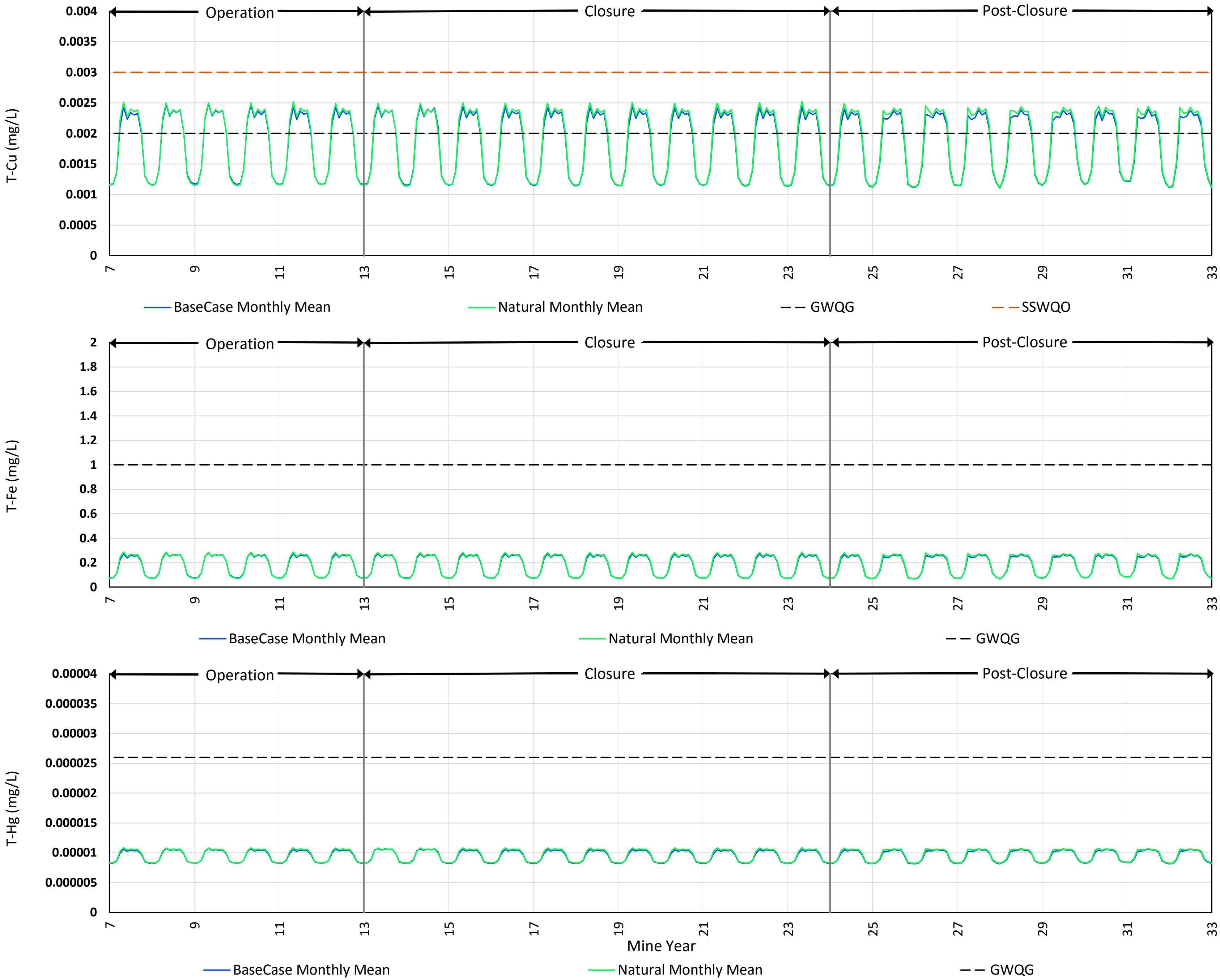

CC3.5
D-Al (mg/L)
Operation
Closure
Post-Closure
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Ag (mg/L)
T-As (mg/L)
Mine Year

CC3.5

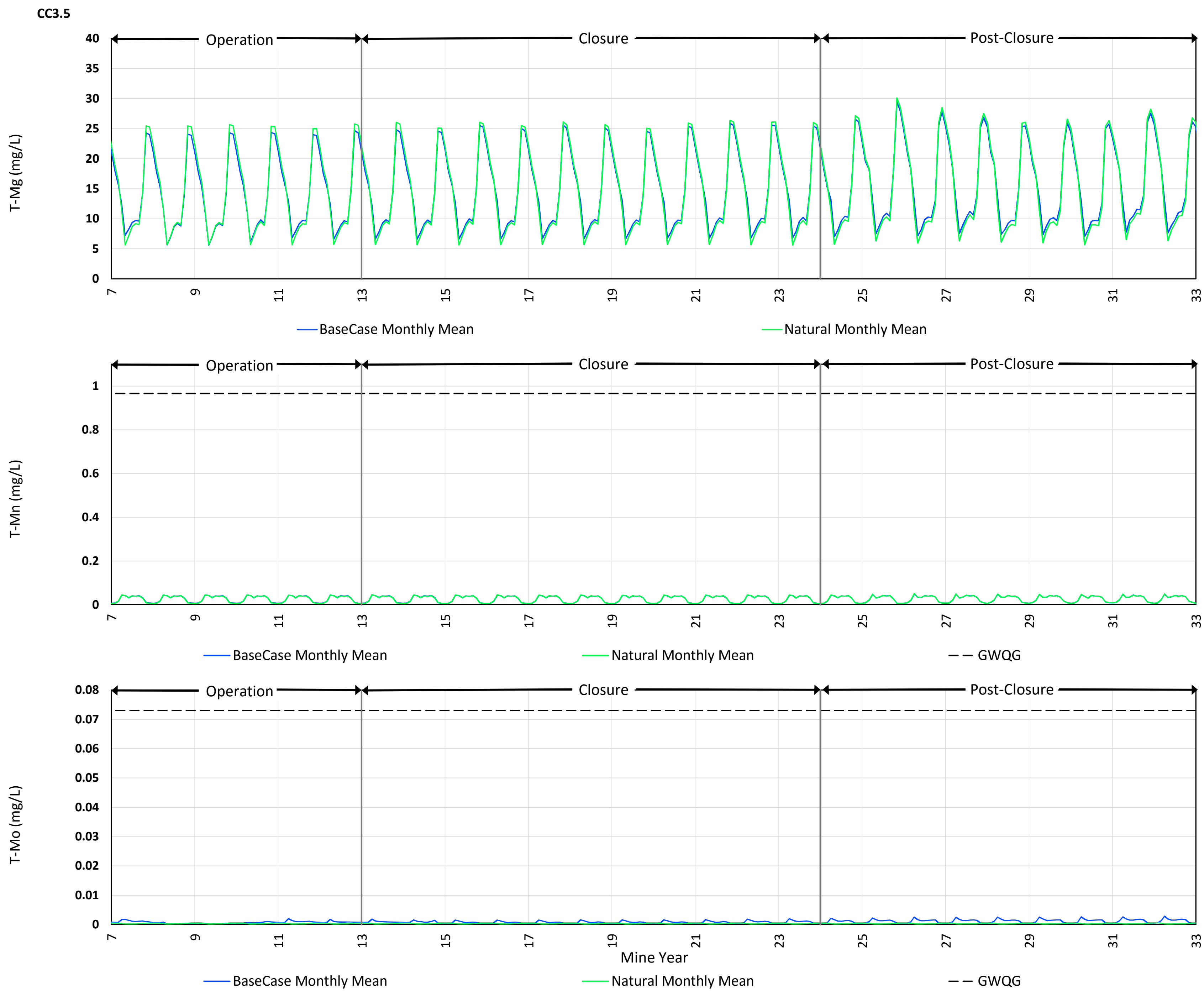


Operation
Closure
Post-Closure
T-Ca (mg/L)
100
90
80
70
60
50
40
30
20
10
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Cd (mg/L)
0.0002
0.00018
0.00016
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
GWQG
T-Cr (mg/L)
0.002
0.0018
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
Mine Year

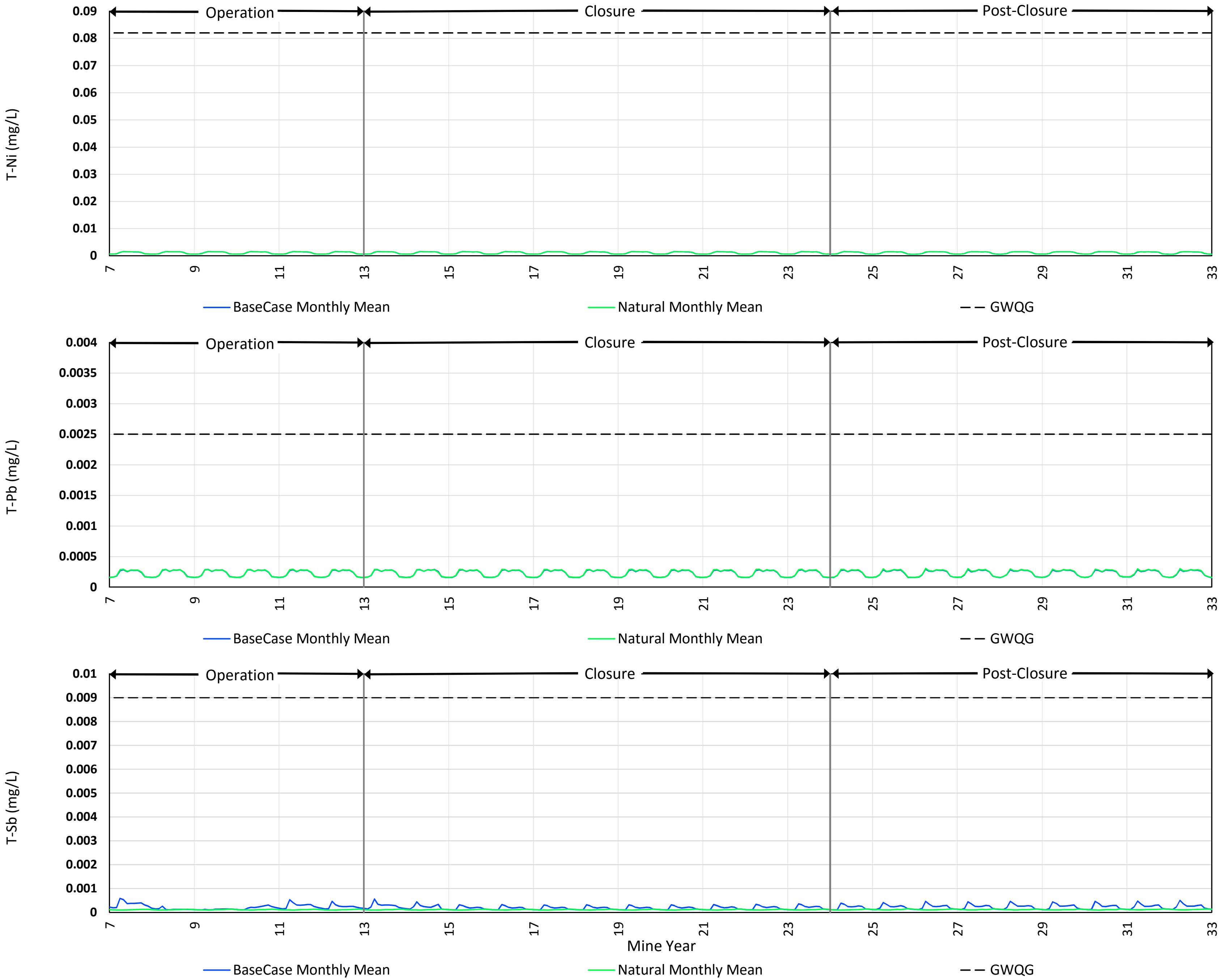
CC3.5



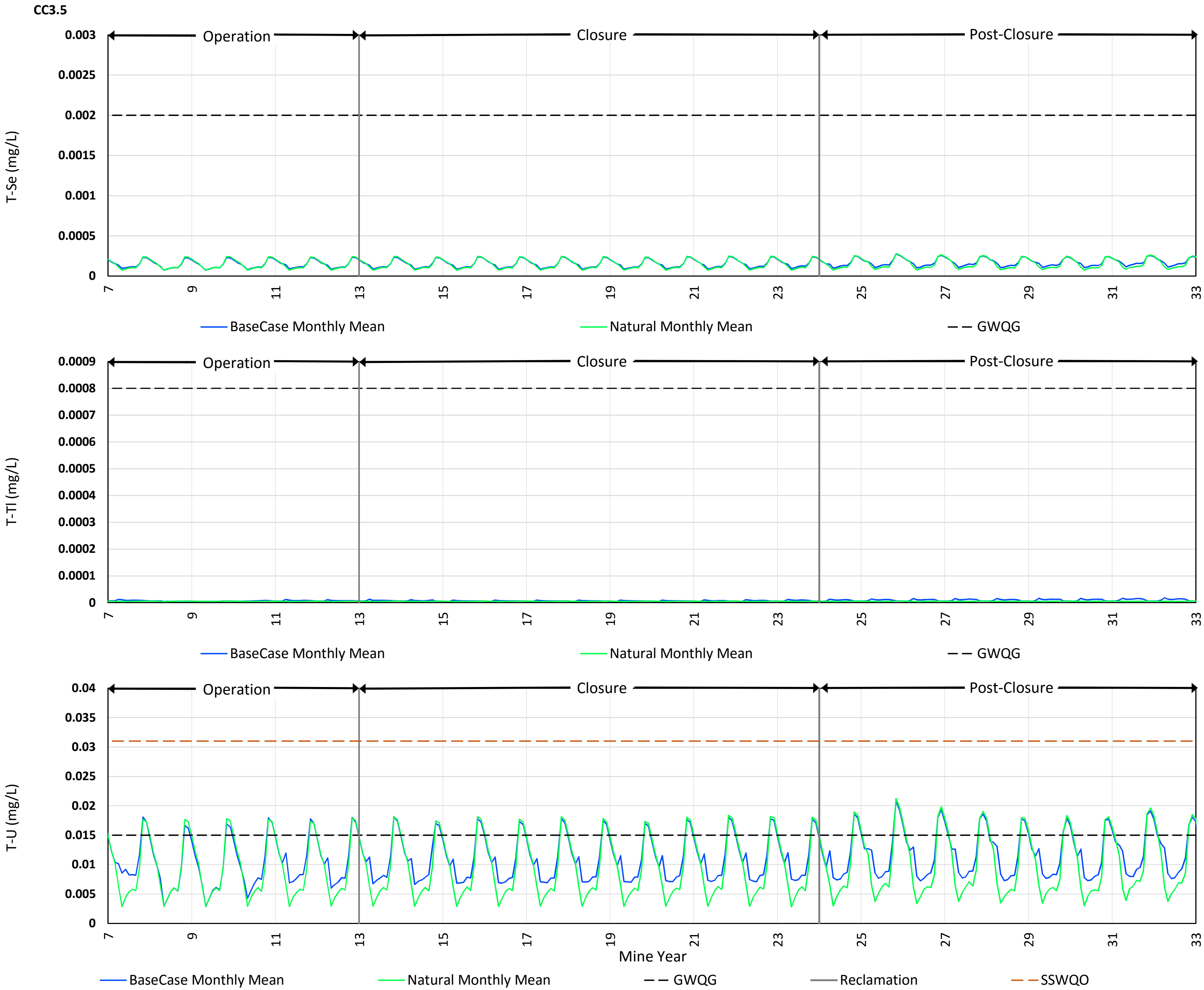
Operation
Closure
Post-Closure
T-Cu (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Fe (mg/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
T-Hg (mg/L)
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
0
Mine Year

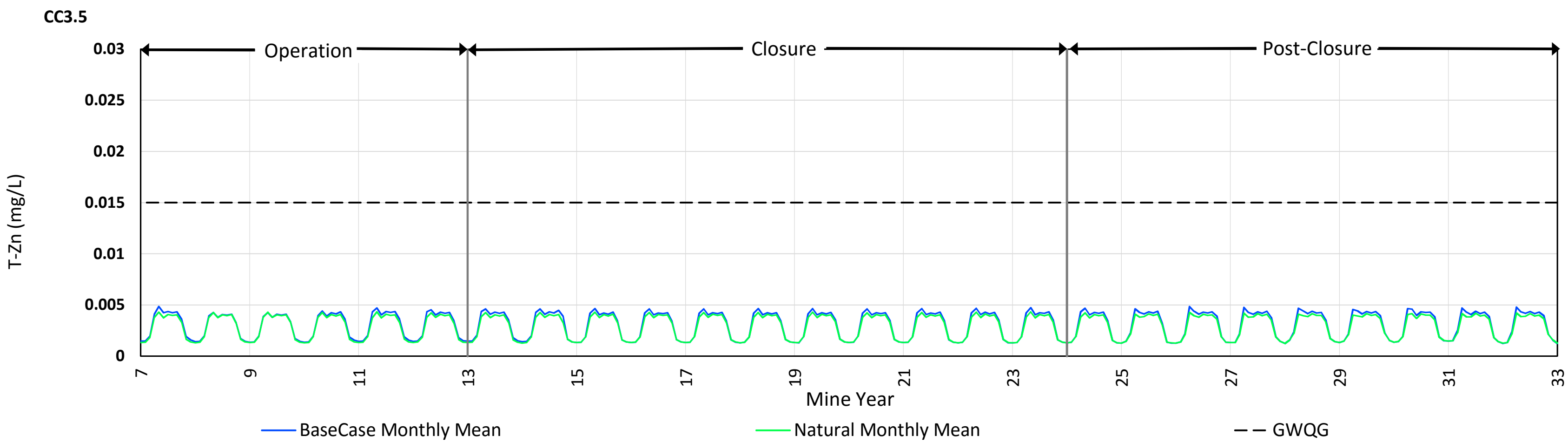

CC3.5
T-Mg (mg/L)
Operation
Closure
Post-Closure
BaseCase Monthly Mean
Natural Monthly Mean
T-Mn (mg/L)
GWQG
T-Mo (mg/L)
Mine Year

CC3.5

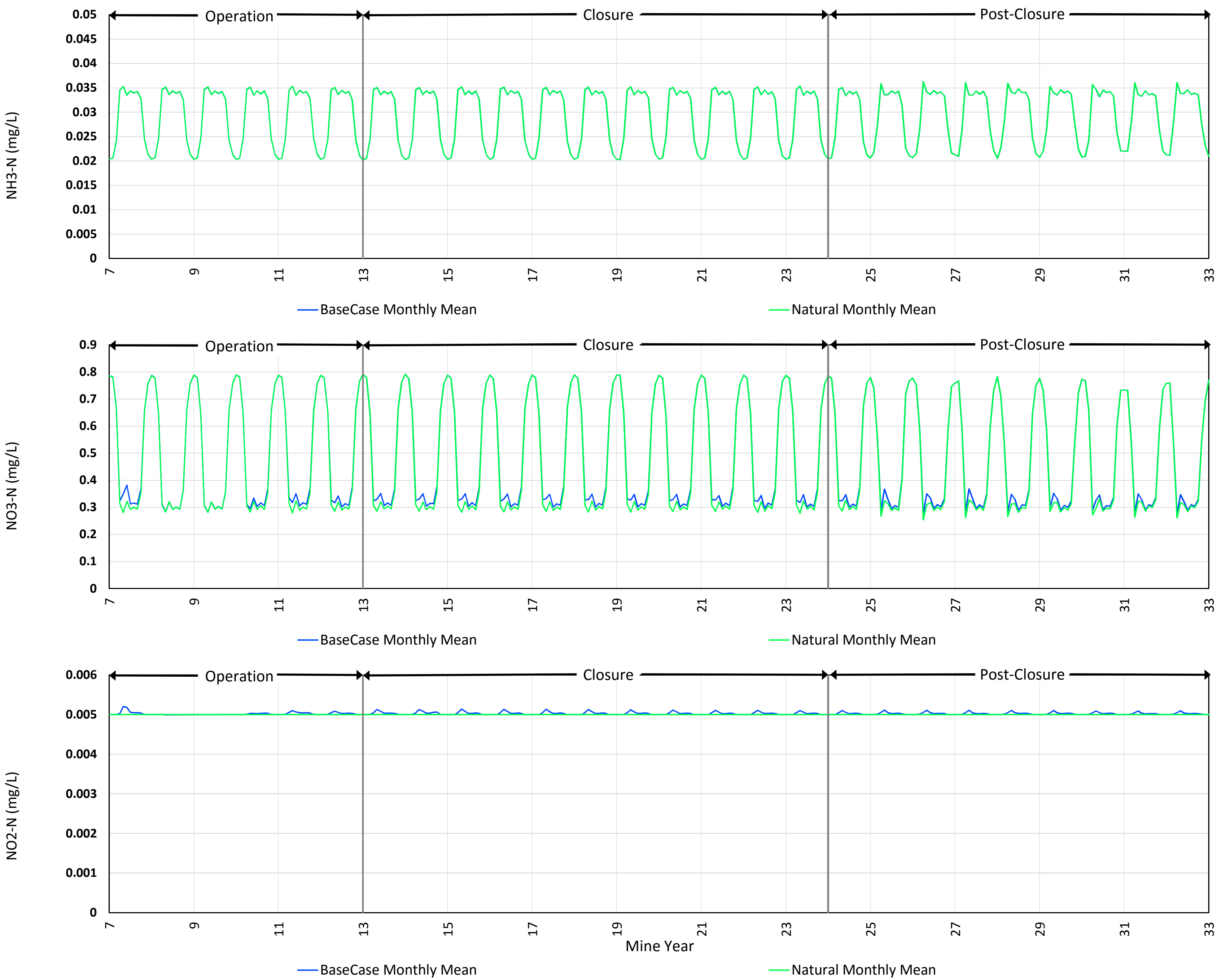


Operation
Closure
Post-Closure
T-Ni (mg/L)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
T-Pb (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
T-Sb (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

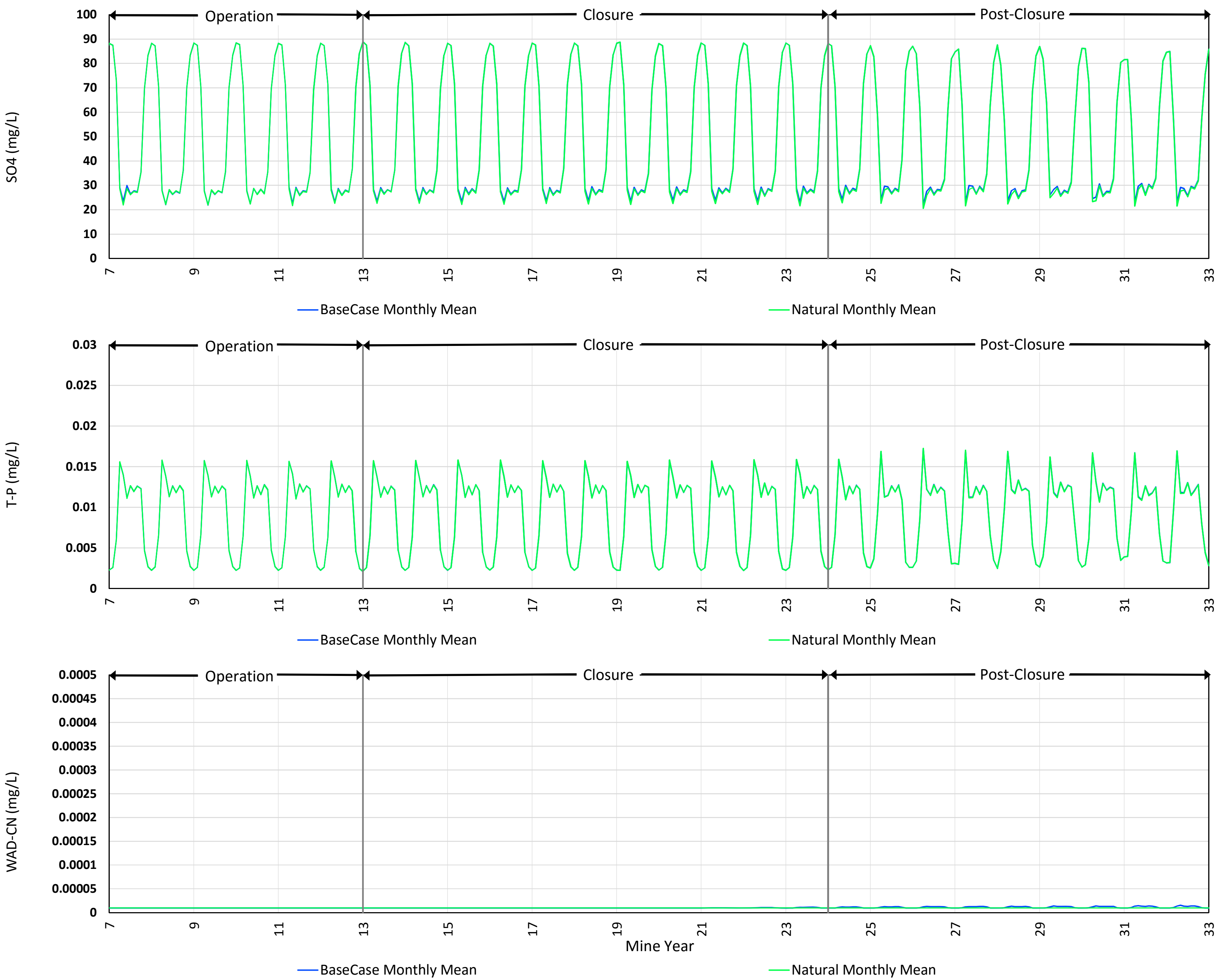

CC3.5
Operation
Closure
Post-Closure
T-Se (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
T-Tl (mg/L)
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
T-U (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Mine Year
Reclamation
SSWQO


CC3.5
Operation
Closure
Post-Closure
T-Zn (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

CC4.5

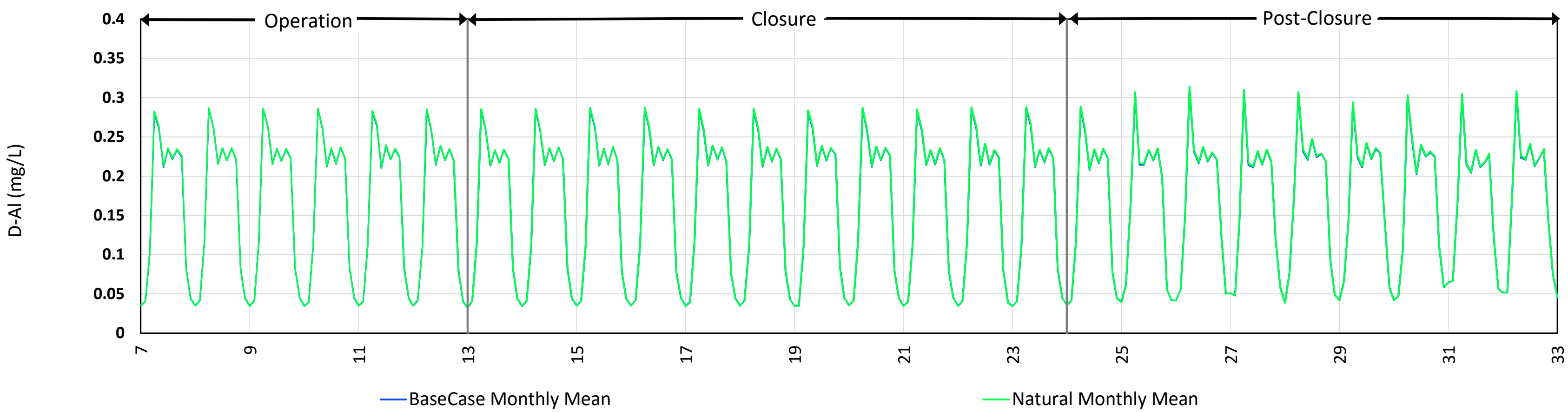

Operation
Closure
Post-Closure
NH3-N (mg/L)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
Operation
Closure
Post-Closure
NO3-N (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
Operation
Closure
Post-Closure
NO2-N (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

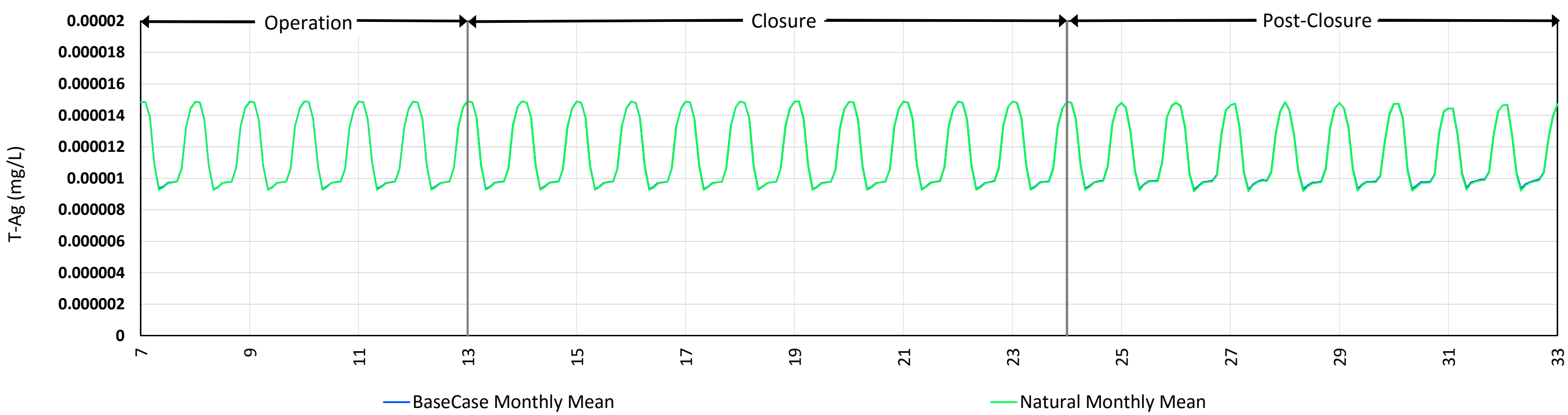
CC4.5

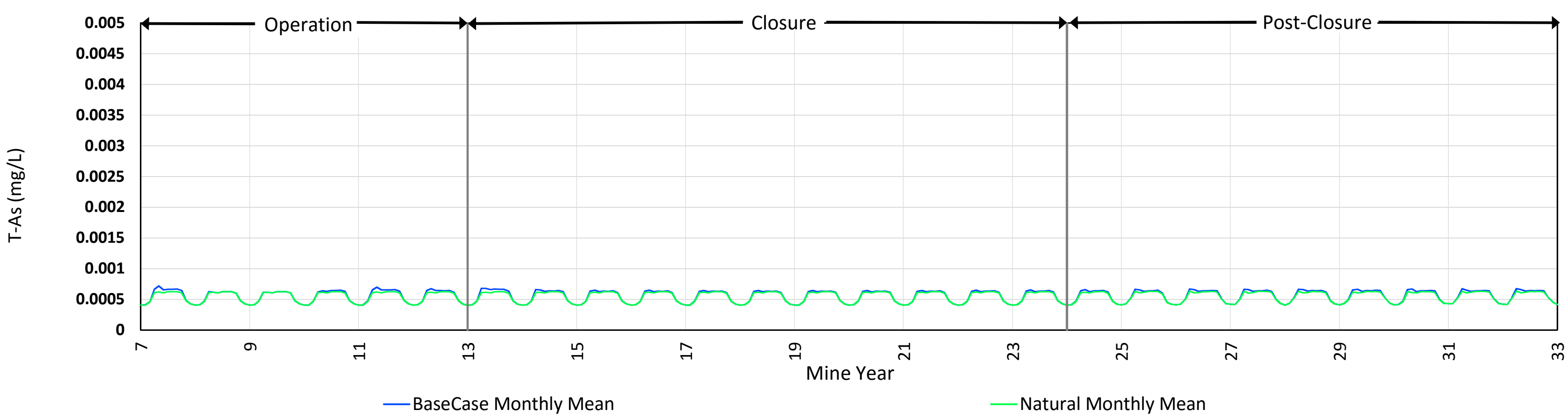


Operation
Closure
Post-Closure
SO4 (mg/L)
100
90
80
70
60
50
40
30
20
10
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
Operation
Closure
Post-Closure
T-P (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
BaseCase Monthly Mean
Natural Monthly Mean
Operation
Closure
Post-Closure
WAD-CN (mg/L)
0.0005
0.00045
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
0
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

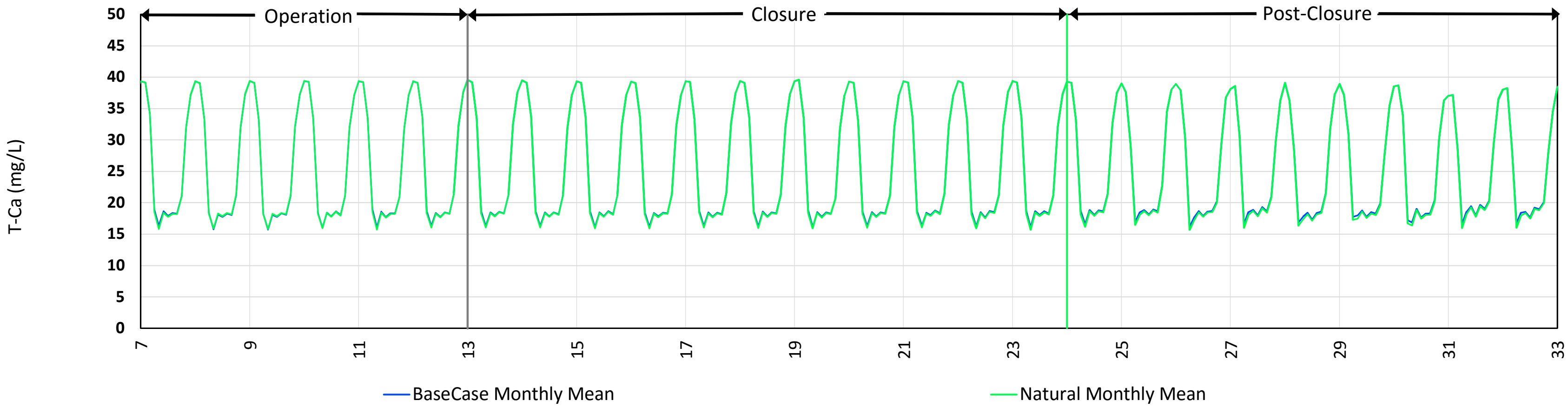
CC4.5


Operation
Closure
Post-Closure
D-Al (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean

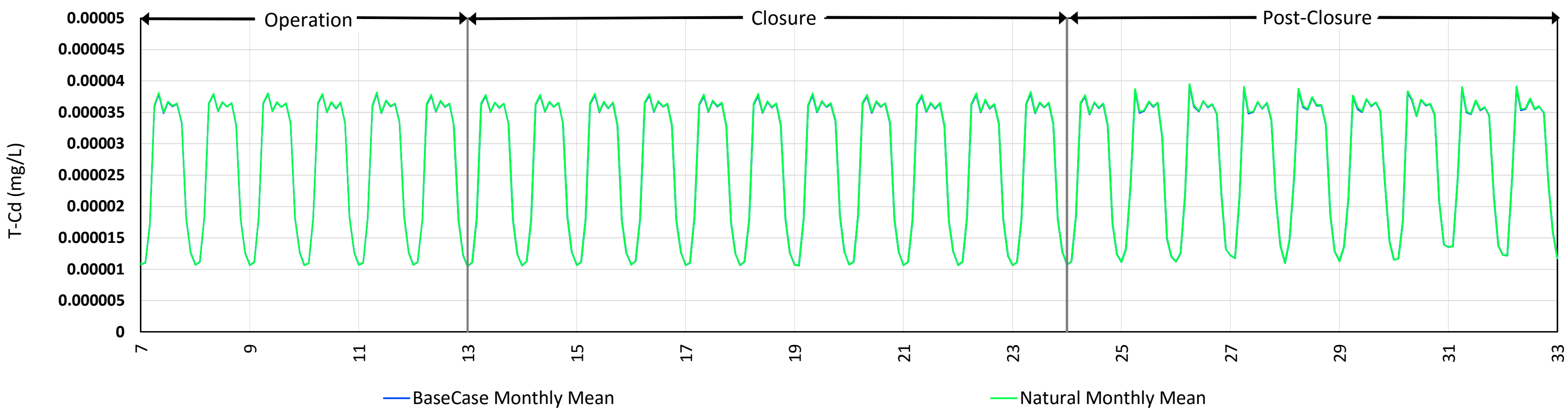

Operation
Closure
Post-Closure
T-Ag (mg/L)
0.00002
0.000018
0.000016
0.000014
0.000012
0.00001
0.000008
0.000006
0.000004
0.000002
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean


Operation
Closure
Post-Closure
T-As (mg/L)
0.005
0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

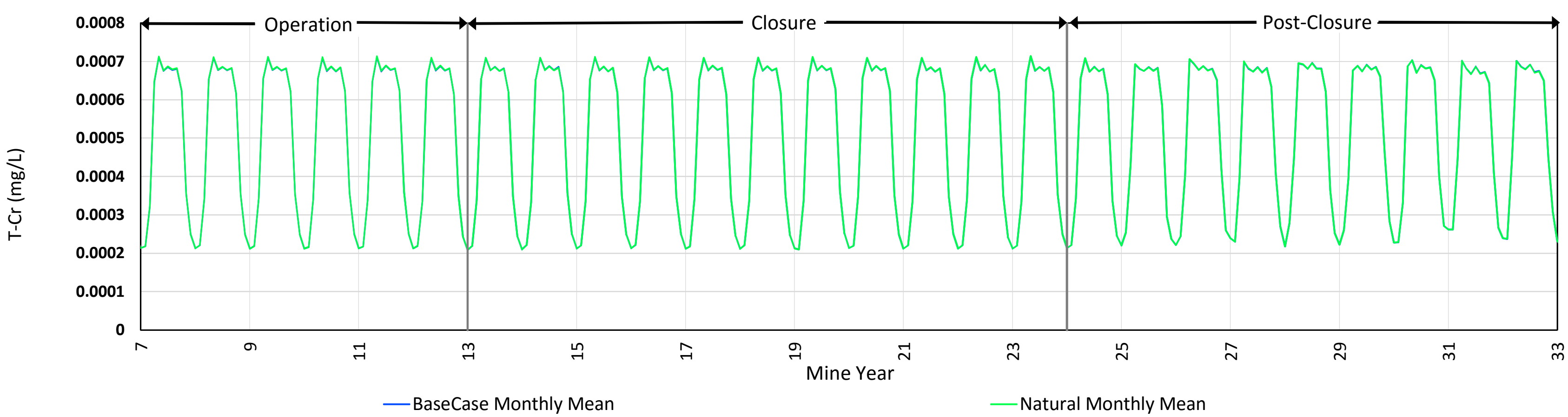
CC4.5



Operation
Closure
Post-Closure
T-Ca (mg/L)
50
45
40
35
30
25
20
15
10
5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean

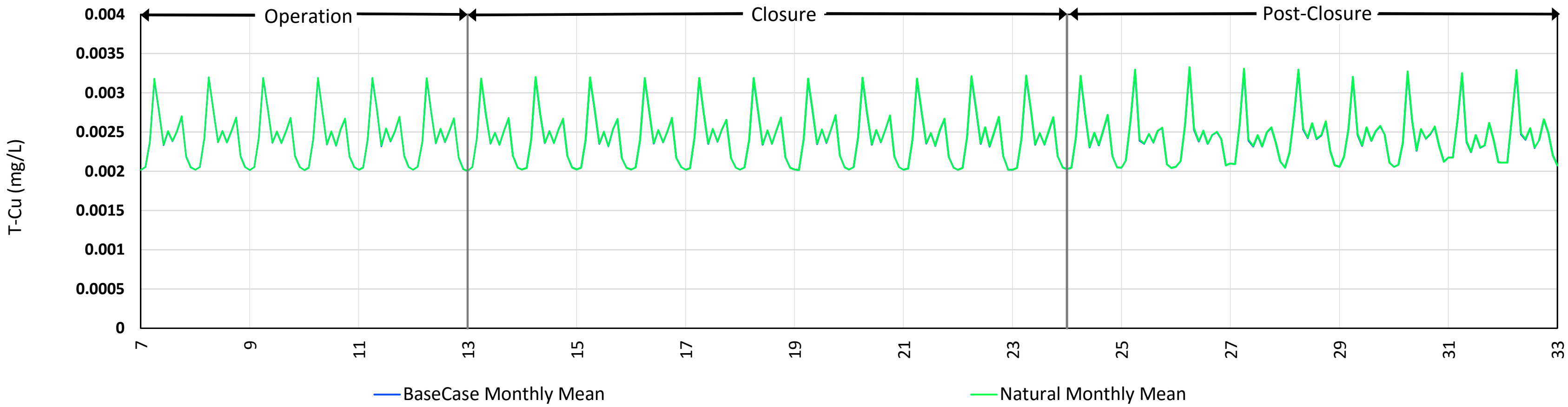


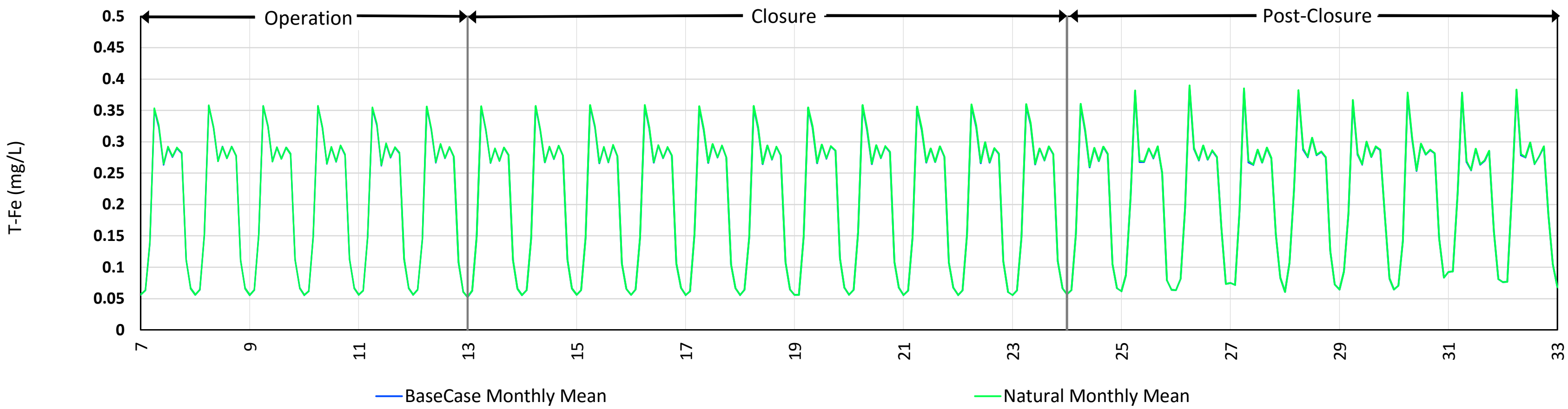
Operation
Closure
Post-Closure
T-Cd (mg/L)
0.00005
0.000045
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean

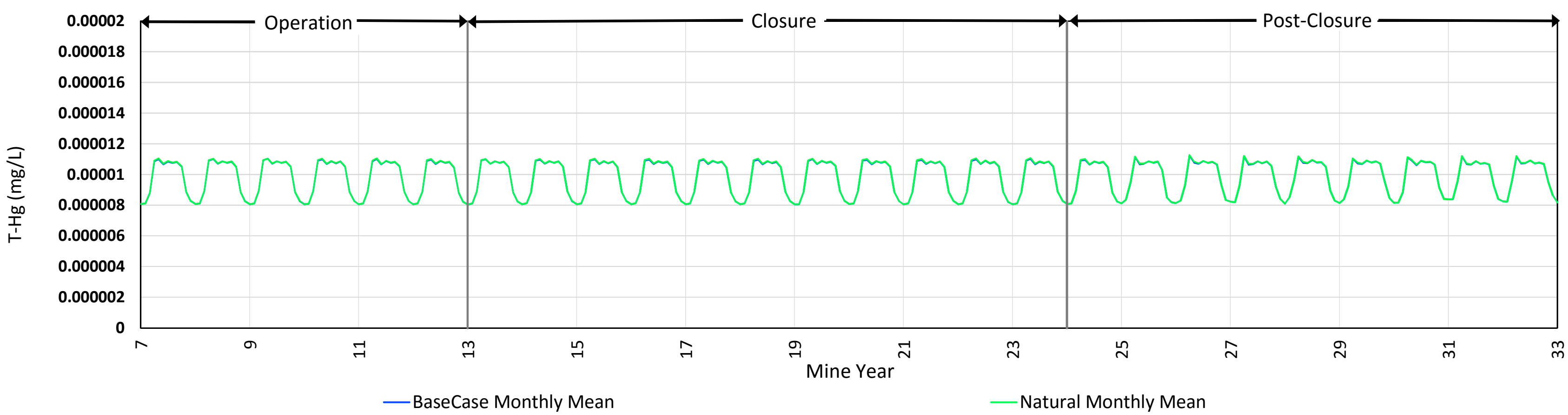


Operation
Closure
Post-Closure
T-Cr (mg/L)
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

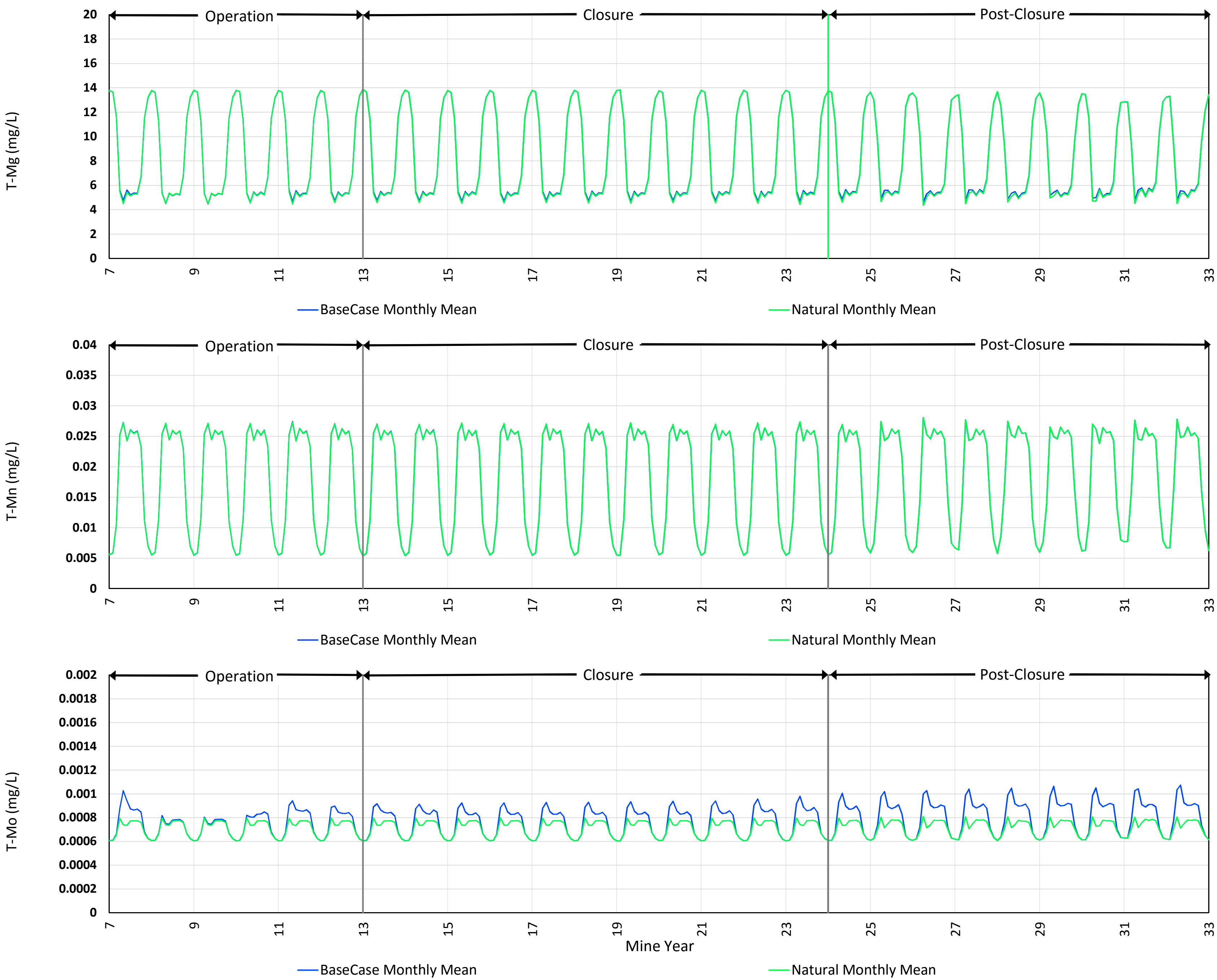
CC4.5


Operation
Closure
Post-Closure
T-Cu (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean


Operation
Closure
Post-Closure
T-Fe (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean

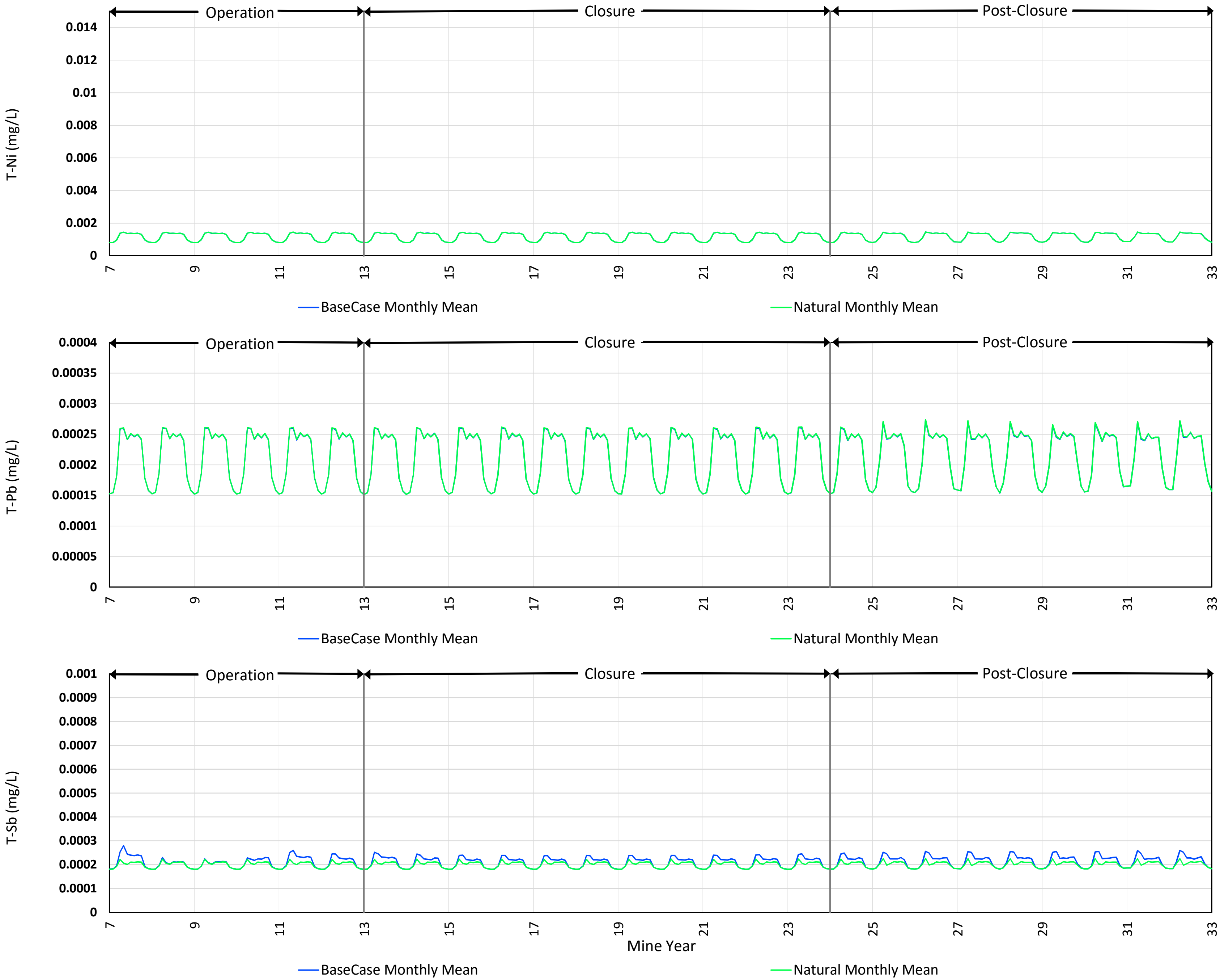

Operation
Closure
Post-Closure
T-Hg (mg/L)
0.00002
0.000018
0.000016
0.000014
0.000012
0.00001
0.000008
0.000006
0.000004
0.000002
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

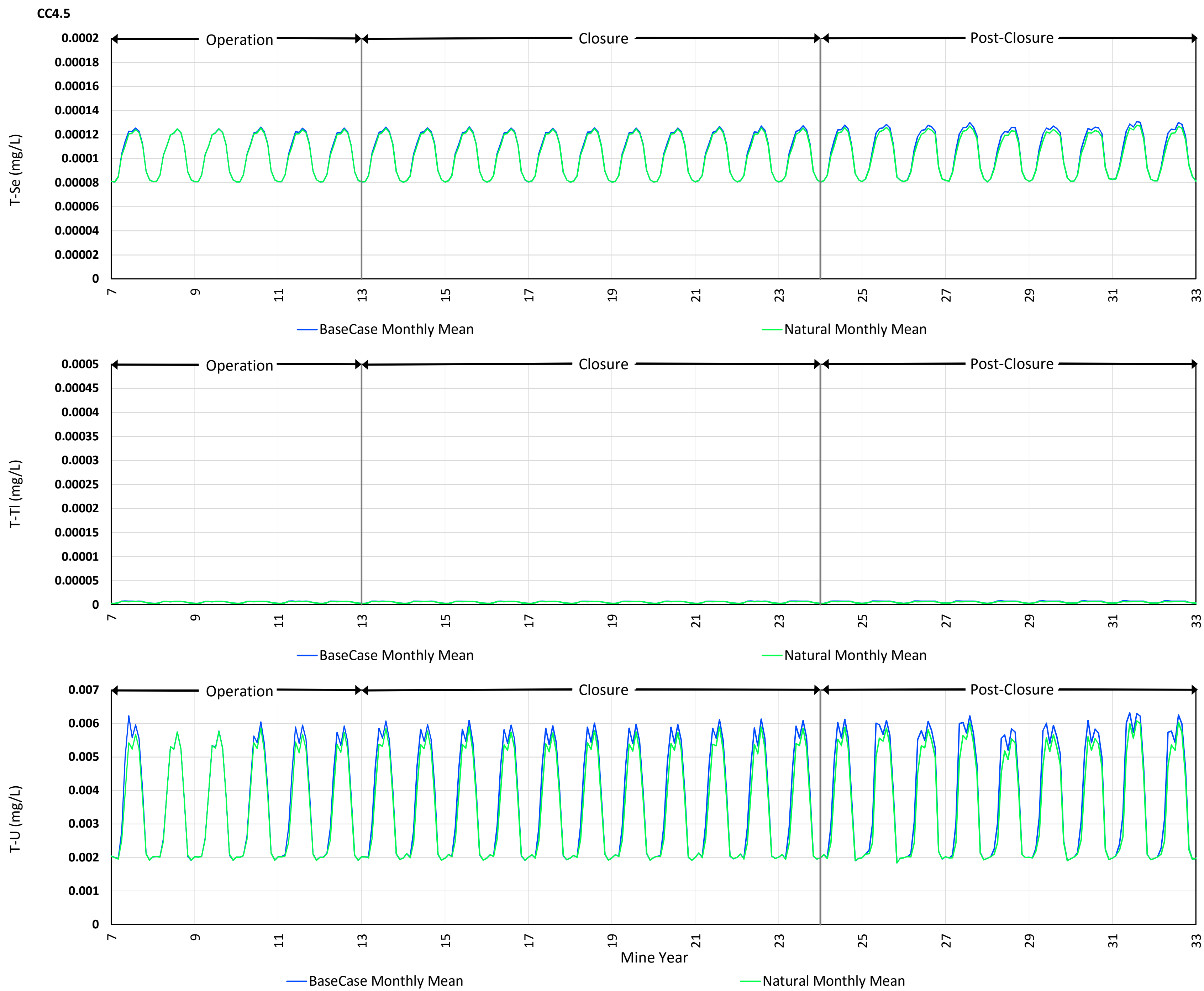
CC4.5



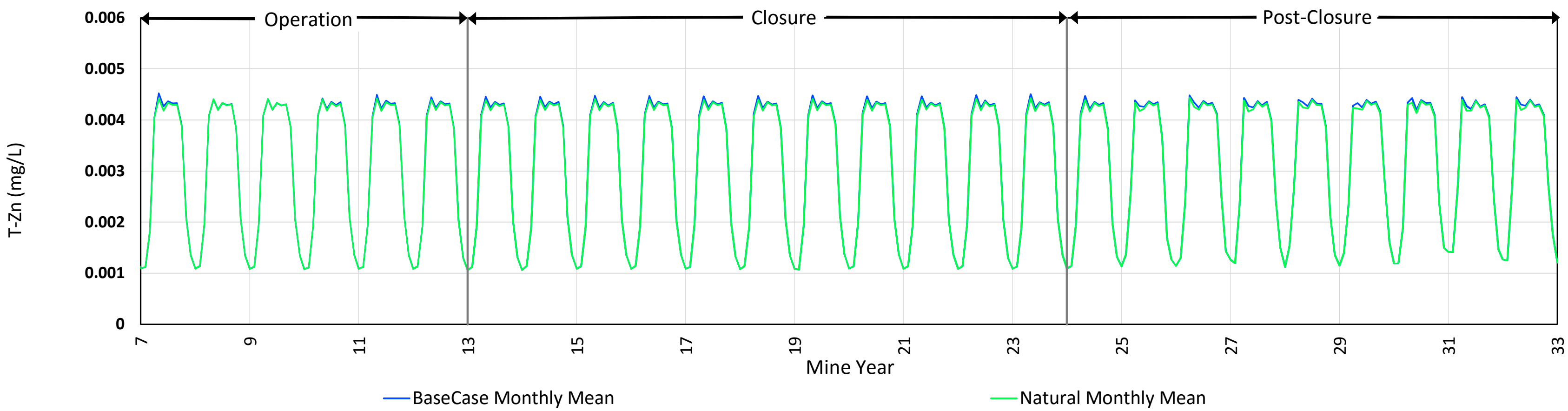
Operation
Closure
Post-Closure
T-Mg (mg/L)
0
2
4
6
8
10
12
14
16
18
20
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Mn (mg/L)
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
T-Mo (mg/L)
0
0.0002
0.0004
0.0006
0.0008
0.001
0.0012
0.0014
0.0016
0.0018
0.002
Mine Year

CC4.5

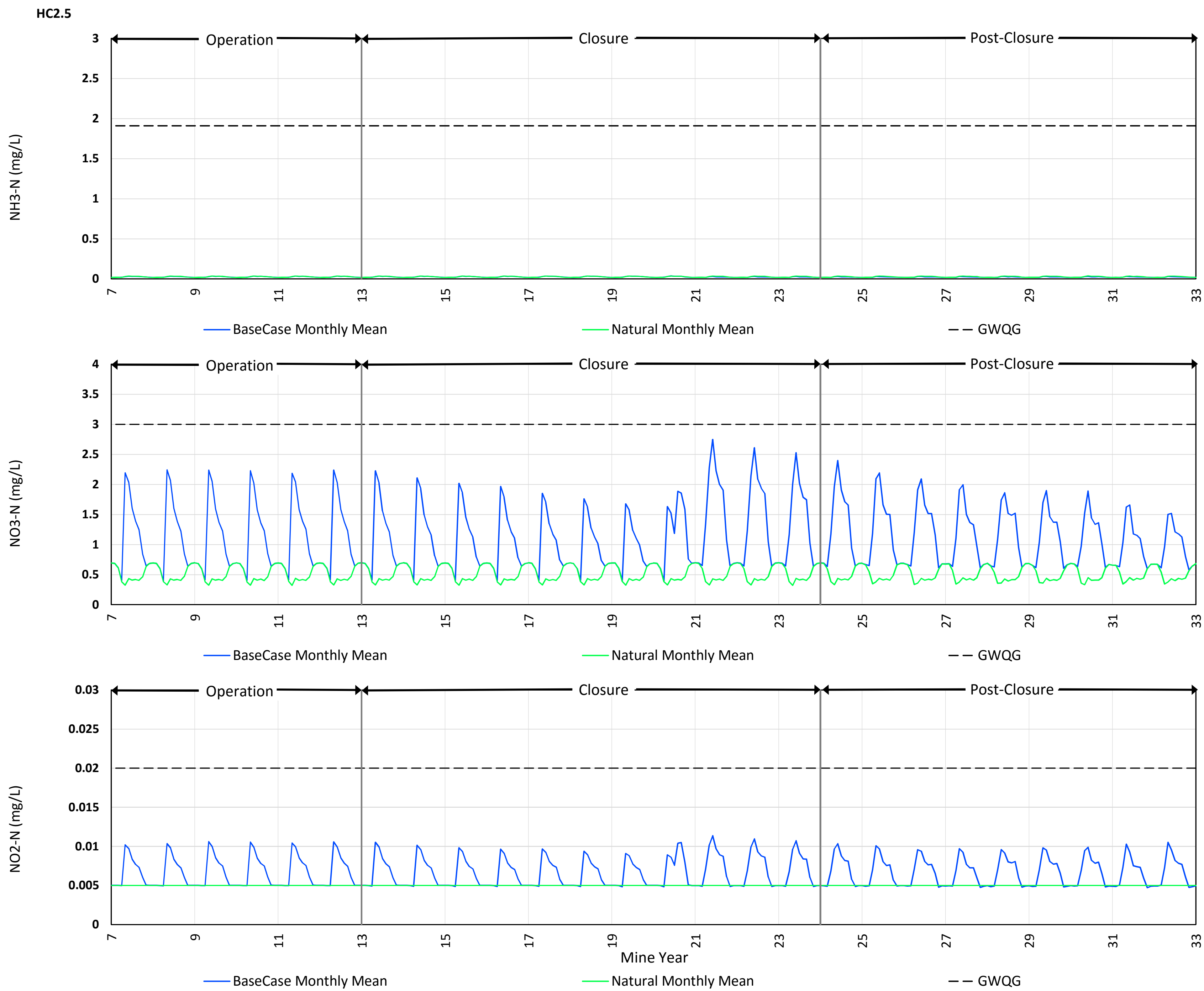

Operation
Closure
Post-Closure
T-Ni (mg/L)
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Pb (mg/L)
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
T-Sb (mg/L)
0.001
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
Mine Year


CC4.5
Operation
Closure
Post-Closure
T-Se (mg/L)
0.0002
0.00018
0.00016
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Tl (mg/L)
0.0005
0.00045
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
T-U (mg/L)
0.007
0.006
0.005
0.004
0.003
0.002
0.001
Mine Year

CC4.5

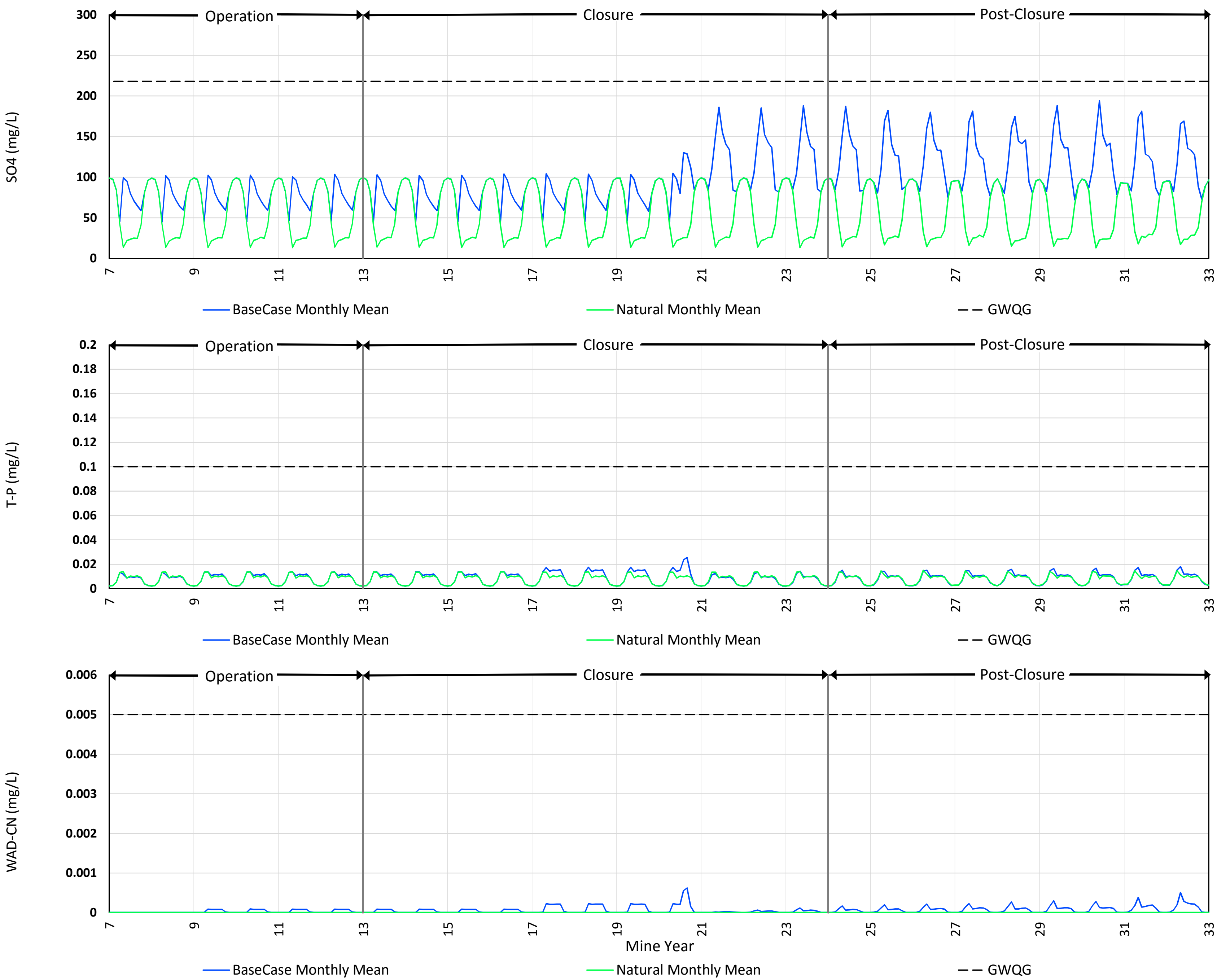


Operation
Closure
Post-Closure
T-Zn (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

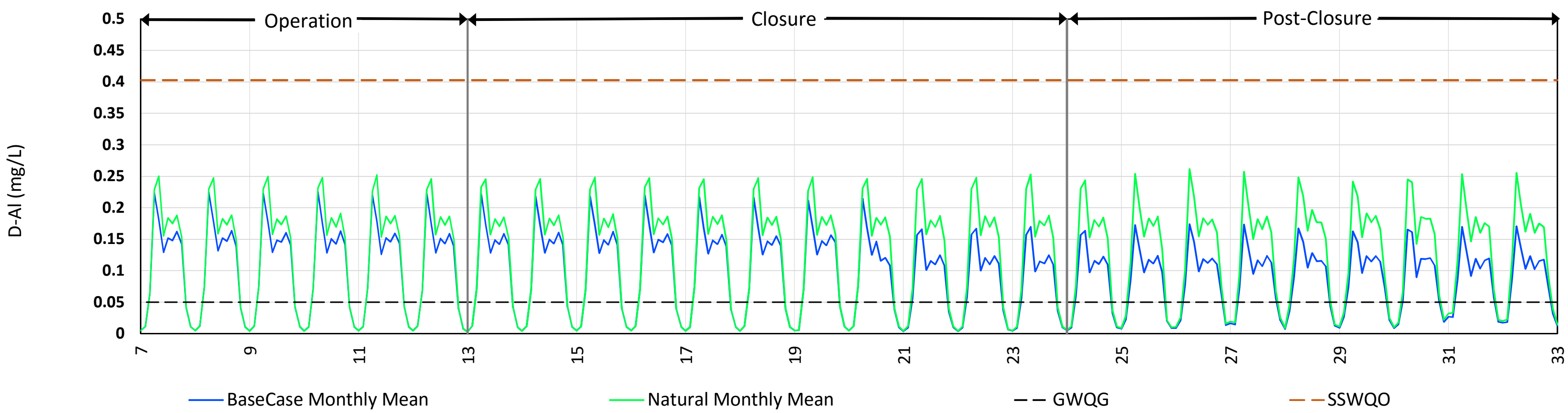


HC2.5
Operation
Closure
Post-Closure
NH3-N (mg/L)
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
NO3-N (mg/L)
NO2-N (mg/L)
Mine Year

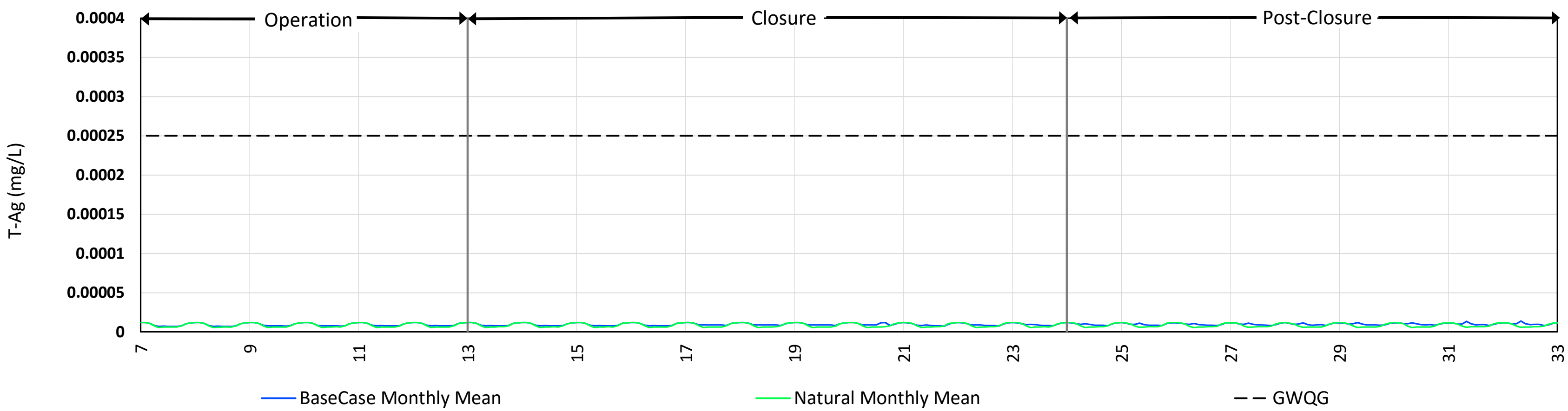
HC2.5


Operation
Closure
Post-Closure
SO4 (mg/L)
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
T-P (mg/L)
WAD-CN (mg/L)
Mine Year

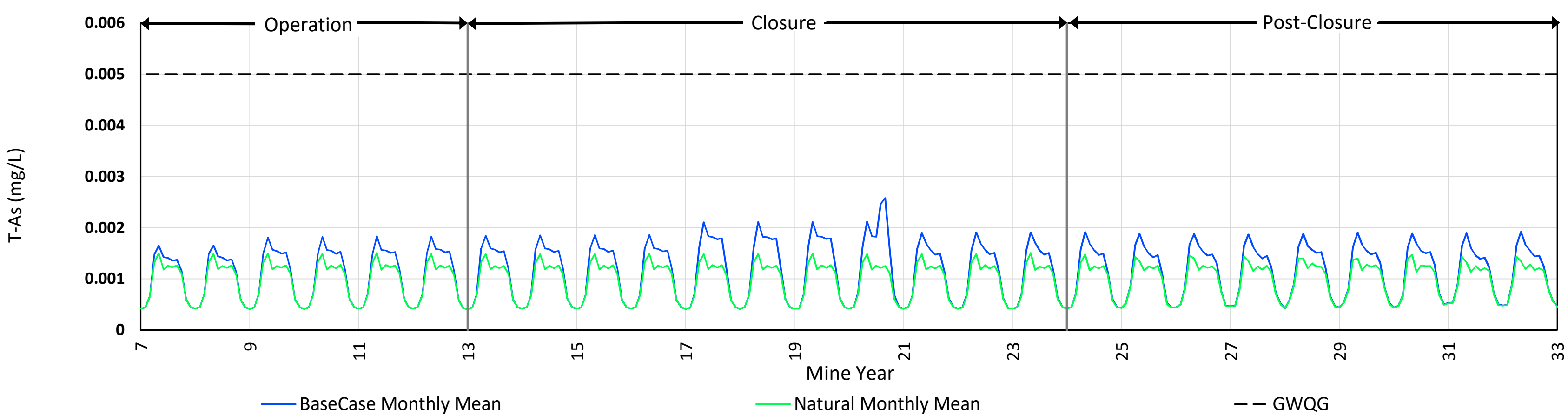
HC2.5



Operation
Closure
Post-Closure
D-Al (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
SSWQO

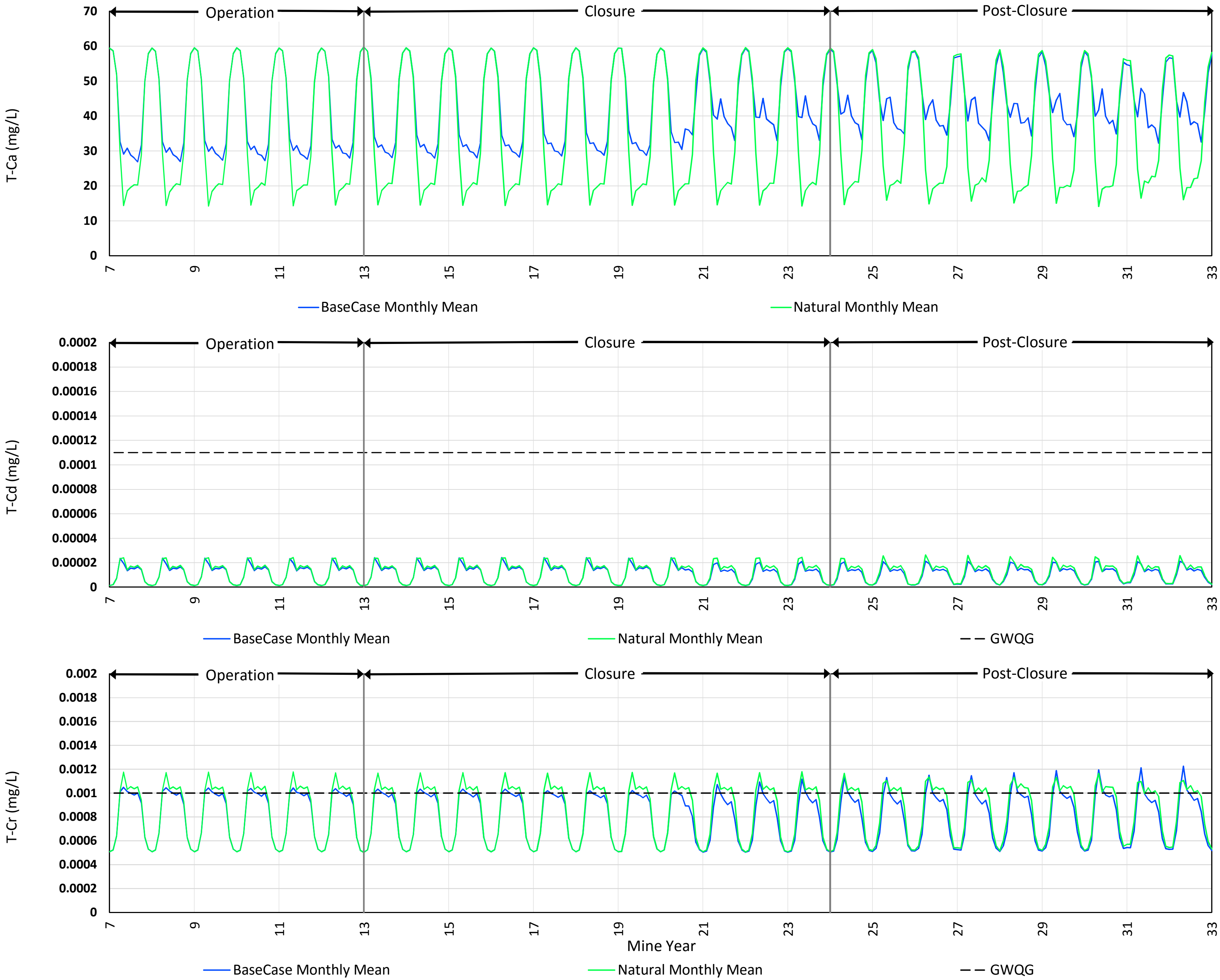


Operation
Closure
Post-Closure
T-Ag (mg/L)
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

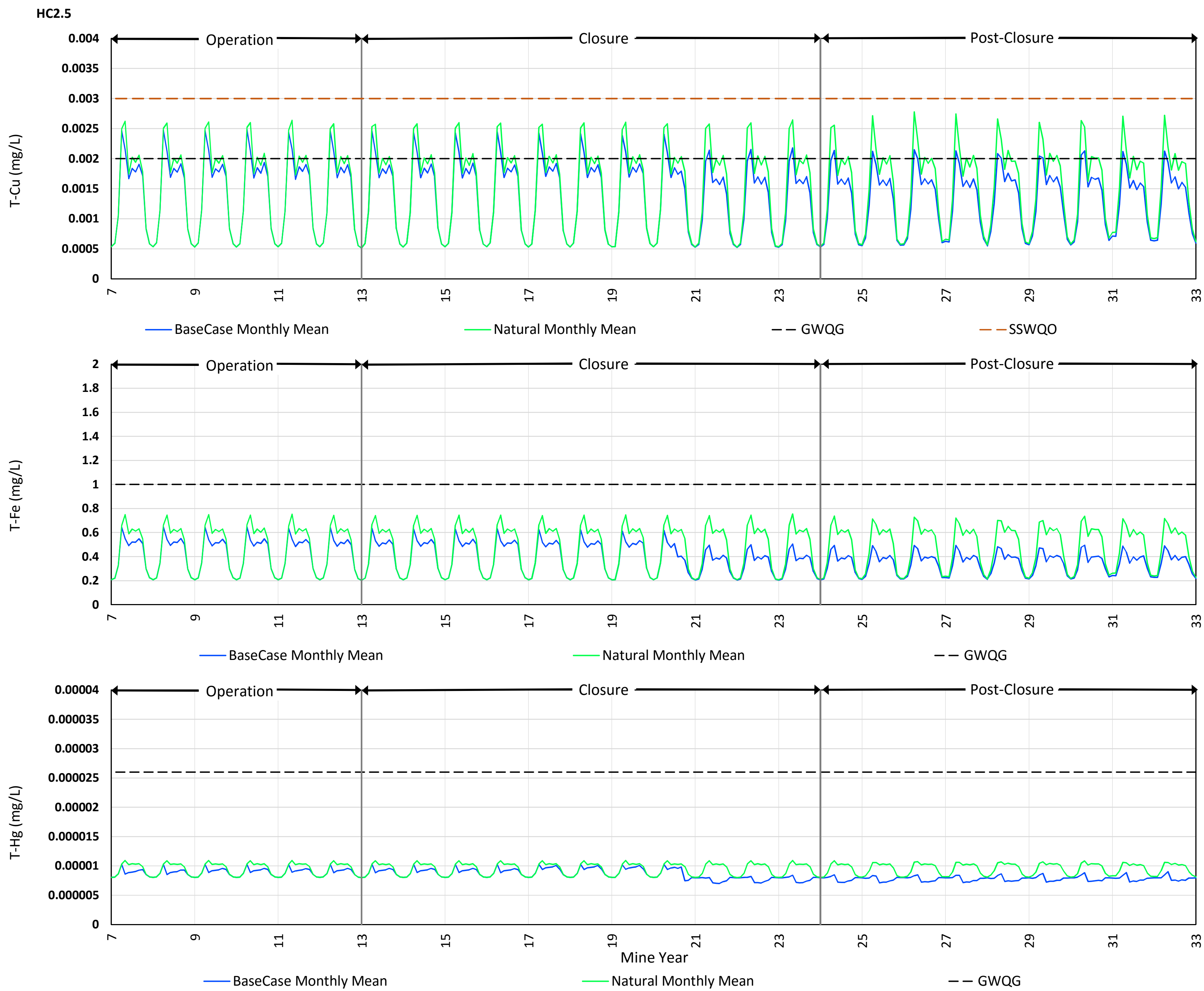


Operation
Closure
Post-Closure
T-As (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

HC2.5

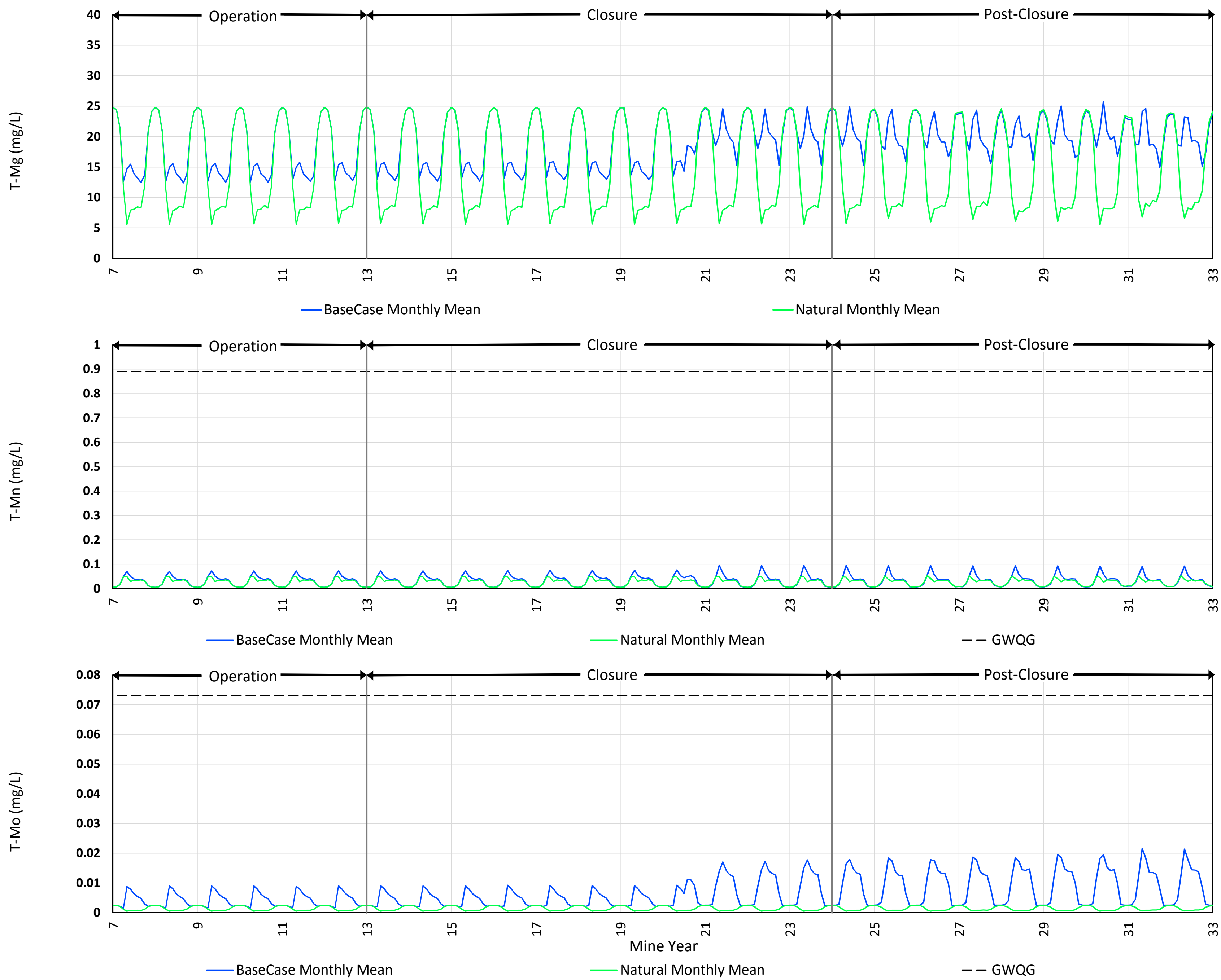


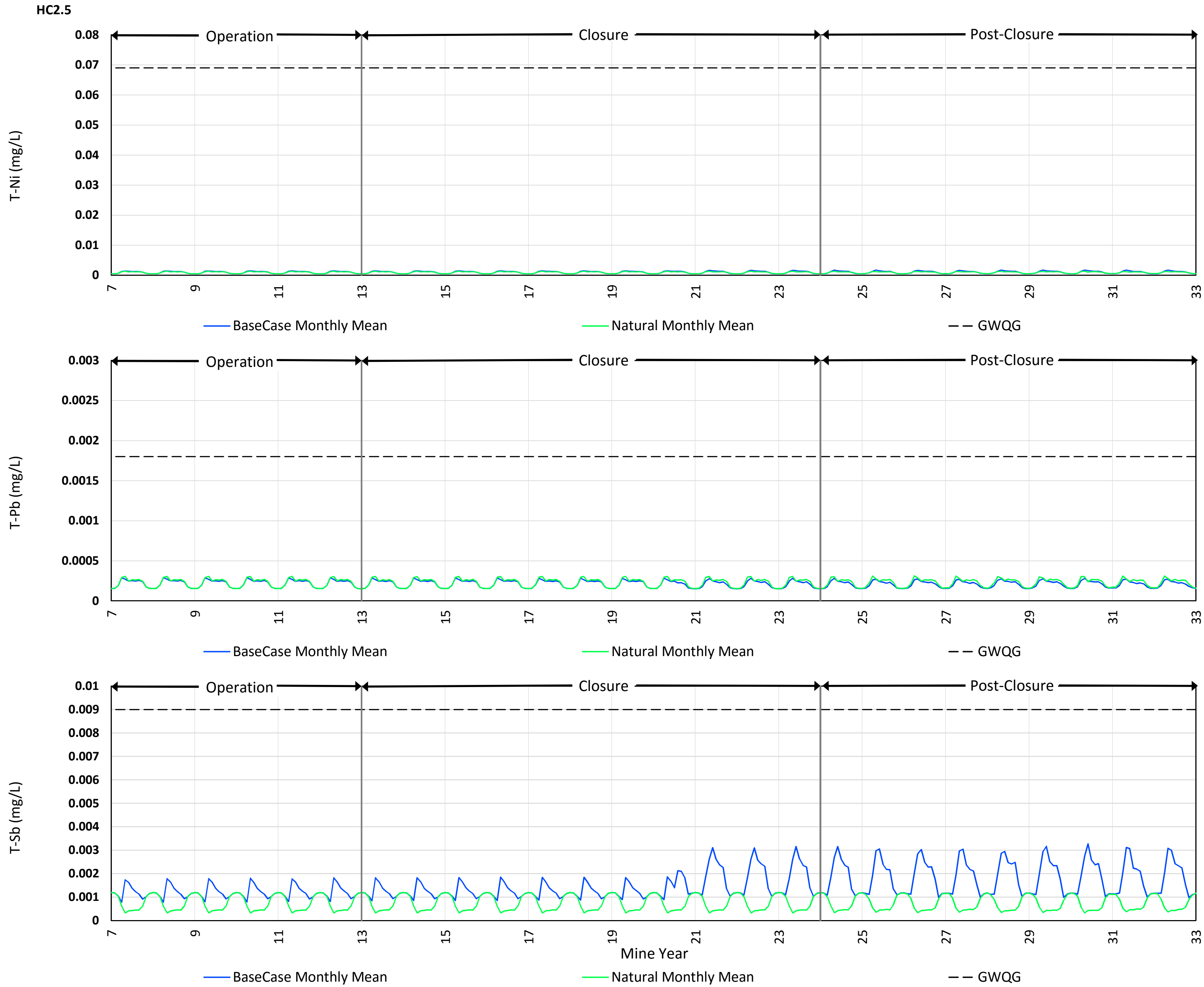
Operation
Closure
Post-Closure
T-Ca (mg/L)
70
60
50
40
30
20
10
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Cd (mg/L)
0.0002
0.00018
0.00016
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
GWQG
T-Cr (mg/L)
0.002
0.0018
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
Mine Year



HC2.5
Operation
Closure
Post-Closure
T-Cu (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Fe (mg/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
T-Hg (mg/L)
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
Mine Year

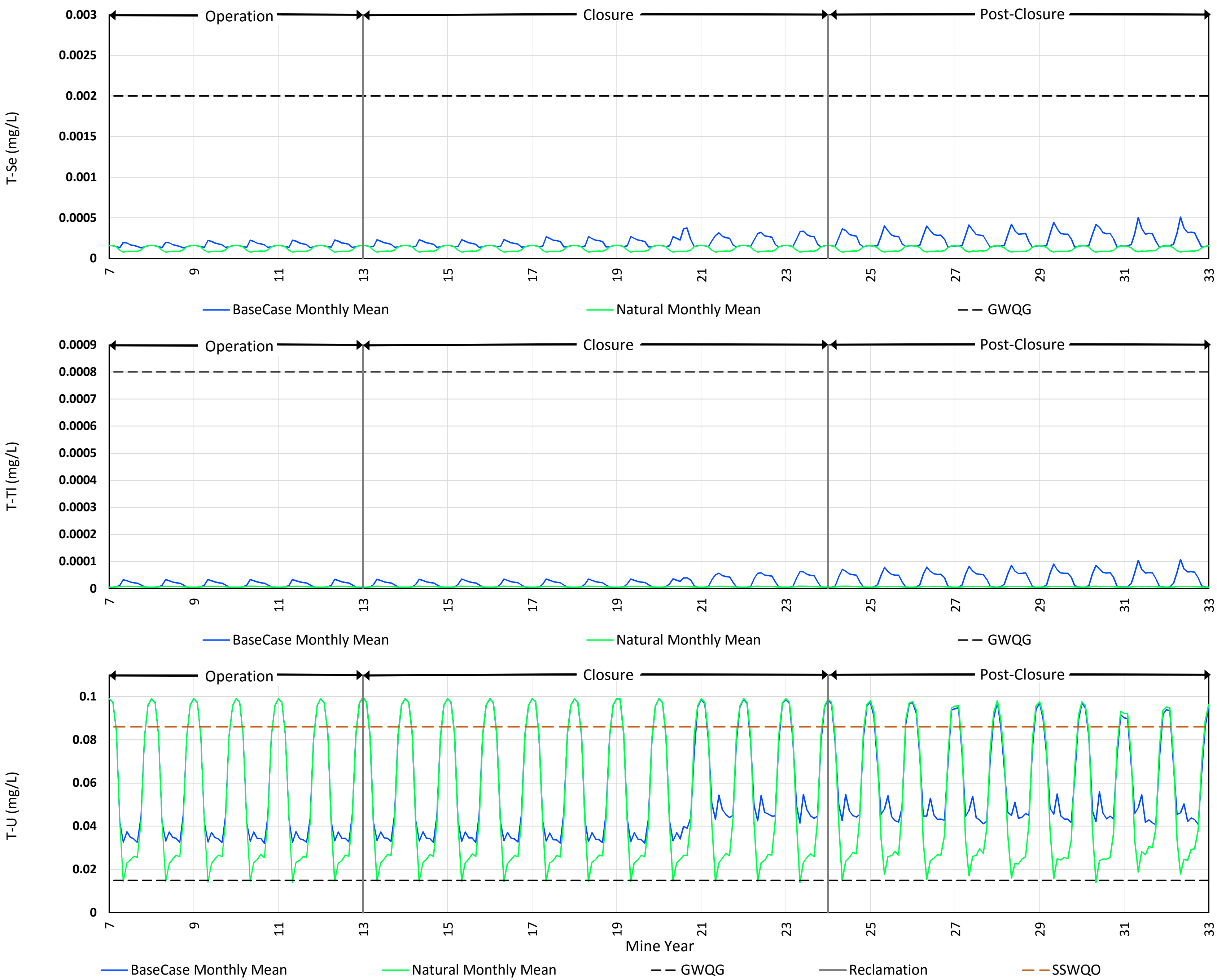
HC2.5


Operation
Closure
Post-Closure
T-Mg (mg/L)
40
35
30
25
20
15
10
5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Mn (mg/L)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
GWQG
T-Mo (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Mine Year

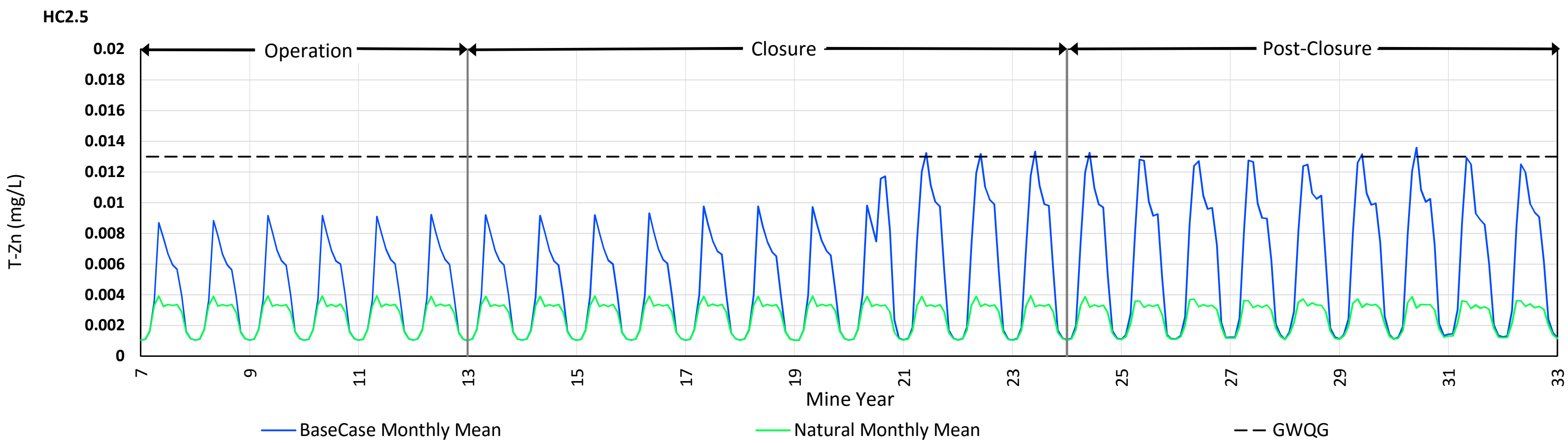


HC2.5
Operation
Closure
Post-Closure
T-Ni (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
T-Pb (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
T-Sb (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
Mine Year

HC2.5

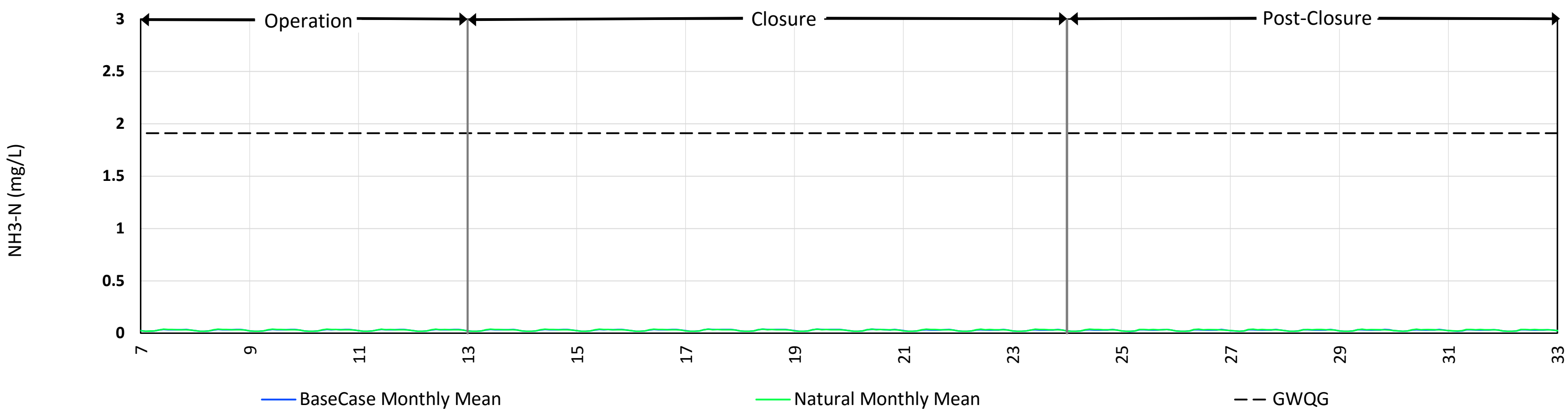


Operation
Closure
Post-Closure
T-Se (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
T-Tl (mg/L)
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
T-U (mg/L)
0.1
0.08
0.06
0.04
0.02
Mine Year
Reclamation
SSWQO

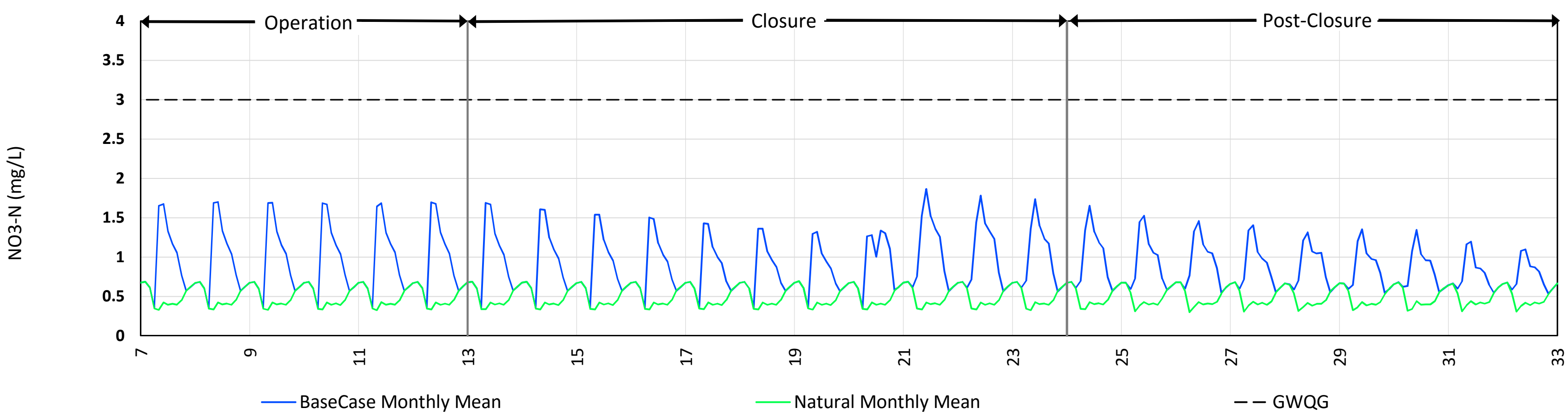


HC2.5
Operation
Closure
Post-Closure
T-Zn (mg/L)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

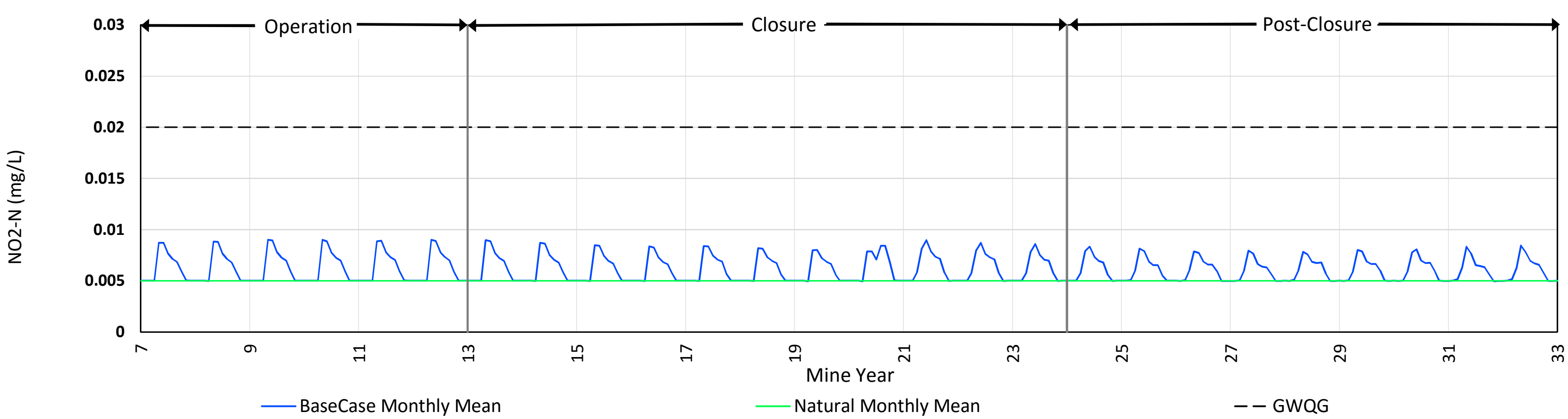
HC5.0



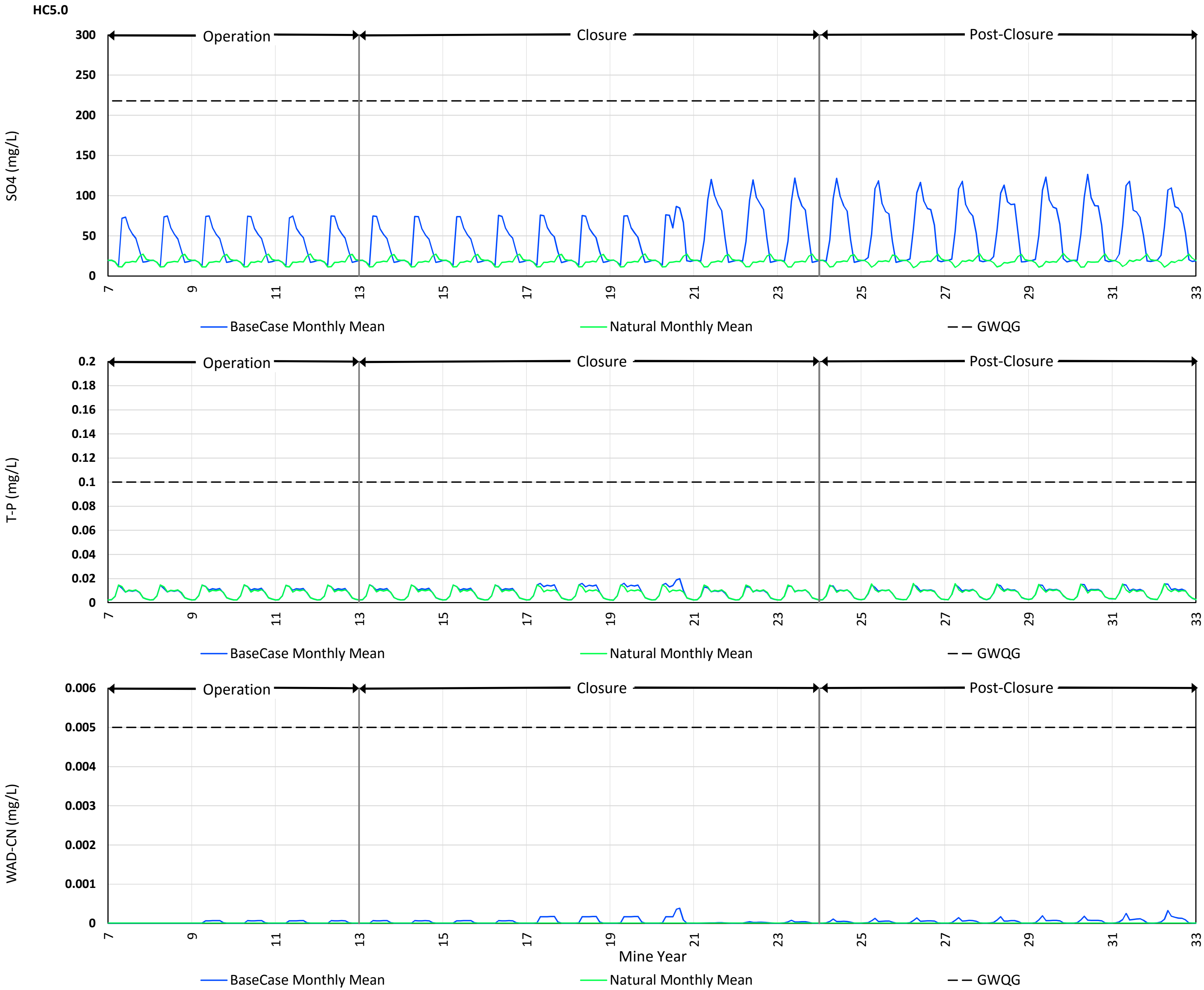
Operation
Closure
Post-Closure
NH3-N (mg/L)
3
2.5
2
1.5
1
0.5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

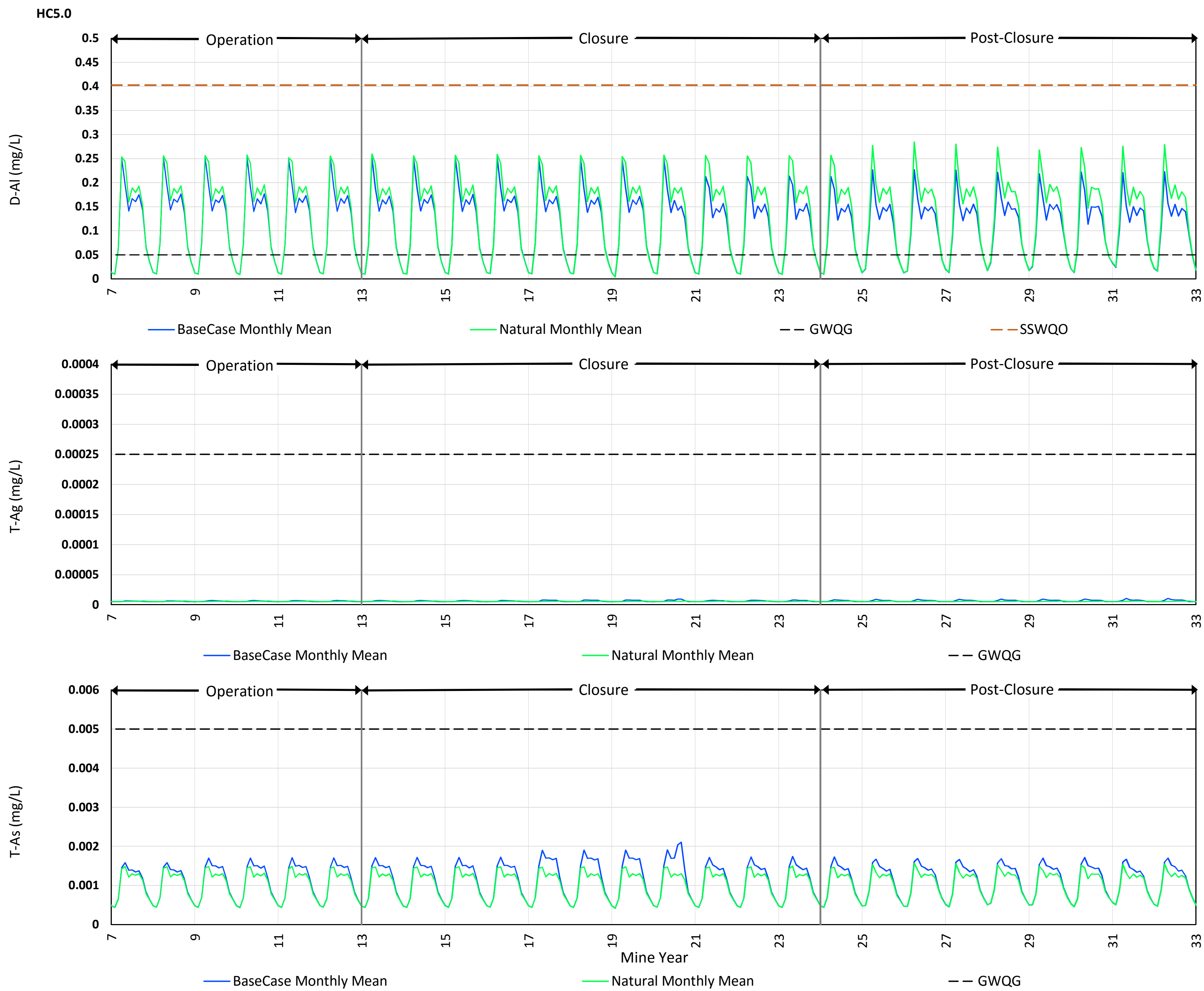


Operation
Closure
Post-Closure
NO3-N (mg/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG



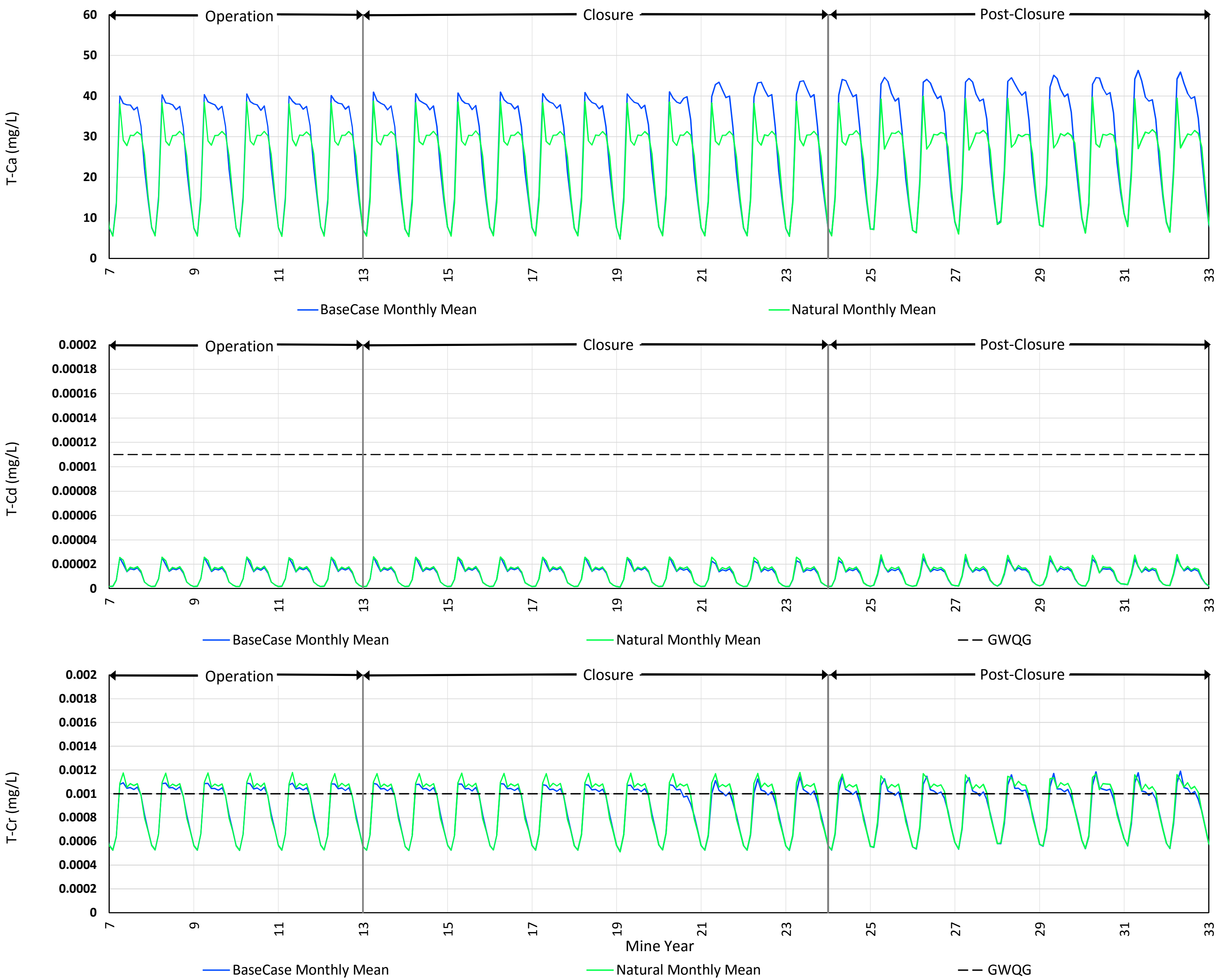
Operation
Closure
Post-Closure
NO2-N (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG


HC5.0
Operation
Closure
Post-Closure
SO4 (mg/L)
300
250
200
150
100
50
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
T-P (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
WAD-CN (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
Mine Year

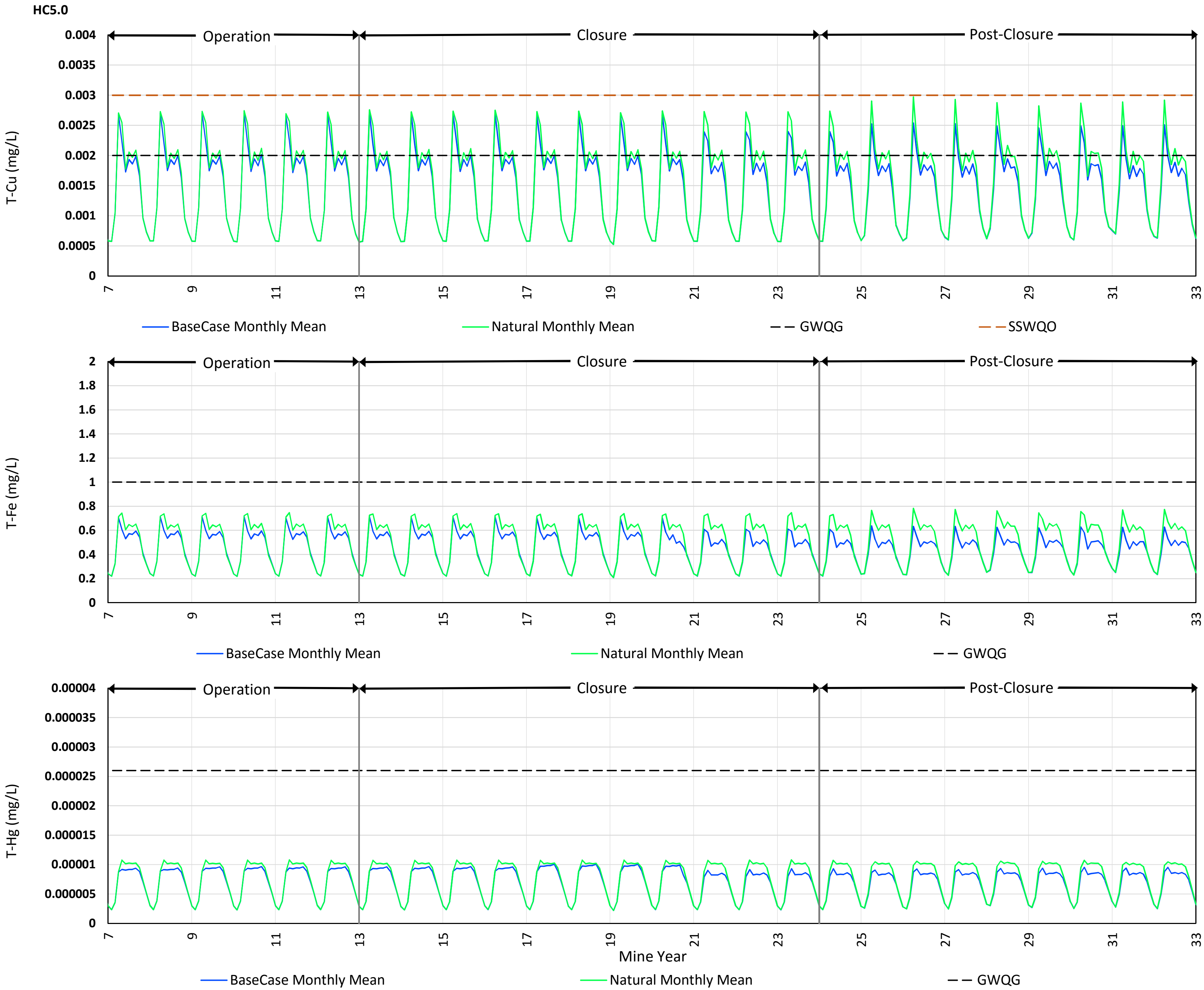


HC5.0
Operation
Closure
Post-Closure
D-Al (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Ag (mg/L)
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
T-As (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
Mine Year

HC5.0

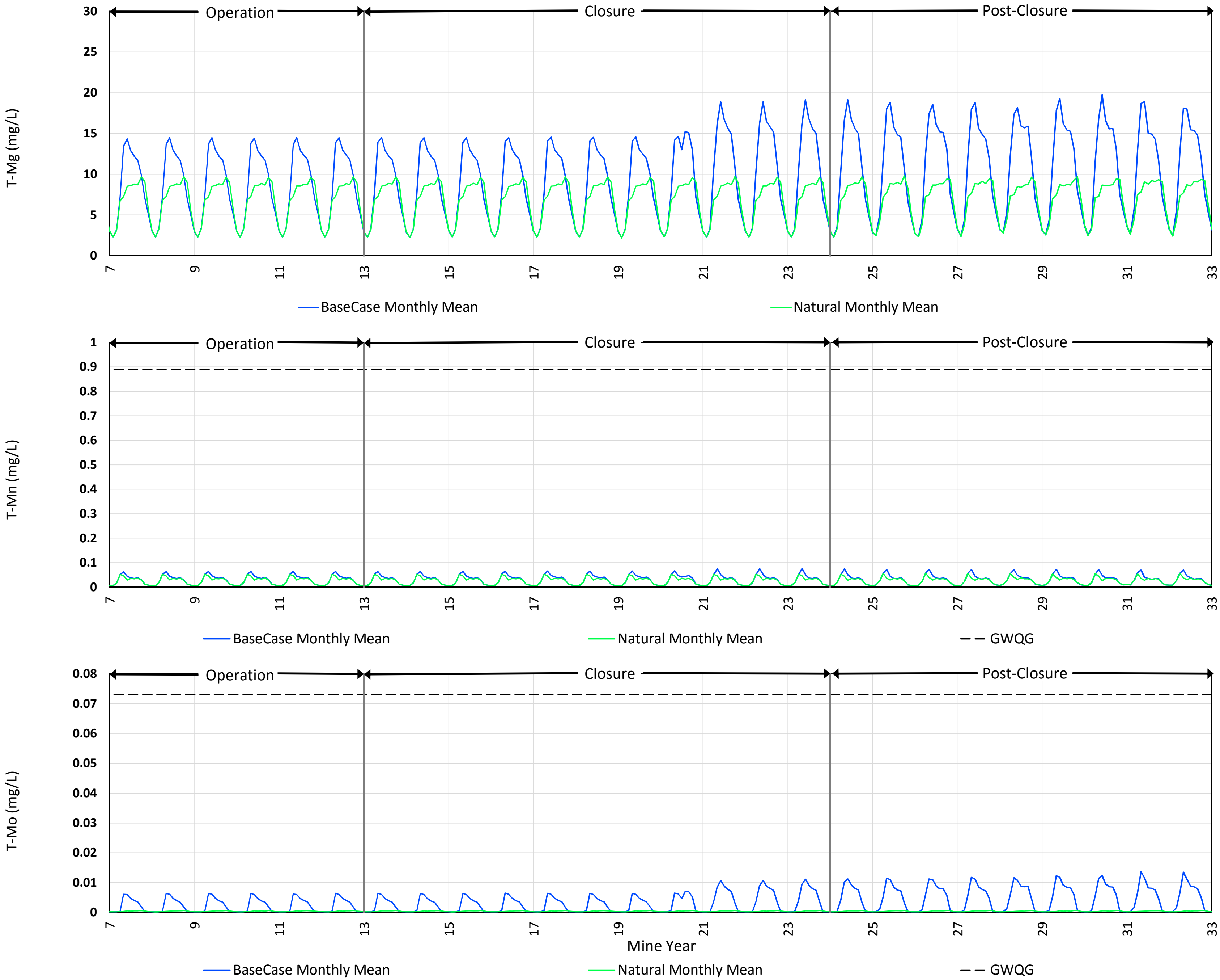


Operation
Closure
Post-Closure
T-Ca (mg/L)
0
10
20
30
40
50
60
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Cd (mg/L)
0
0.00002
0.00004
0.00006
0.00008
0.0001
0.00012
0.00014
0.00016
0.00018
0.0002
GWQG
T-Cr (mg/L)
0
0.0002
0.0004
0.0006
0.0008
0.001
0.0012
0.0014
0.0016
0.0018
0.002
Mine Year



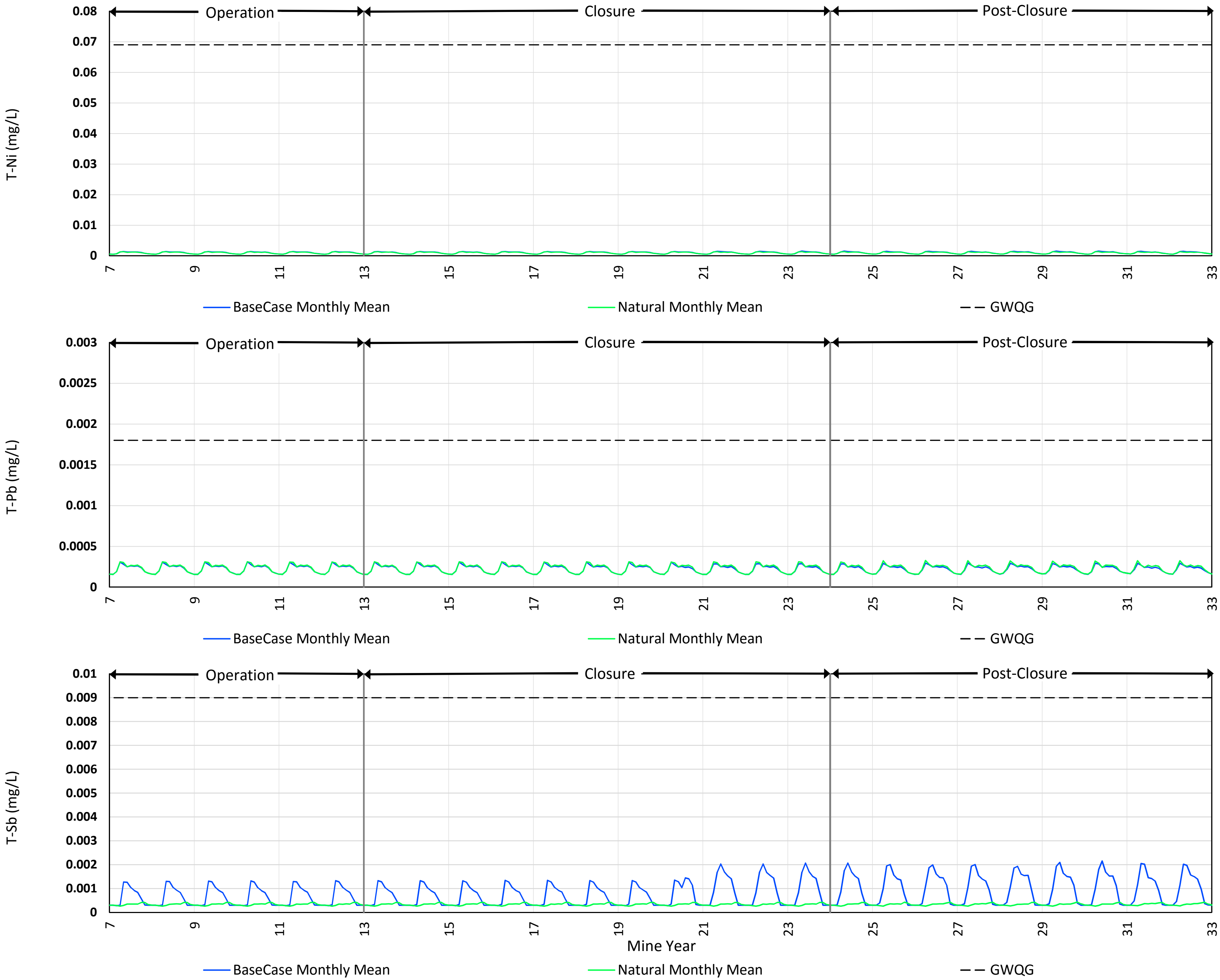
HC5.0
Operation
Closure
Post-Closure
T-Cu (mg/L)
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Fe (mg/L)
T-Hg (mg/L)
Mine Year

HC5.0



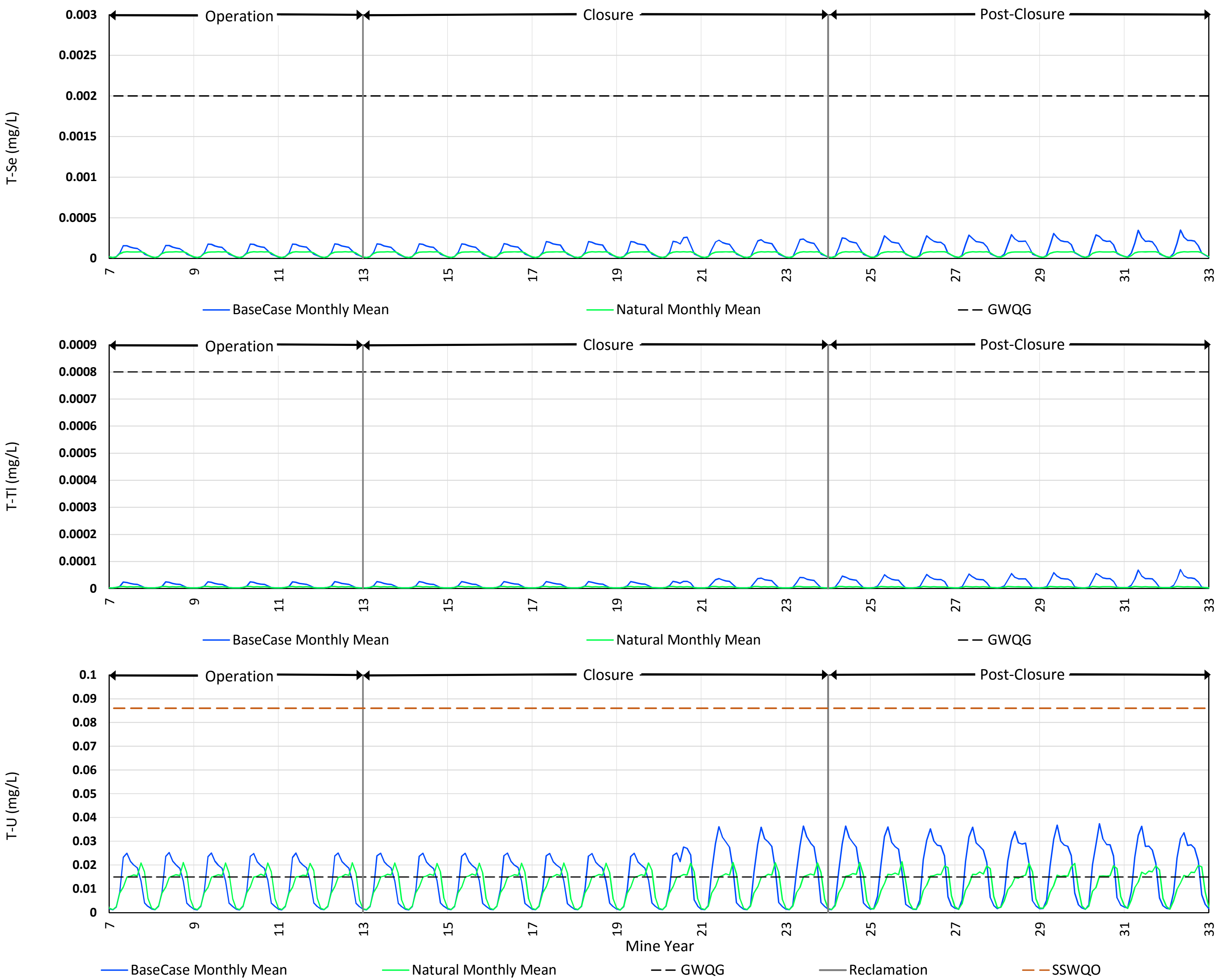
Operation
Closure
Post-Closure
T-Mg (mg/L)
30
25
20
15
10
5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Mn (mg/L)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
GWQG
T-Mo (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
Mine Year

HC5.0

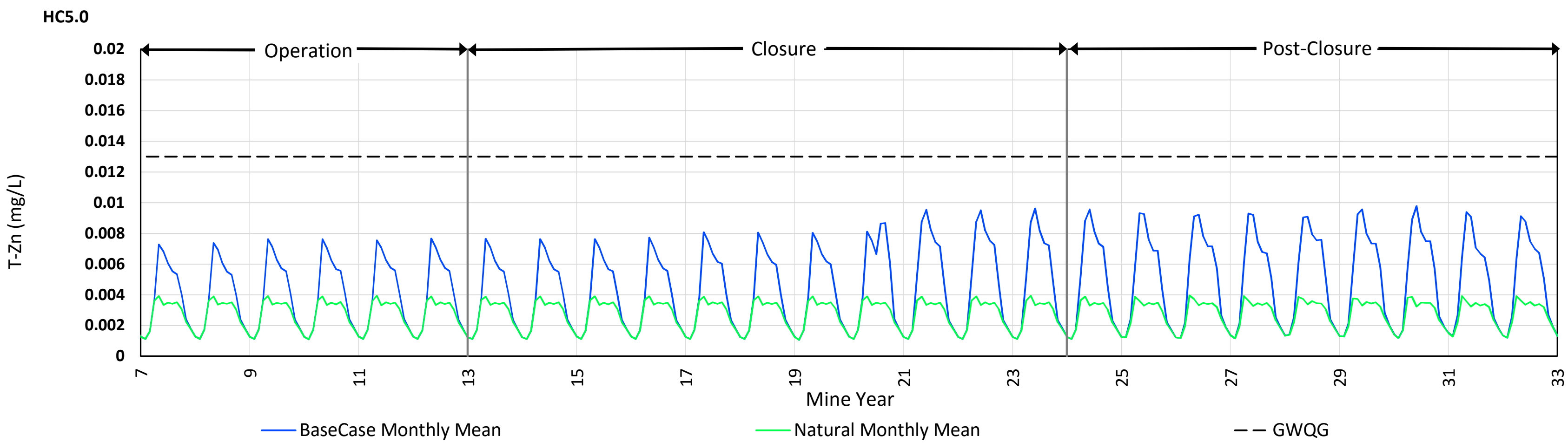


Operation
Closure
Post-Closure
T-Ni (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
T-Pb (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
T-Sb (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year

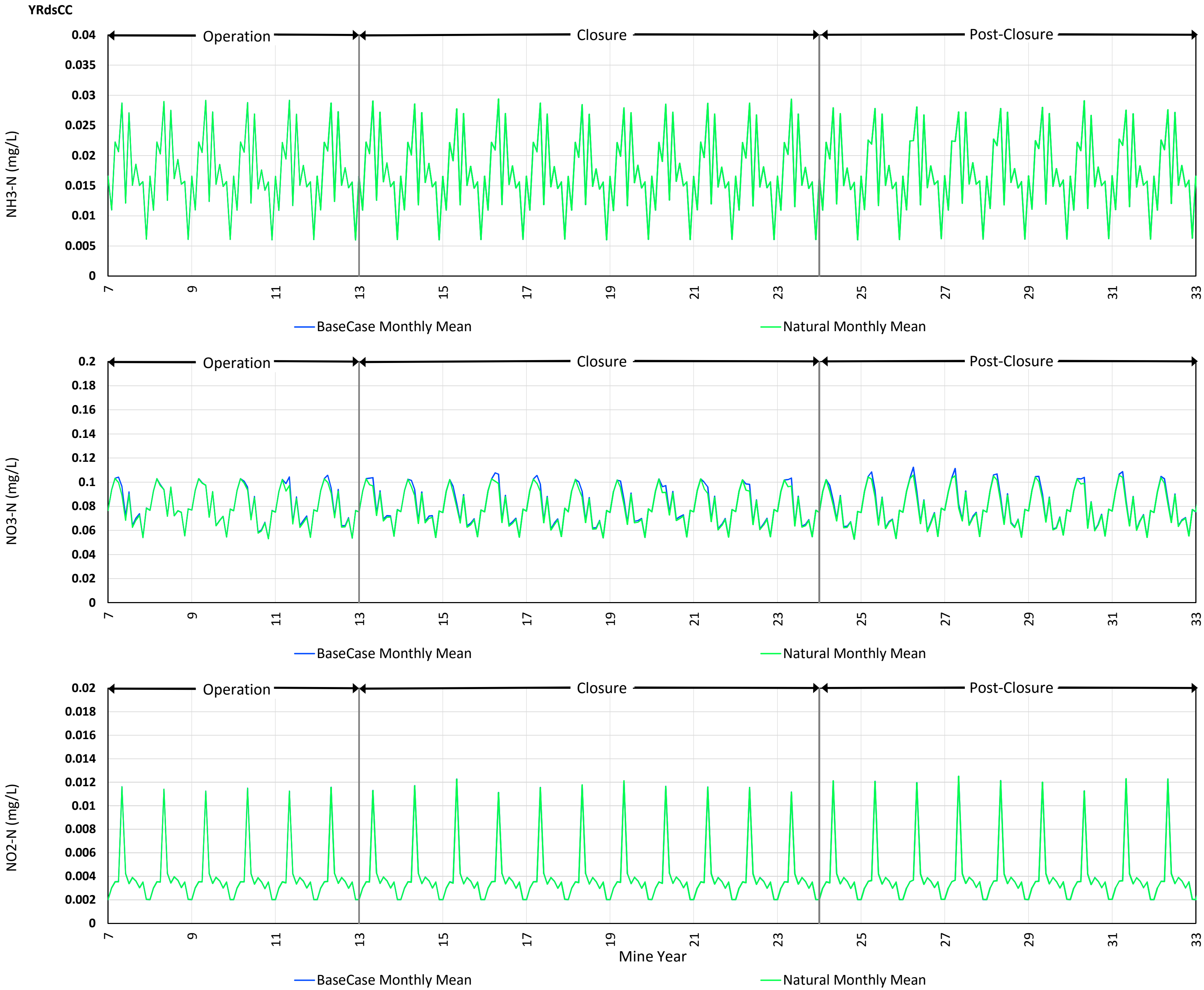
HC5.0



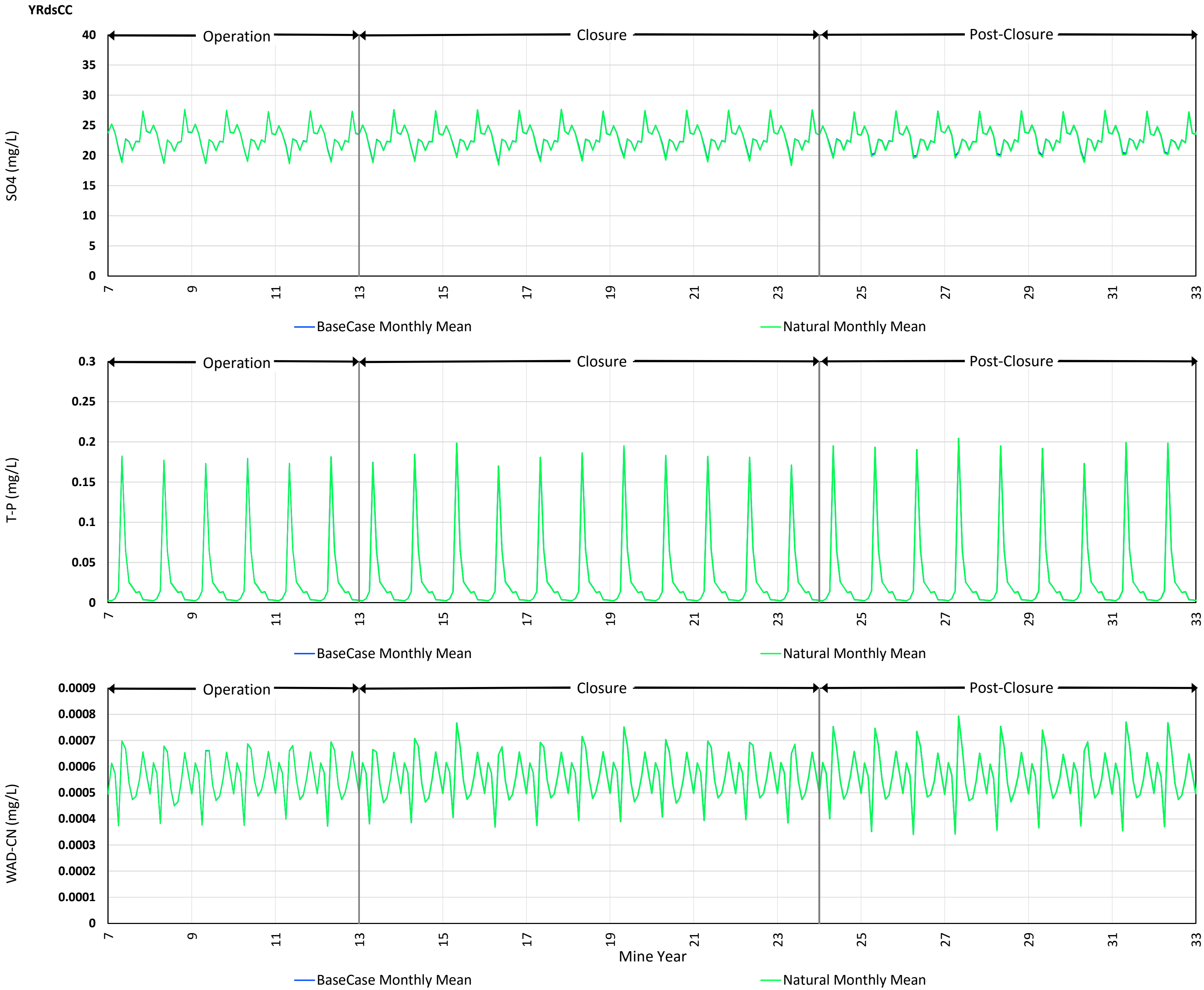
Operation
Closure
Post-Closure
T-Se (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7 9 11 13 15 17 19 21 23 25 27 29 31 33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
T-Tl (mg/L)
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
7 9 11 13 15 17 19 21 23 25 27 29 31 33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
T-U (mg/L)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
7 9 11 13 15 17 19 21 23 25 27 29 31 33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
Reclamation
SSWQO



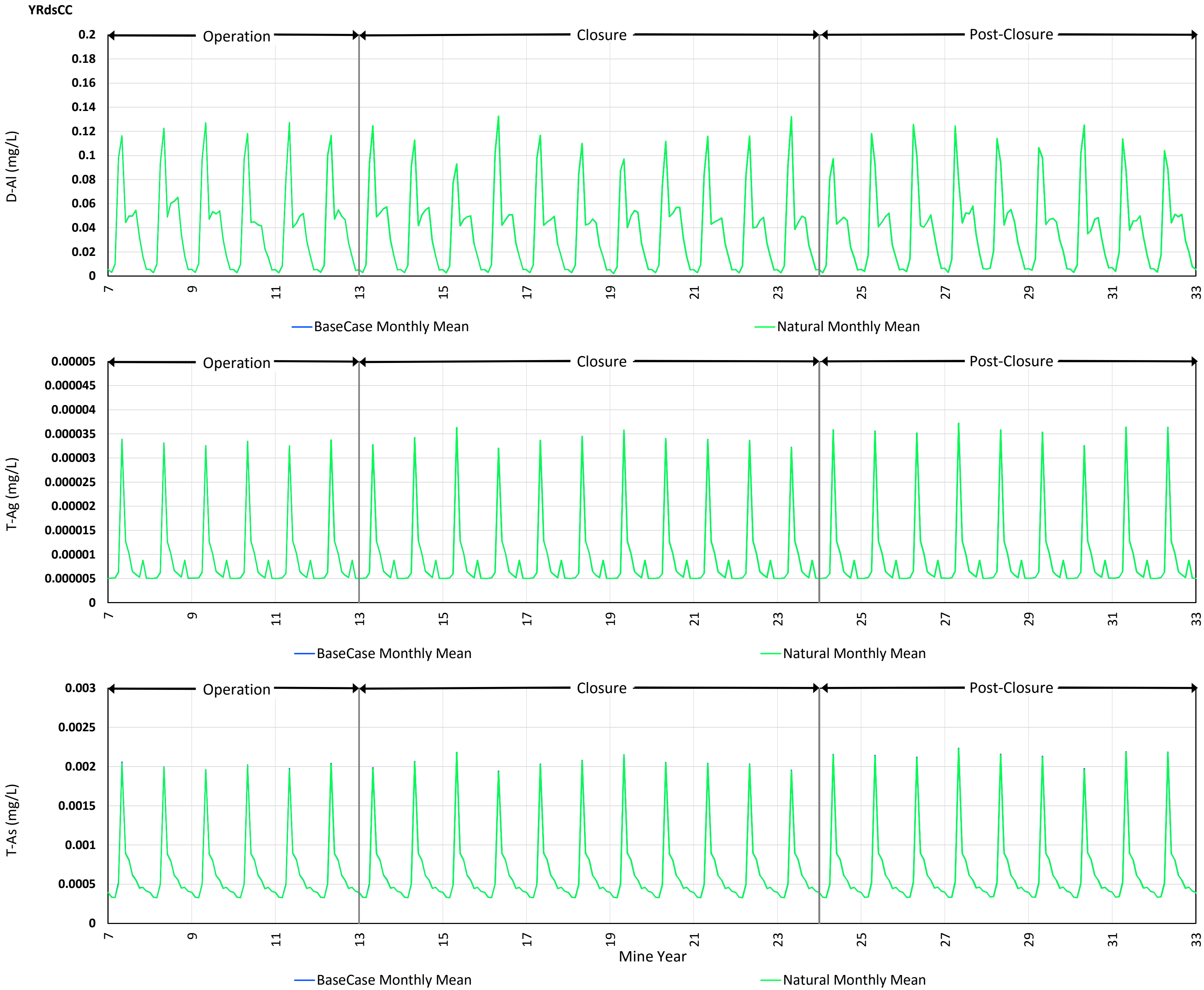
HC5.0
Operation
Closure
Post-Closure
T-Zn (mg/L)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

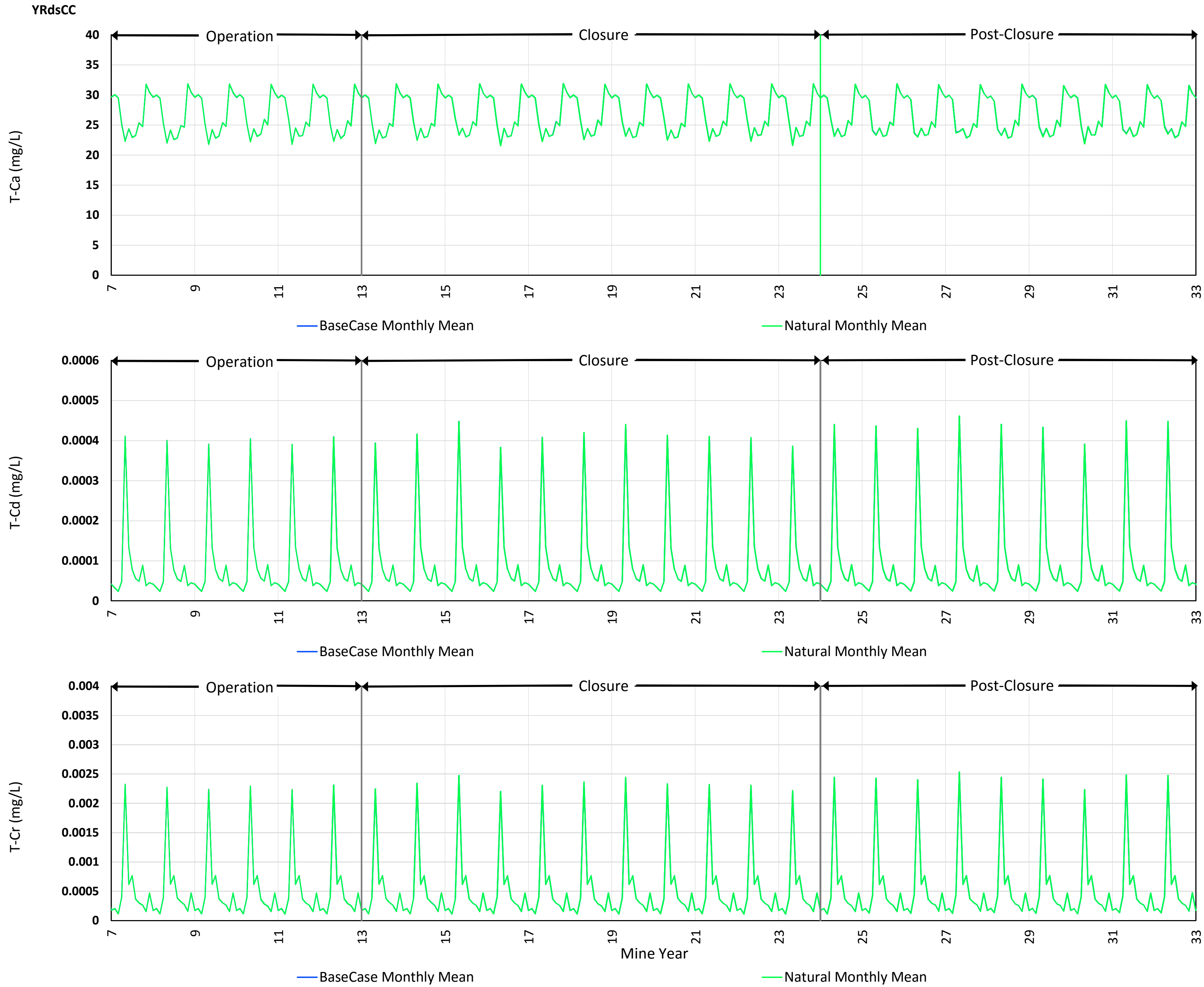


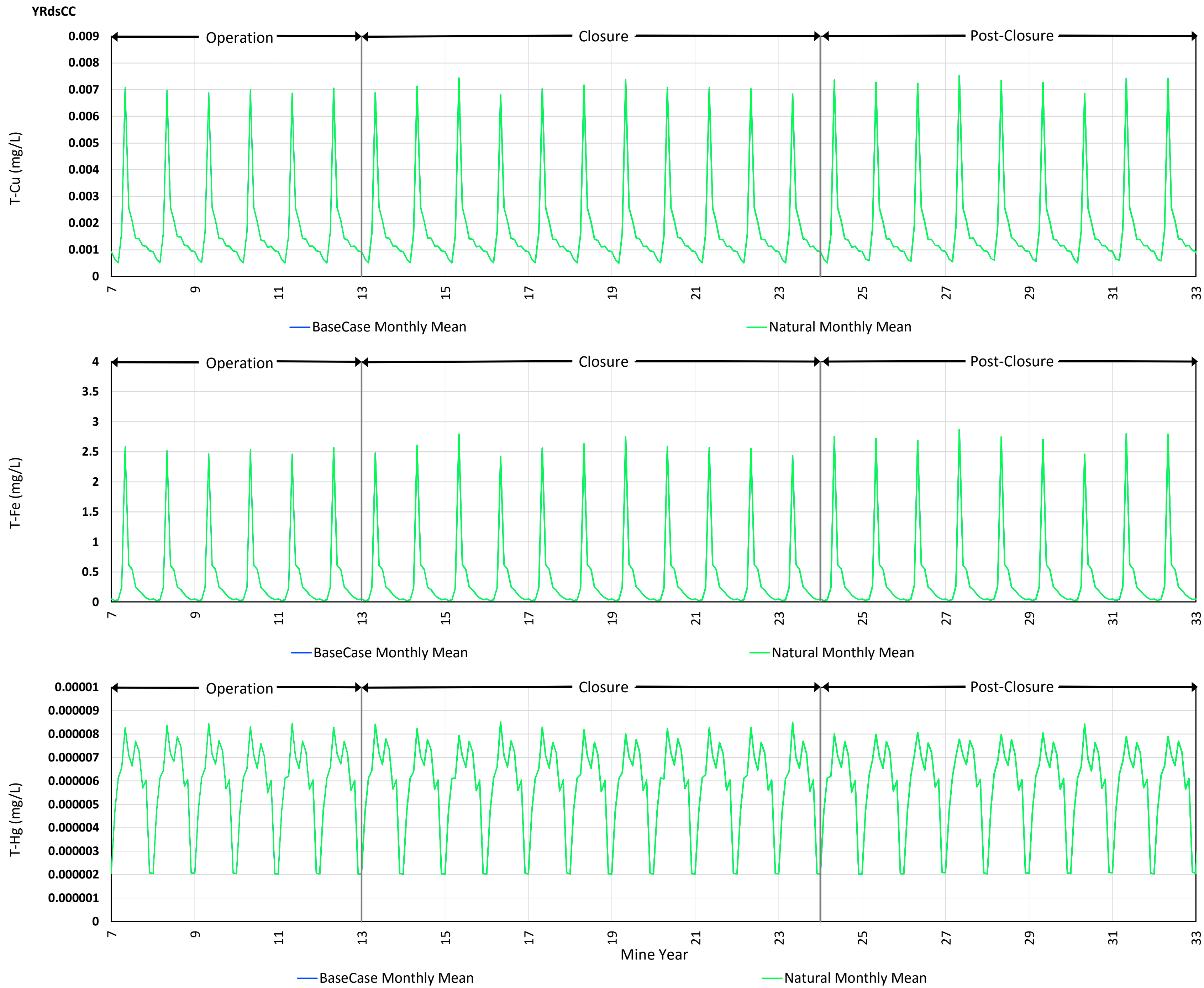
YRdsCC
NH3-N (mg/L)
NO3-N (mg/L)
NO2-N (mg/L)
Operation
Closure
Post-Closure
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

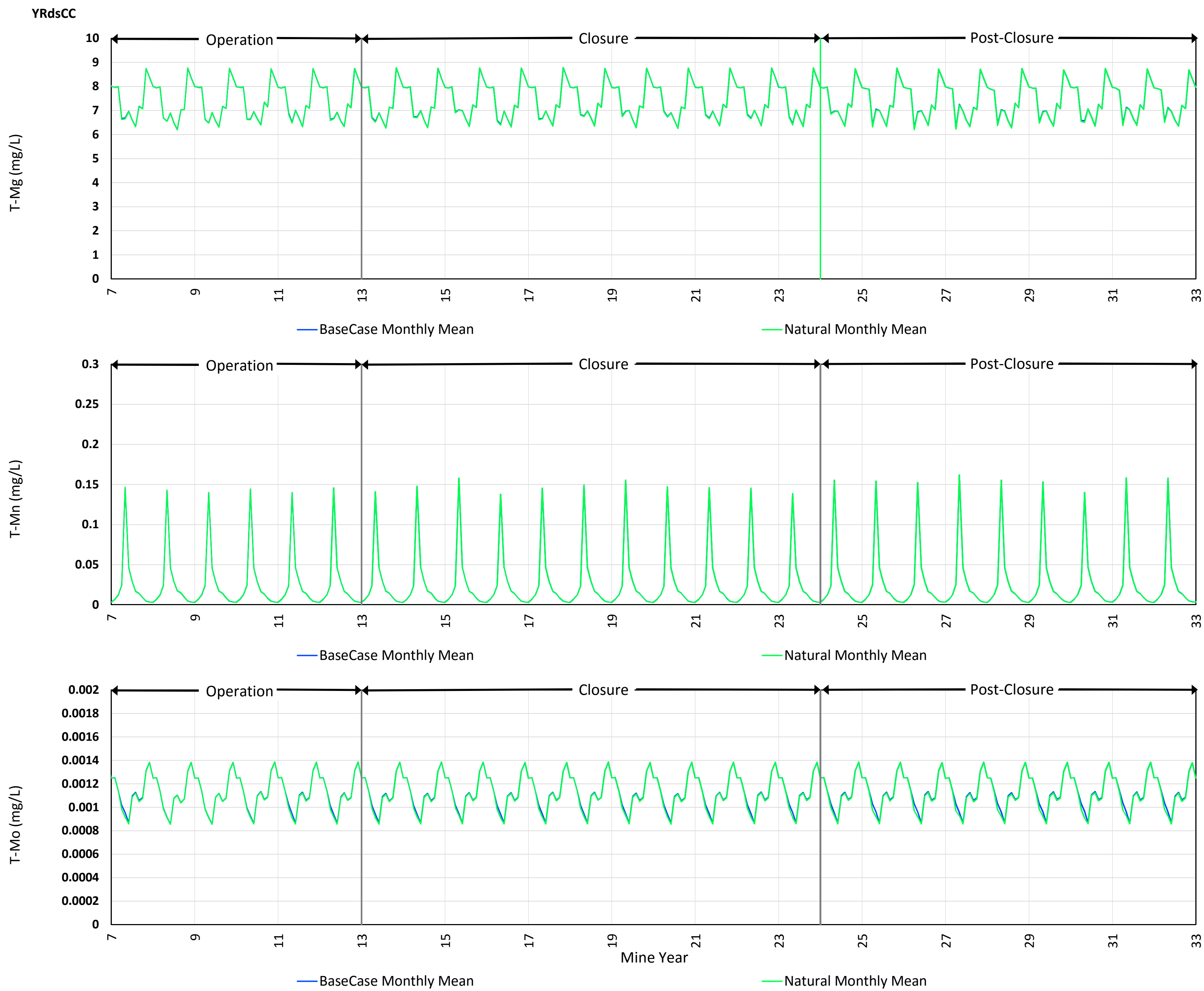


YRdsCC
Operation
Closure
Post-Closure
SO4 (mg/L)
40
35
30
25
20
15
10
5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-P (mg/L)
0.3
0.25
0.2
0.15
0.1
0.05
0
WAD-CN (mg/L)
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
Mine Year


YRdsCC
Operation
Closure
Post-Closure
D-Al (mg/L)
T-Ag (mg/L)
T-As (mg/L)
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

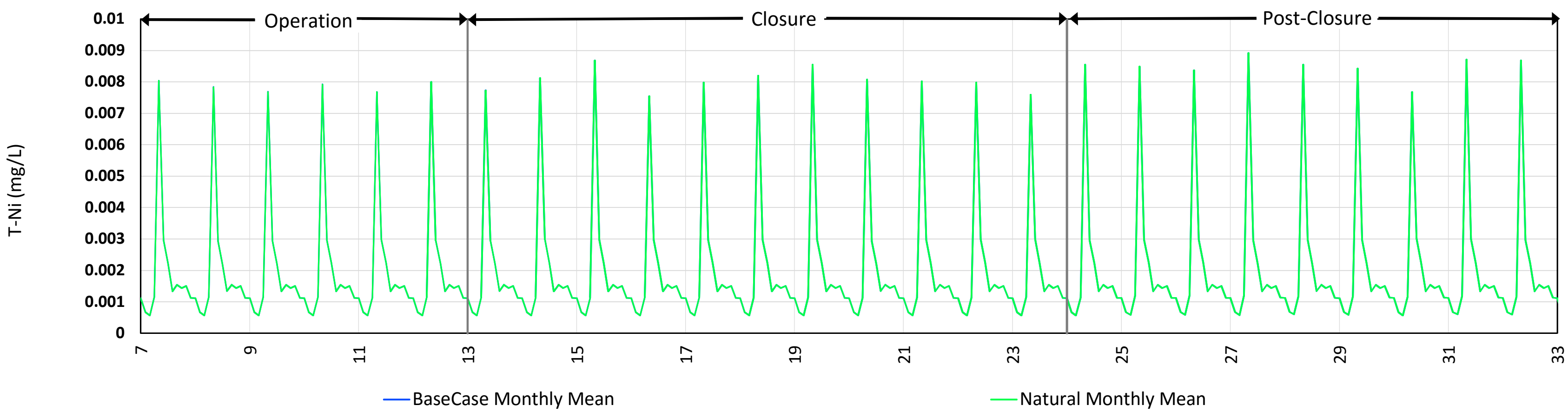

YRdsCC
Operation
Closure
Post-Closure
T-Ca (mg/L)
T-Cd (mg/L)
T-Cr (mg/L)
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

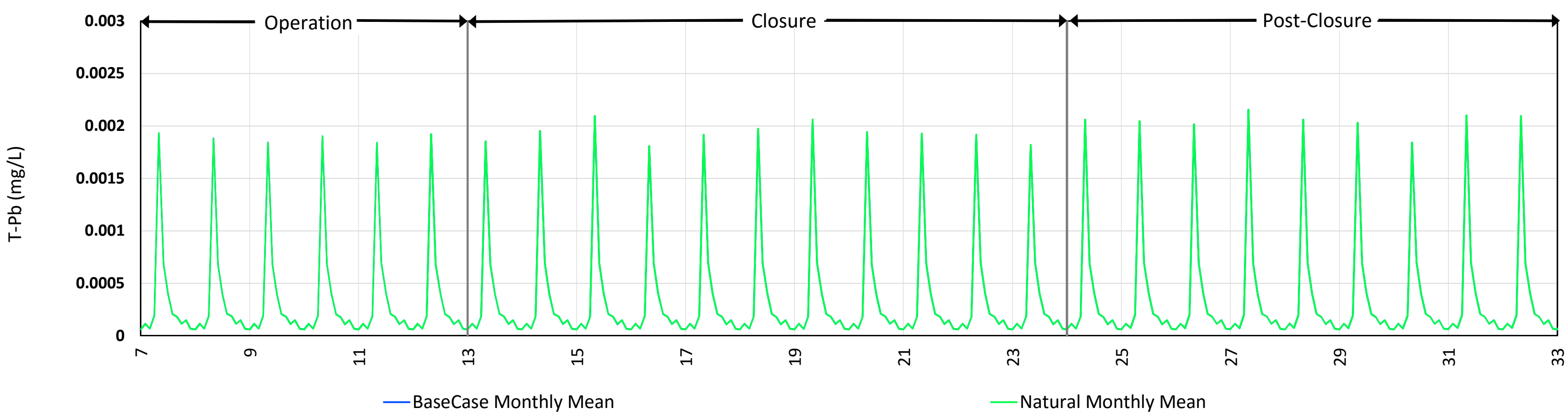

YRdsCC
Operation
Closure
Post-Closure
T-Cu (mg/L)
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
7 9 11 13 15 17 19 21 23 25 27 29 31 33
BaseCase Monthly Mean
Natural Monthly Mean
T-Fe (mg/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
T-Hg (mg/L)
0.00001
0.000009
0.000008
0.000007
0.000006
0.000005
0.000004
0.000003
0.000002
0.000001
0
Mine Year

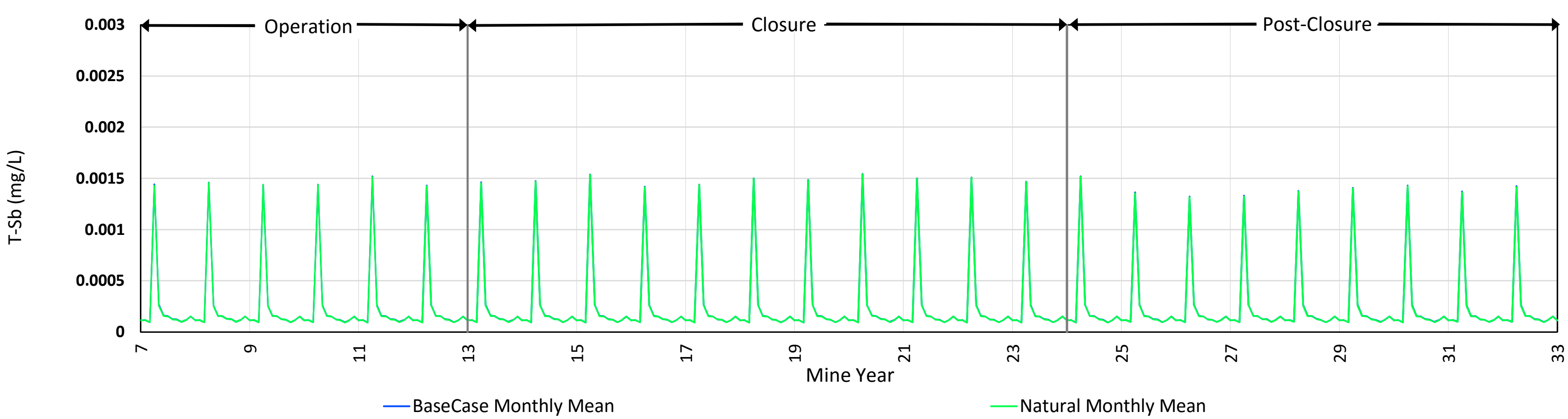


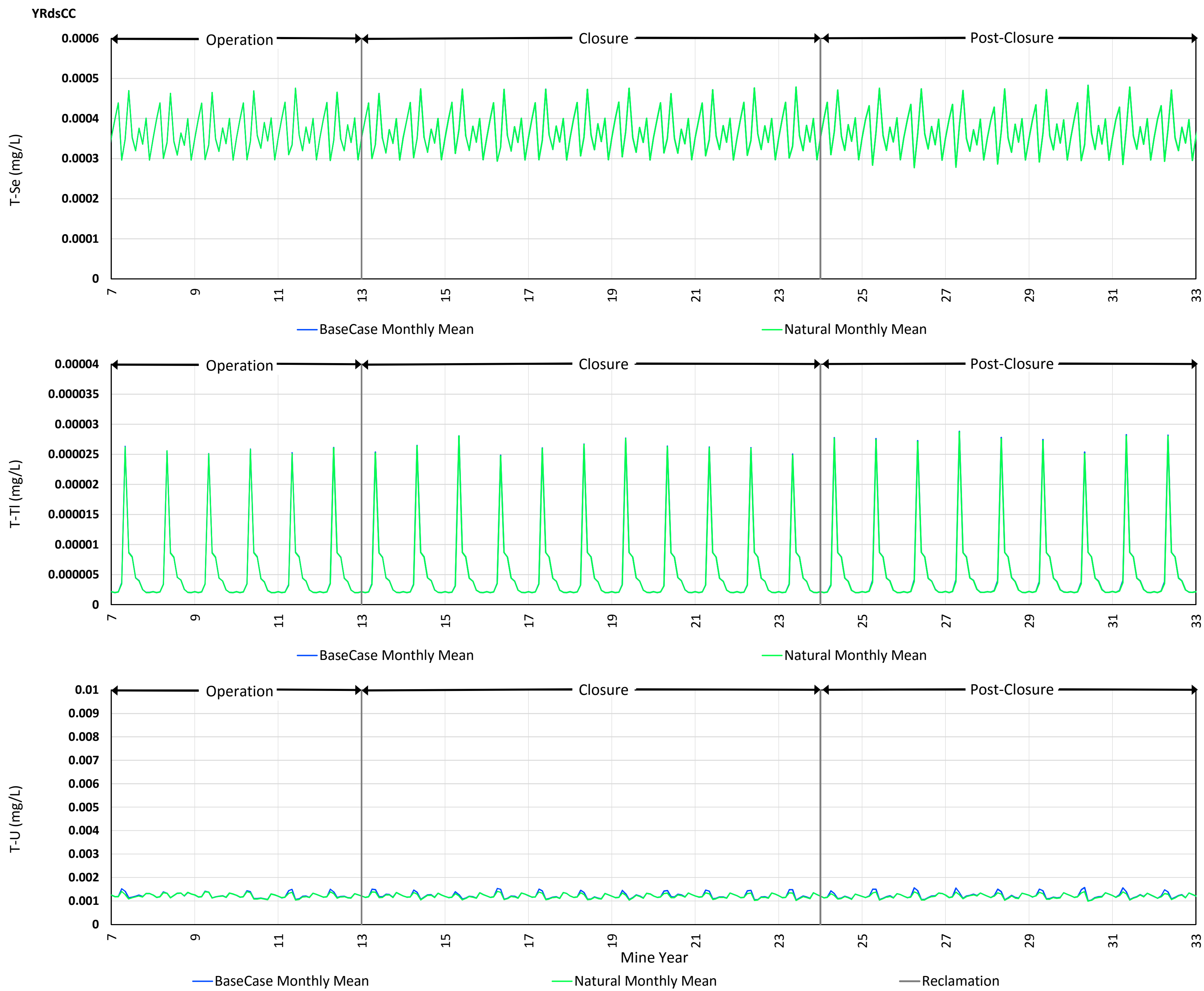
YRdsCC
Operation
Closure
Post-Closure
T-Mg (mg/L)
T-Mn (mg/L)
T-Mo (mg/L)
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

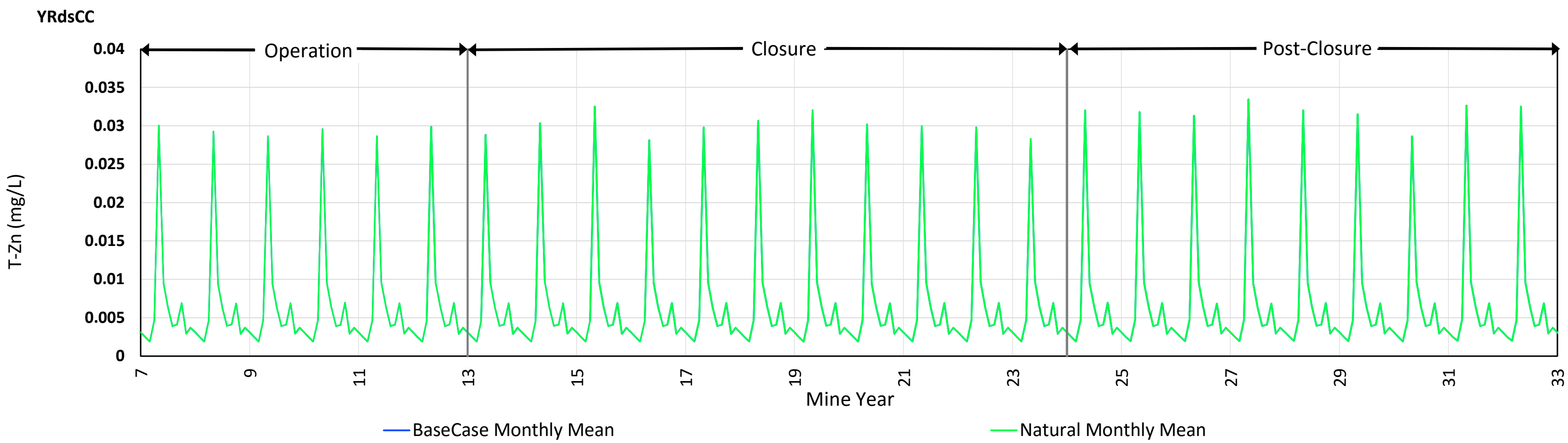
YRdsCC


Operation
Closure
Post-Closure
T-Ni (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean

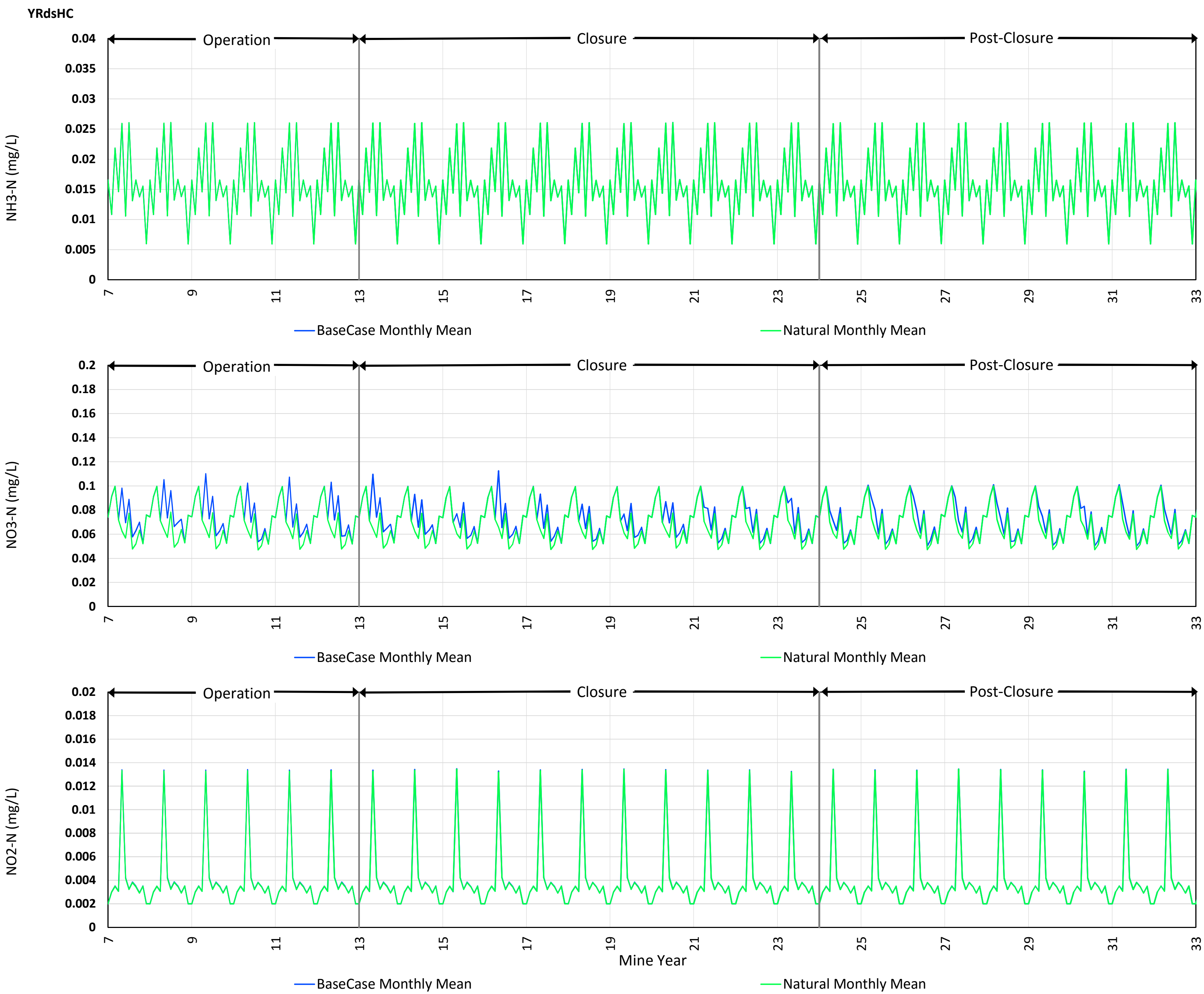

Operation
Closure
Post-Closure
T-Pb (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean


Operation
Closure
Post-Closure
T-Sb (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

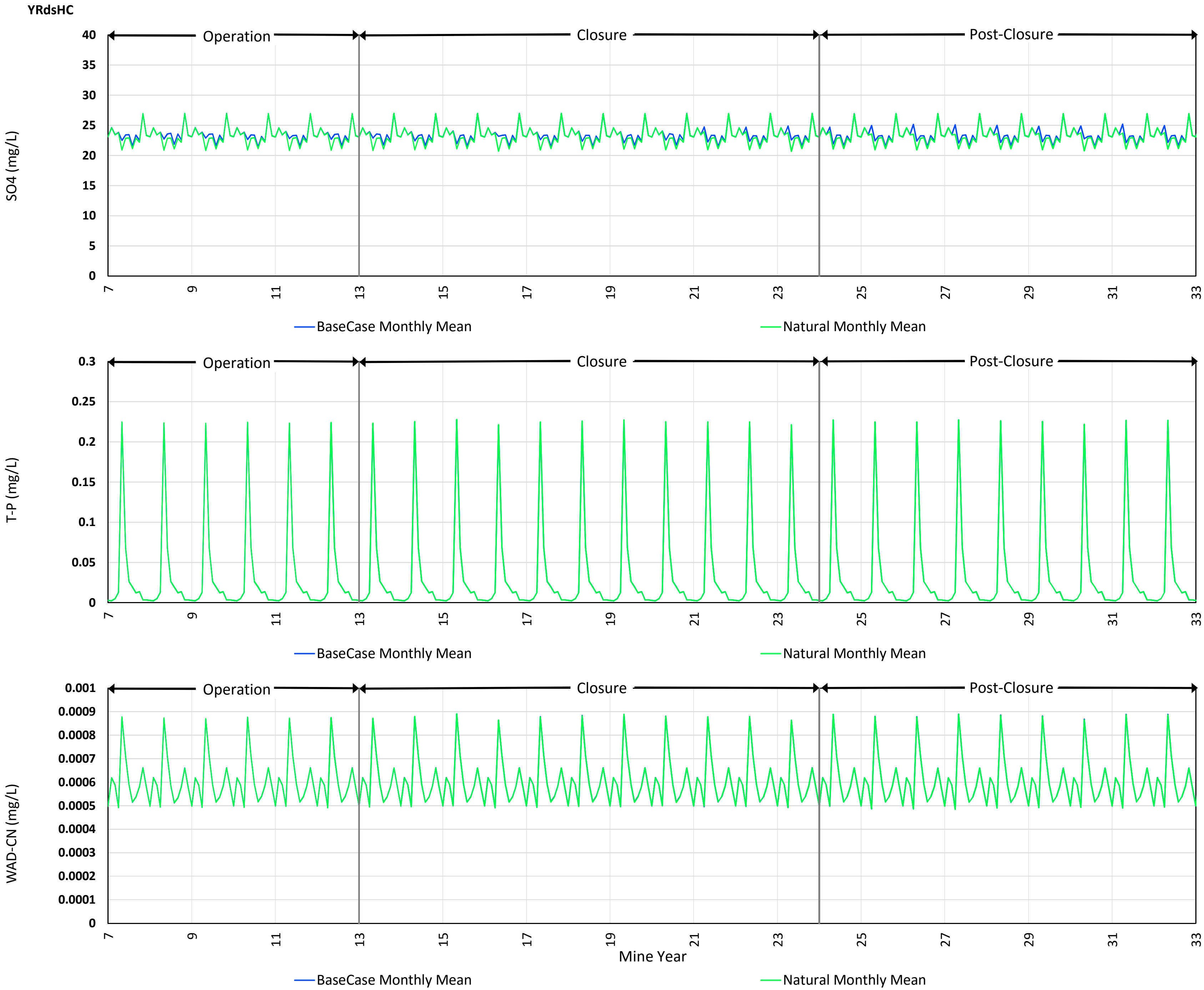

YRdsCC
Operation
Closure
Post-Closure
T-Se (mg/L)
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Tl (mg/L)
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
T-U (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
Mine Year
Reclamation

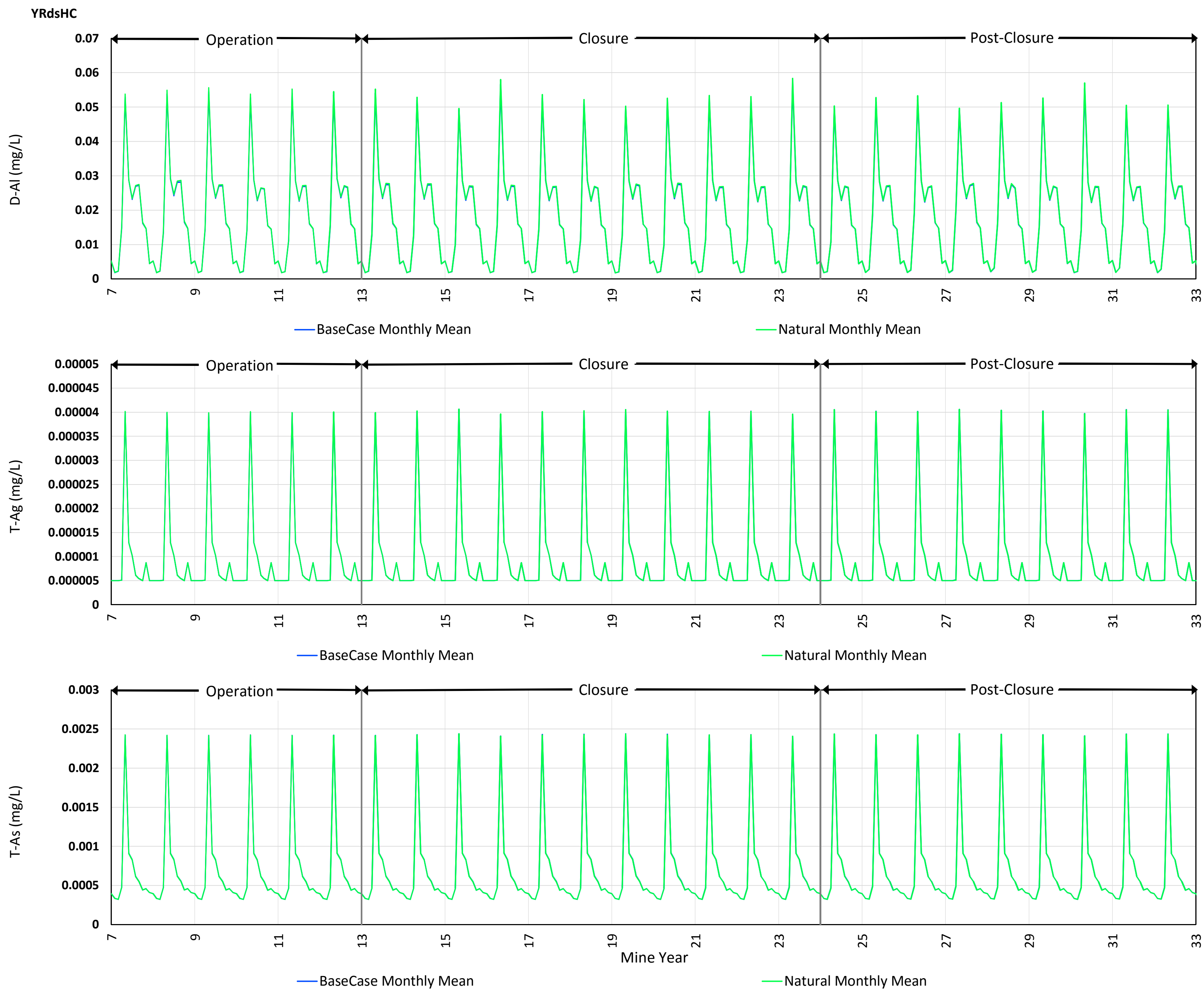


YRdsCC
Operation
Closure
Post-Closure
T-Zn (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

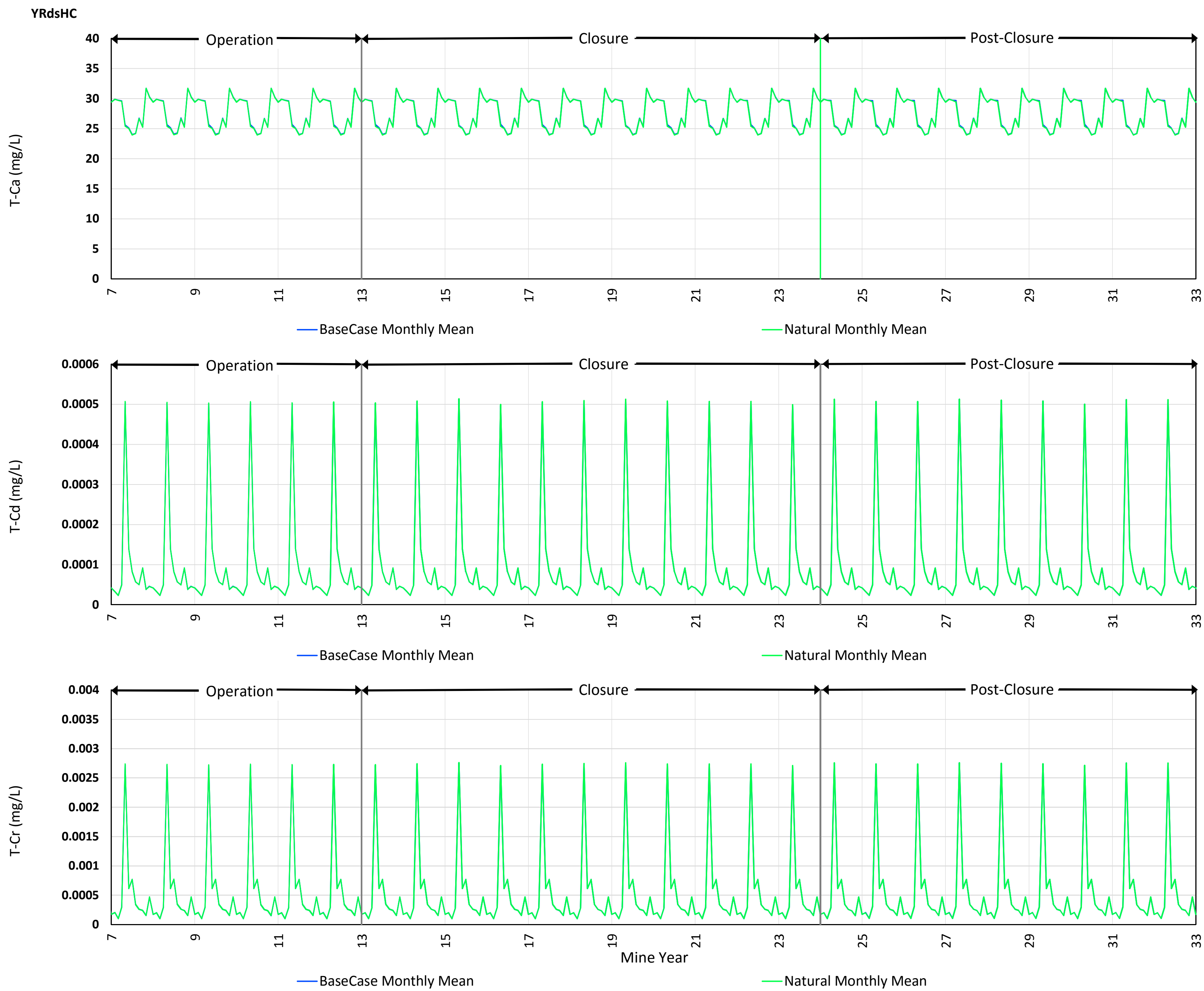


YRdsHC
Operation
Closure
Post-Closure
NH3-N (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
NO3-N (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
NO2-N (mg/L)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Mine Year

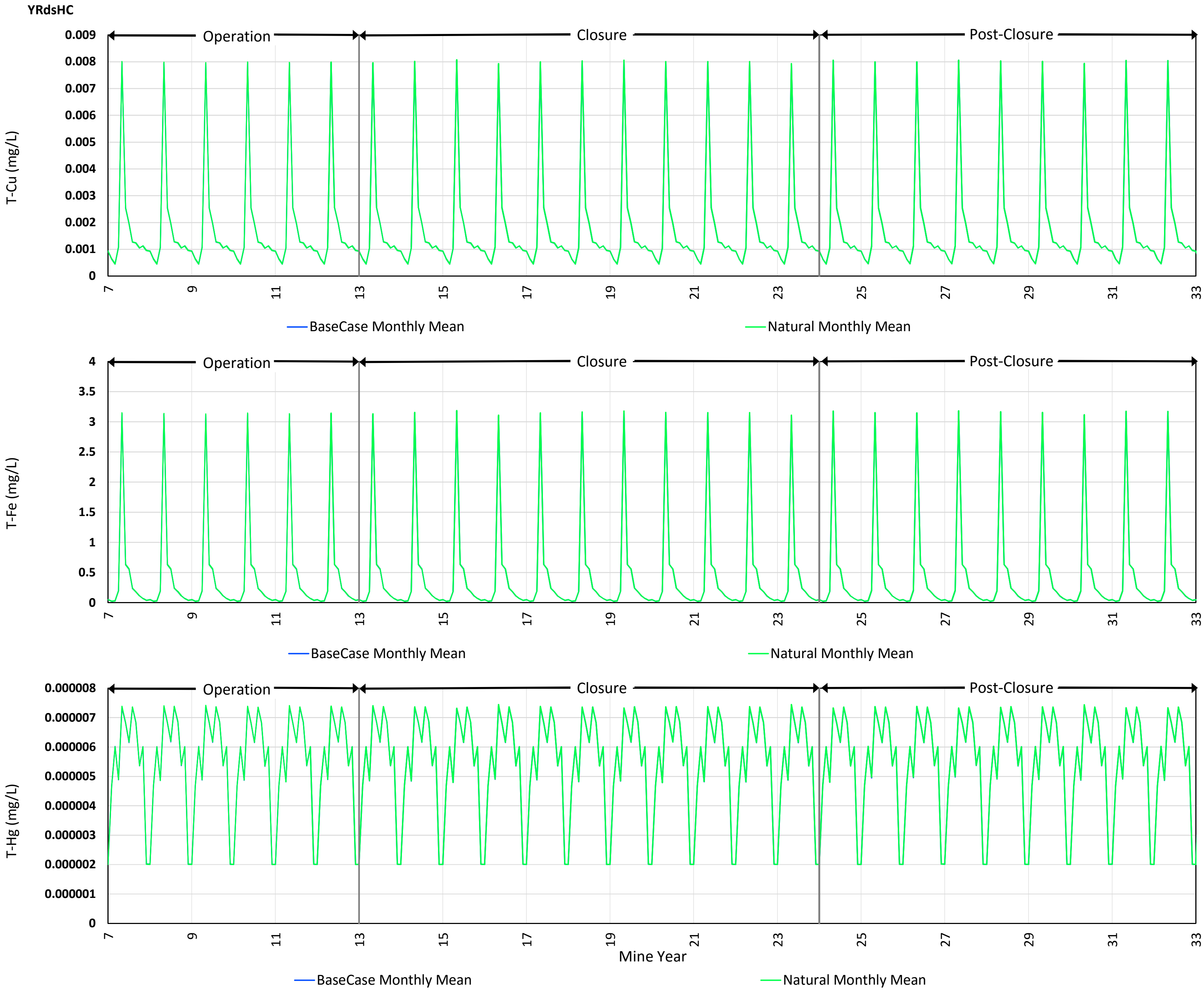

YRdsHC
Operation
Closure
Post-Closure
SO4 (mg/L)
40
35
30
25
20
15
10
5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-P (mg/L)
0.3
0.25
0.2
0.15
0.1
0.05
0
WAD-CN (mg/L)
0.001
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
Mine Year

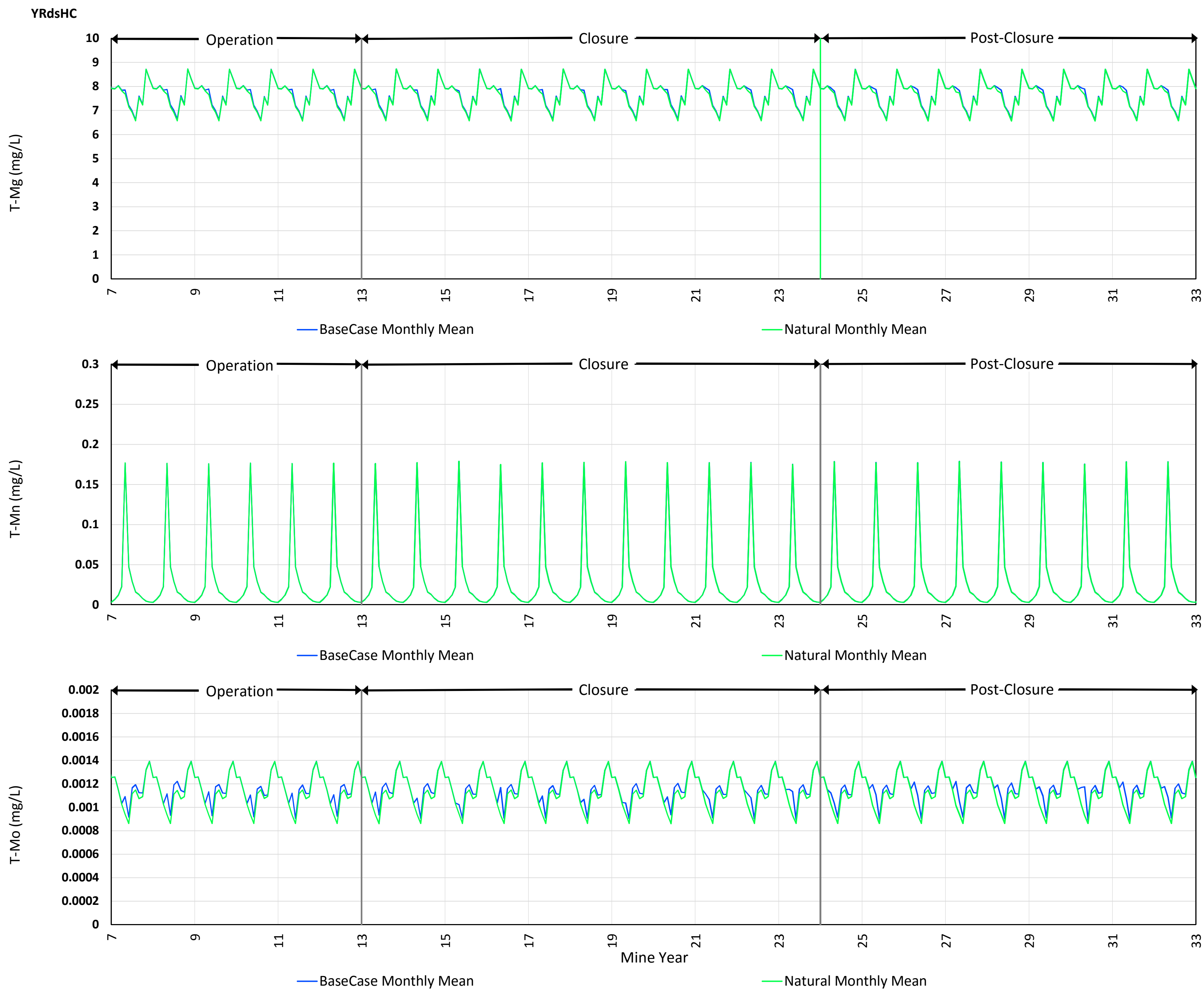


YRdsHC
Operation
Closure
Post-Closure
D-Al (mg/L)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Ag (mg/L)
0.00005
0.000045
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
T-As (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
Mine Year



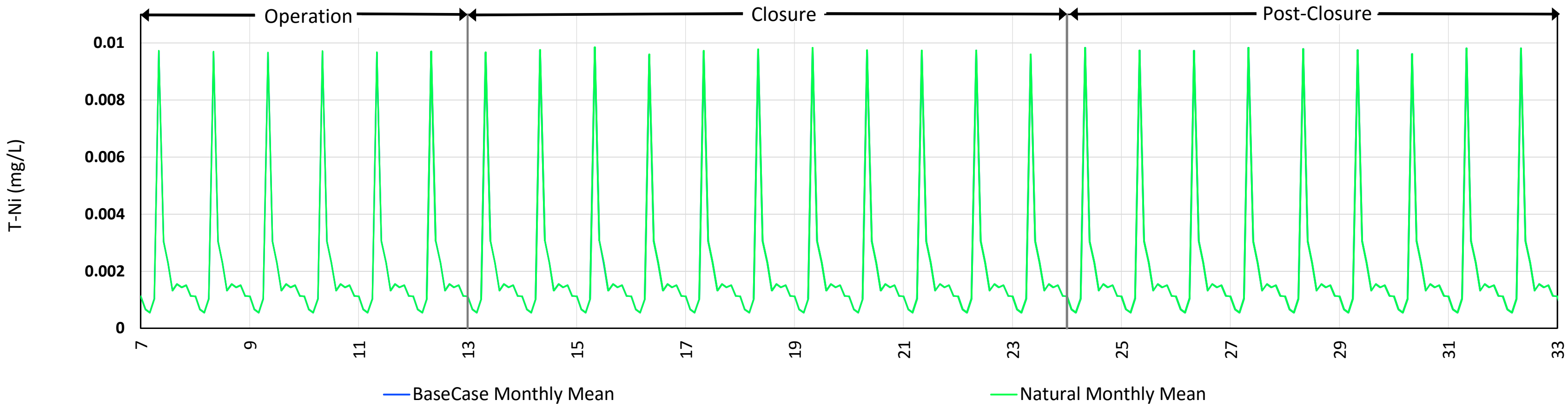
YRdsHC
Operation
Closure
Post-Closure
T-Ca (mg/L)
0
5
10
15
20
25
30
35
40
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
Operation
Closure
Post-Closure
T-Cd (mg/L)
0
0.0001
0.0002
0.0003
0.0004
0.0005
0.0006
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
Operation
Closure
Post-Closure
T-Cr (mg/L)
0
0.0005
0.001
0.0015
0.002
0.0025
0.003
0.0035
0.004
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean


YRdsHC
Operation
Closure
Post-Closure
T-Cu (mg/L)
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Fe (mg/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
T-Hg (mg/L)
0.000008
0.000007
0.000006
0.000005
0.000004
0.000003
0.000002
0.000001
Mine Year

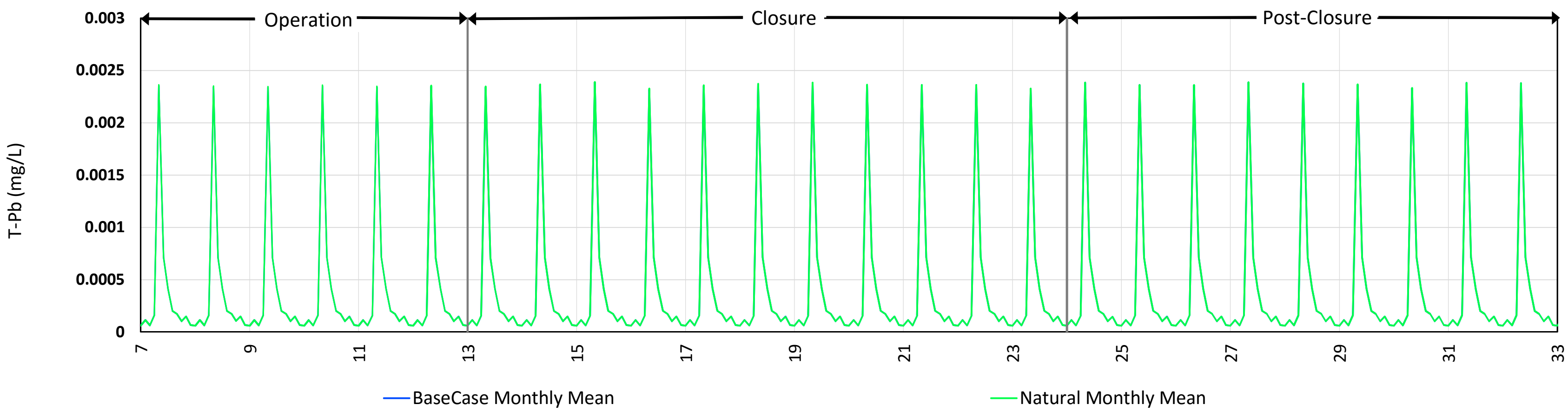


YRdsHC
Operation
Closure
Post-Closure
T-Mg (mg/L)
T-Mn (mg/L)
T-Mo (mg/L)
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

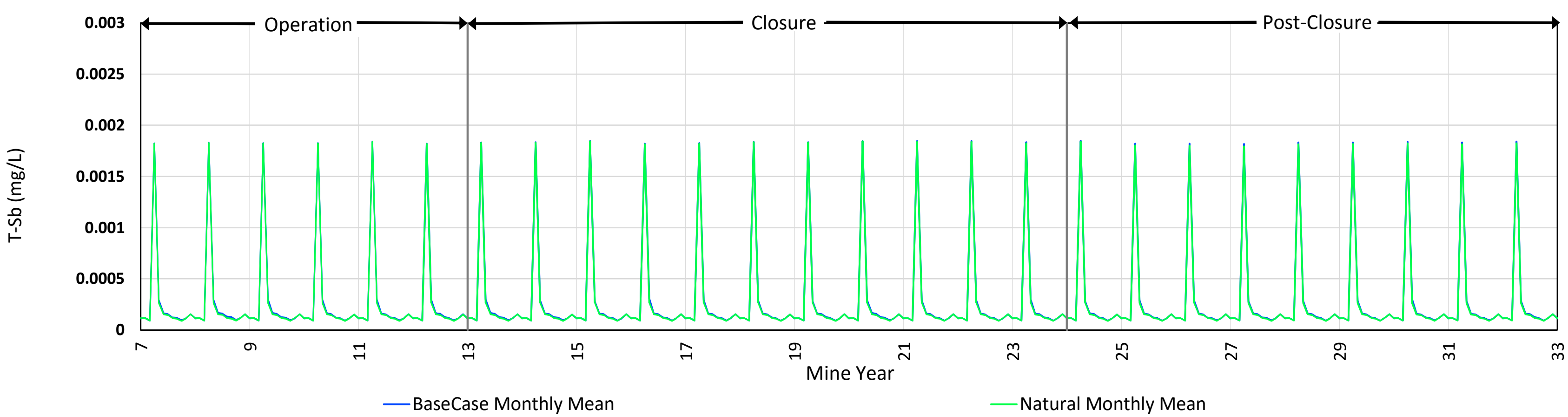
YRdsHC



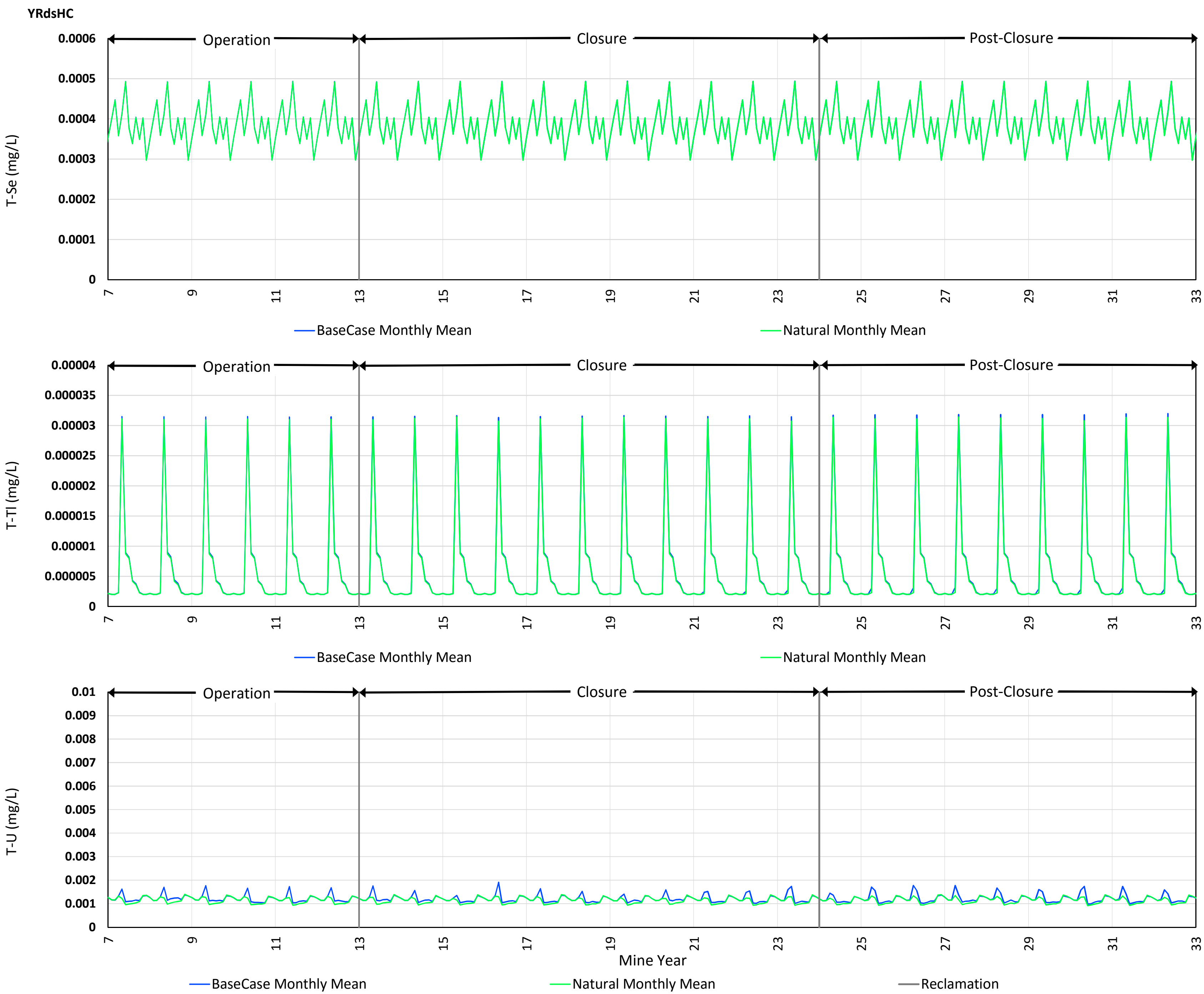
Operation
Closure
Post-Closure
T-Ni (mg/L)
0.01
0.008
0.006
0.004
0.002
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean

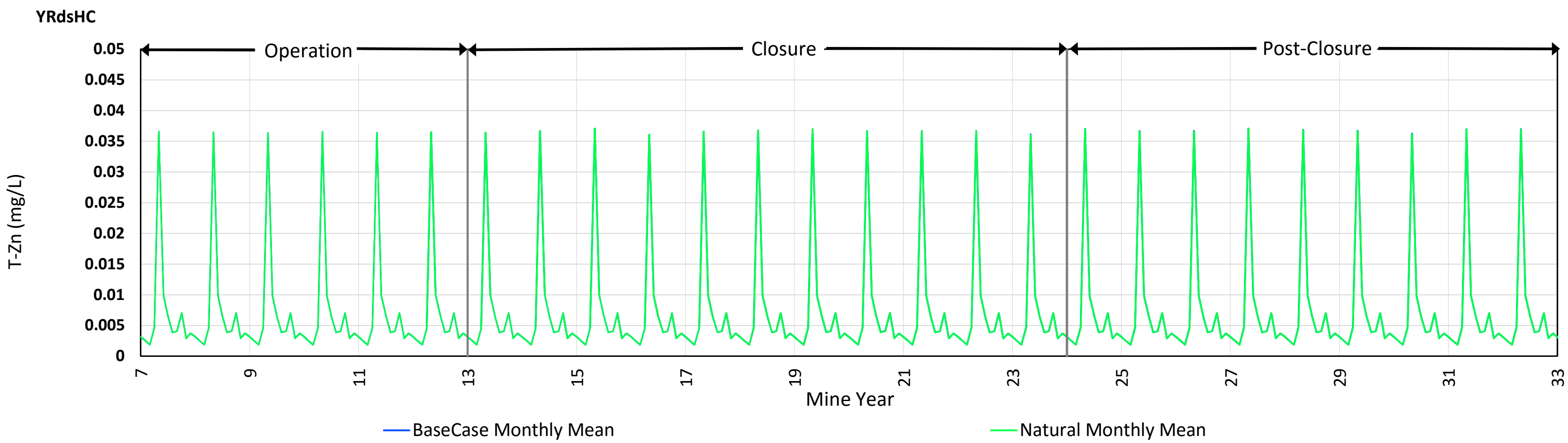


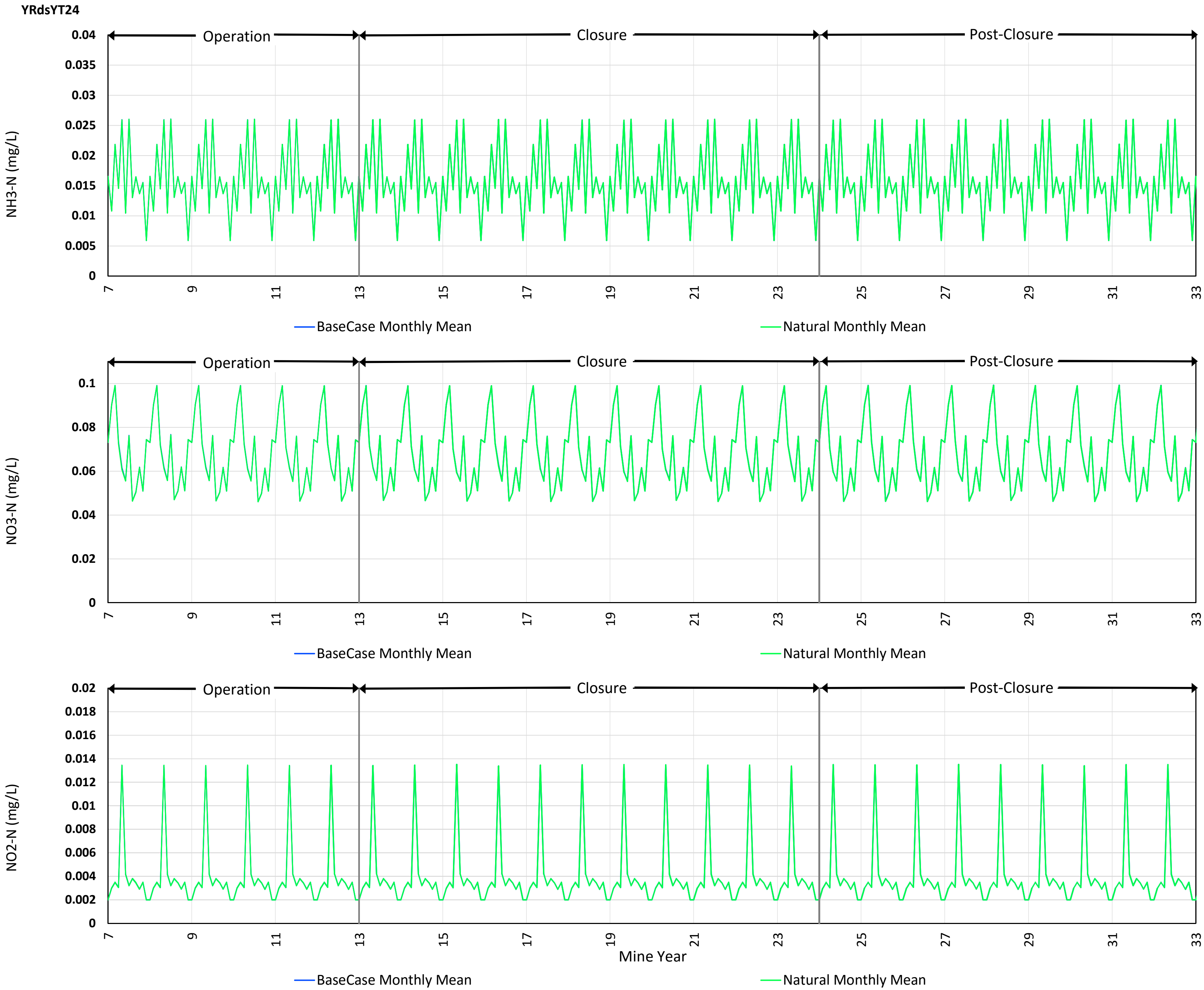
Operation
Closure
Post-Closure
T-Pb (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean



Operation
Closure
Post-Closure
T-Sb (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

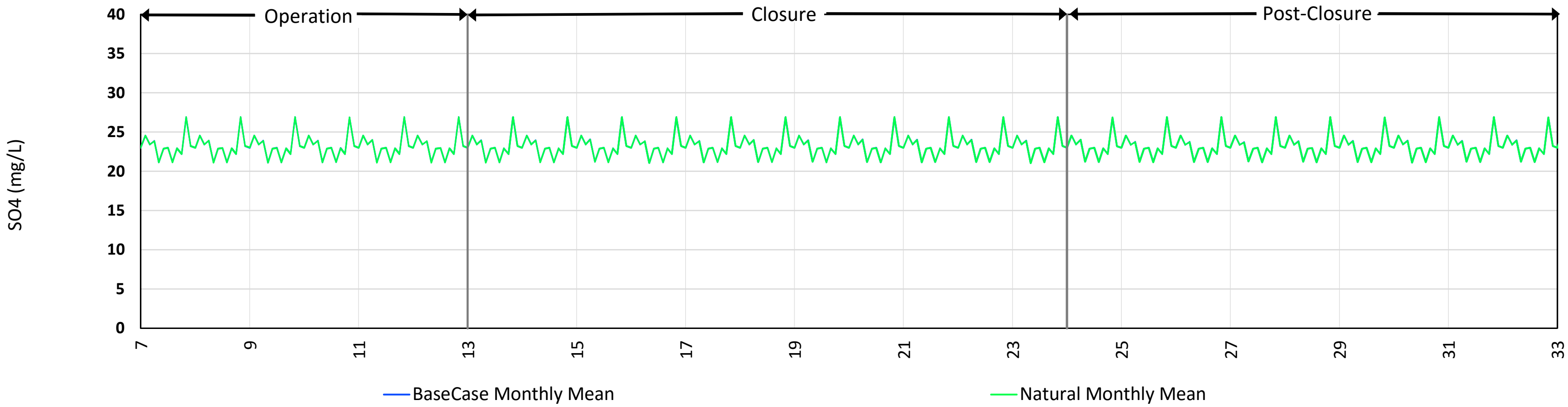

YRdsHC
Operation
Closure
Post-Closure
T-Se (mg/L)
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Tl (mg/L)
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
T-U (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
Mine Year
Reclamation


YRdsHC
Operation
Closure
Post-Closure
T-Zn (mg/L)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

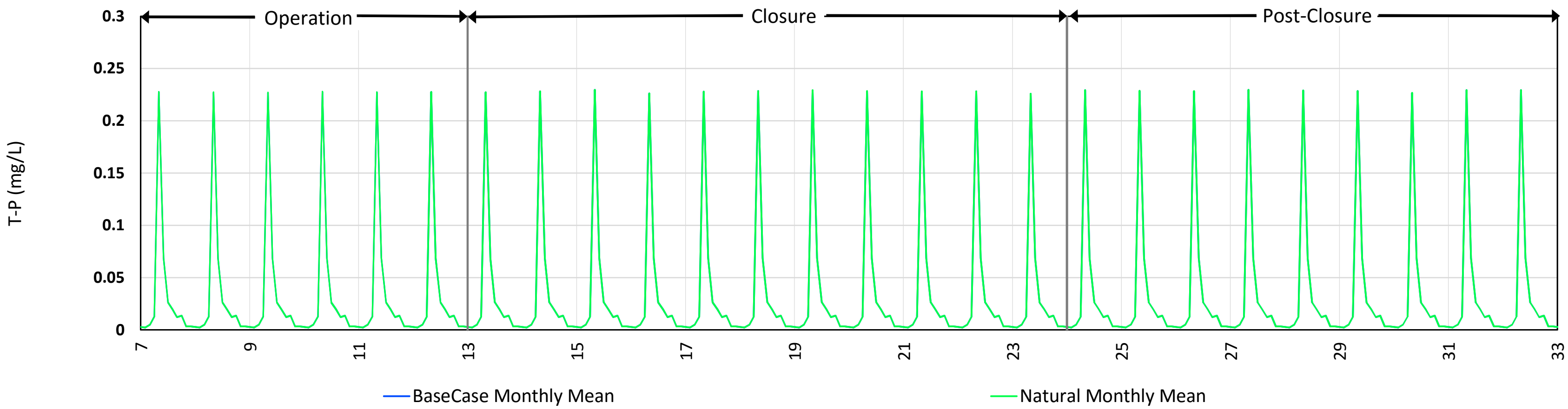


YRdsYT24
Operation
Closure
Post-Closure
NH3-N (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
NO3-N (mg/L)
0.1
0.08
0.06
0.04
0.02
0
NO2-N (mg/L)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Mine Year

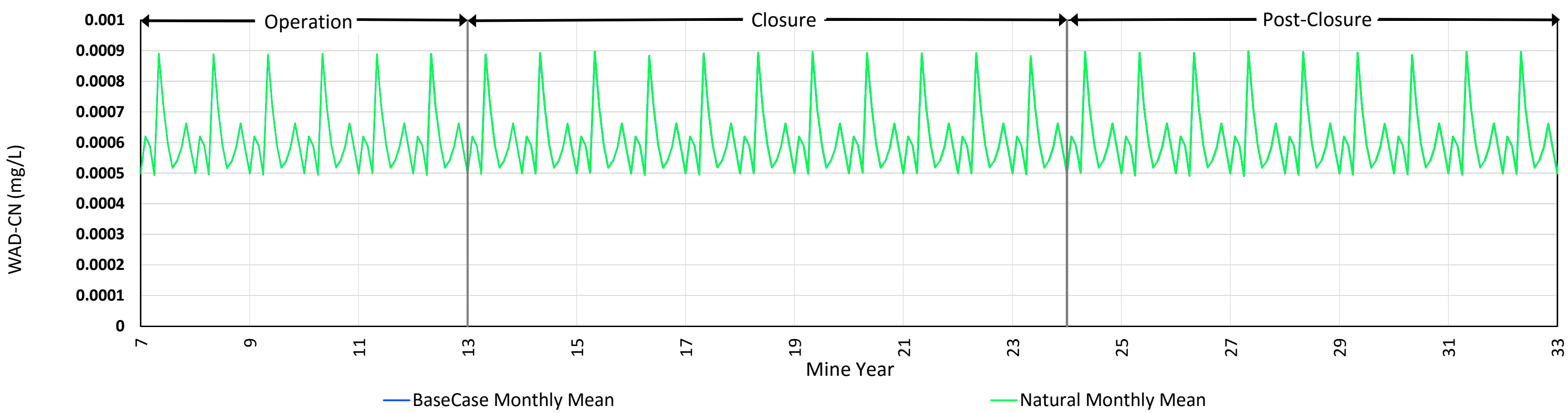
YRdsYT24



Operation
Closure
Post-Closure
SO4 (mg/L)
40
35
30
25
20
15
10
5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean

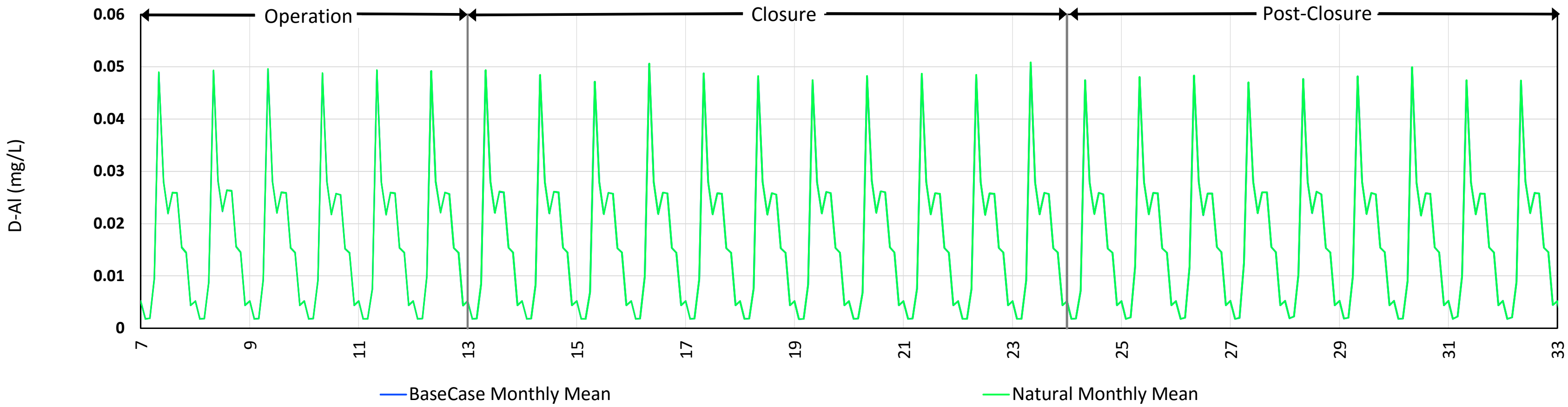


Operation
Closure
Post-Closure
T-P (mg/L)
0.3
0.25
0.2
0.15
0.1
0.05
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean

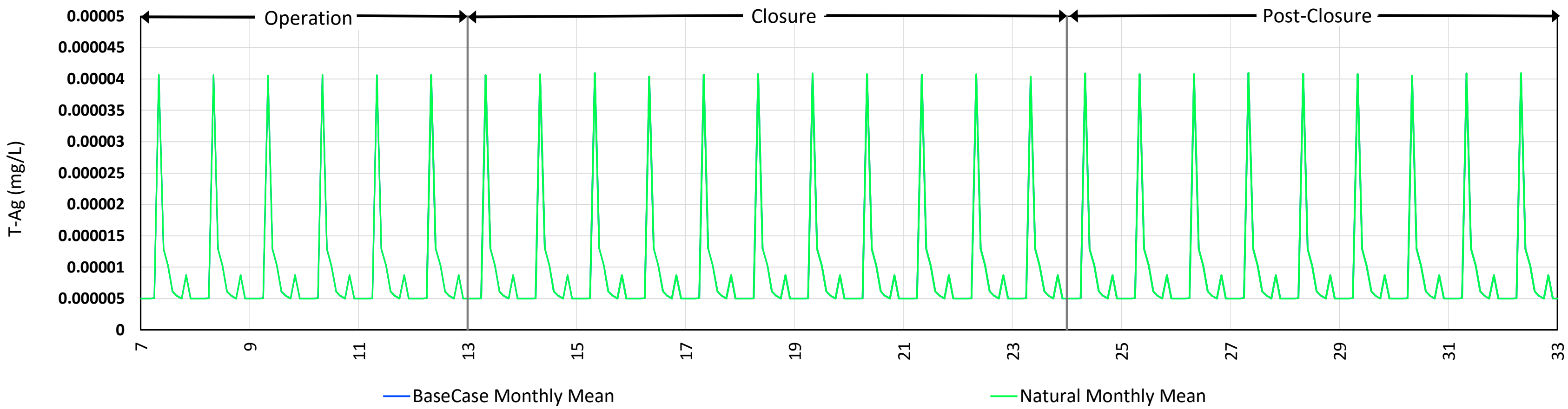


Operation
Closure
Post-Closure
WAD-CN (mg/L)
0.001
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

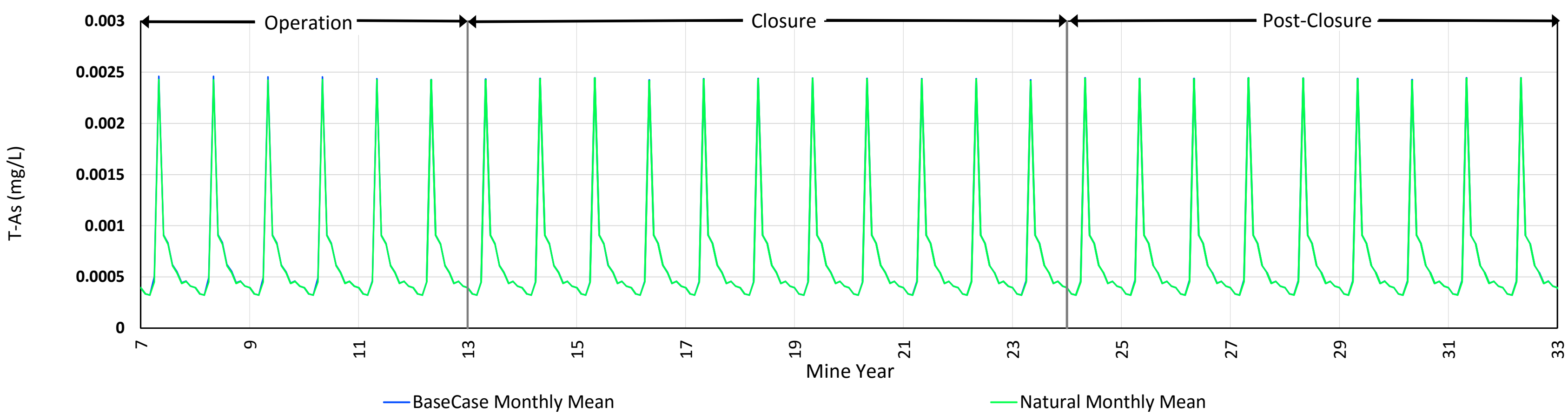
YRdsYT24



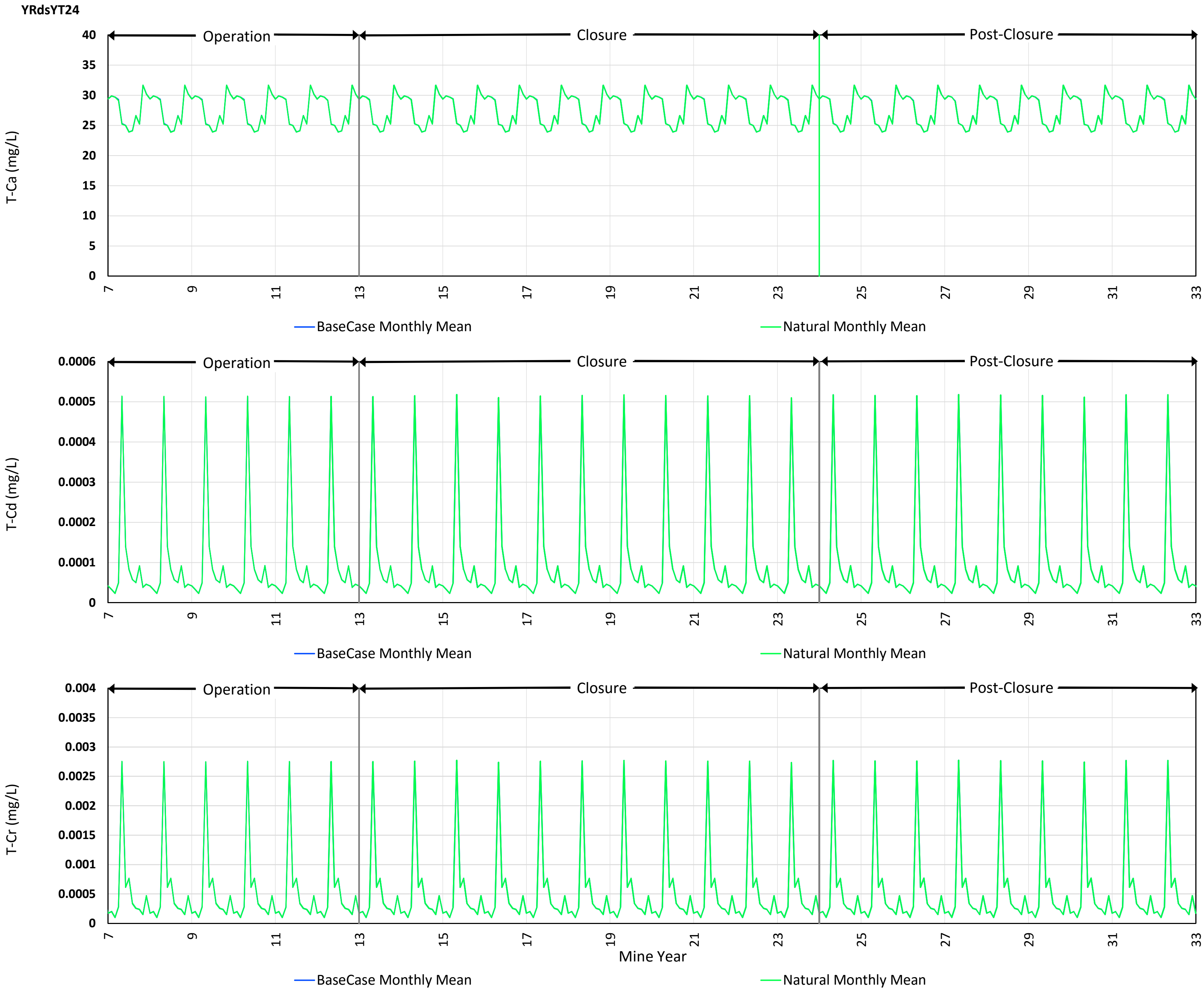
Operation
Closure
Post-Closure
D-Al (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean



Operation
Closure
Post-Closure
T-Ag (mg/L)
0.00005
0.000045
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean

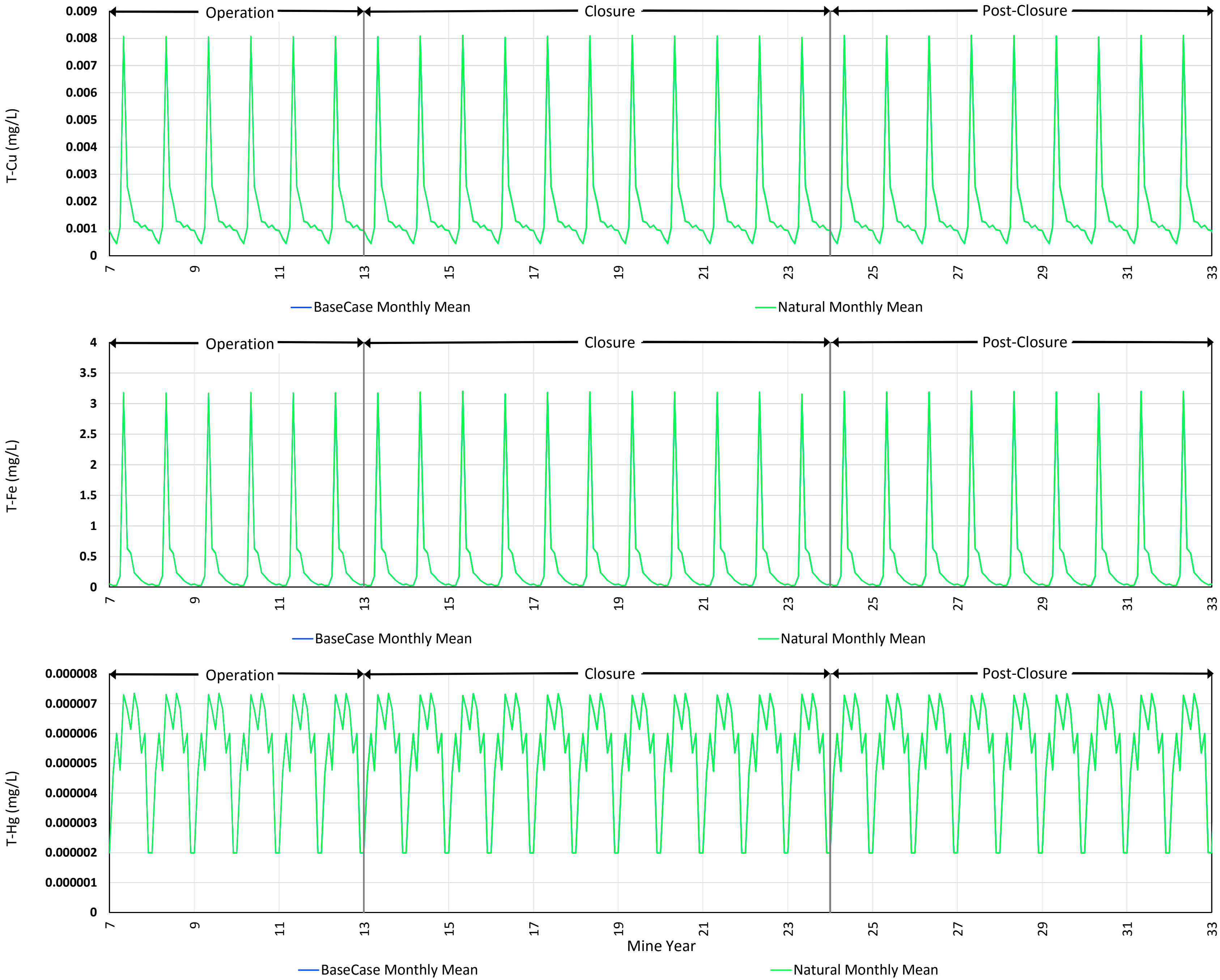


Operation
Closure
Post-Closure
T-As (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

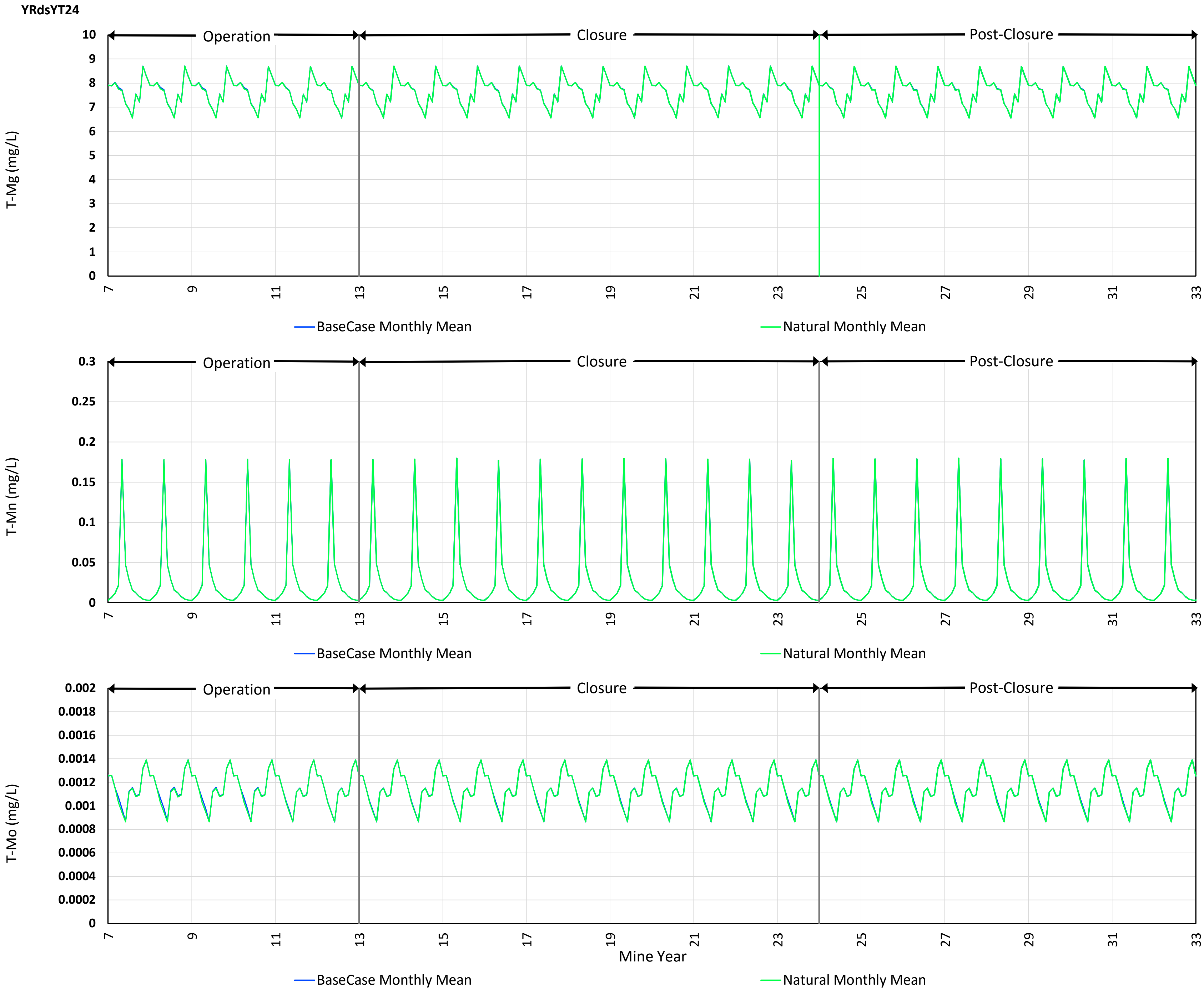


YRdsYT24
Operation
Closure
Post-Closure
T-Ca (mg/L)
T-Cd (mg/L)
T-Cr (mg/L)
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

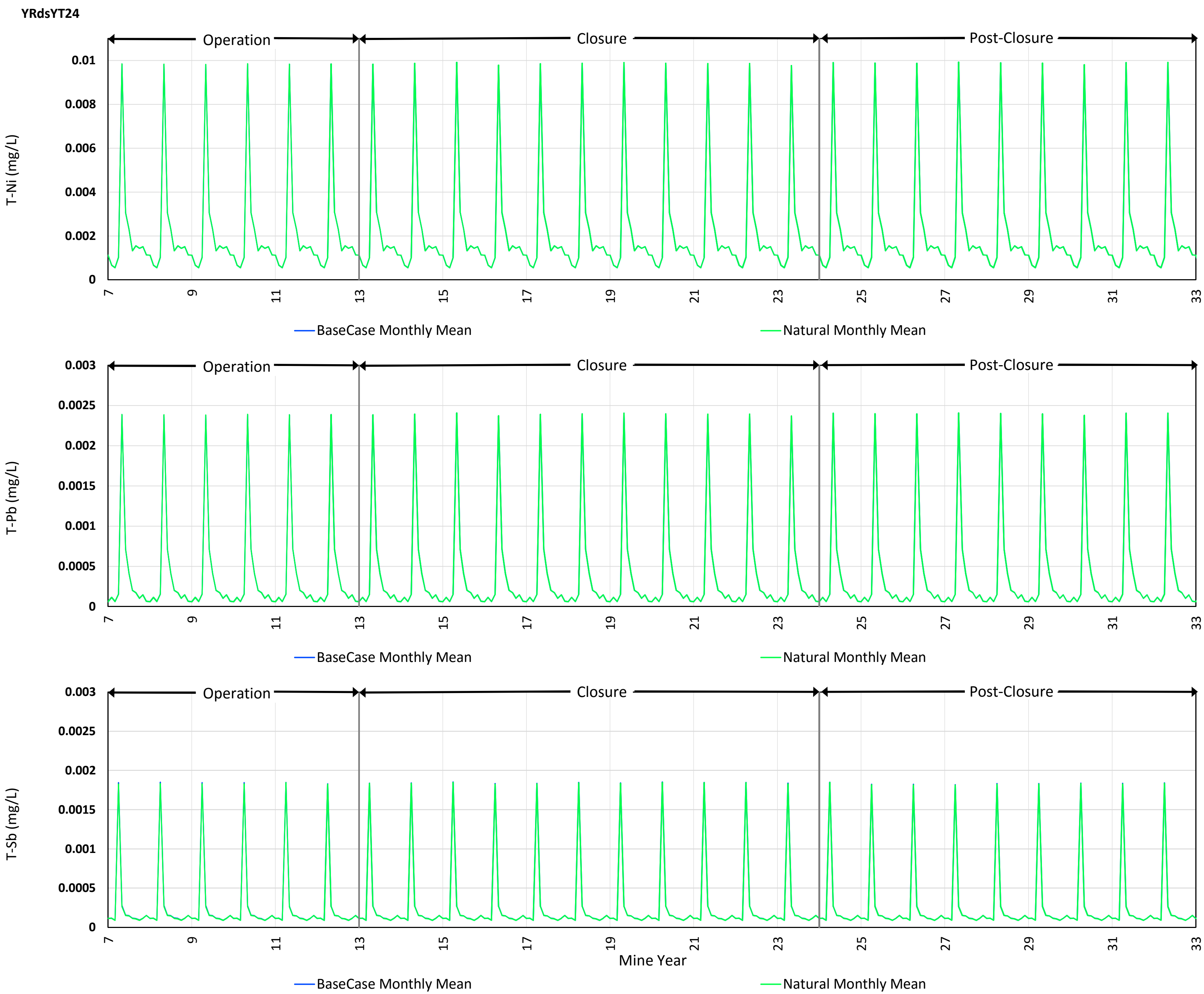
YRdsYT24



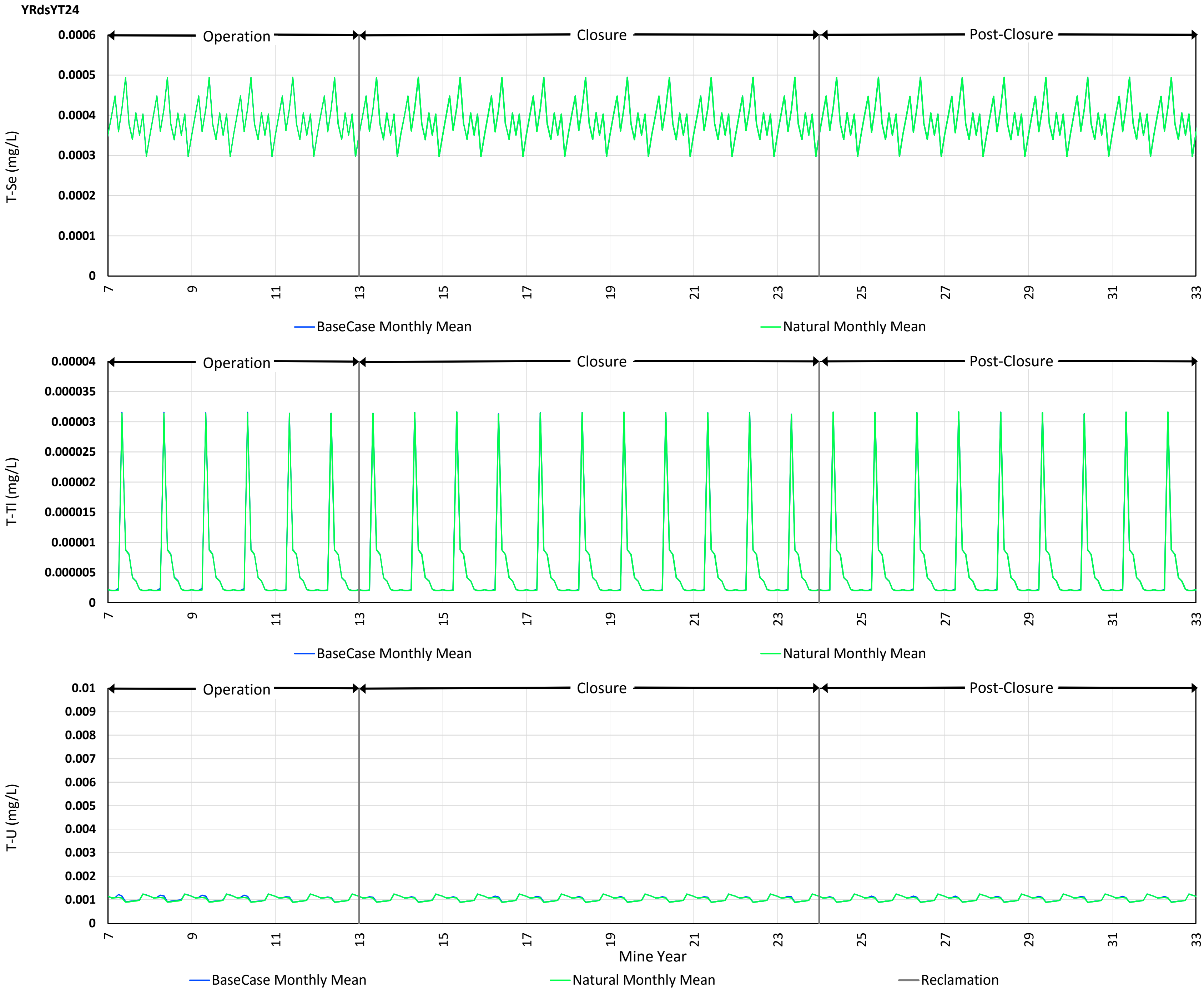
Operation
Closure
Post-Closure
T-Cu (mg/L)
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Fe (mg/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
T-Hg (mg/L)
0.000008
0.000007
0.000006
0.000005
0.000004
0.000003
0.000002
0.000001
0
Mine Year



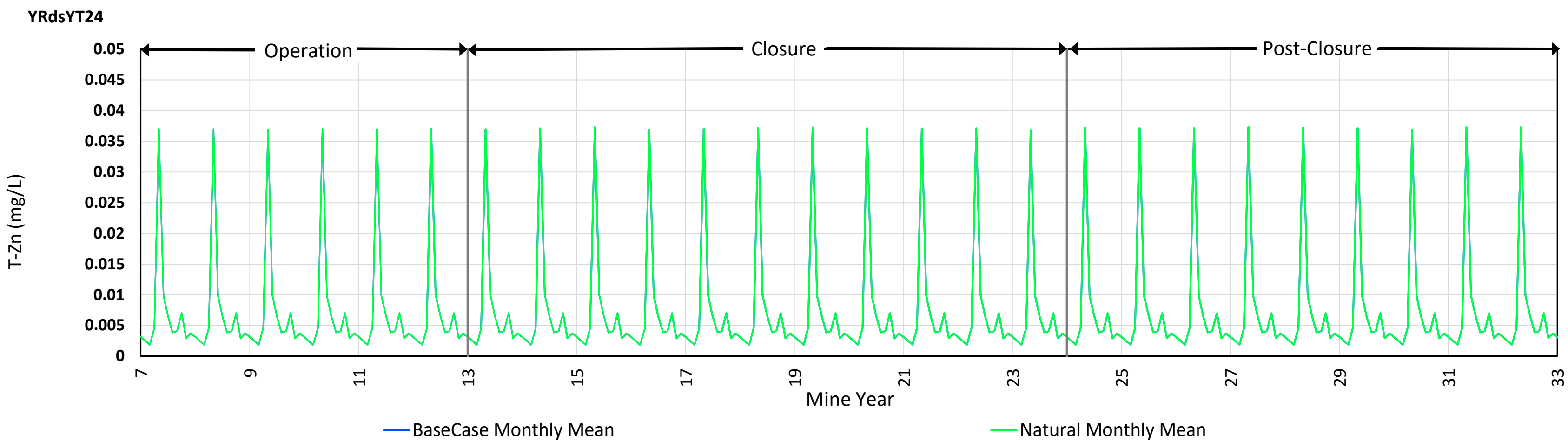
YRdsYT24
Operation
Closure
Post-Closure
T-Mg (mg/L)
BaseCase Monthly Mean
Natural Monthly Mean
T-Mn (mg/L)
T-Mo (mg/L)
Mine Year



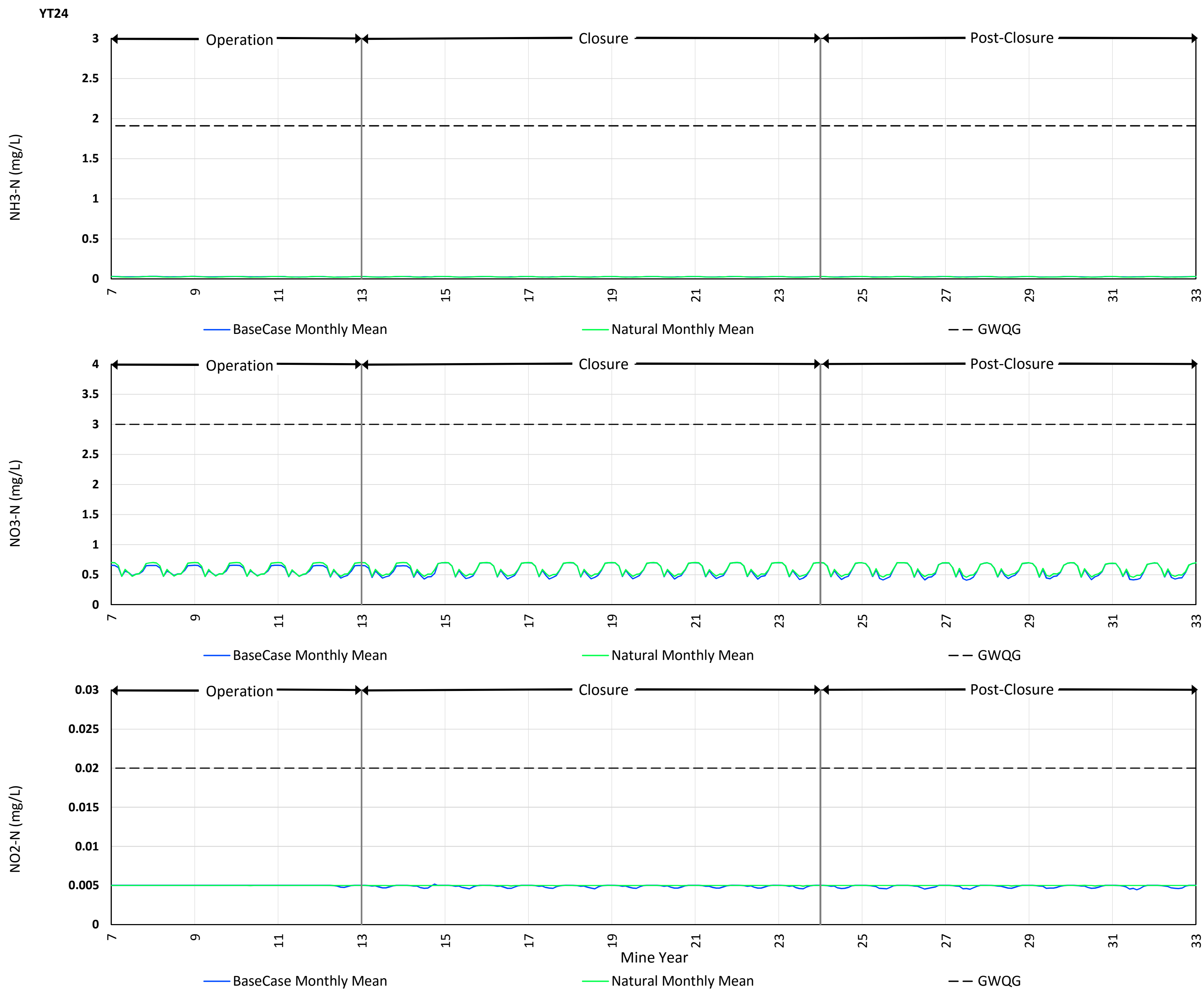
YRdsYT24
Operation
Closure
Post-Closure
T-Ni (mg/L)
0.01
0.008
0.006
0.004
0.002
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Pb (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
T-Sb (mg/L)
Mine Year

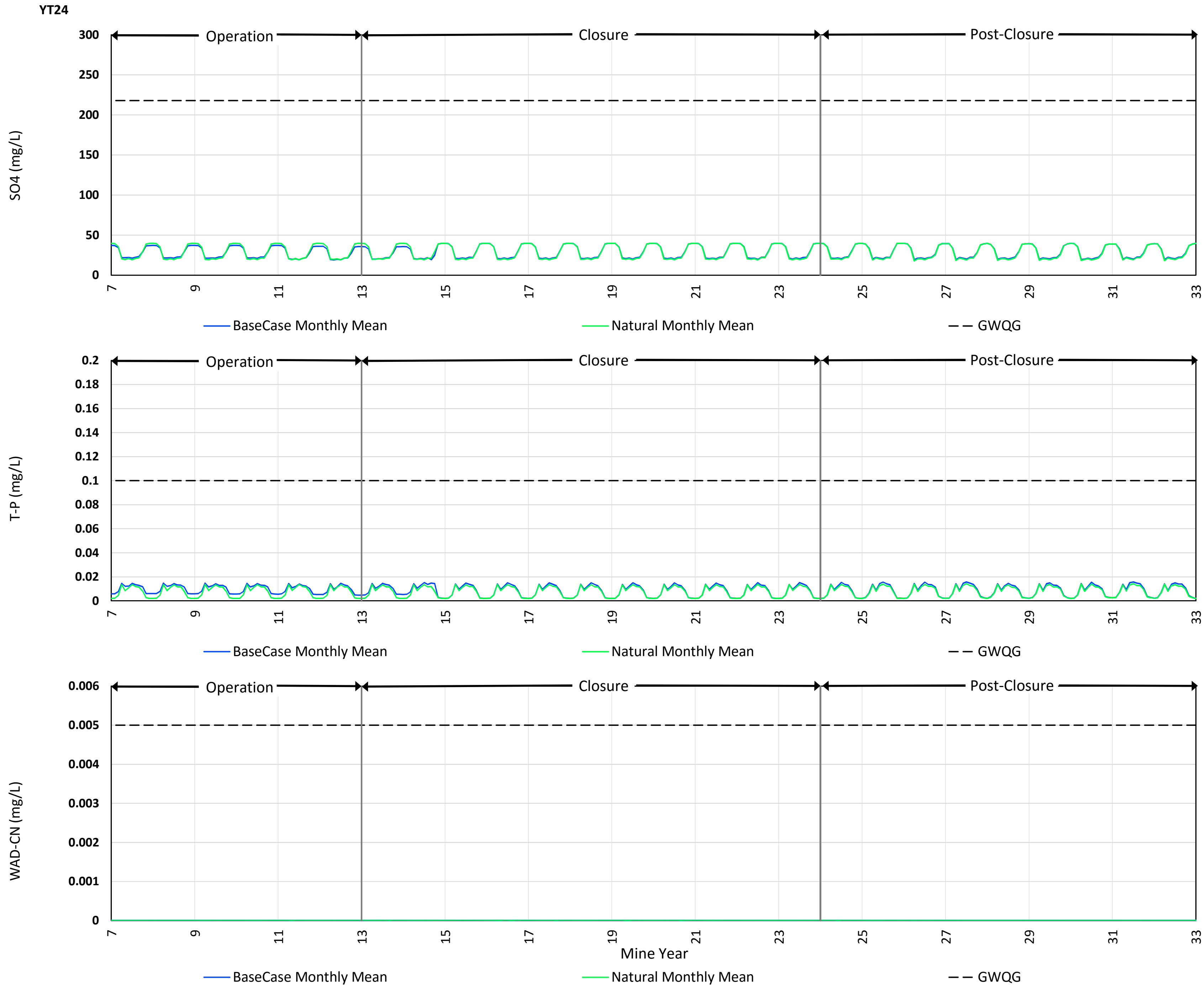


YRdsYT24
Operation
Closure
Post-Closure
T-Se (mg/L)
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Tl (mg/L)
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
T-U (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
Mine Year
Reclamation

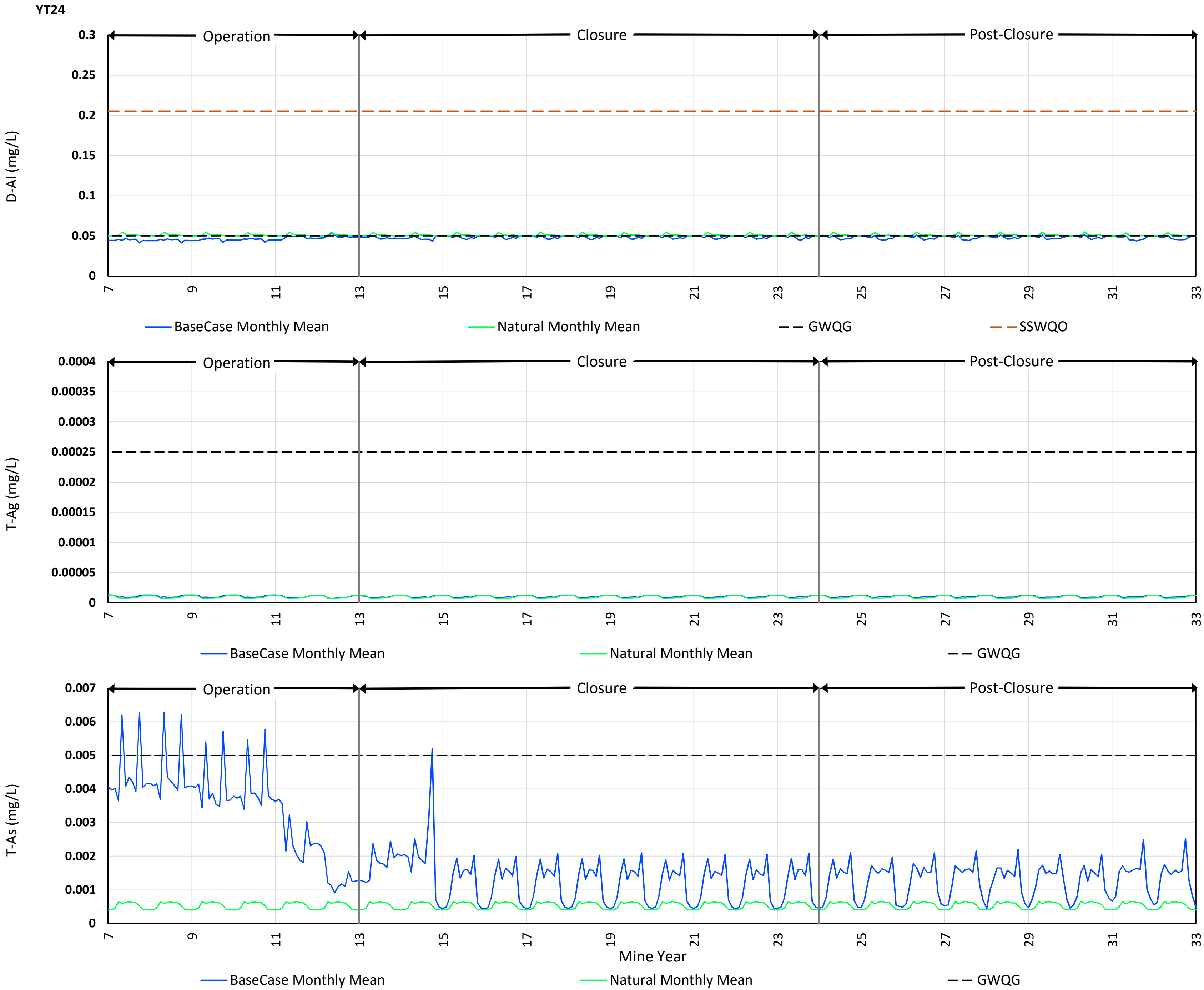


YRdsYT24
Operation
Closure
Post-Closure
T-Zn (mg/L)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean

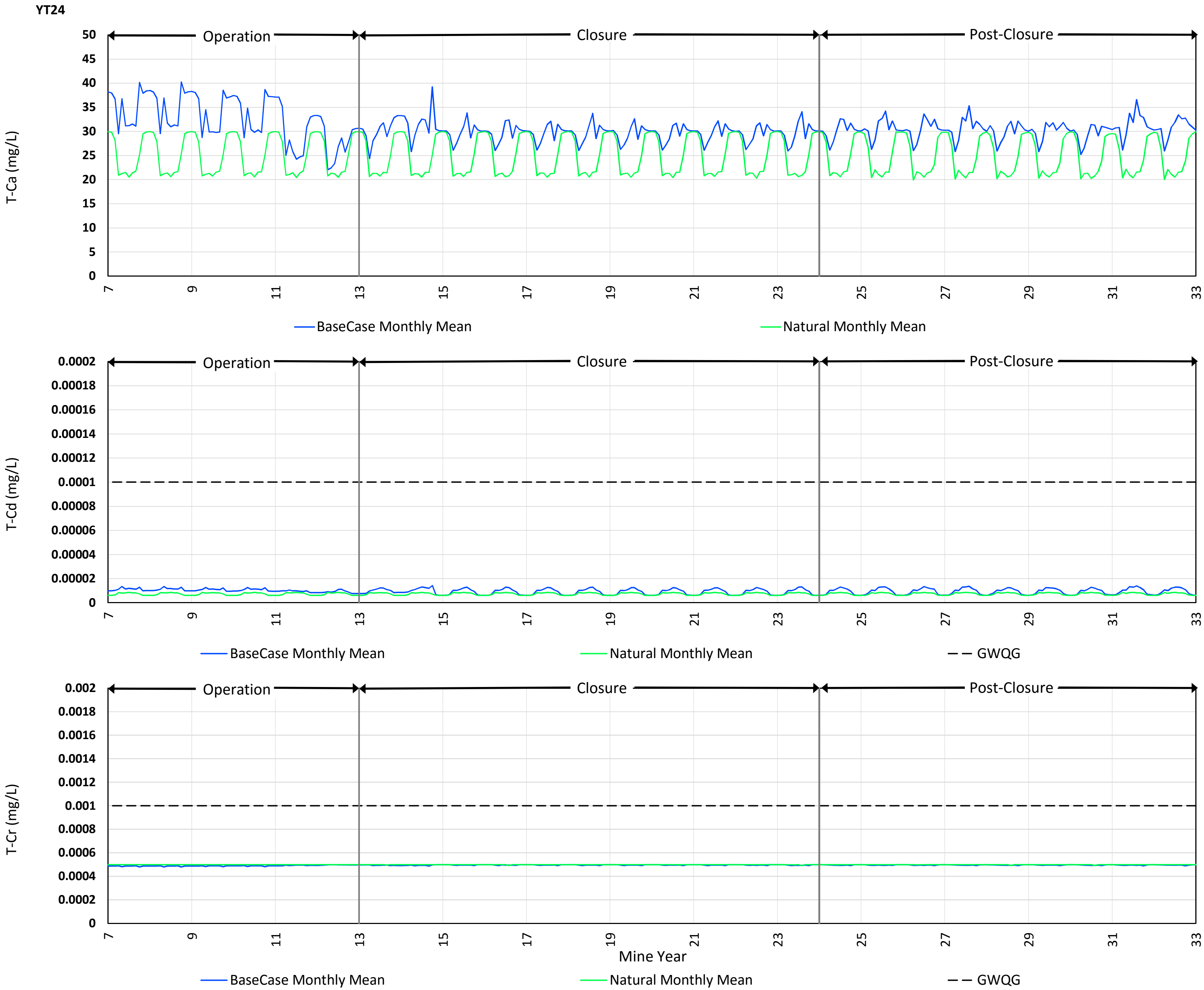

YT24
Operation
Closure
Post-Closure
NH3-N (mg/L)
NO3-N (mg/L)
NO2-N (mg/L)
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG



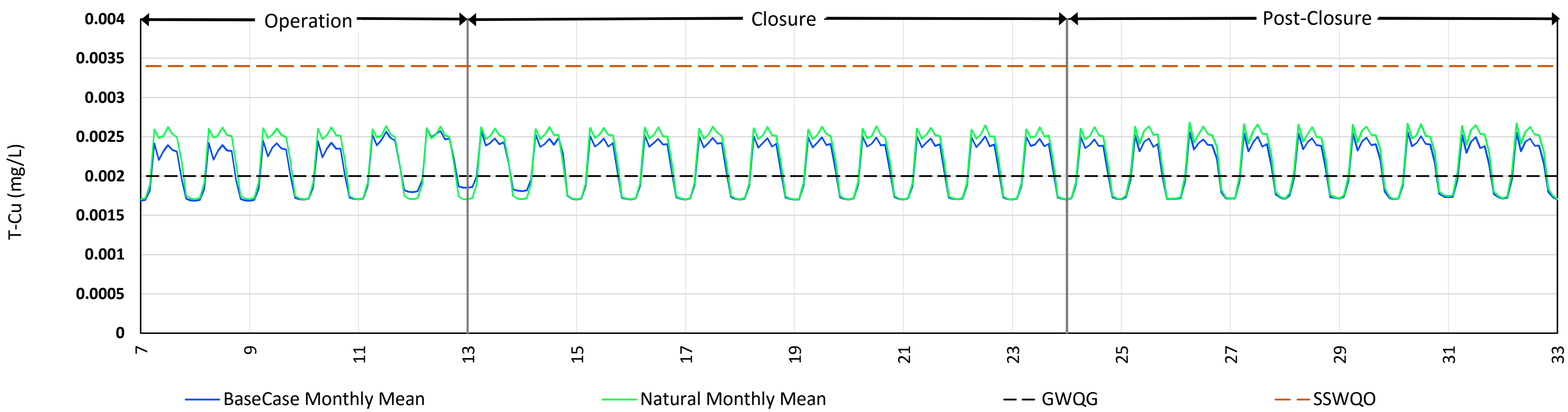
YT24
Operation
Closure
Post-Closure
SO4 (mg/L)
300
250
200
150
100
50
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
T-P (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
WAD-CN (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
Mine Year



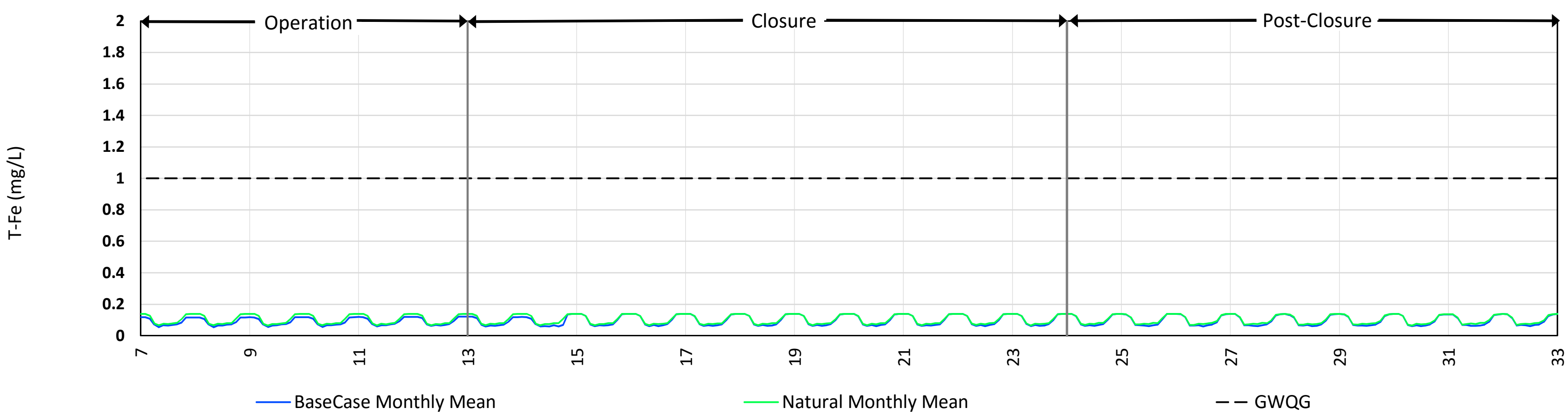
YT24
Operation
Closure
Post-Closure
D-Al (mg/L)
0.3
0.25
0.2
0.15
0.1
0.05
0
7 9 11 13 15 17 19 21 23 25 27 29 31 33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
Operation
Closure
Post-Closure
T-Ag (mg/L)
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
0
7 9 11 13 15 17 19 21 23 25 27 29 31 33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
T-As (mg/L)
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
7 9 11 13 15 17 19 21 23 25 27 29 31 33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG


YT24
Operation
Closure
Post-Closure
T-Ca (mg/L)
50
45
40
35
30
25
20
15
10
5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Cd (mg/L)
0.0002
0.00018
0.00016
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
GWQG
T-Cr (mg/L)
0.002
0.0018
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
Mine Year

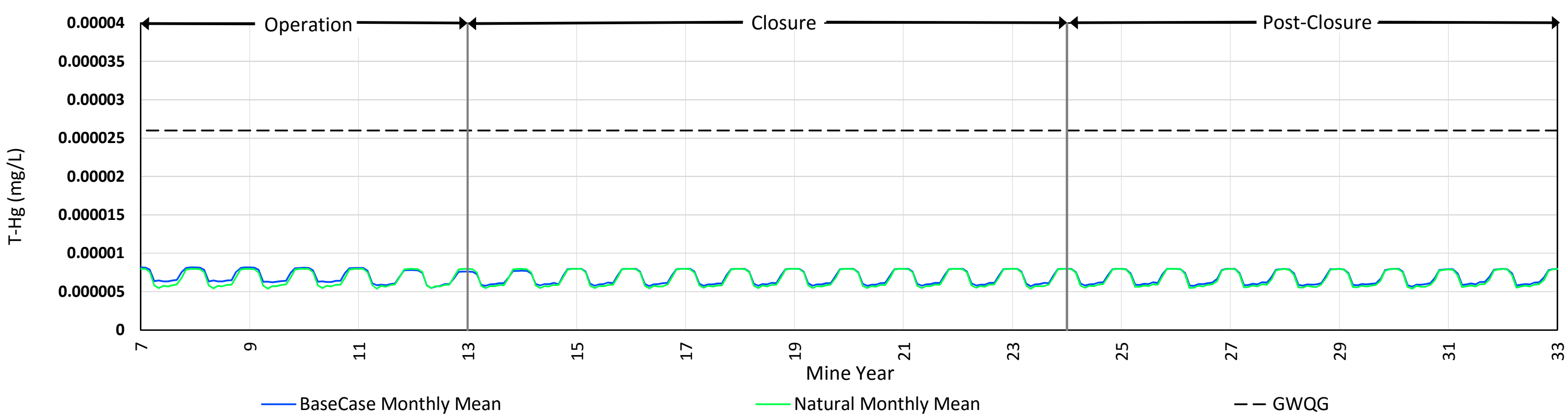
YT24



Operation
Closure
Post-Closure
T-Cu (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
SSWQO

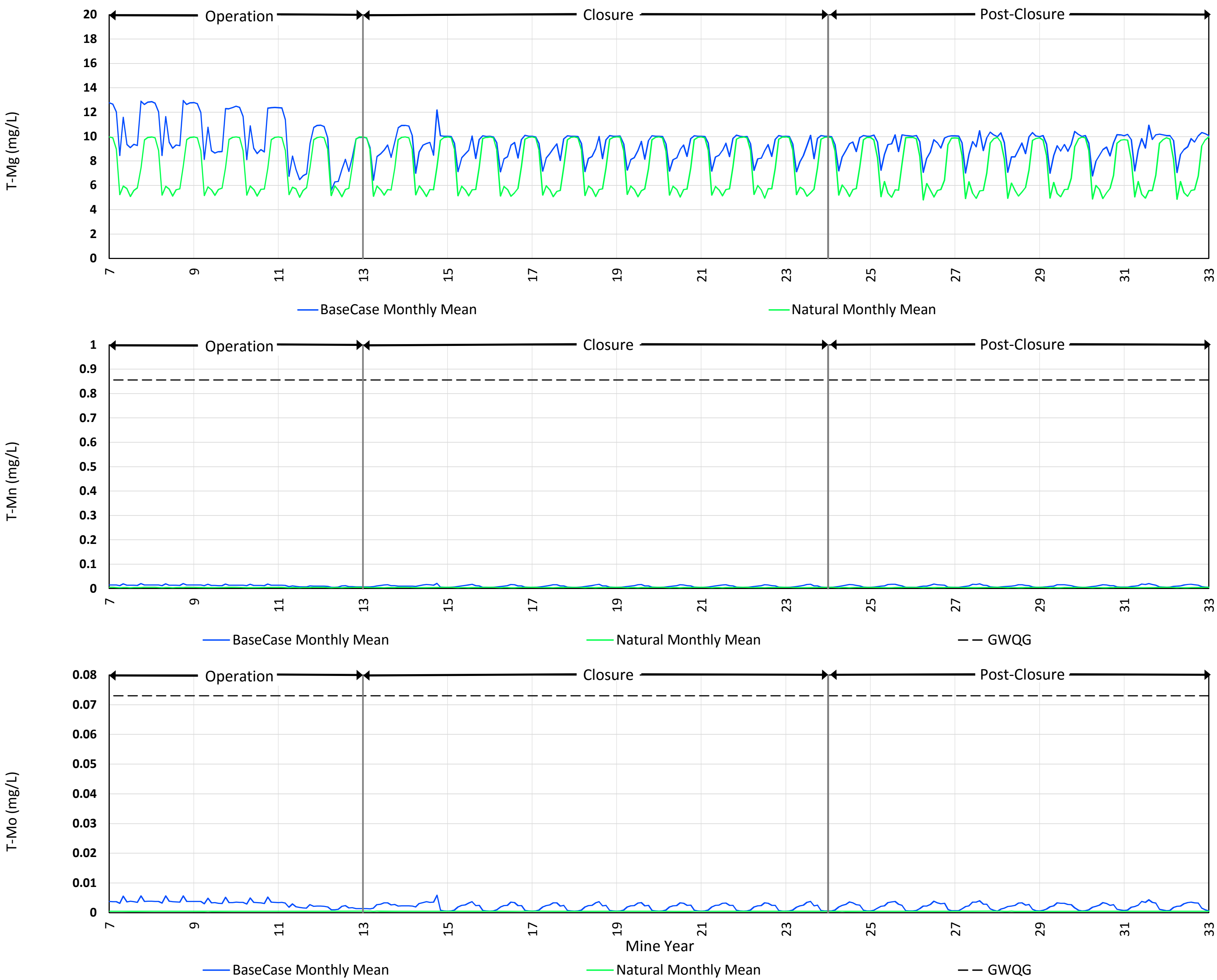


Operation
Closure
Post-Closure
T-Fe (mg/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG



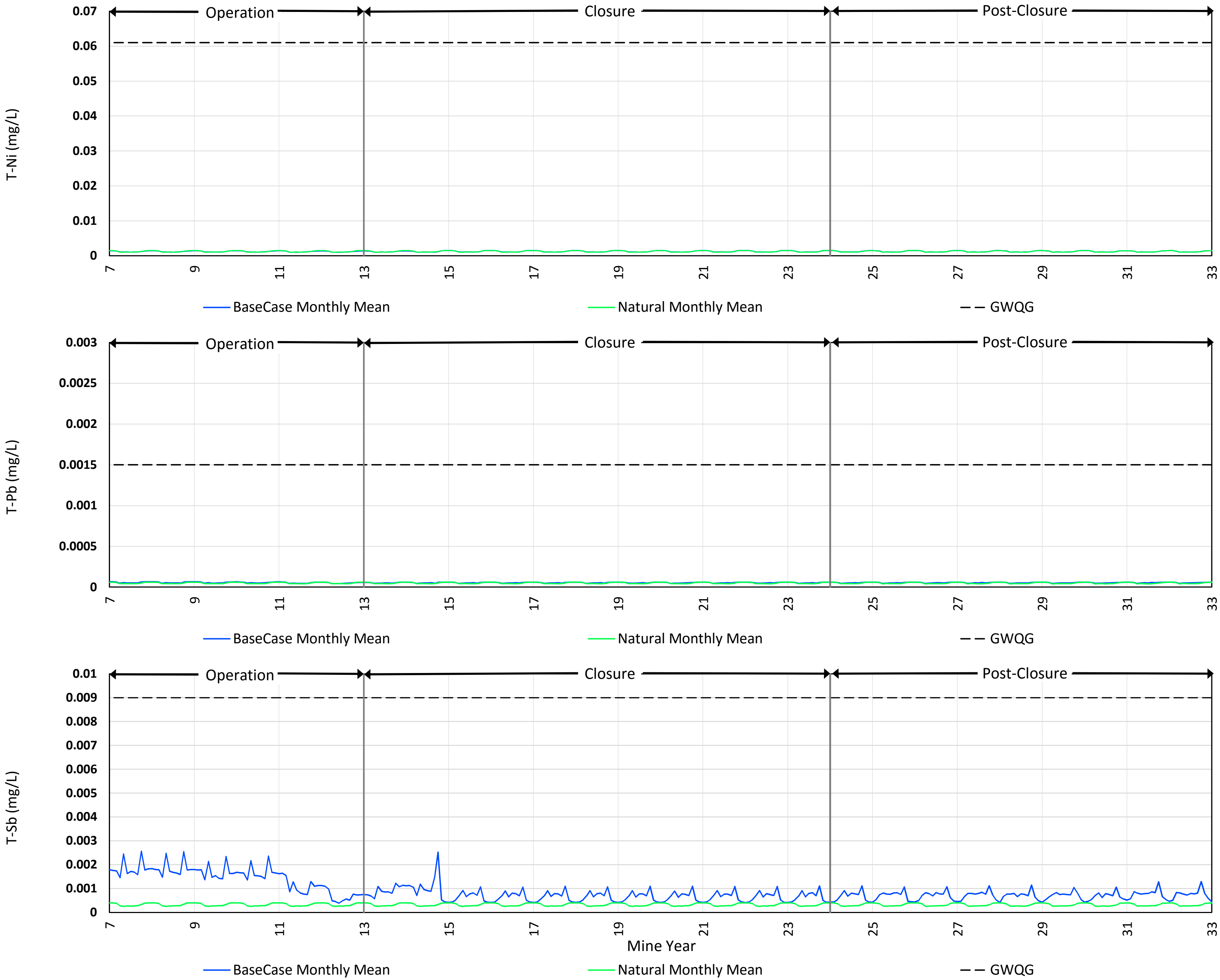
Operation
Closure
Post-Closure
T-Hg (mg/L)
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

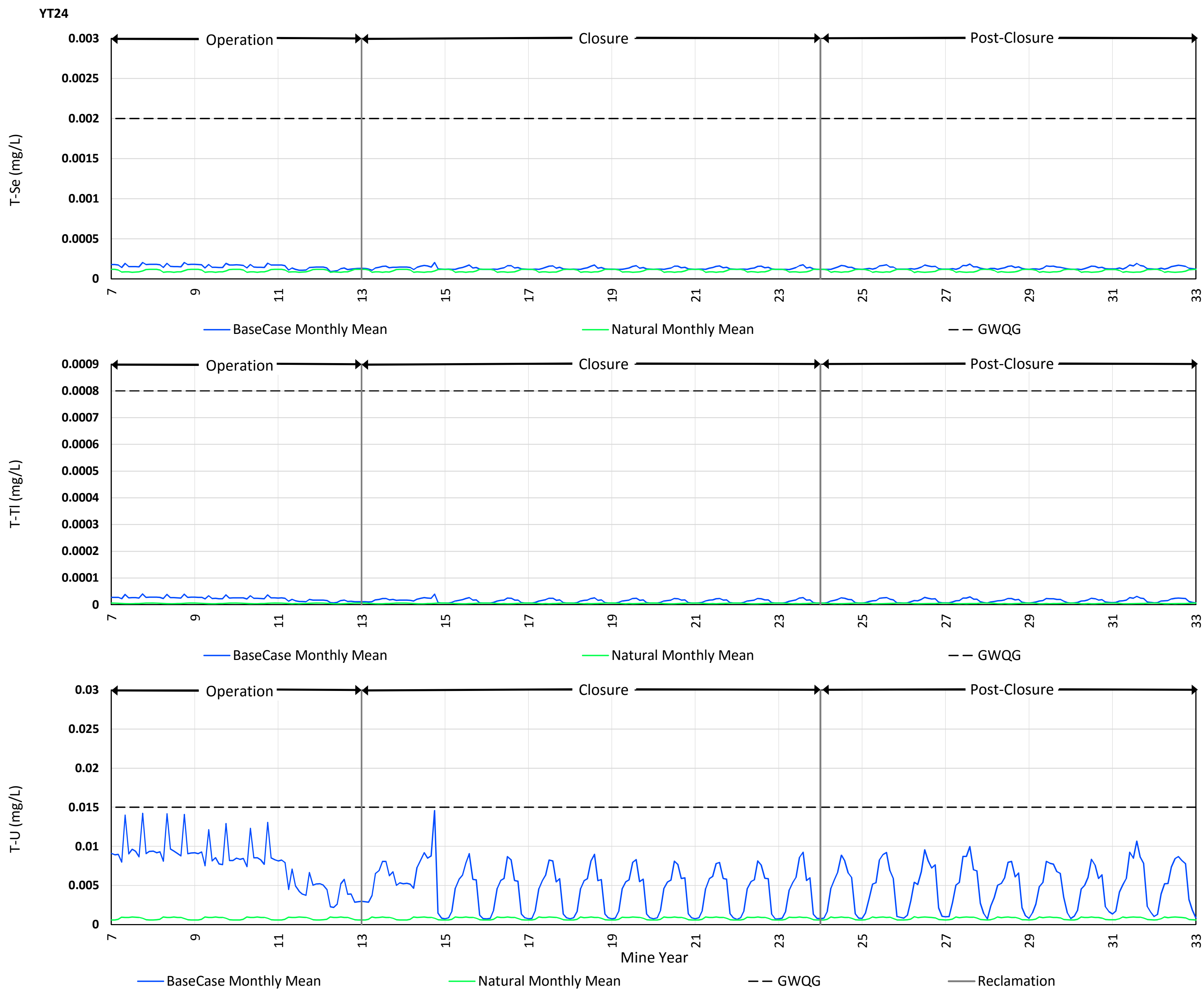
YT24



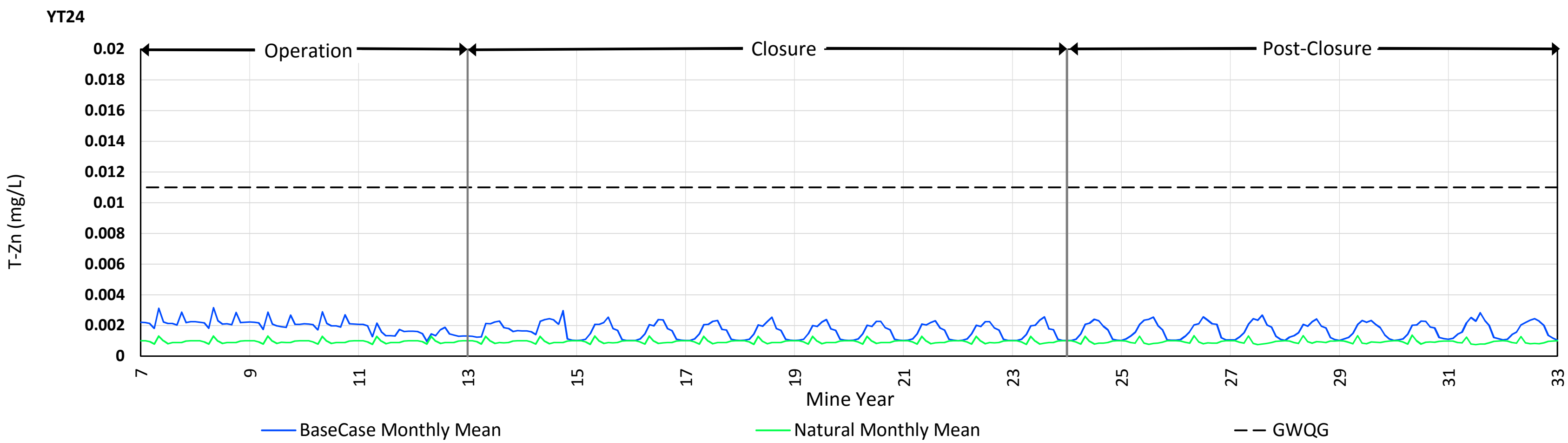
Operation
Closure
Post-Closure
T-Mg (mg/L)
20
18
16
14
12
10
8
6
4
2
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
T-Mn (mg/L)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
GWQG
T-Mo (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Mine Year

YT24


T-Ni (mg/L)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Operation
Closure
Post-Closure
7
9
11
13
15
17
19
21
23
25
27
29
31
33
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
T-Pb (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
T-Sb (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
Mine Year

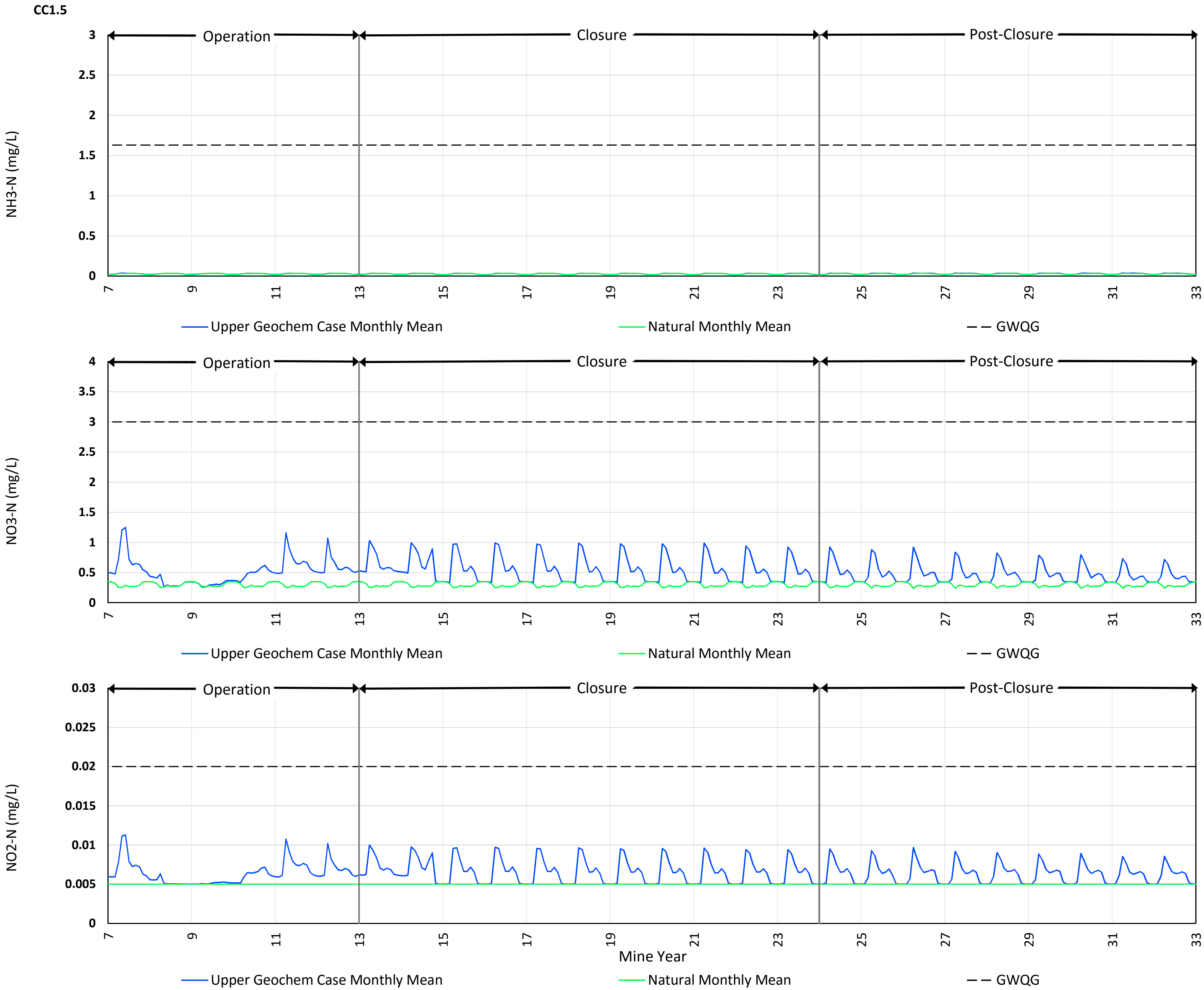


YT24
T-Se (mg/L)
T-Tl (mg/L)
T-U (mg/L)
Operation
Closure
Post-Closure
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG
Reclamation

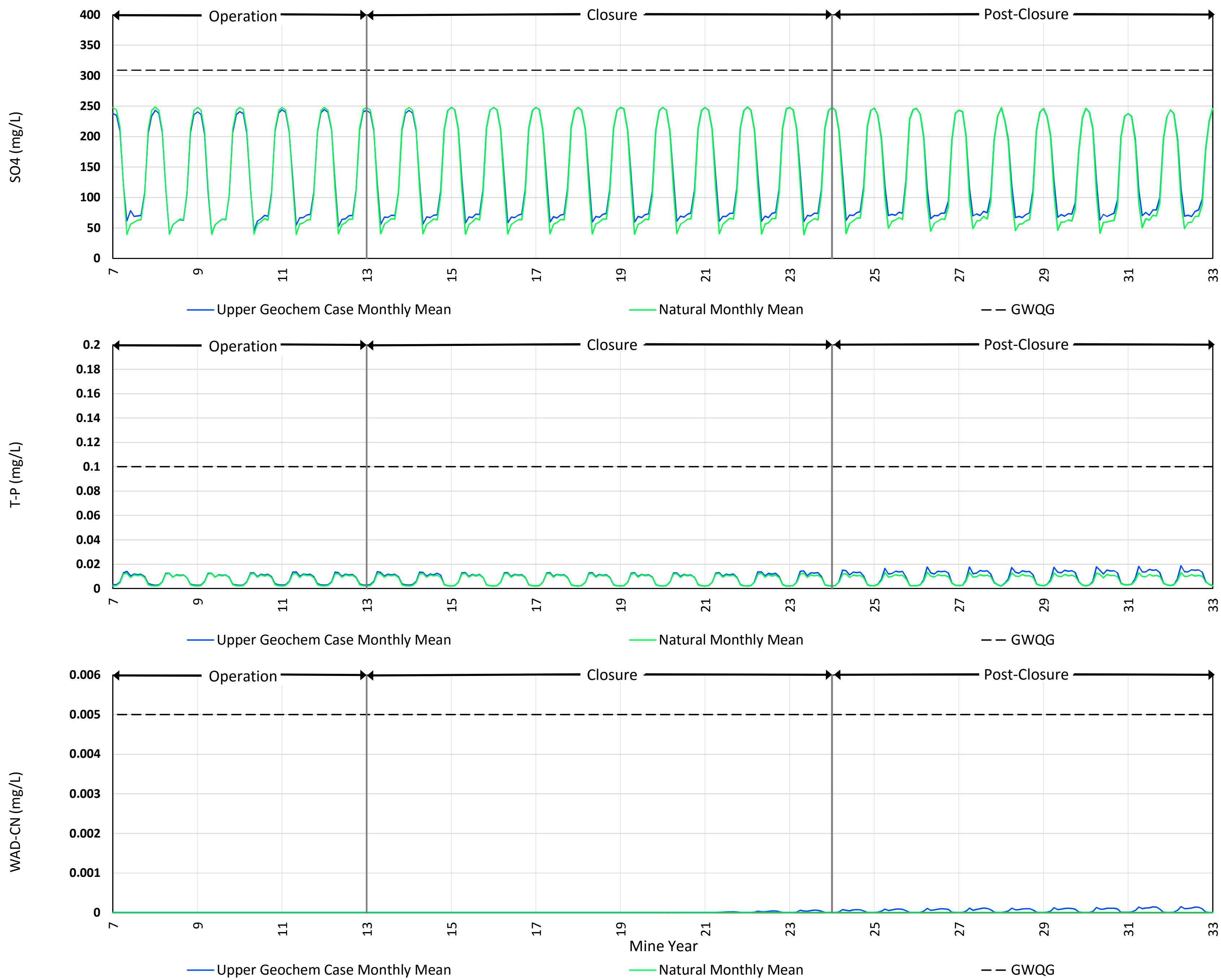

YT24
Operation
Closure
Post-Closure
T-Zn (mg/L)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
BaseCase Monthly Mean
Natural Monthly Mean
GWQG

Appendix 12-C-6: Upper Geochemistry Case Water Quality Model Results

GOLDCORP

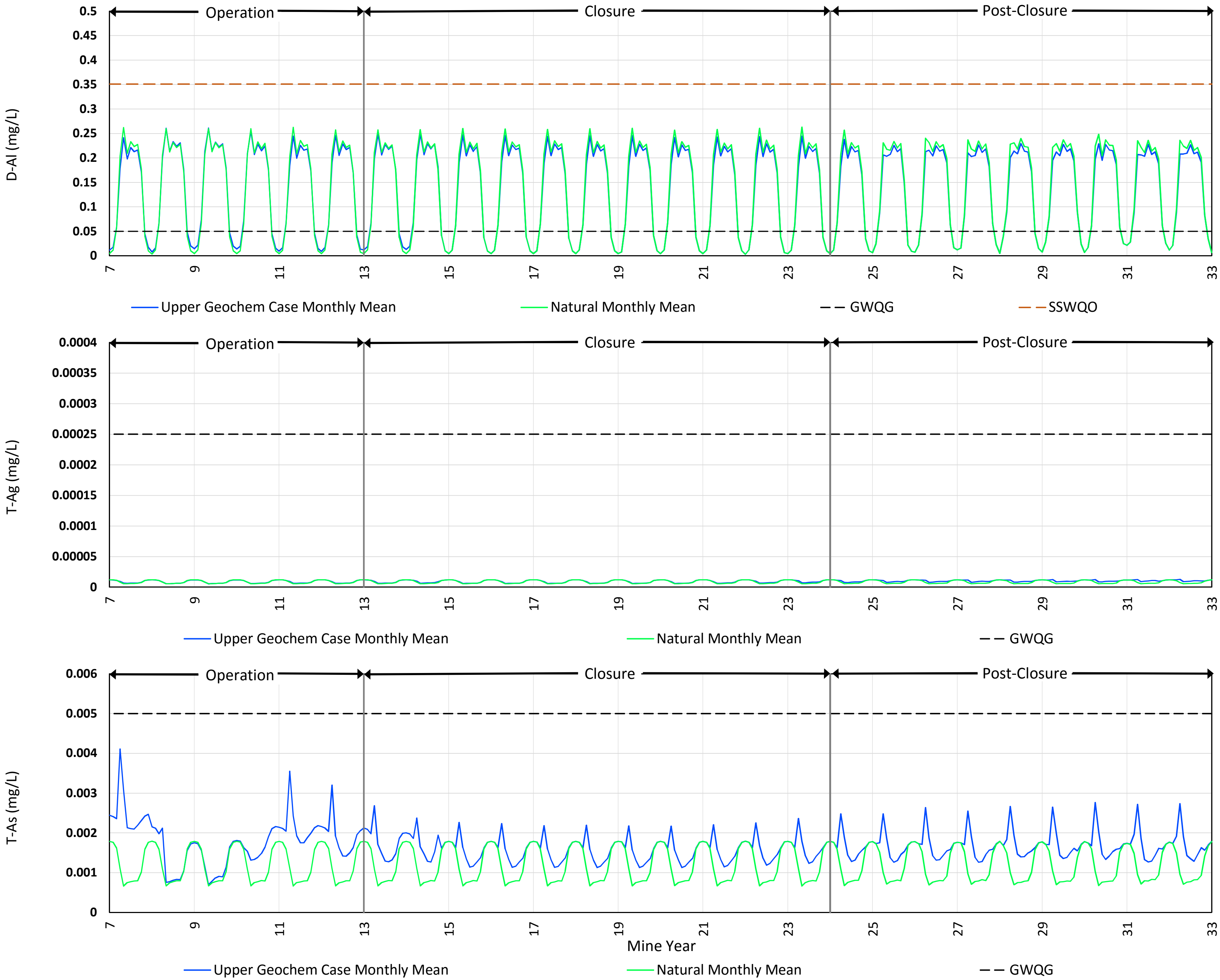

CC1.5
Operation
Closure
Post-Closure
NH3-N (mg/L)
0
0.5
1
1.5
2
2.5
3
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
NO3-N (mg/L)
0
0.5
1
1.5
2
2.5
3
3.5
4
NO2-N (mg/L)
0
0.005
0.01
0.015
0.02
0.025
0.03
Mine Year

CC1.5



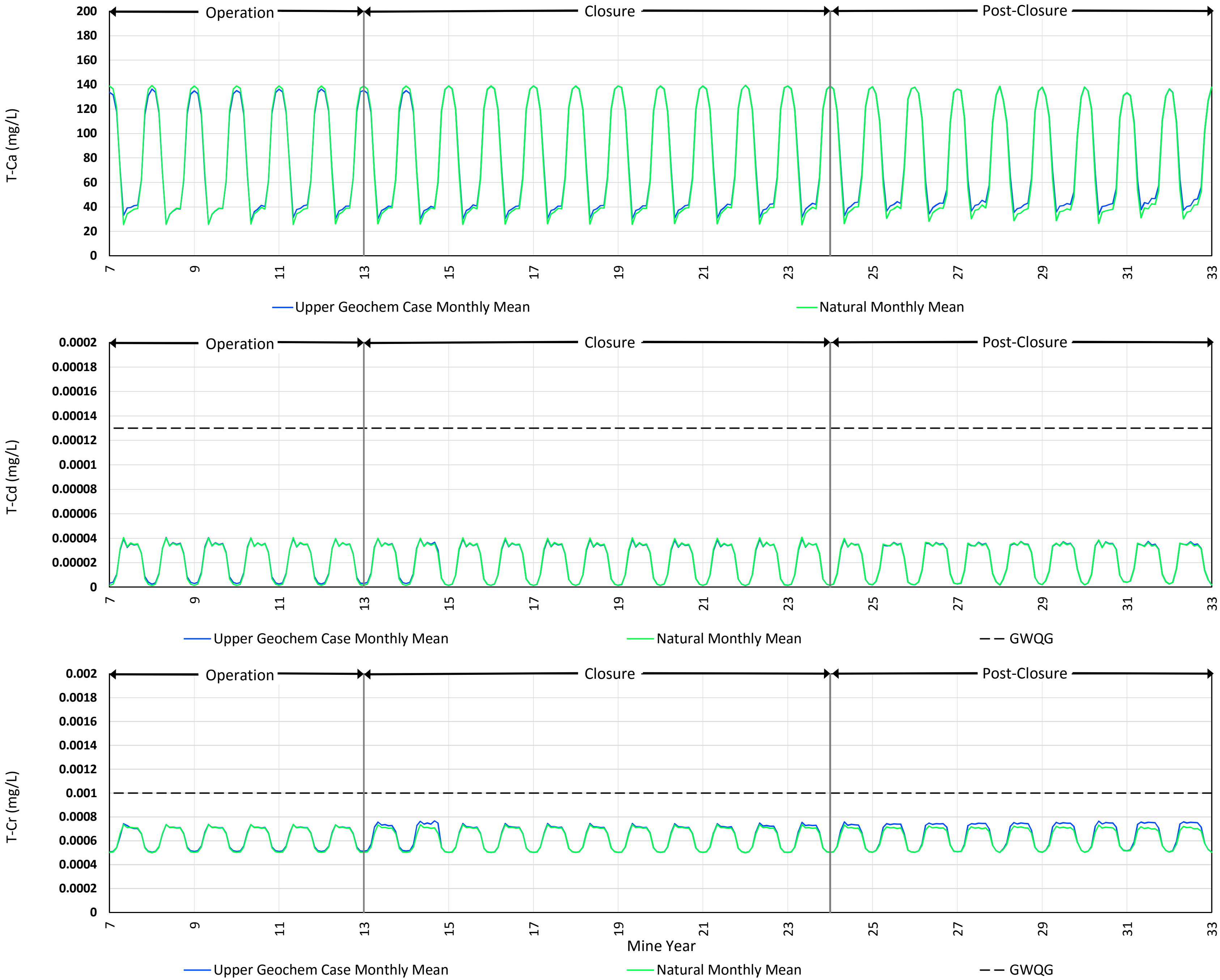
Operation
Closure
Post-Closure
SO4 (mg/L)
400
350
300
250
200
150
100
50
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
T-P (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
WAD-CN (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
Mine Year

CC1.5

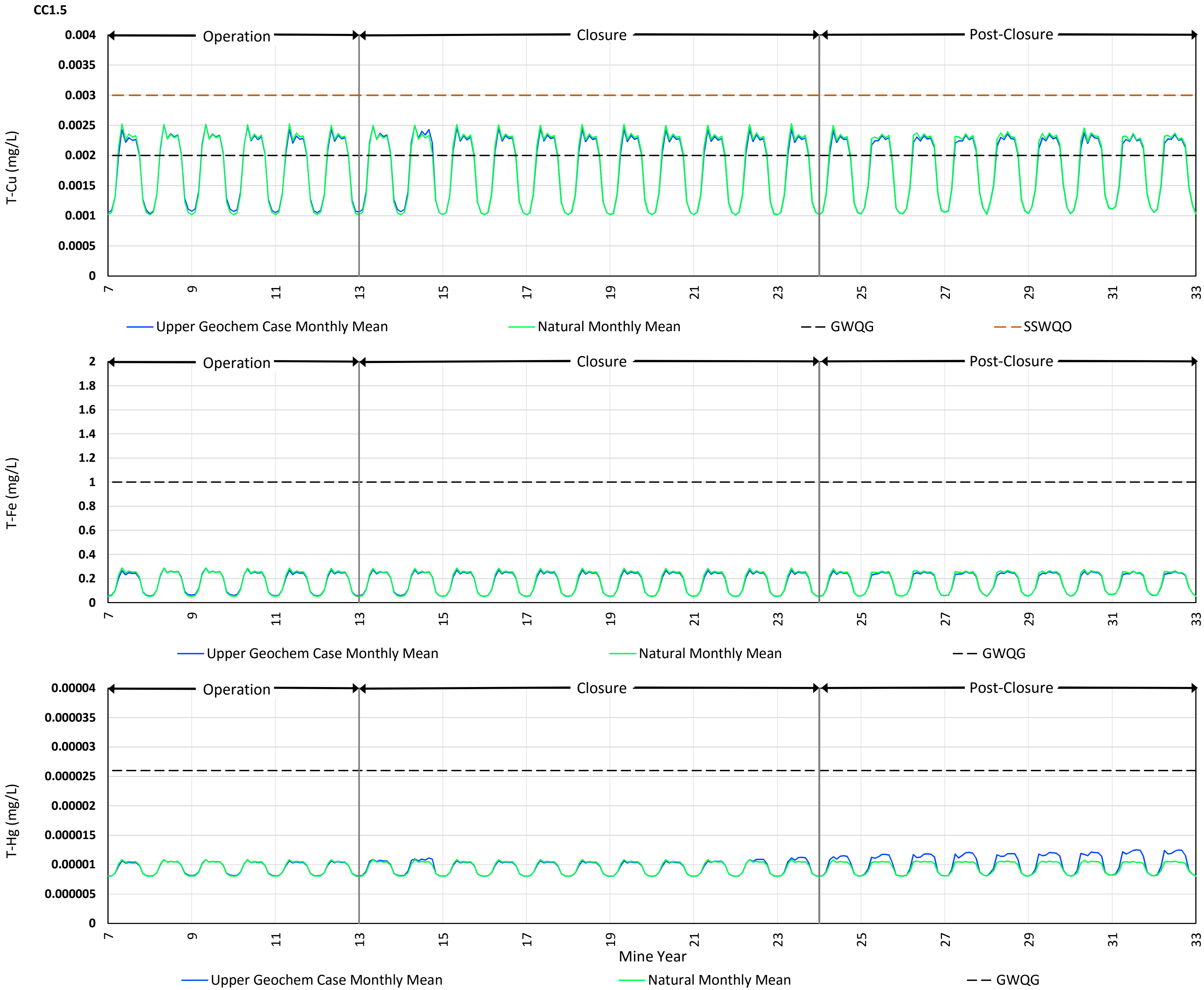


Operation
Closure
Post-Closure
D-Al (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7 9 11 13 15 17 19 21 23 25 27 29 31 33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Ag (mg/L)
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
0
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
T-As (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG

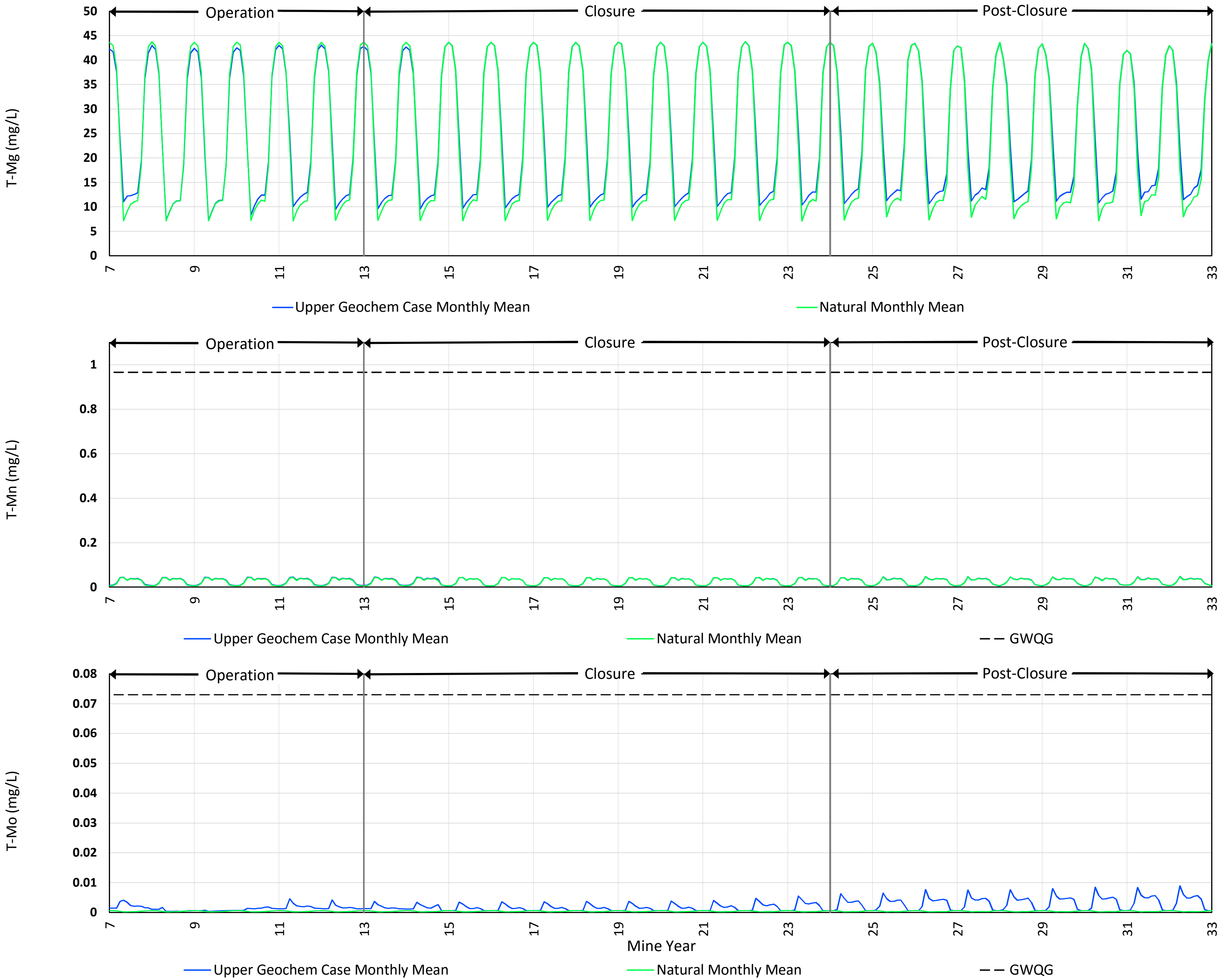
CC1.5



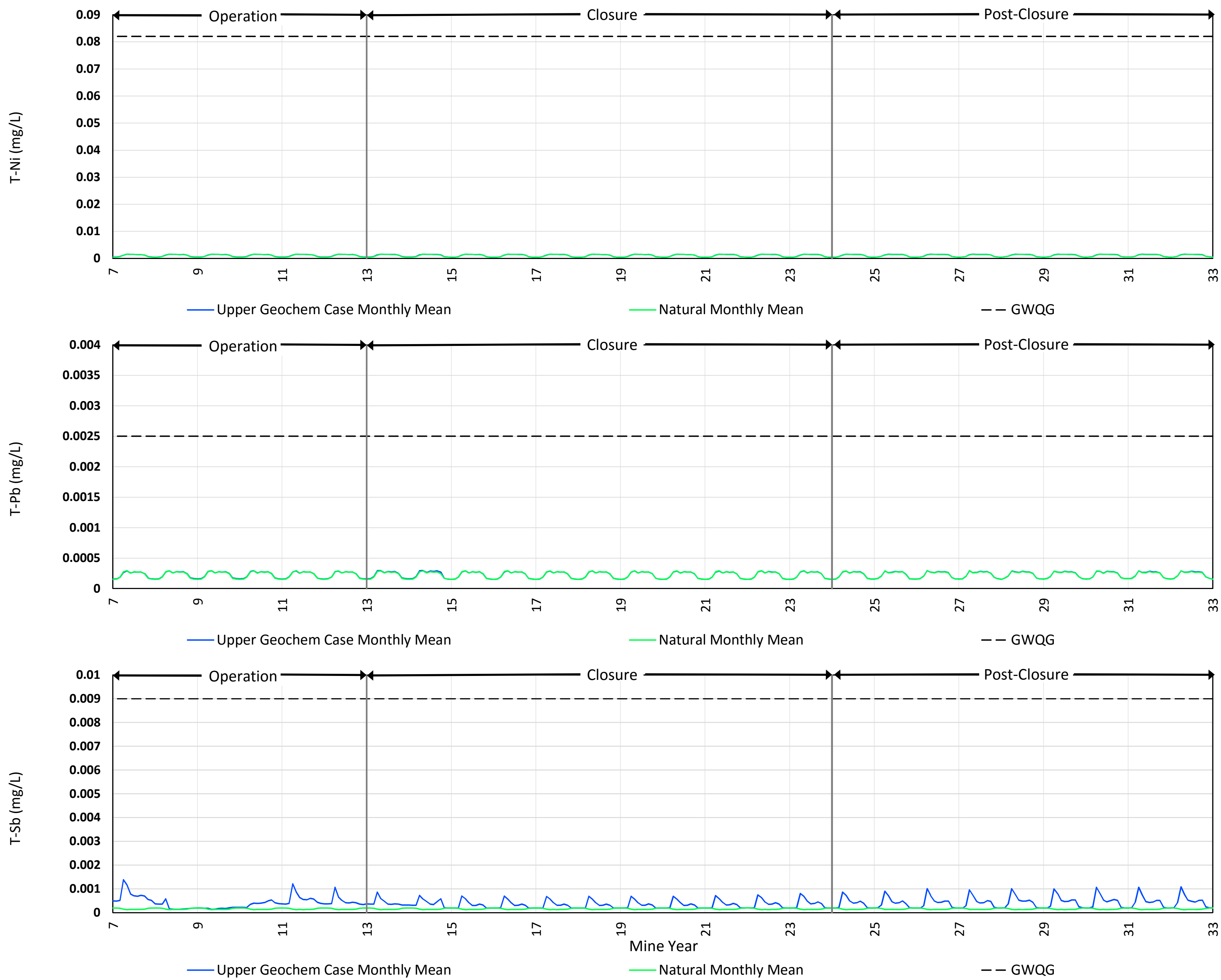
Operation
Closure
Post-Closure
T-Ca (mg/L)
200
180
160
140
120
100
80
60
40
20
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Cd (mg/L)
0.0002
0.00018
0.00016
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
GWQG
T-Cr (mg/L)
0.002
0.0018
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
Mine Year

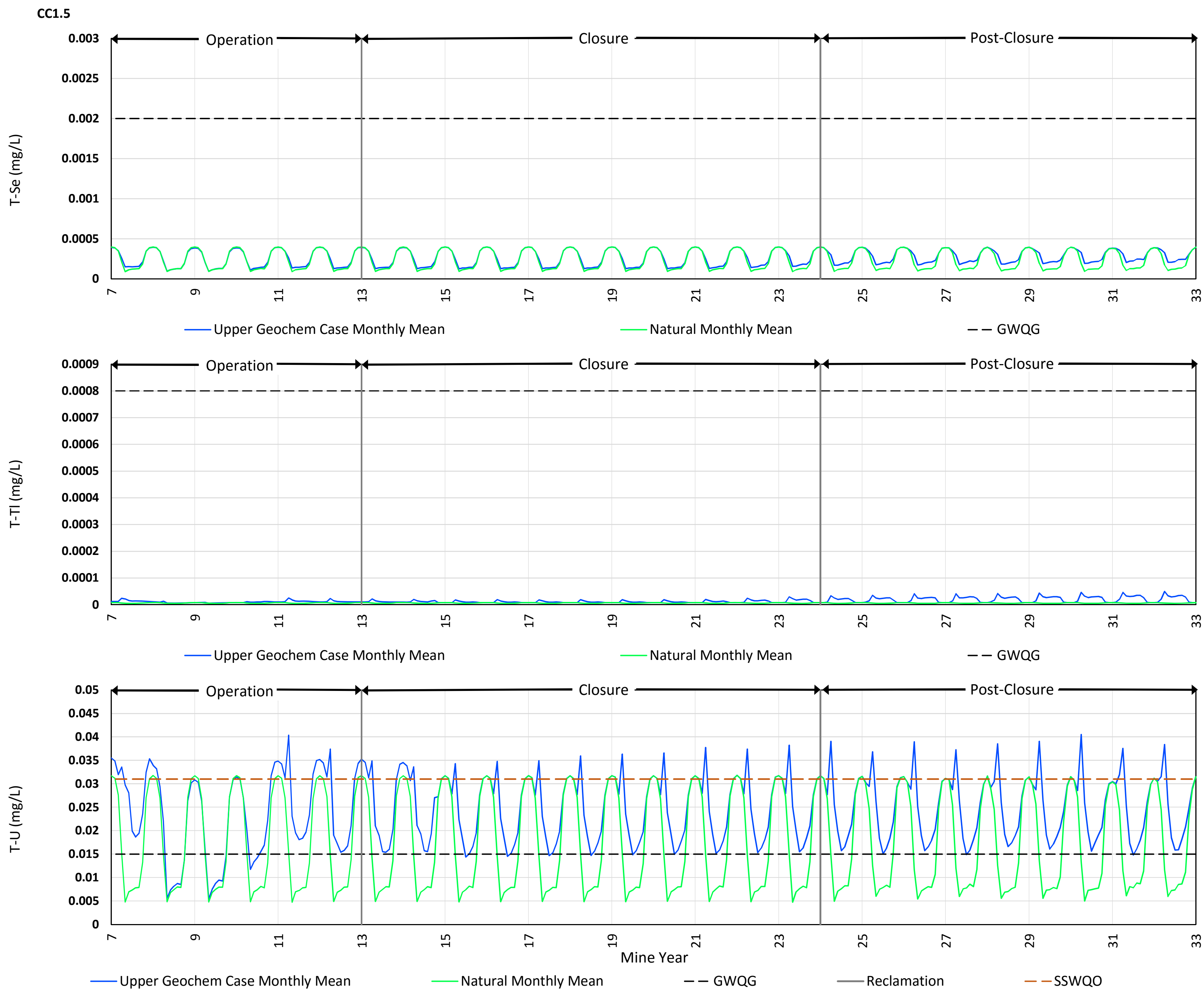

CC1.5
Operation
Closure
Post-Closure
T-Cu (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Fe (mg/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
T-Hg (mg/L)
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
0
Mine Year

CC1.5

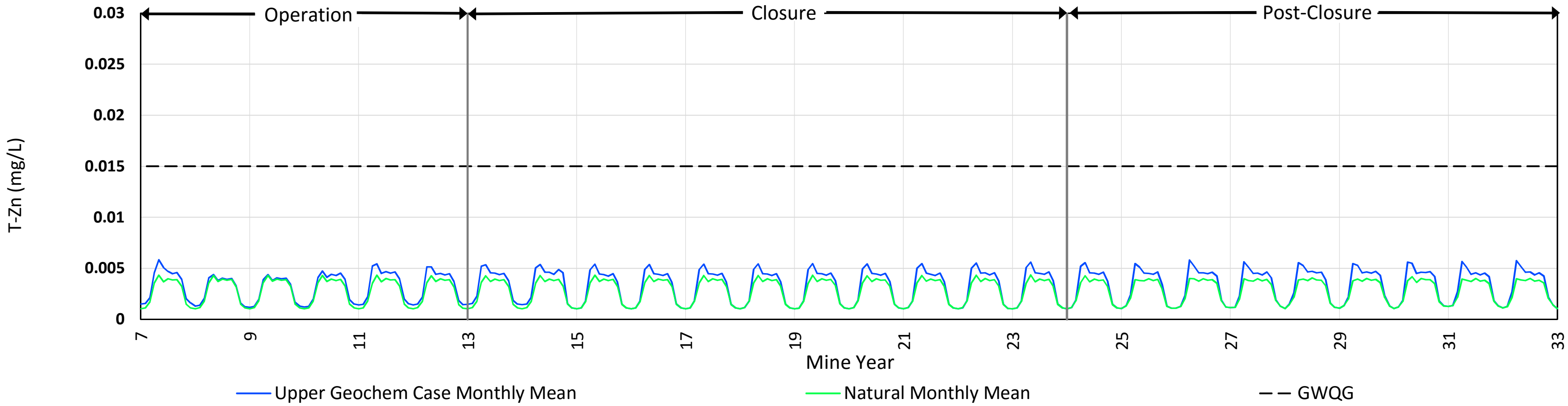

Operation
Closure
Post-Closure
T-Mg (mg/L)
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Mn (mg/L)
GWQG
T-Mo (mg/L)
Mine Year

CC1.5

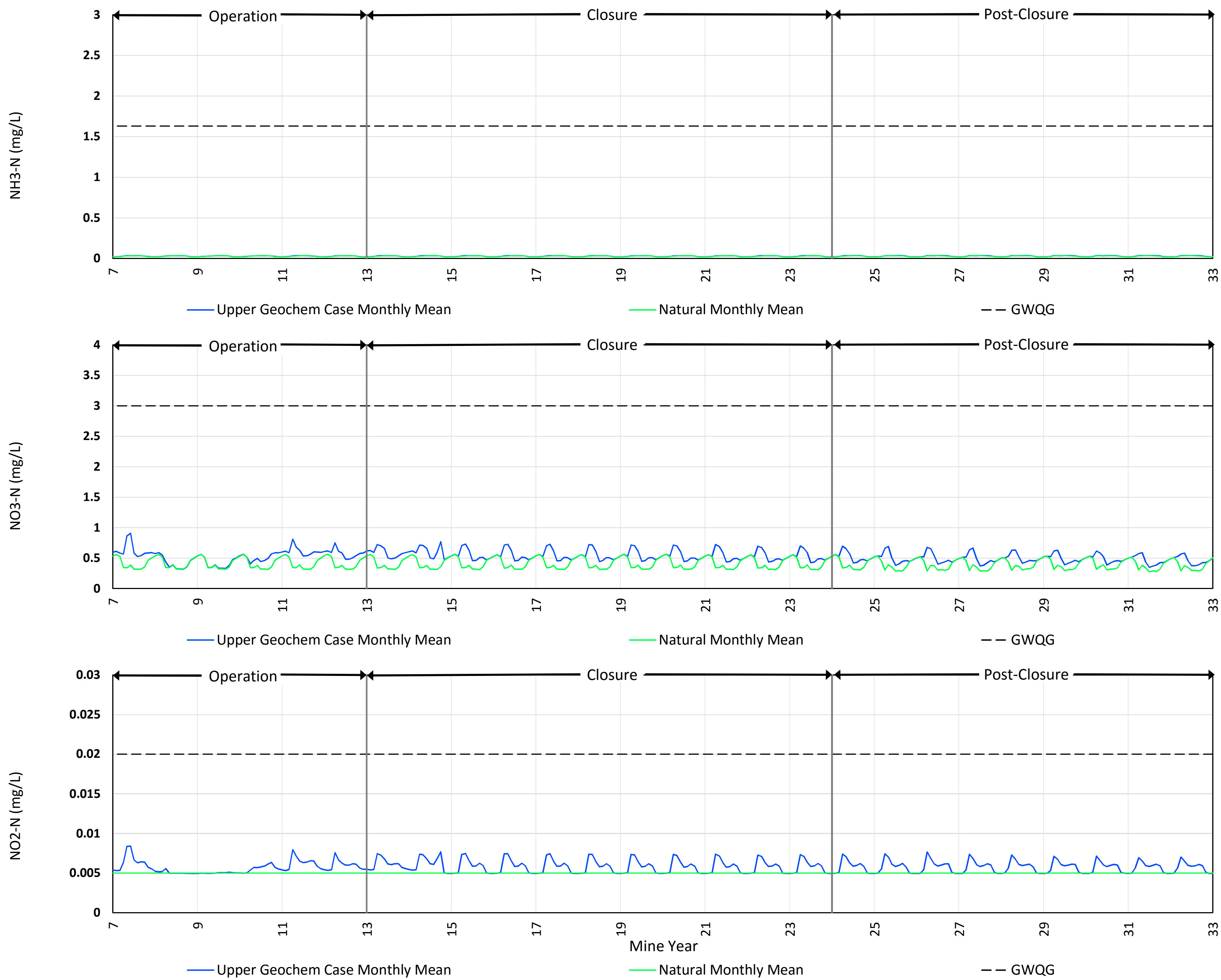

Operation
Closure
Post-Closure
T-Ni (mg/L)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
T-Pb (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
T-Sb (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG


CC1.5
Operation
Closure
Post-Closure
T-Se (mg/L)
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
T-Tl (mg/L)
T-U (mg/L)
Mine Year
Reclamation
SSWQO

CC1.5

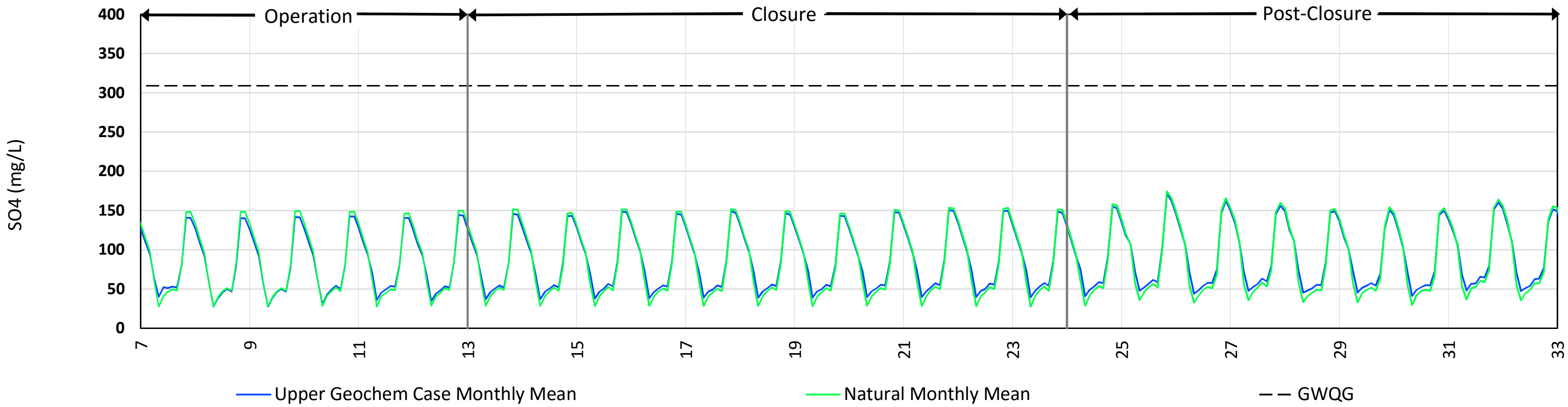

Operation
Closure
Post-Closure
0.03
0.025
0.02
0.015
0.01
0.005
0
T-Zn (mg/L)
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG

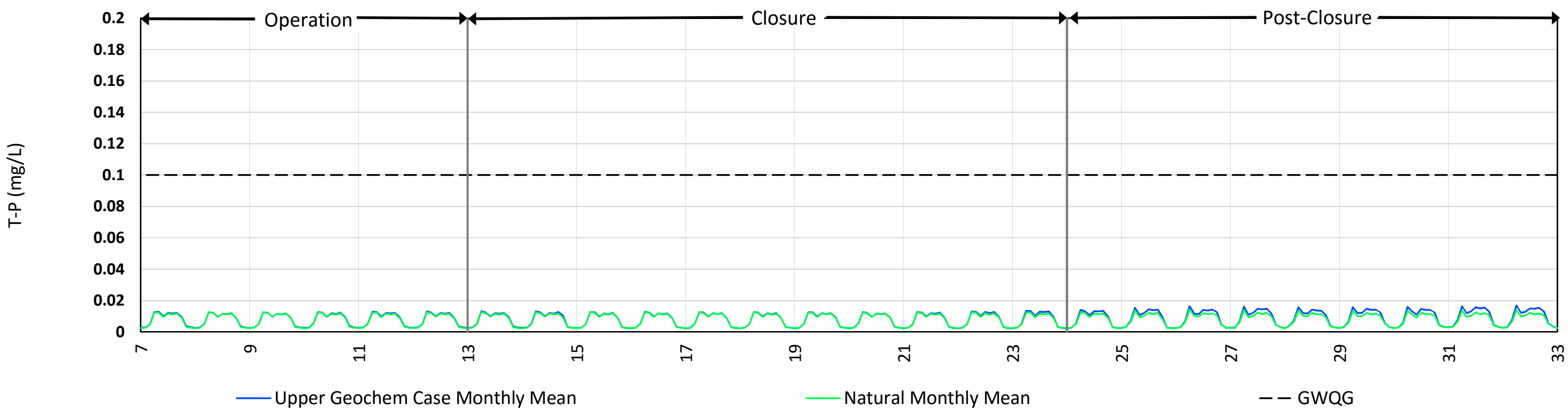
CC3.5

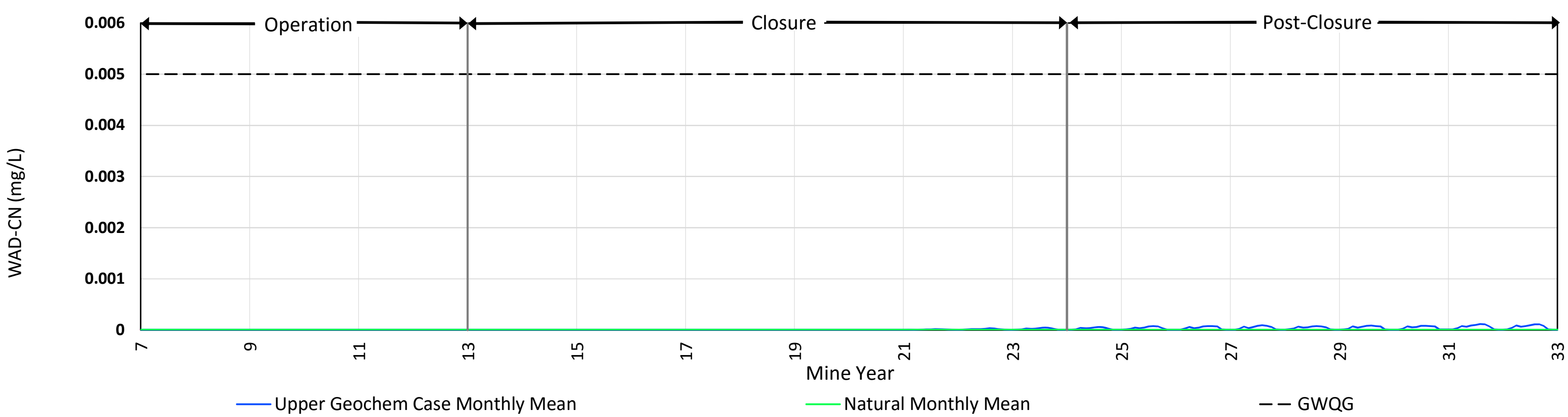


Operation
Closure
Post-Closure
NH3-N (mg/L)
NO3-N (mg/L)
NO2-N (mg/L)
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG

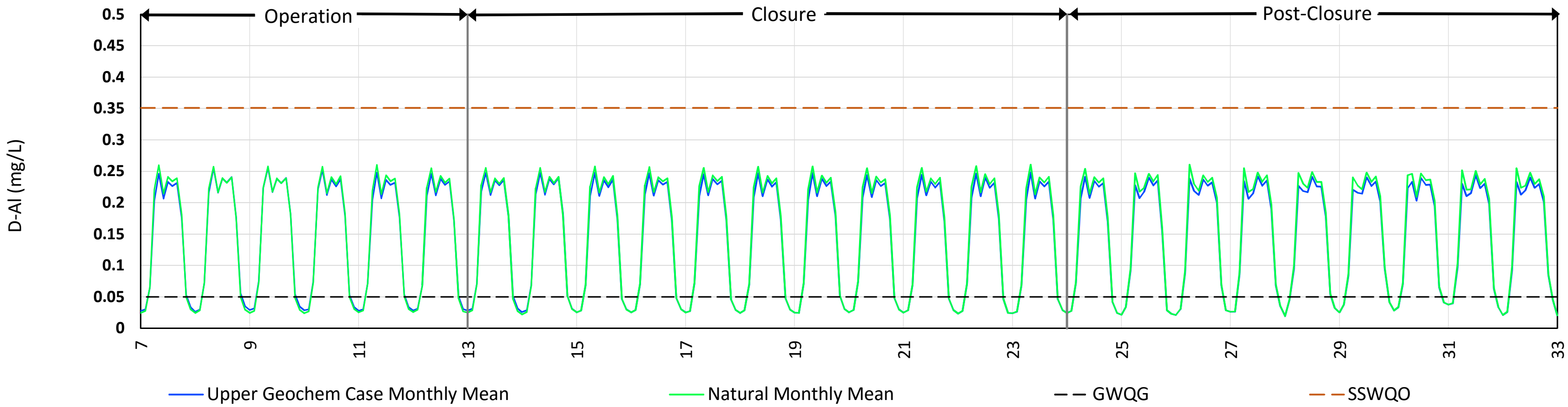
CC3.5


Operation
Closure
Post-Closure
SO4 (mg/L)
400
350
300
250
200
150
100
50
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG

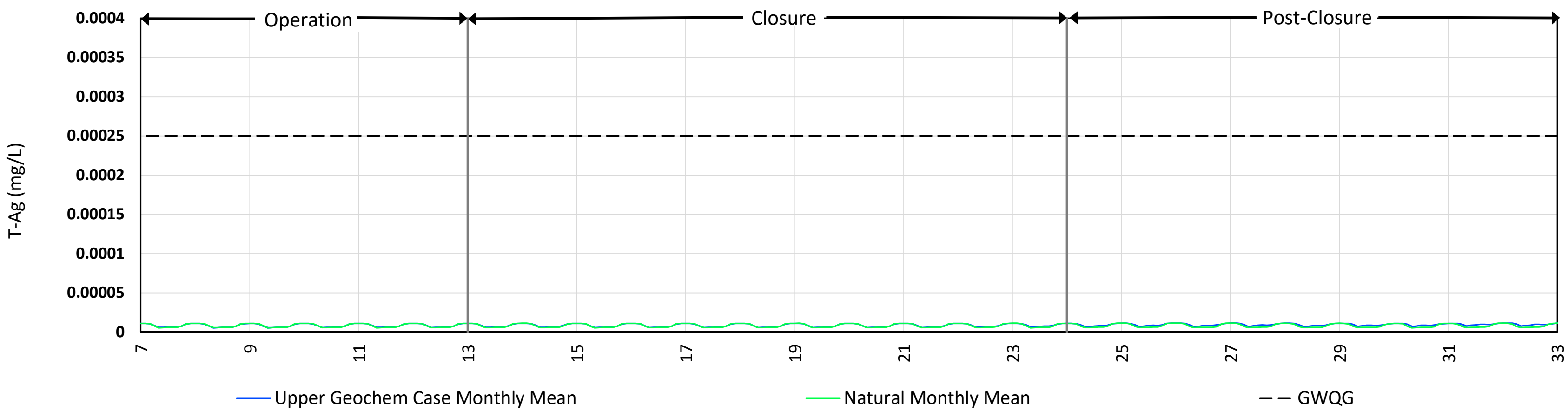

Operation
Closure
Post-Closure
T-P (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG


Operation
Closure
Post-Closure
WAD-CN (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG

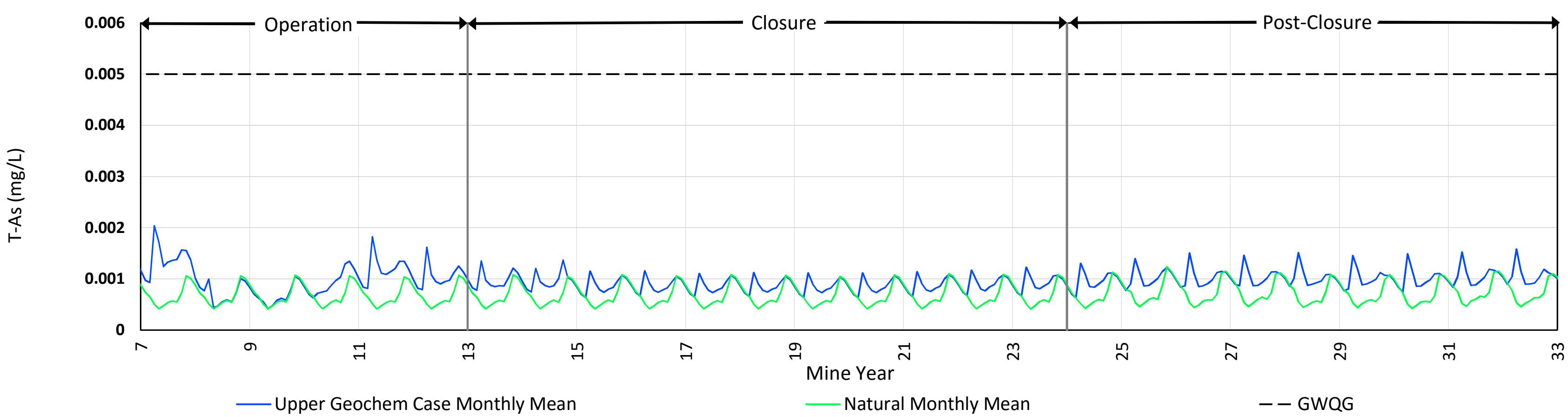
CC3.5



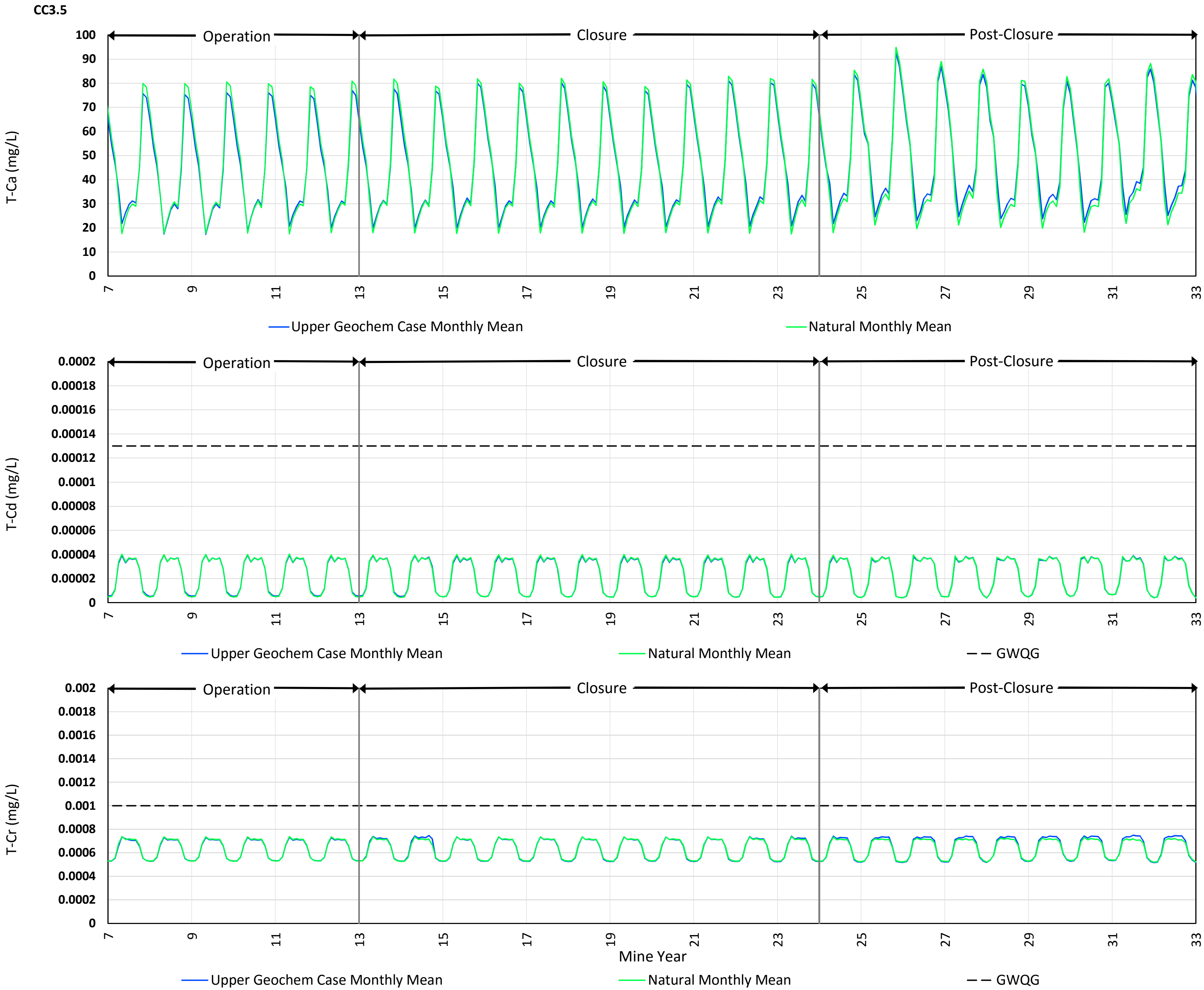
Operation
Closure
Post-Closure
D-Al (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
SSWQO



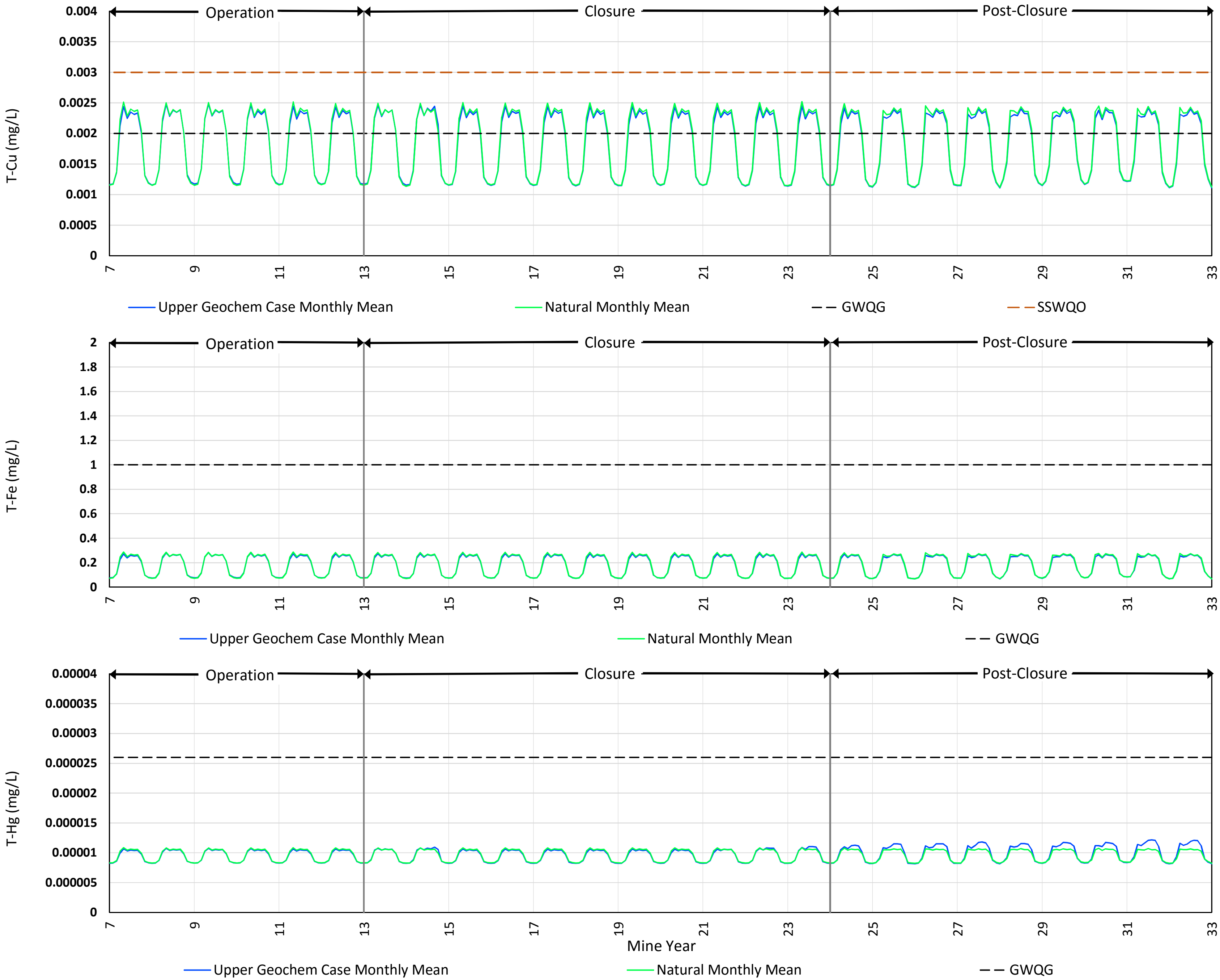
Operation
Closure
Post-Closure
T-Ag (mg/L)
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG



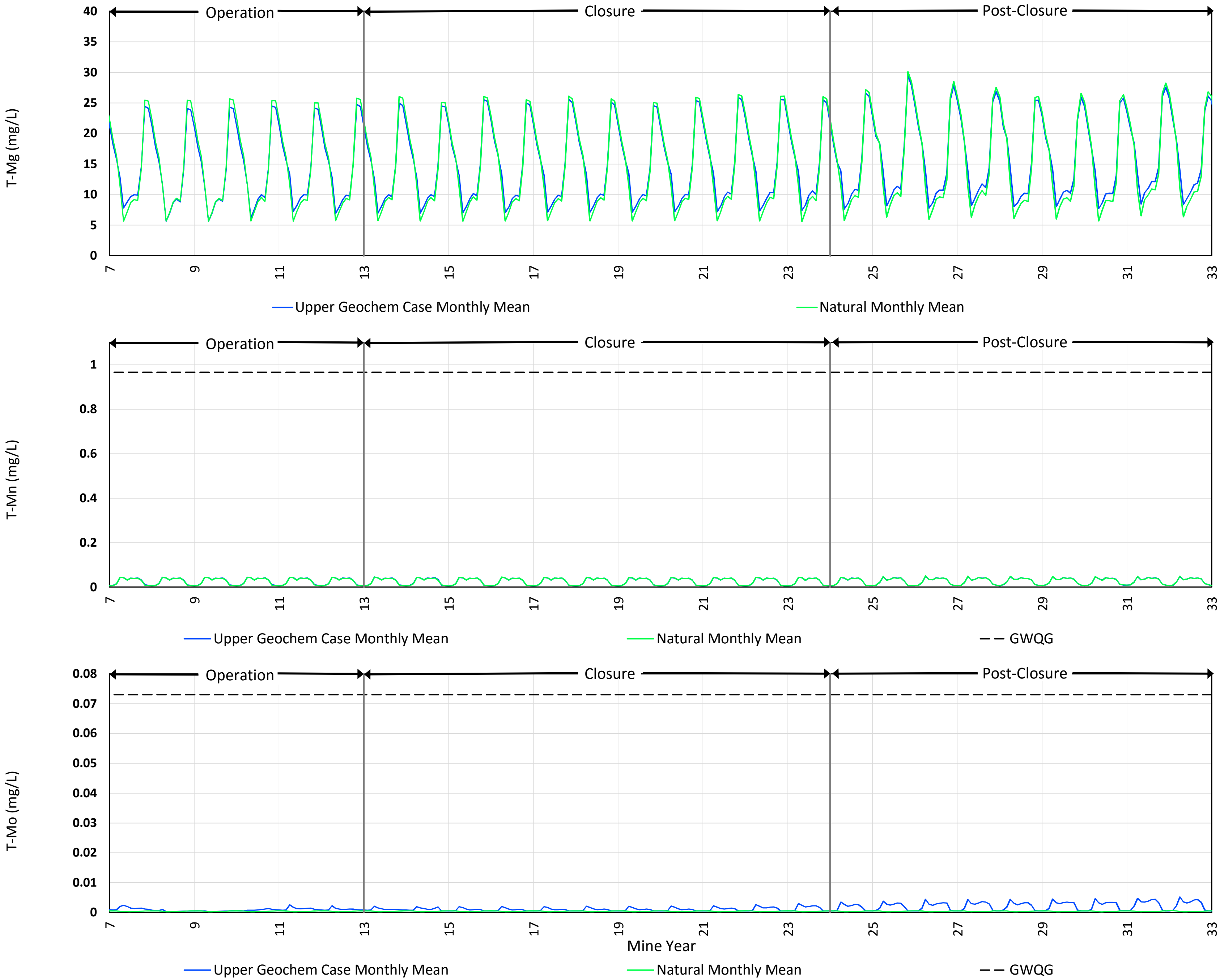
Operation
Closure
Post-Closure
T-As (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG


CC3.5
Operation
Closure
Post-Closure
T-Ca (mg/L)
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Cd (mg/L)
GWQG
T-Cr (mg/L)
Mine Year

CC3.5

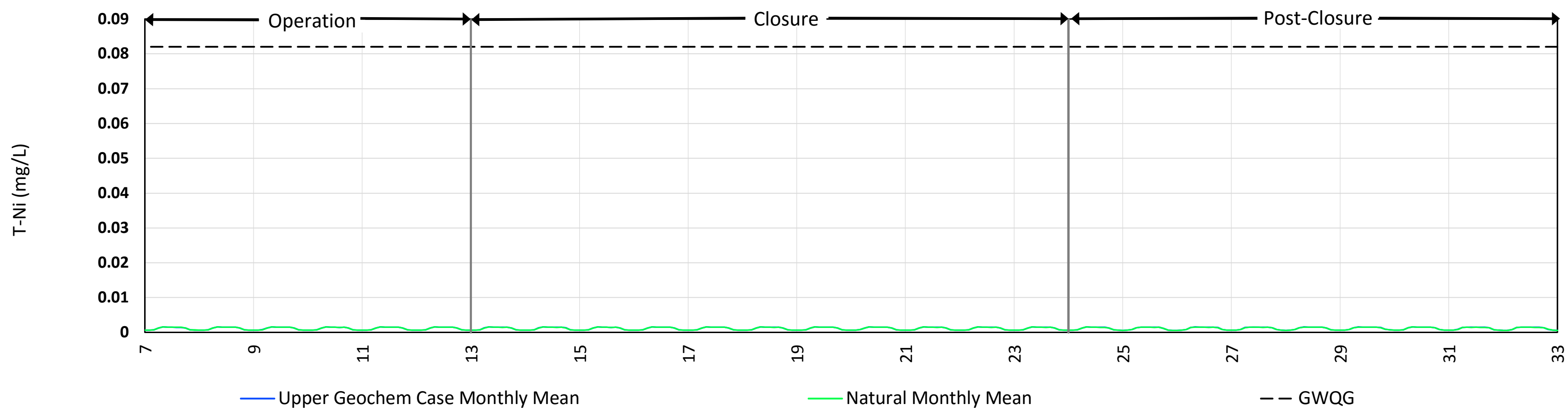

Operation
Closure
Post-Closure
T-Cu (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Fe (mg/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
T-Hg (mg/L)
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
0
Mine Year

CC3.5

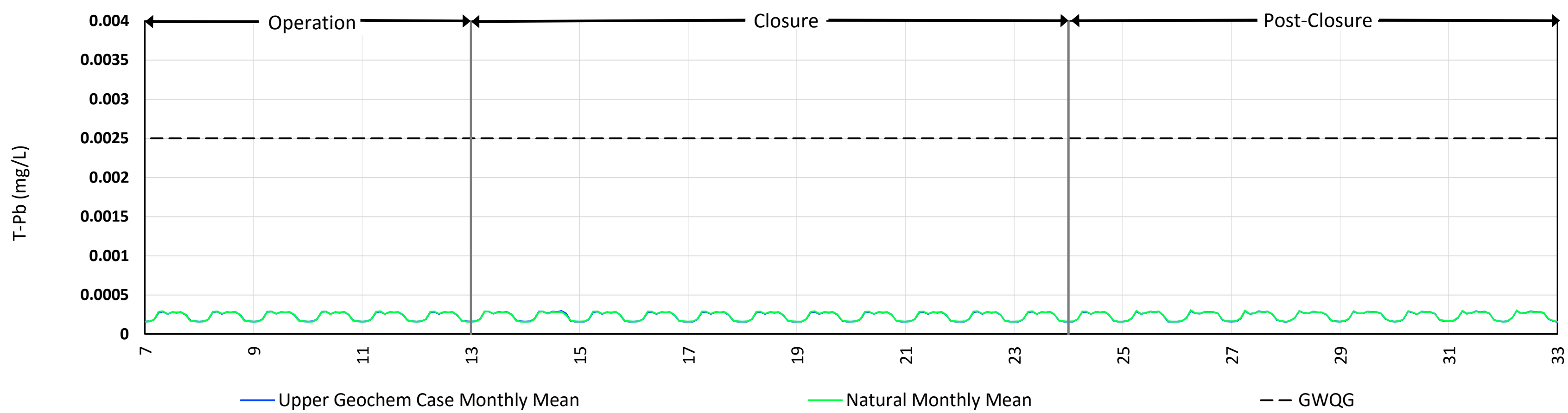


Operation
Closure
Post-Closure
40
35
30
25
20
15
10
5
0
T-Mg (mg/L)
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
1
0.8
0.6
0.4
0.2
T-Mn (mg/L)
GWQG
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
T-Mo (mg/L)
Mine Year

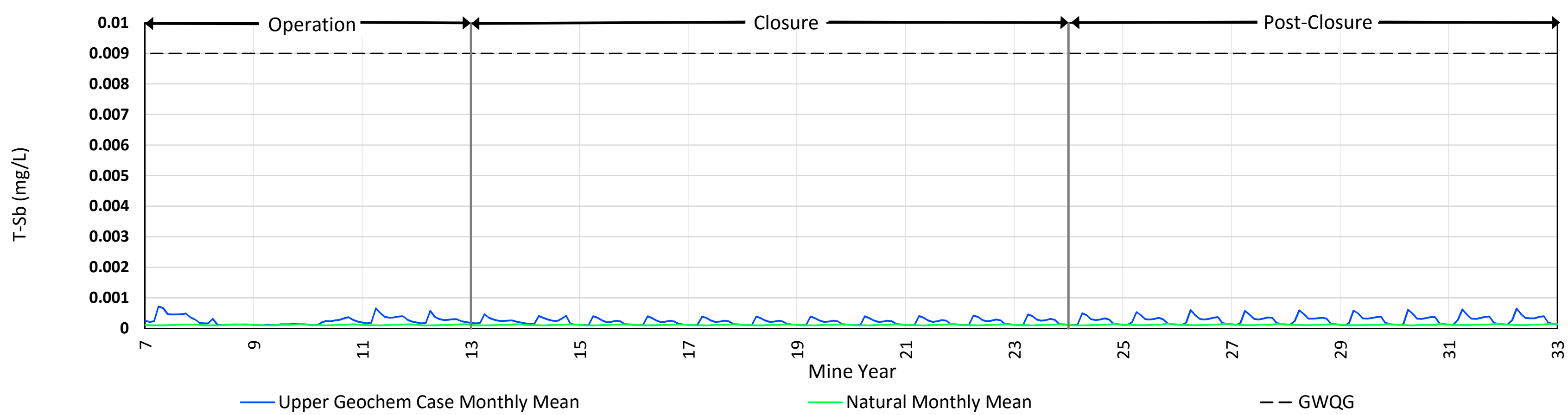
CC3.5



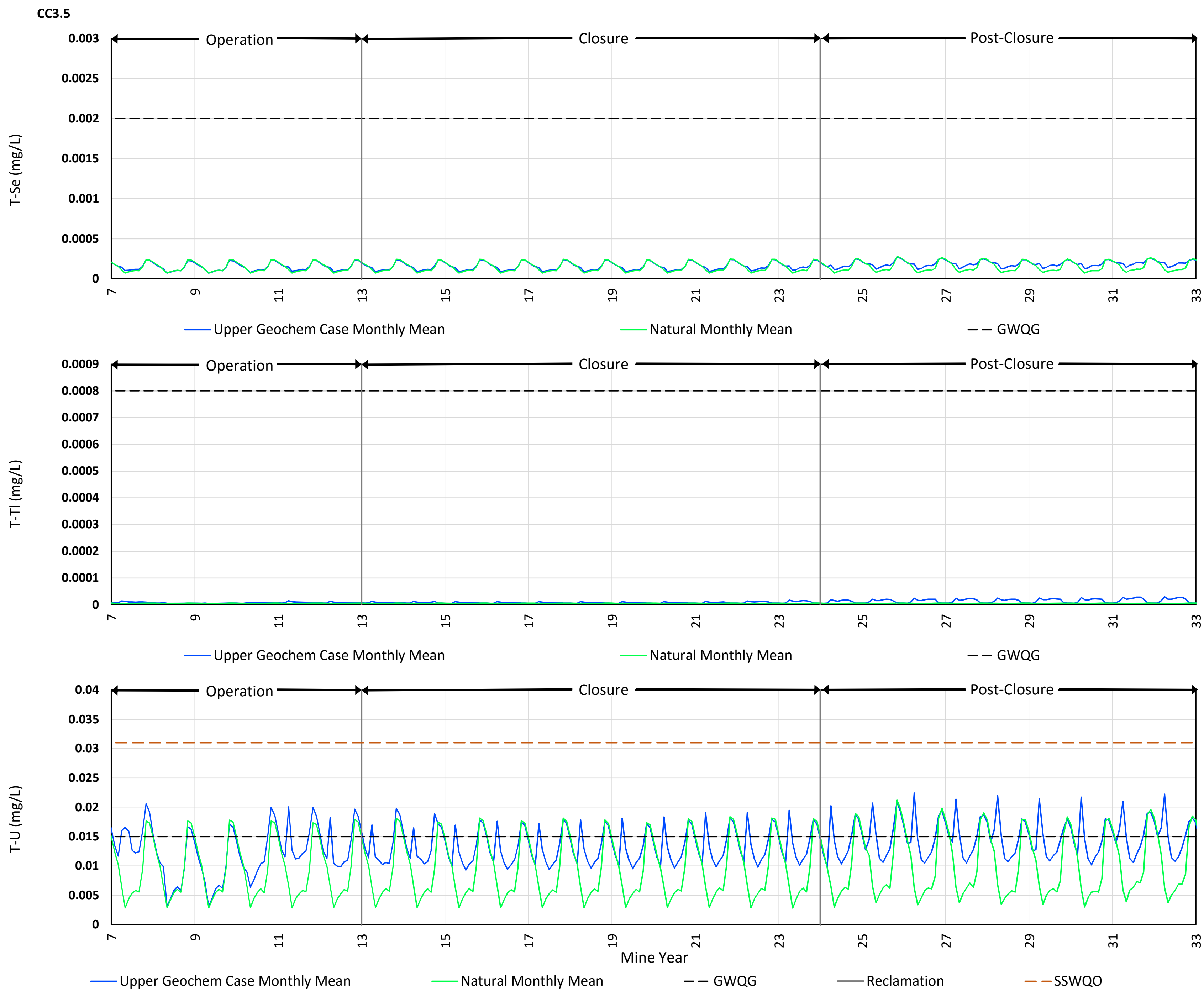
Operation
Closure
Post-Closure
T-Ni (mg/L)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG



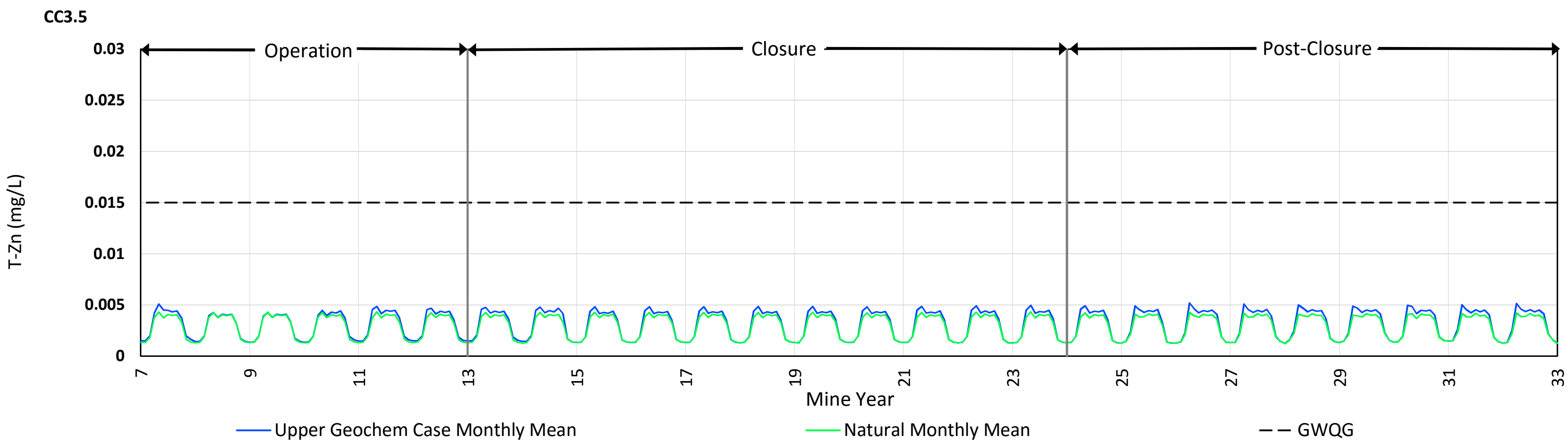
Operation
Closure
Post-Closure
T-Pb (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG



Operation
Closure
Post-Closure
T-Sb (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG

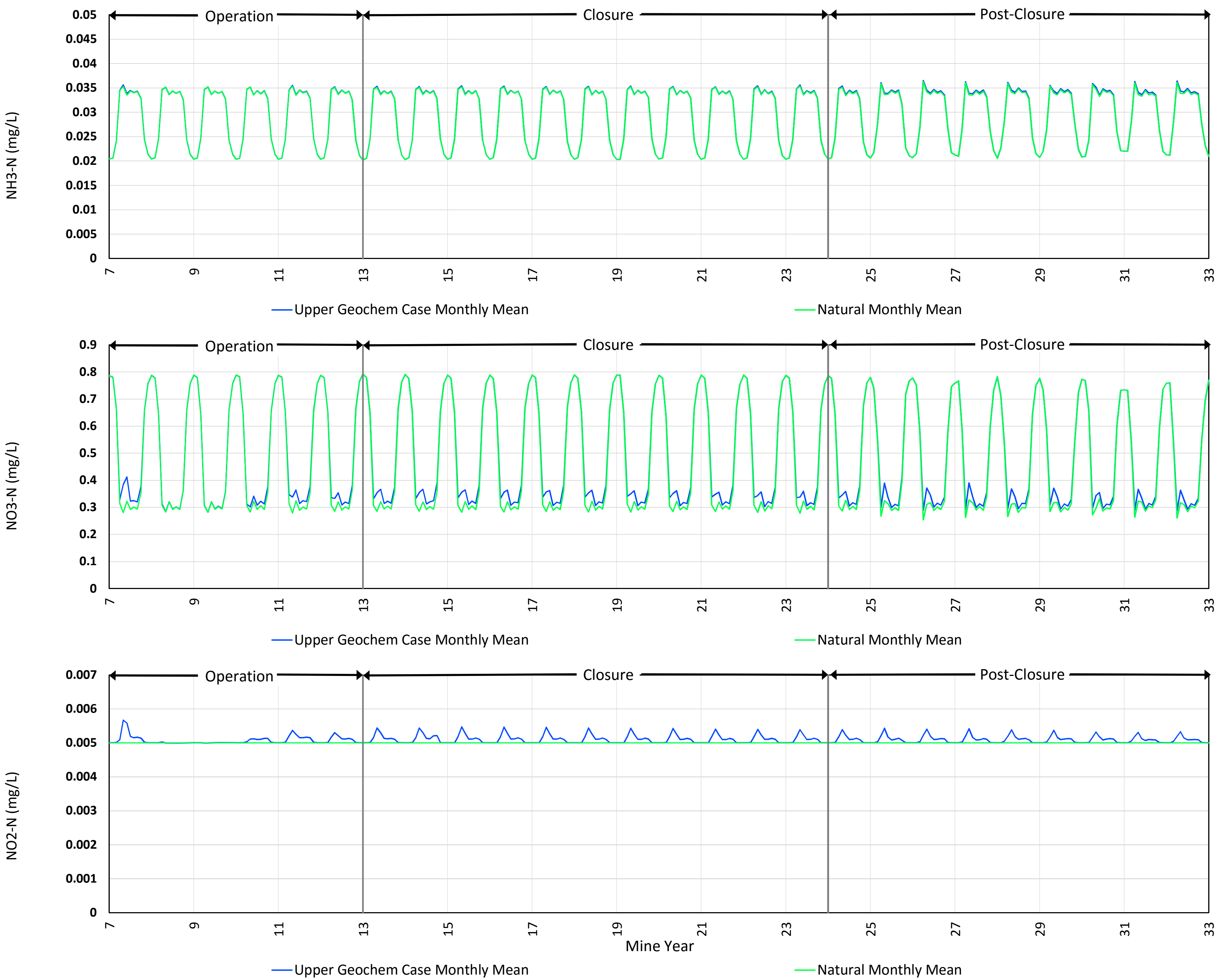


CC3.5
Operation
Closure
Post-Closure
T-Se (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
T-Tl (mg/L)
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
T-U (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
Reclamation
SSWQO



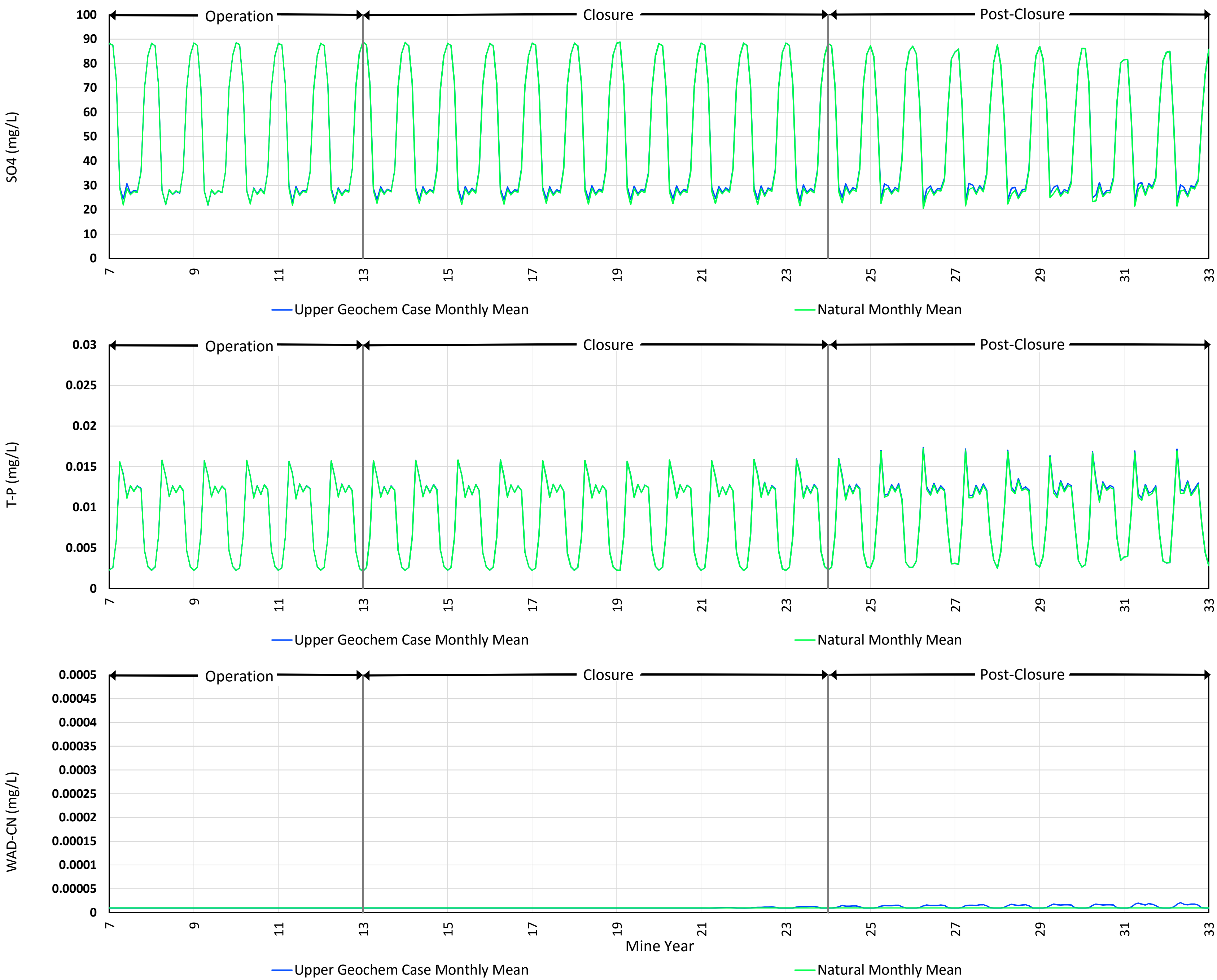
CC3.5
Operation
Closure
Post-Closure
T-Zn (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG

CC4.5

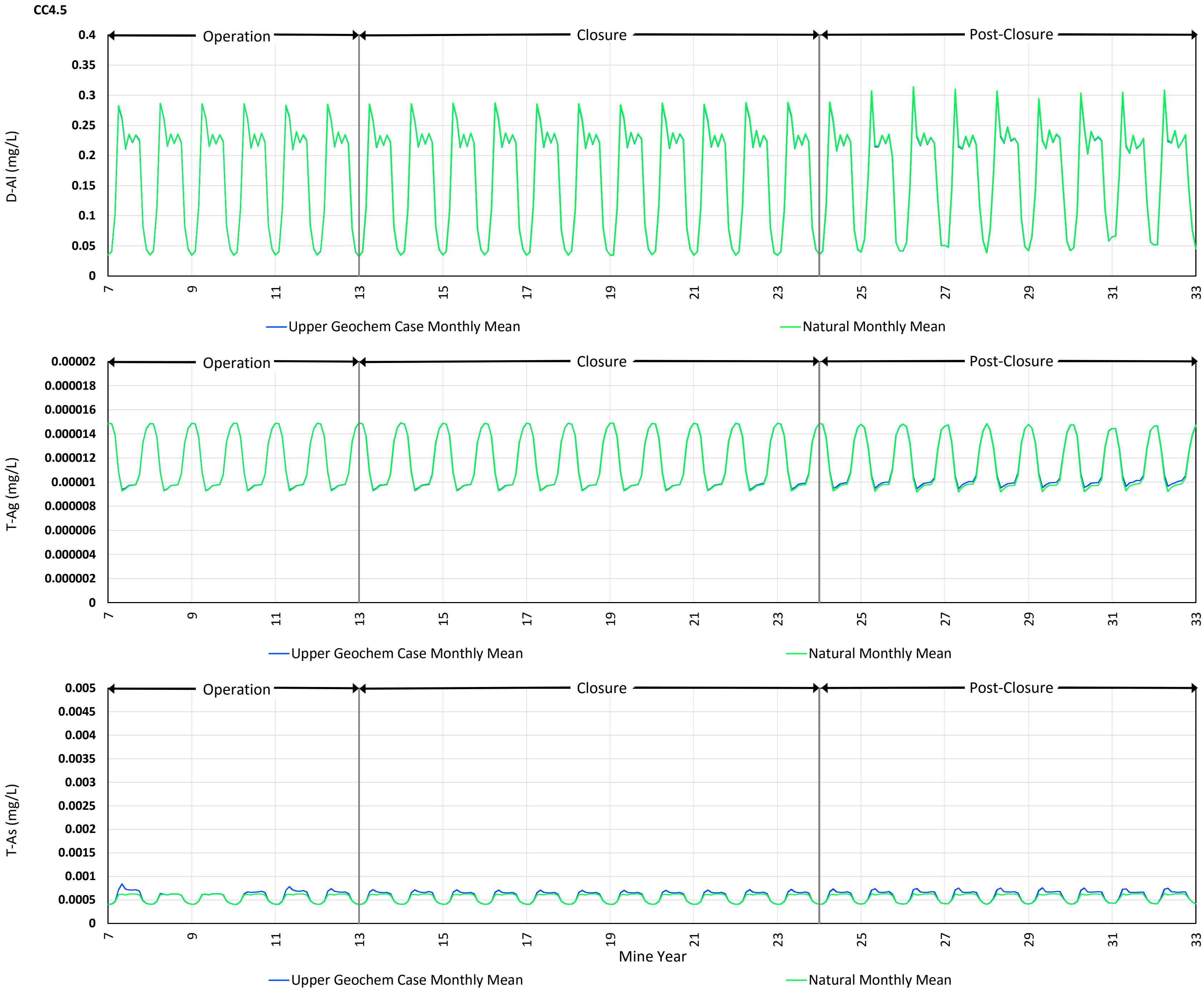


Operation
Closure
Post-Closure
NH3-N (mg/L)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
Operation
Closure
Post-Closure
NO3-N (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
Operation
Closure
Post-Closure
NO2-N (mg/L)
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean

CC4.5

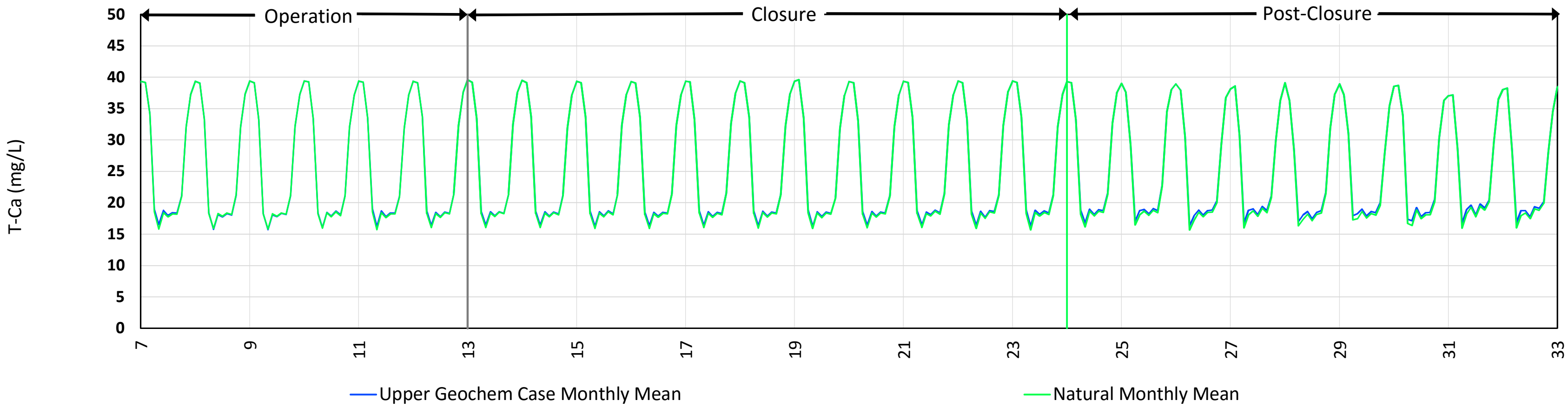


Operation
Closure
Post-Closure
SO4 (mg/L)
100
90
80
70
60
50
40
30
20
10
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-P (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
WAD-CN (mg/L)
0.0005
0.00045
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
0
Mine Year

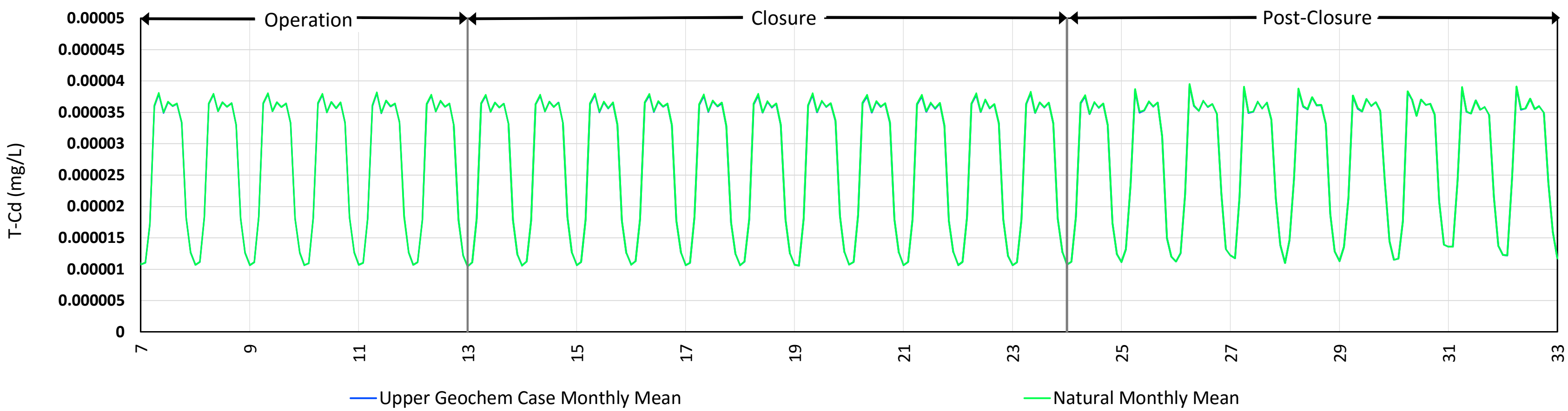


CC4.5
Operation
Closure
Post-Closure
D-Al (mg/L)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Ag (mg/L)
0.00002
0.000018
0.000016
0.000014
0.000012
0.00001
0.000008
0.000006
0.000004
0.000002
T-As (mg/L)
0.005
0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
Mine Year

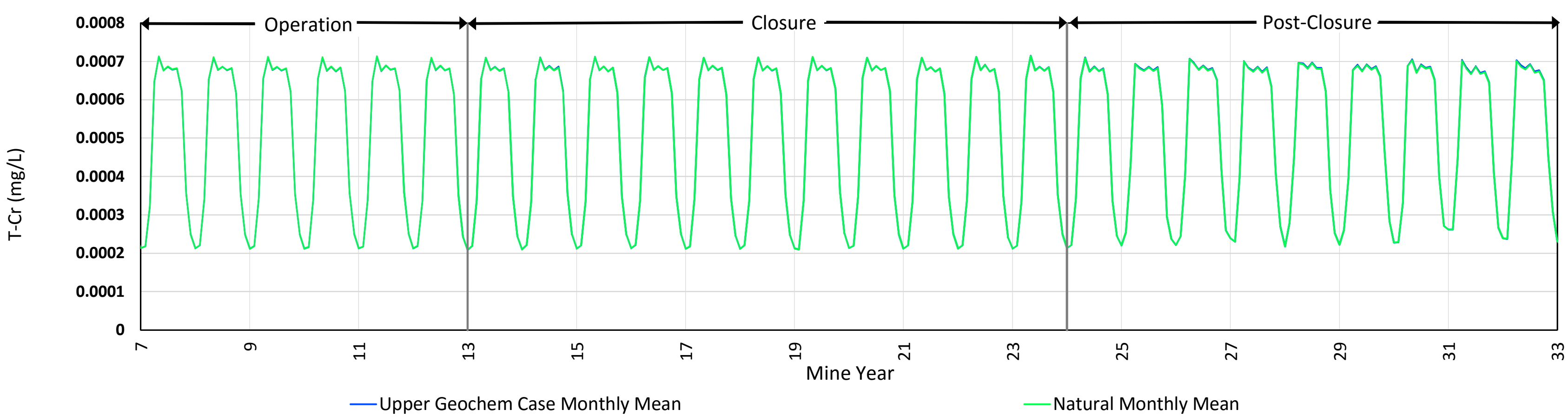
CC4.5



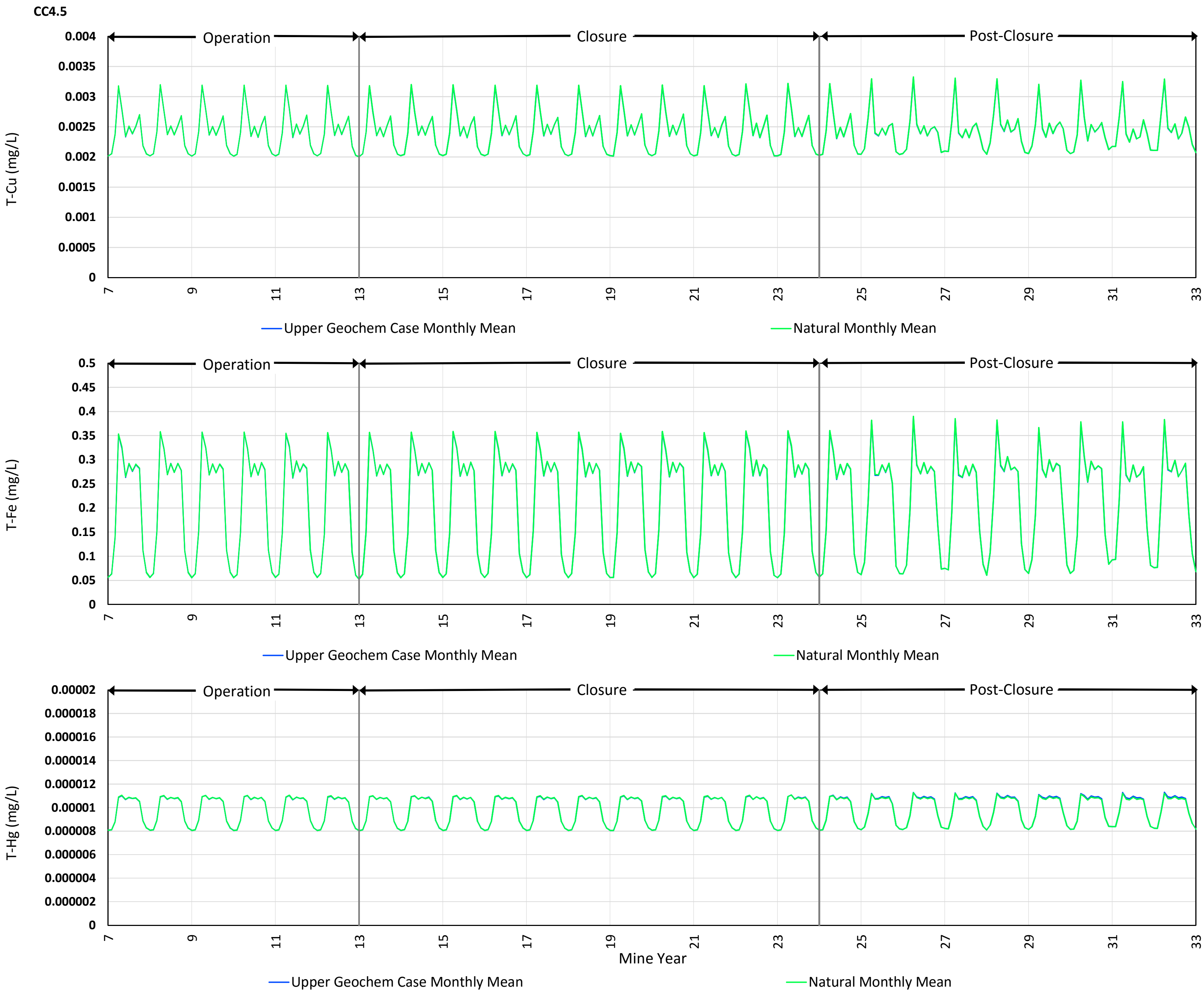
Operation
Closure
Post-Closure
T-Ca (mg/L)
50
45
40
35
30
25
20
15
10
5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean



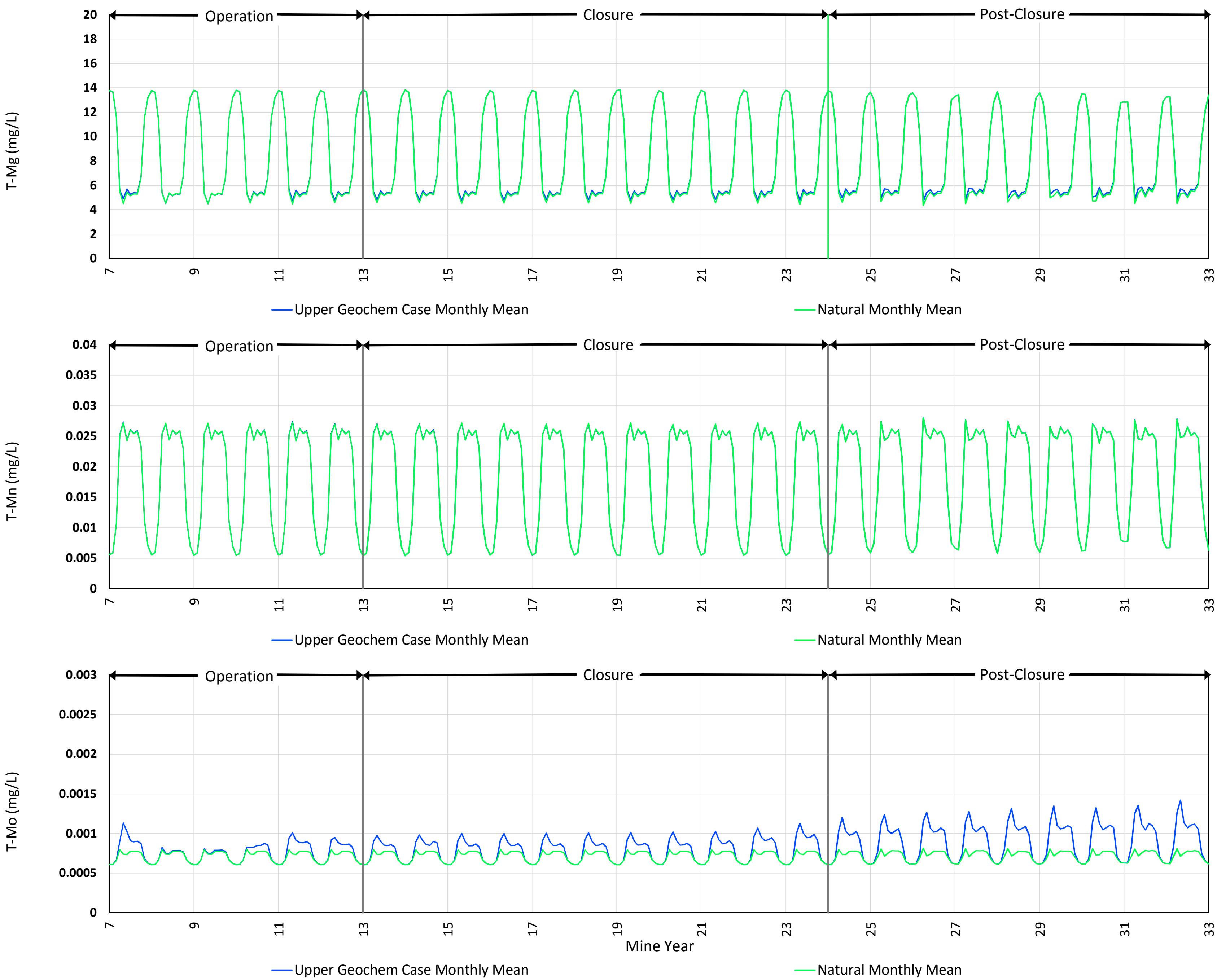
Operation
Closure
Post-Closure
T-Cd (mg/L)
0.00005
0.000045
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean



Operation
Closure
Post-Closure
T-Cr (mg/L)
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean

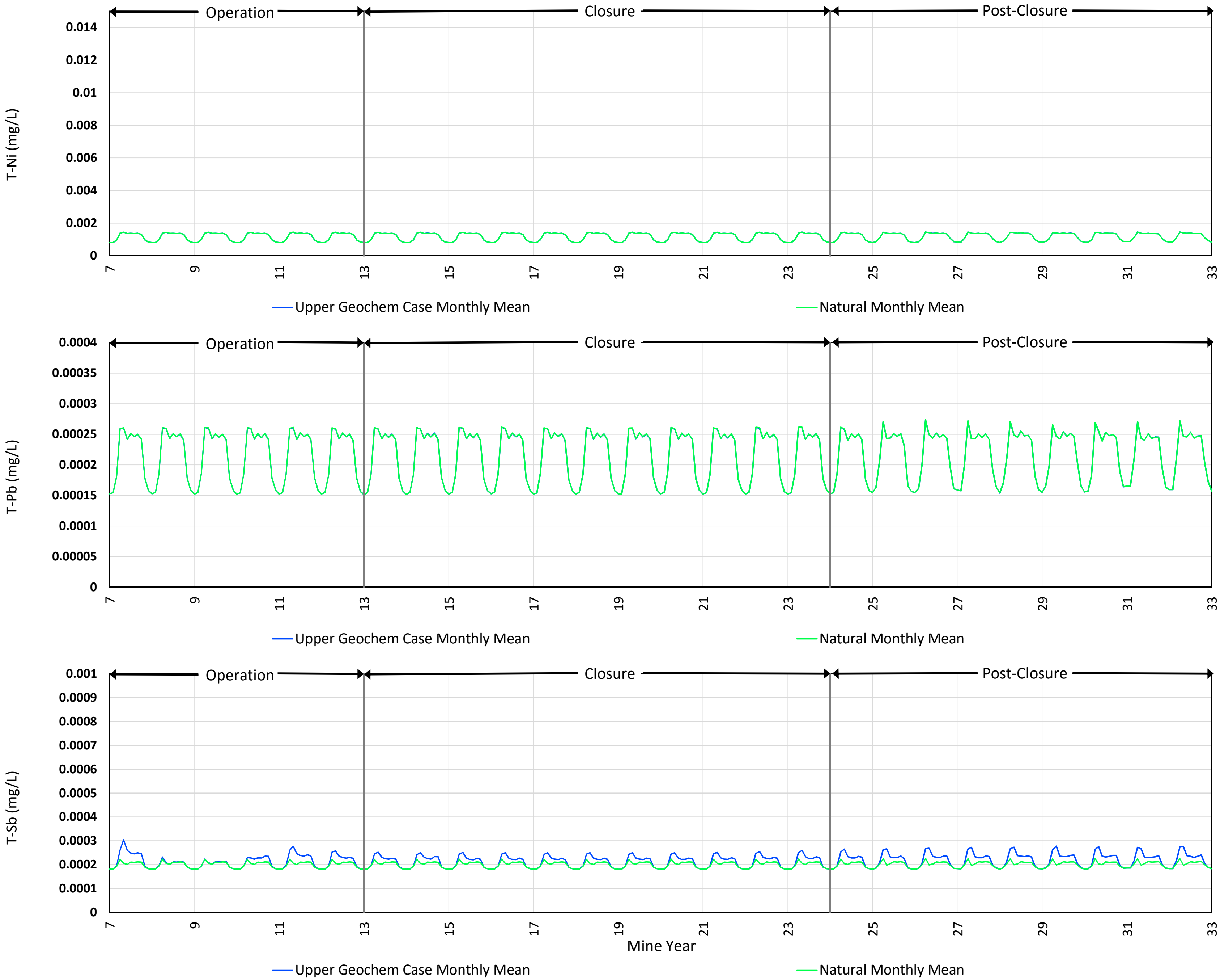

CC4.5
Operation
Closure
Post-Closure
T-Cu (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Fe (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
T-Hg (mg/L)
0.00002
0.000018
0.000016
0.000014
0.000012
0.00001
0.000008
0.000006
0.000004
0.000002
0
Mine Year

CC4.5



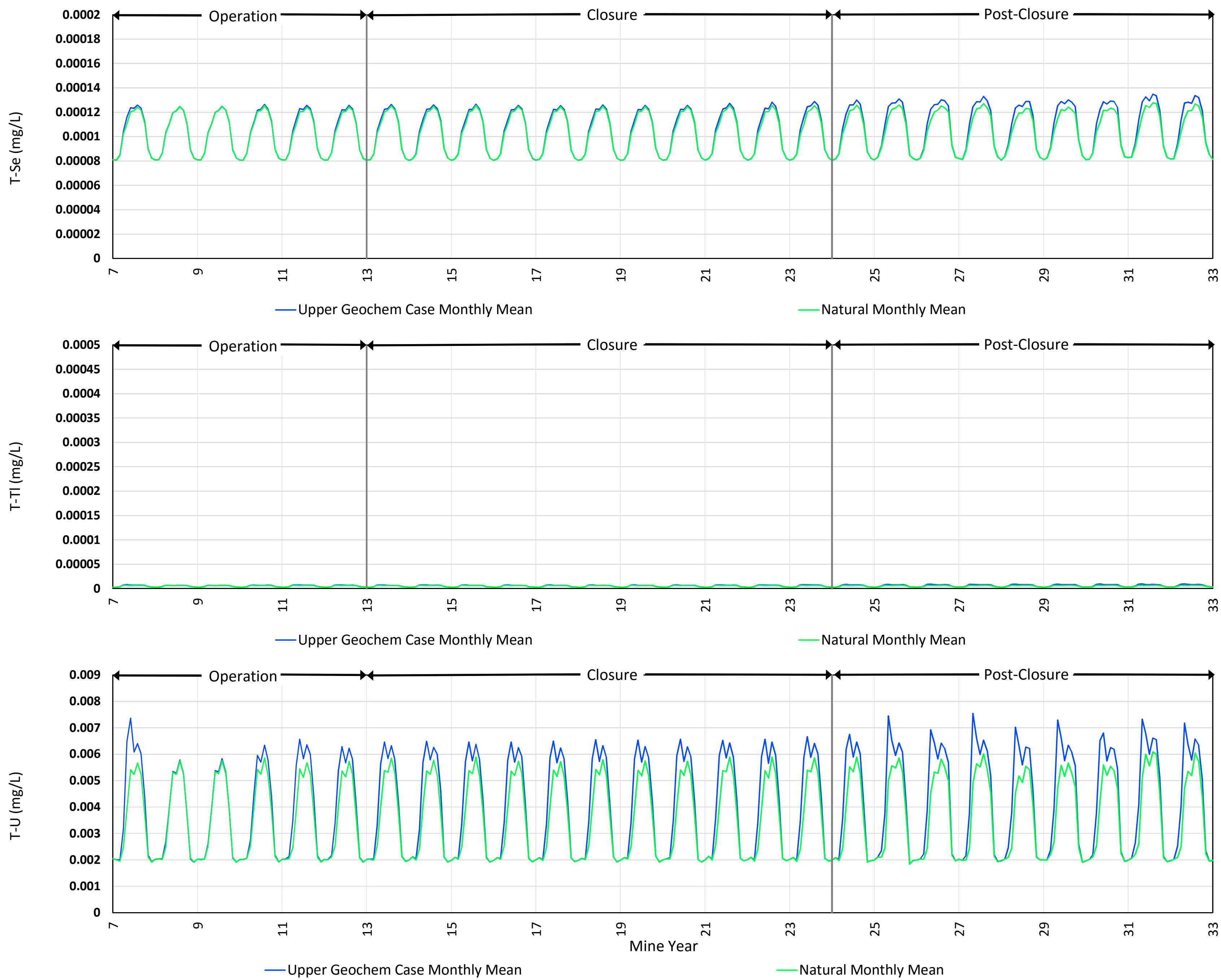
Operation
Closure
Post-Closure
T-Mg (mg/L)
20
18
16
14
12
10
8
6
4
2
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Mn (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
T-Mo (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
Mine Year

CC4.5

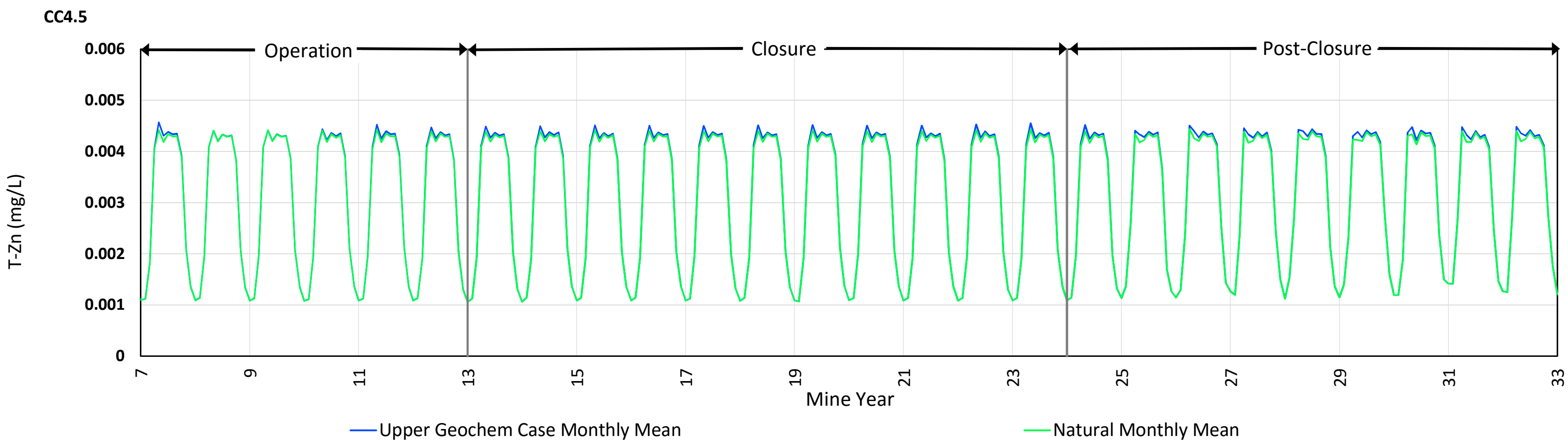


Operation
Closure
Post-Closure
T-Ni (mg/L)
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Pb (mg/L)
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
T-Sb (mg/L)
0.001
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
Mine Year

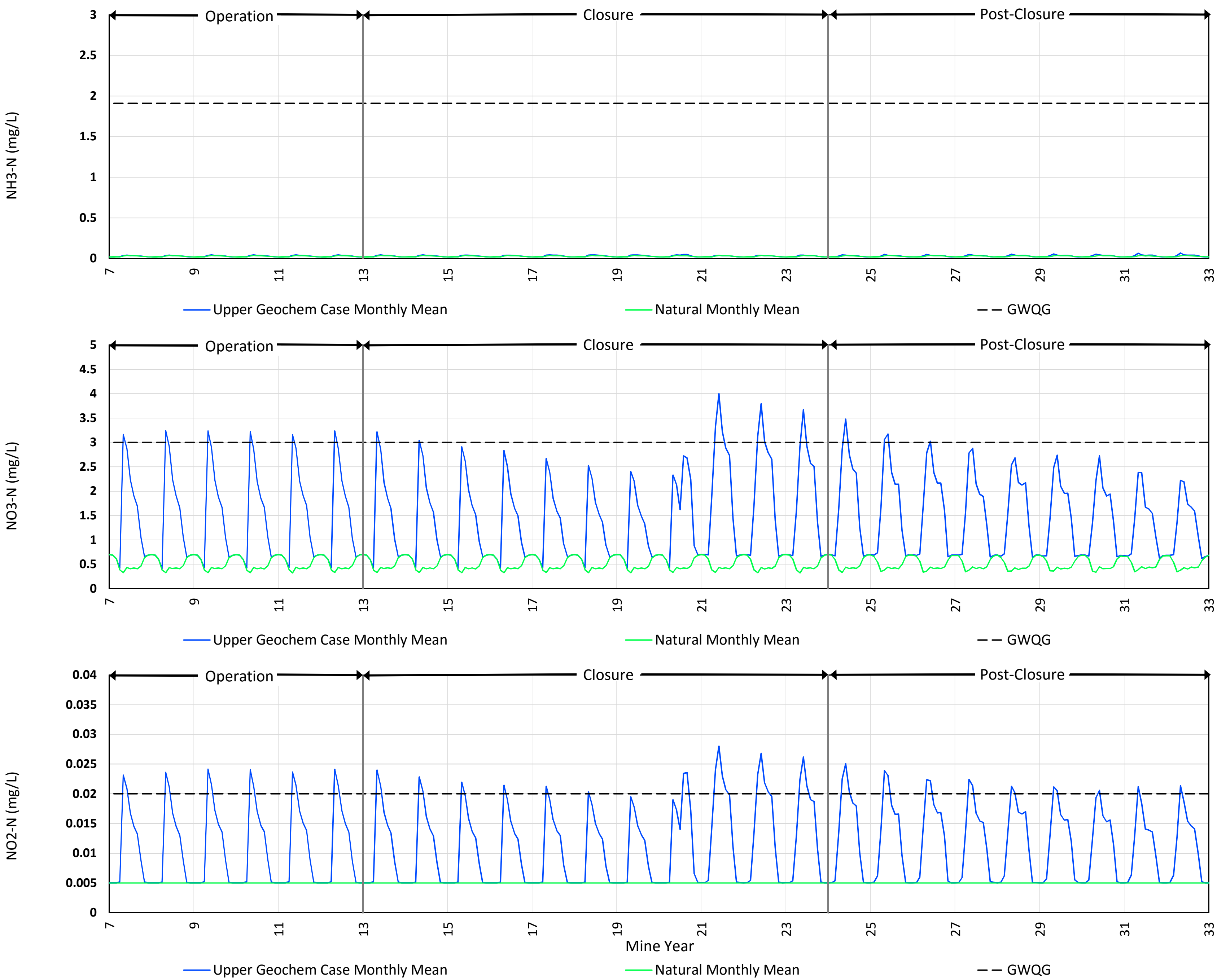
CC4.5



Operation
Closure
Post-Closure
T-Se (mg/L)
T-Tl (mg/L)
T-U (mg/L)
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean

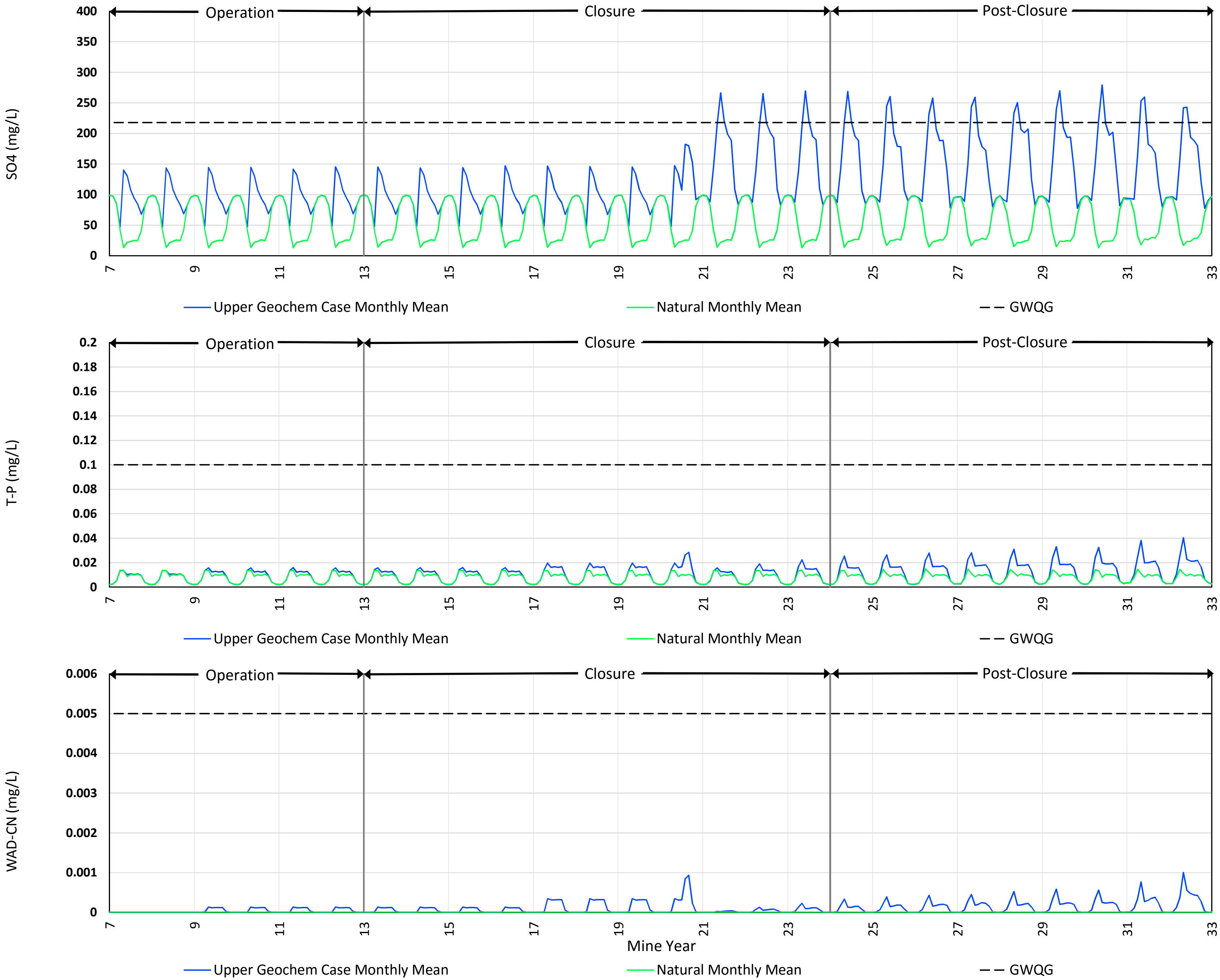

CC4.5
Operation
Closure
Post-Closure
T-Zn (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean

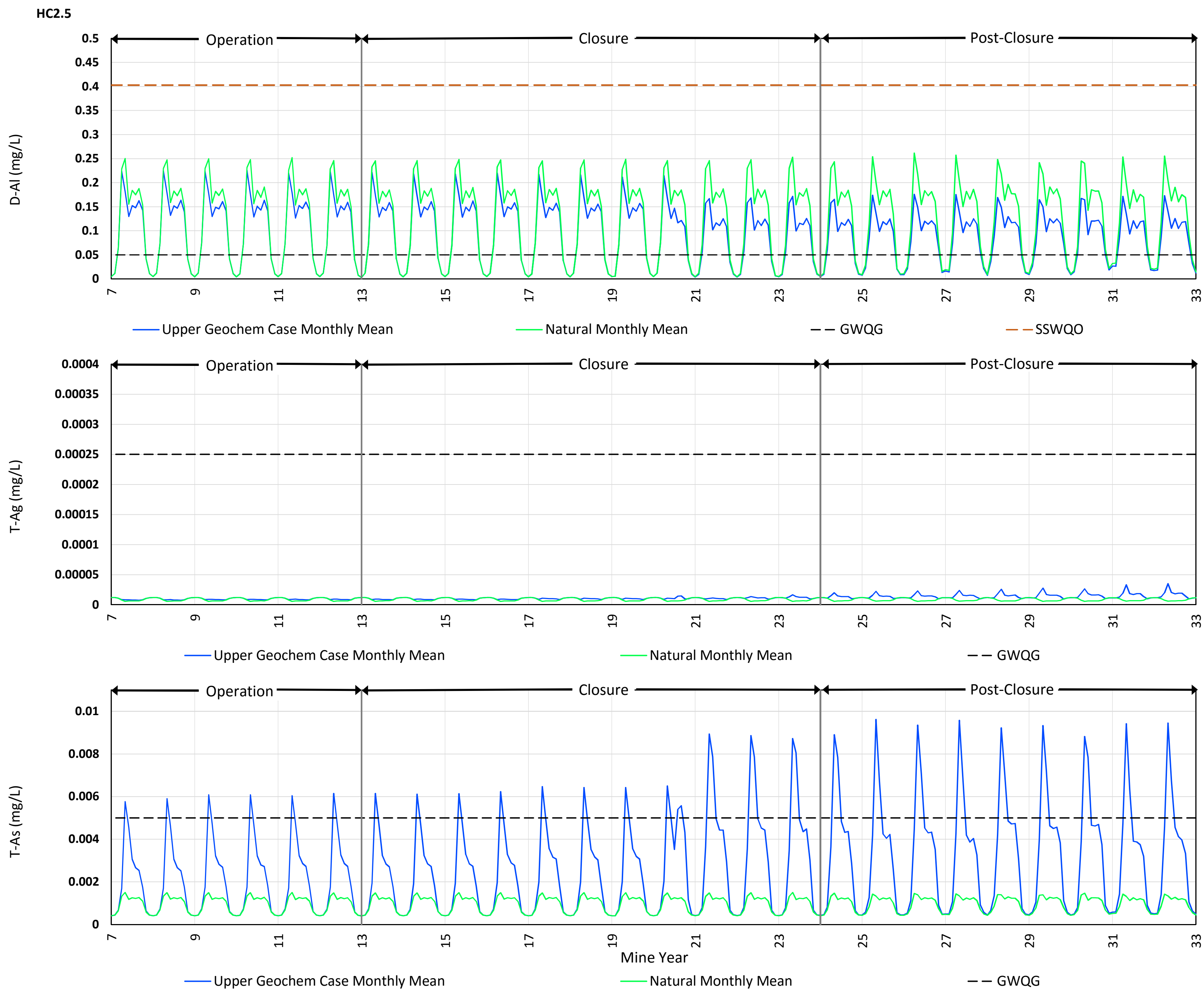
HC2.5



Operation
Closure
Post-Closure
NH3-N (mg/L)
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
NO3-N (mg/L)
NO2-N (mg/L)
Mine Year

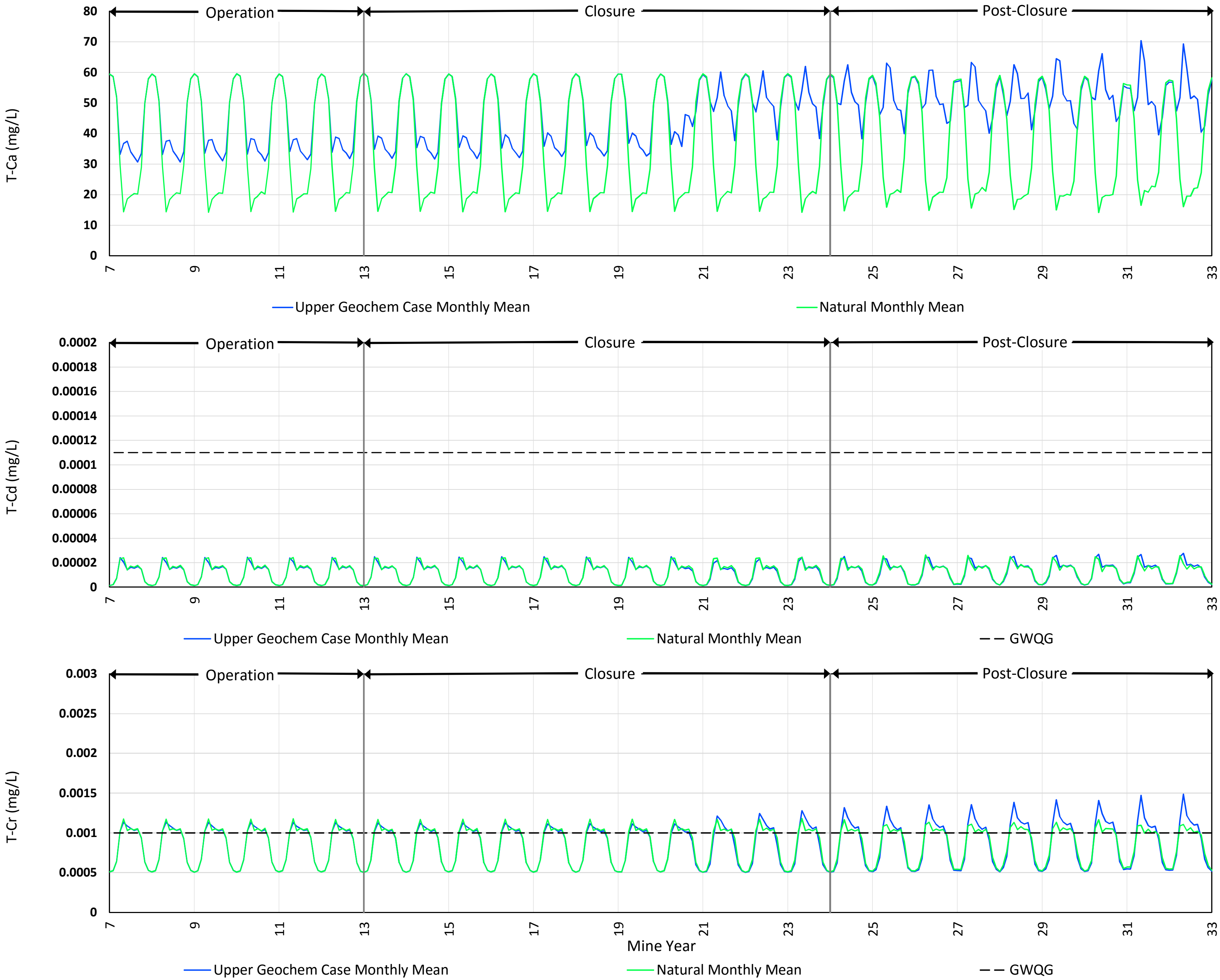
HC2.5


Operation
Closure
Post-Closure
400
350
300
250
200
150
100
50
0
SO4 (mg/L)
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
T-P (mg/L)
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
0.006
0.005
0.004
0.003
0.002
0.001
0
WAD-CN (mg/L)
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG

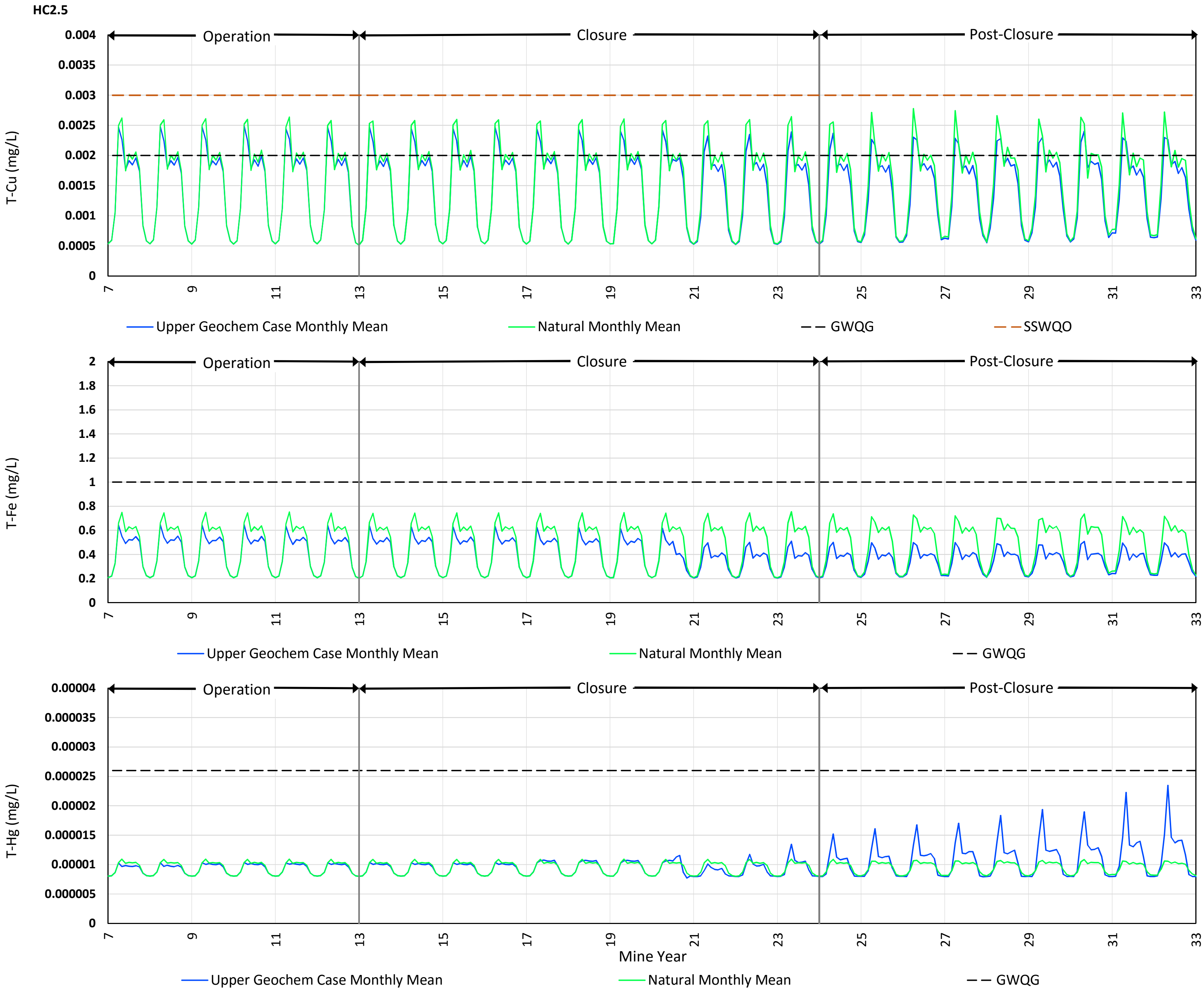


HC2.5
Operation
Closure
Post-Closure
D-Al (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Ag (mg/L)
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
T-As (mg/L)
0.01
0.008
0.006
0.004
0.002
Mine Year

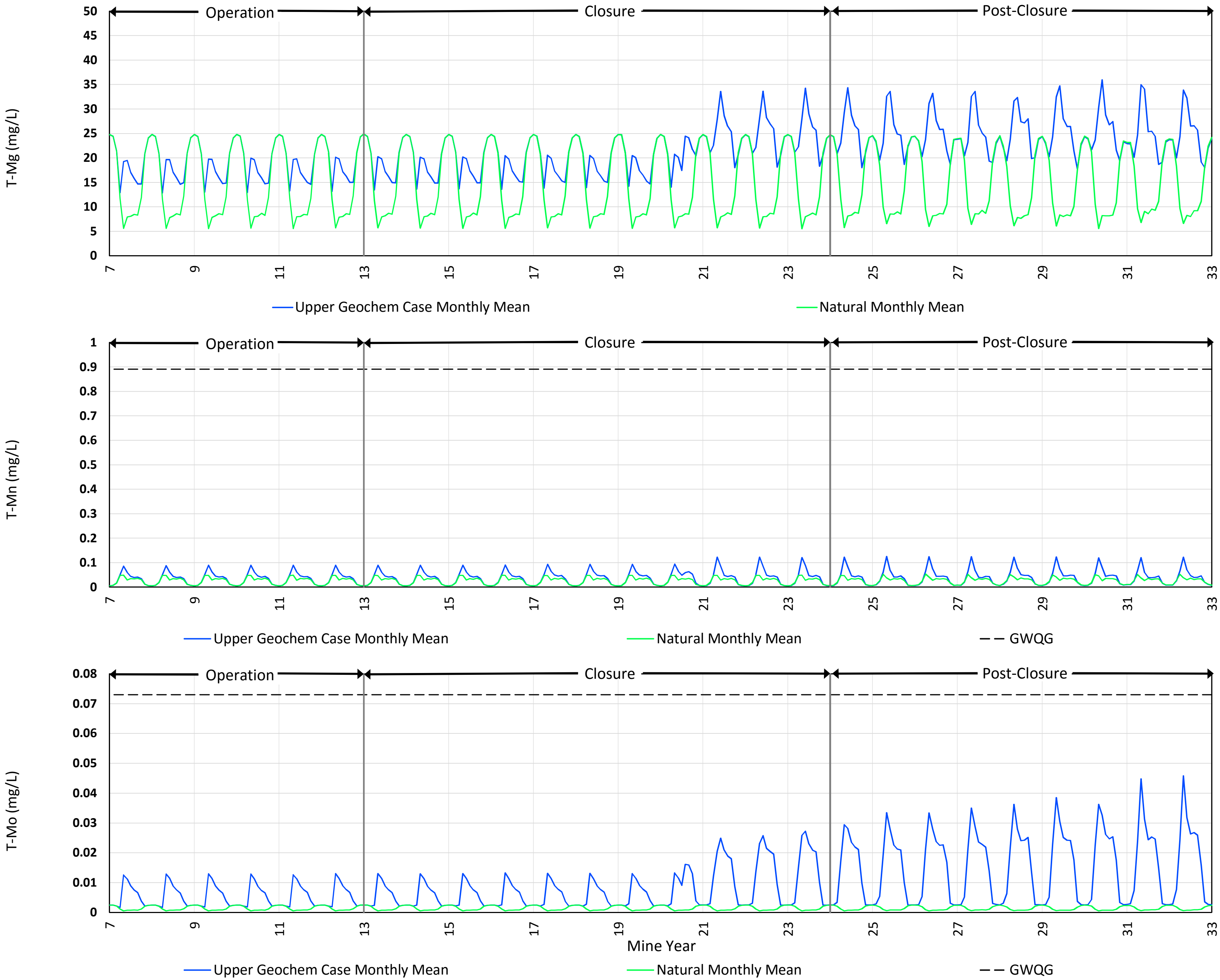
HC2.5



Operation
Closure
Post-Closure
T-Ca (mg/L)
80
70
60
50
40
30
20
10
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Cd (mg/L)
0.0002
0.00018
0.00016
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
GWQG
T-Cr (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
Mine Year

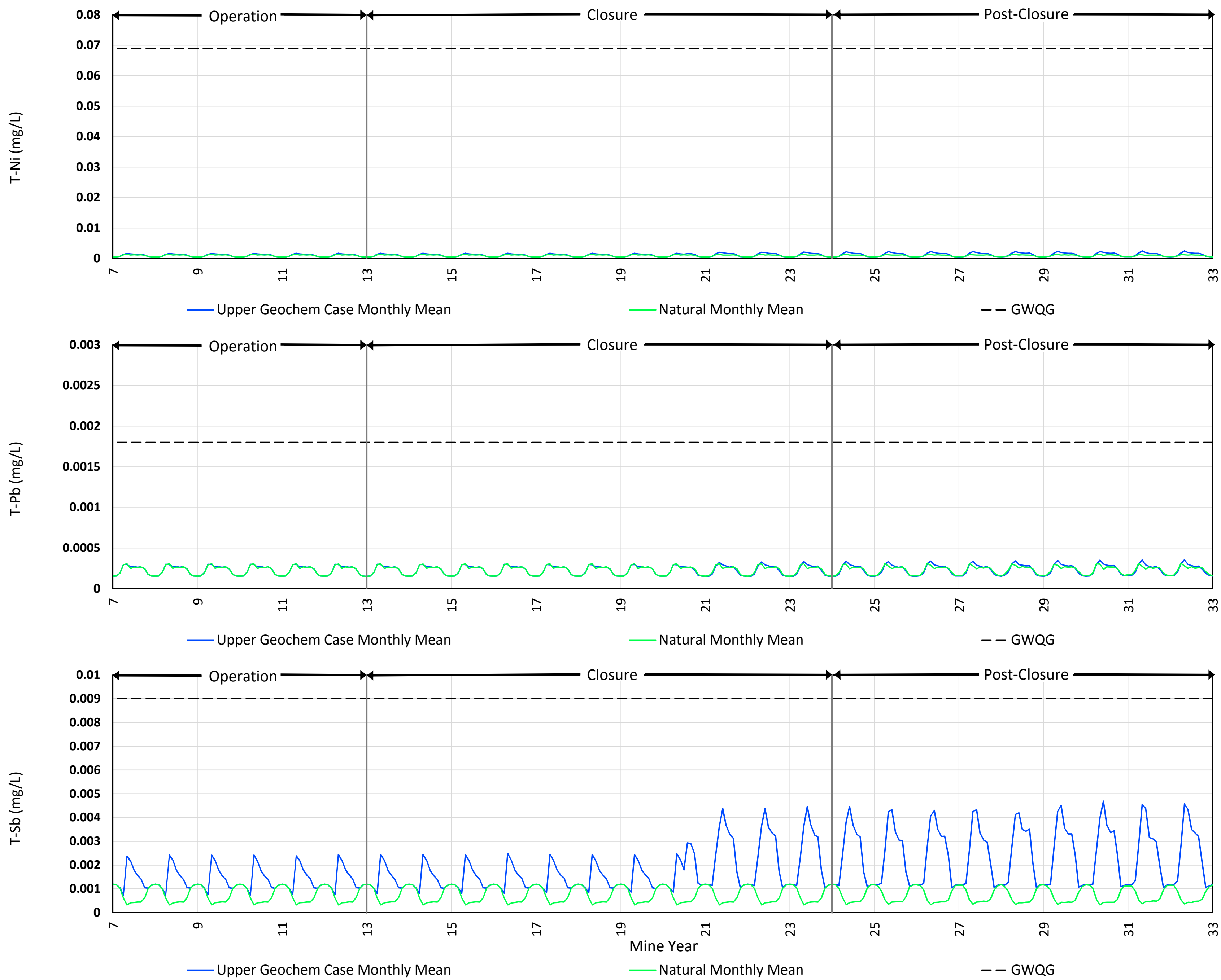

HC2.5
Operation
Closure
Post-Closure
T-Cu (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Fe (mg/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
T-Hg (mg/L)
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
0
Mine Year

HC2.5



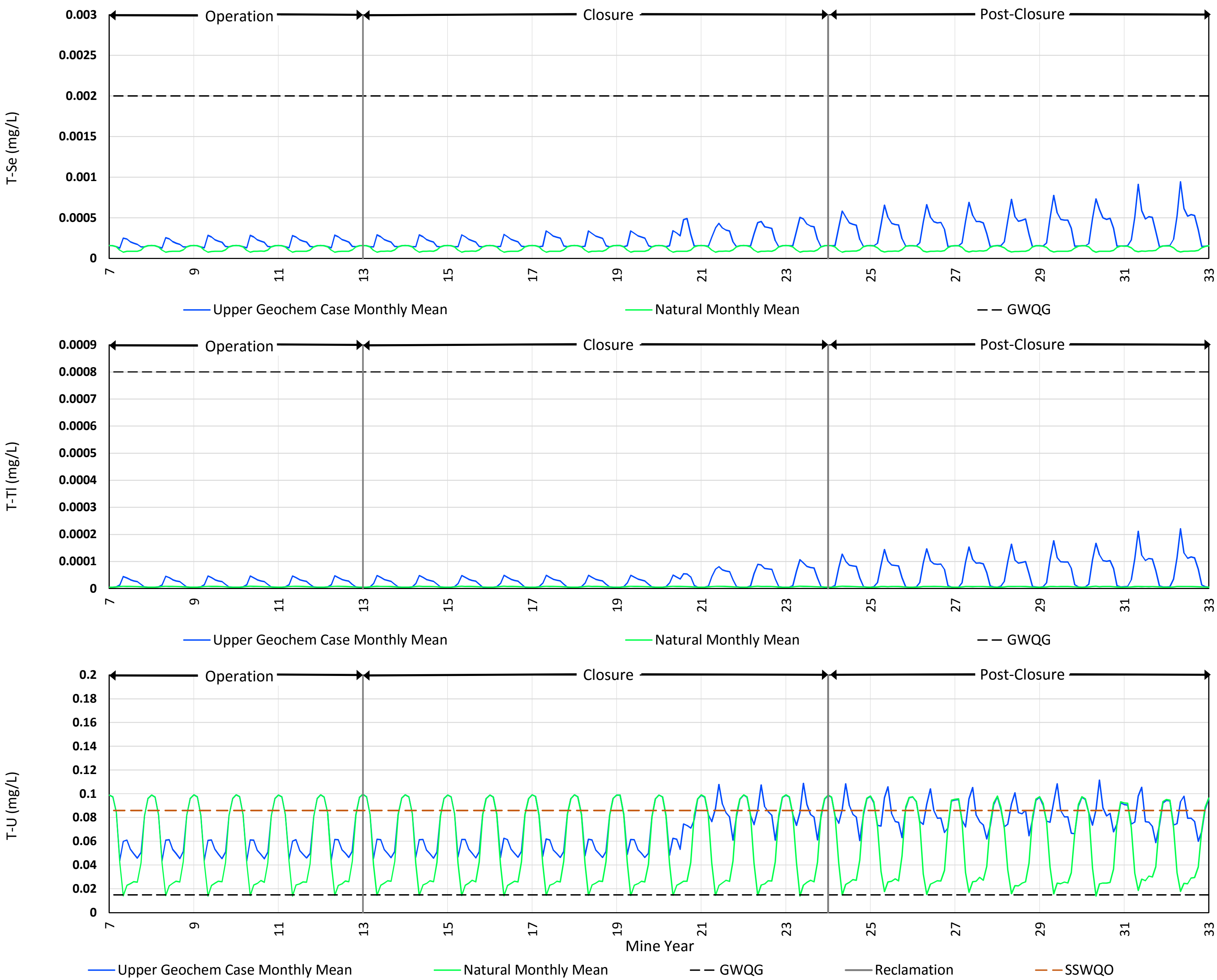
Operation
Closure
Post-Closure
T-Mg (mg/L)
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Mn (mg/L)
GWQG
T-Mo (mg/L)
Mine Year

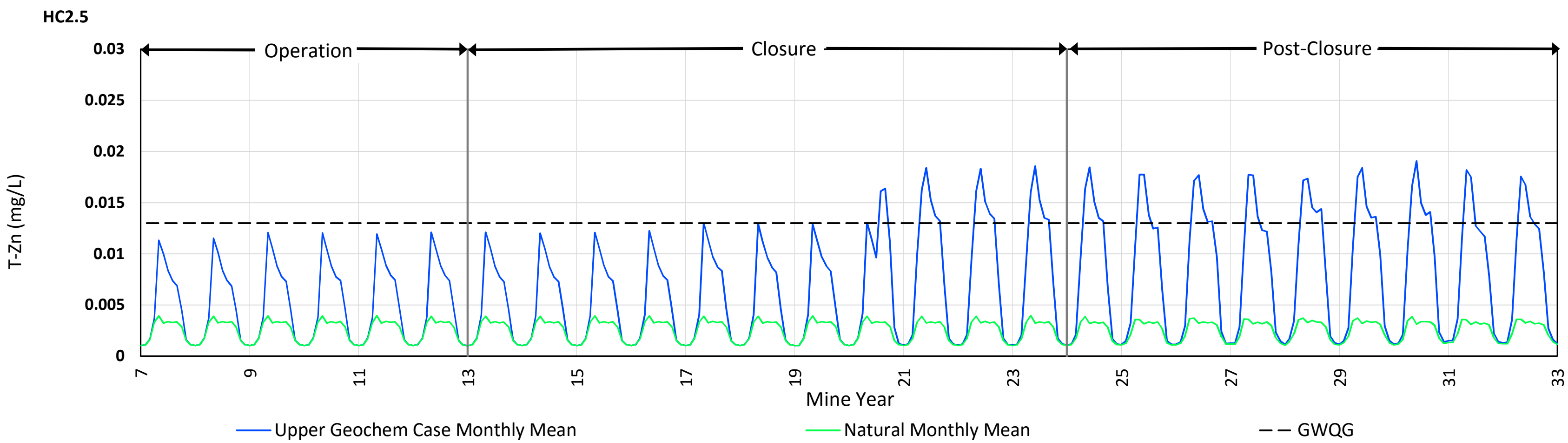
HC2.5



Operation
Closure
Post-Closure
T-Ni (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
T-Pb (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
T-Sb (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
Mine Year

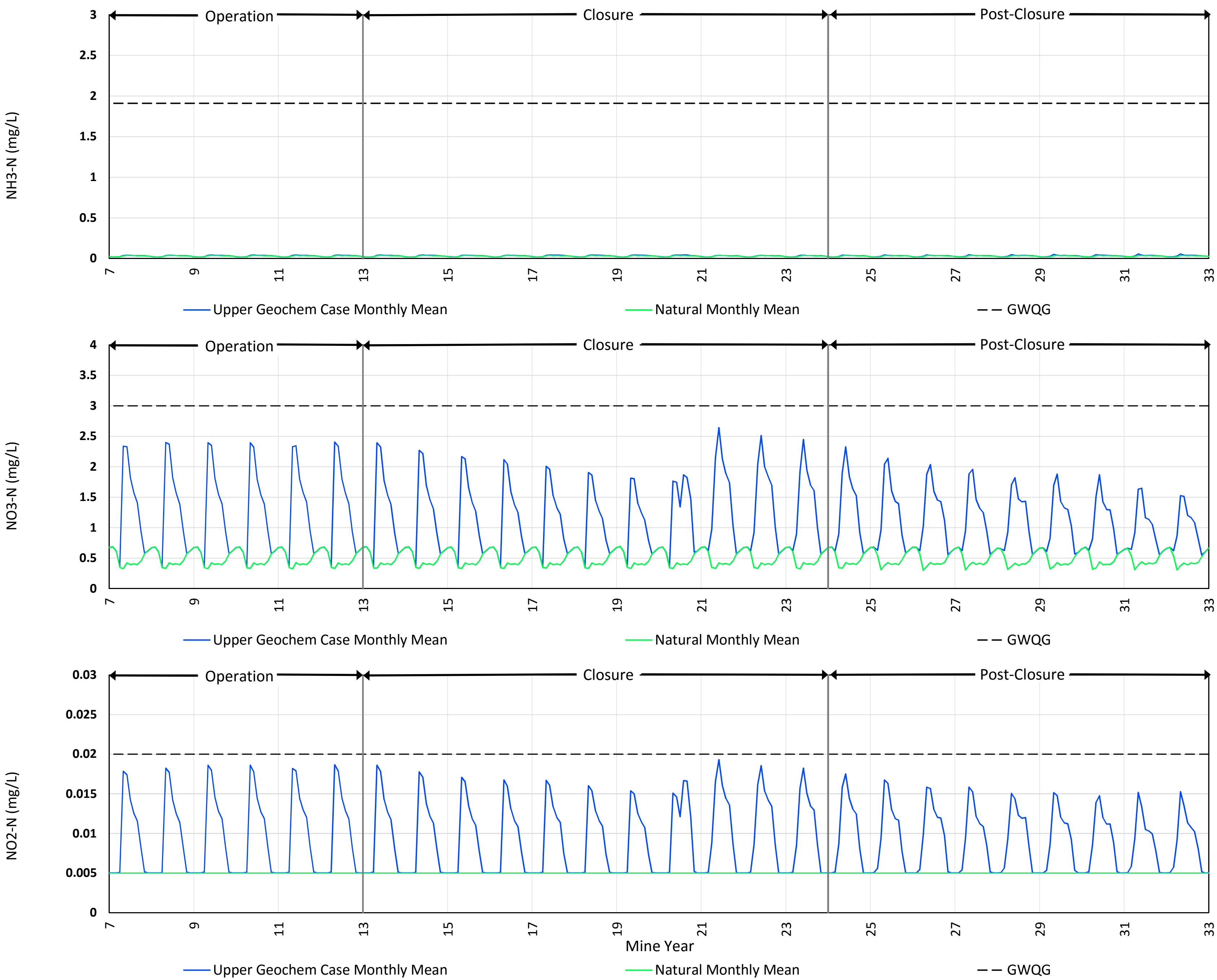
HC2.5


Operation
Closure
Post-Closure
T-Se (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
T-Tl (mg/L)
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
T-U (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Reclamation
SSWQO

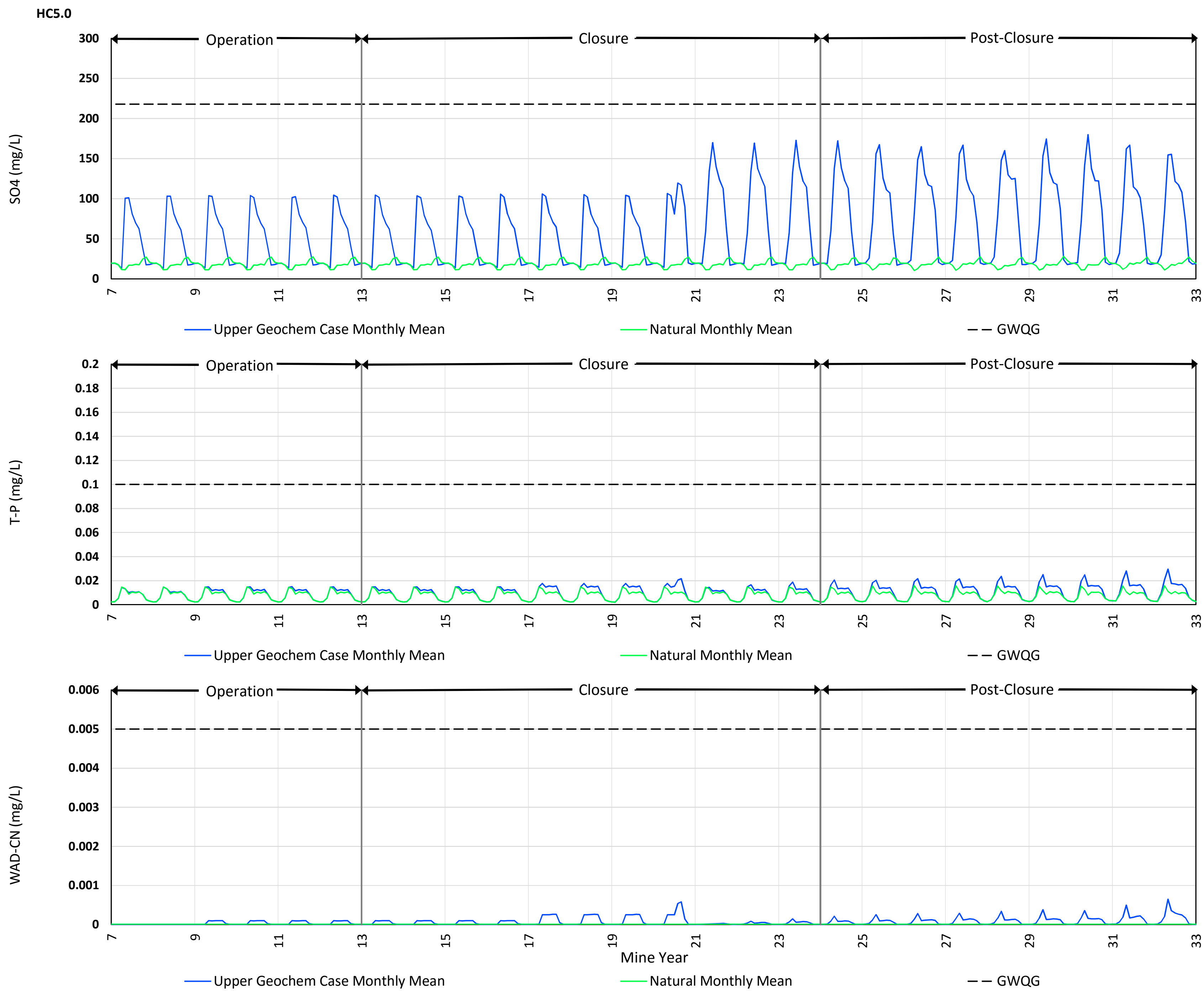


HC2.5
Operation
Closure
Post-Closure
0.03
0.025
0.02
0.015
0.01
0.005
0
T-Zn (mg/L)
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG

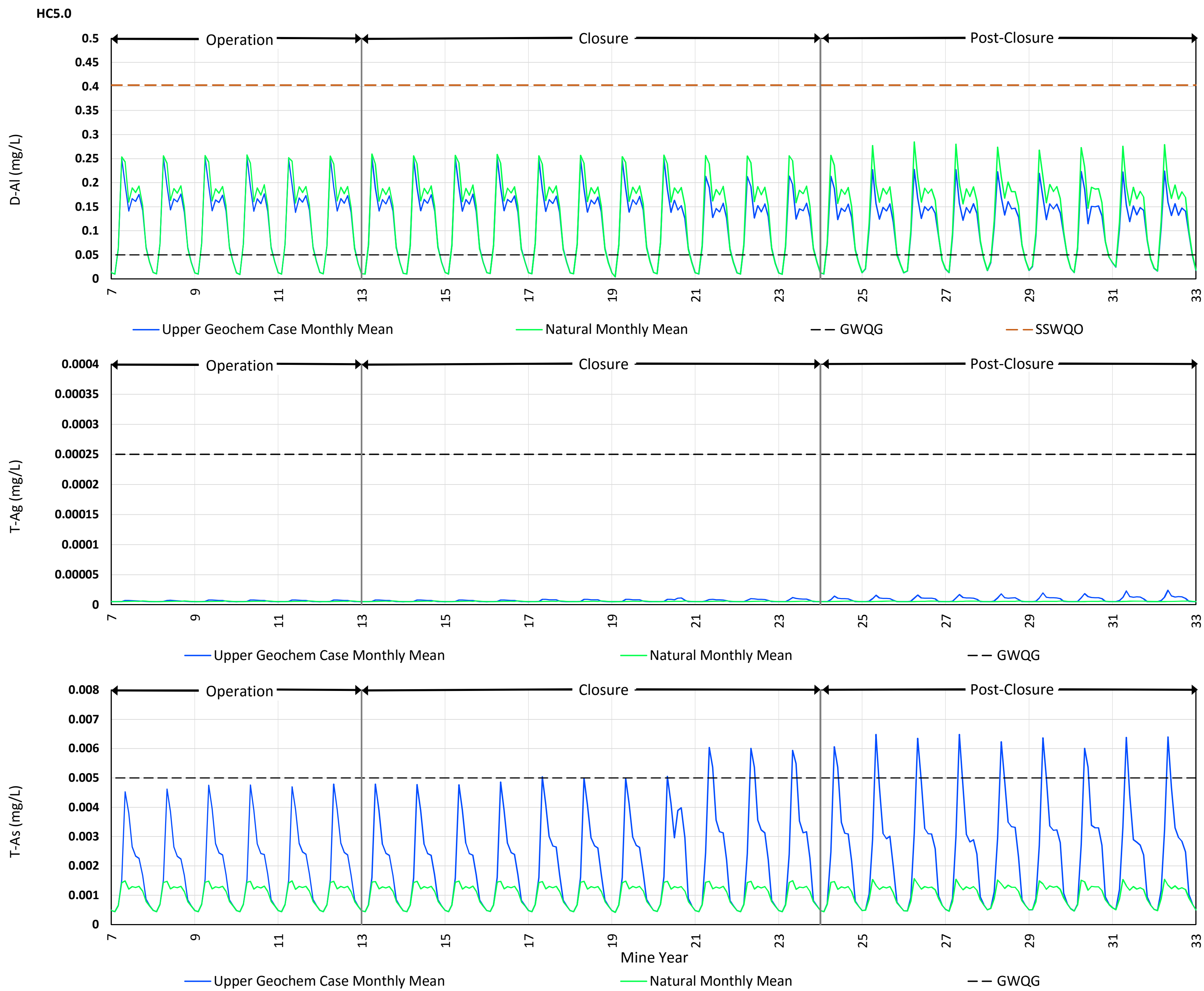
HC5.0



Operation
Closure
Post-Closure
NH3-N (mg/L)
3
2.5
2
1.5
1
0.5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
NO3-N (mg/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
NO2-N (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG

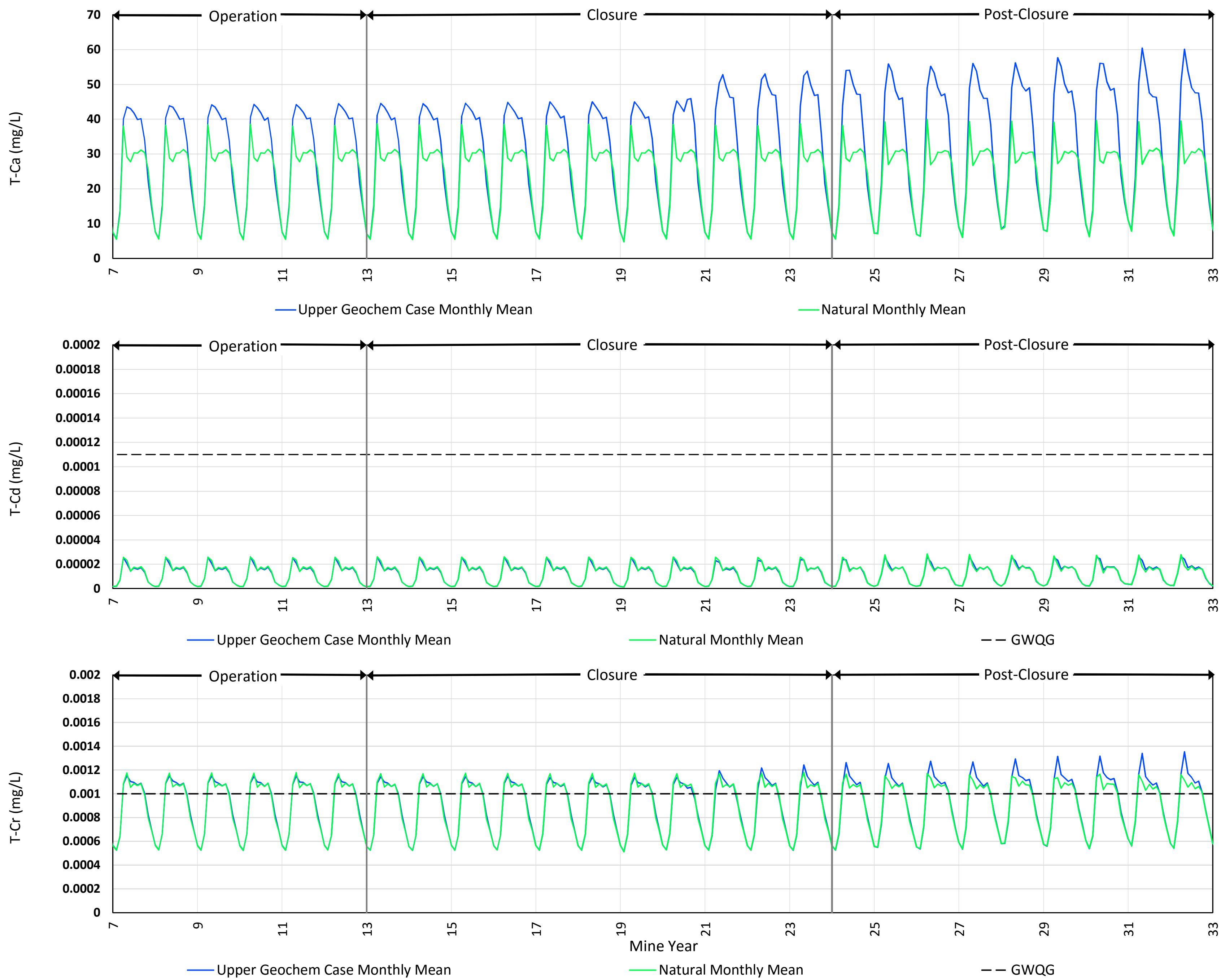


HC5.0
Operation
Closure
Post-Closure
SO4 (mg/L)
300
250
200
150
100
50
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
T-P (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
WAD-CN (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
Mine Year

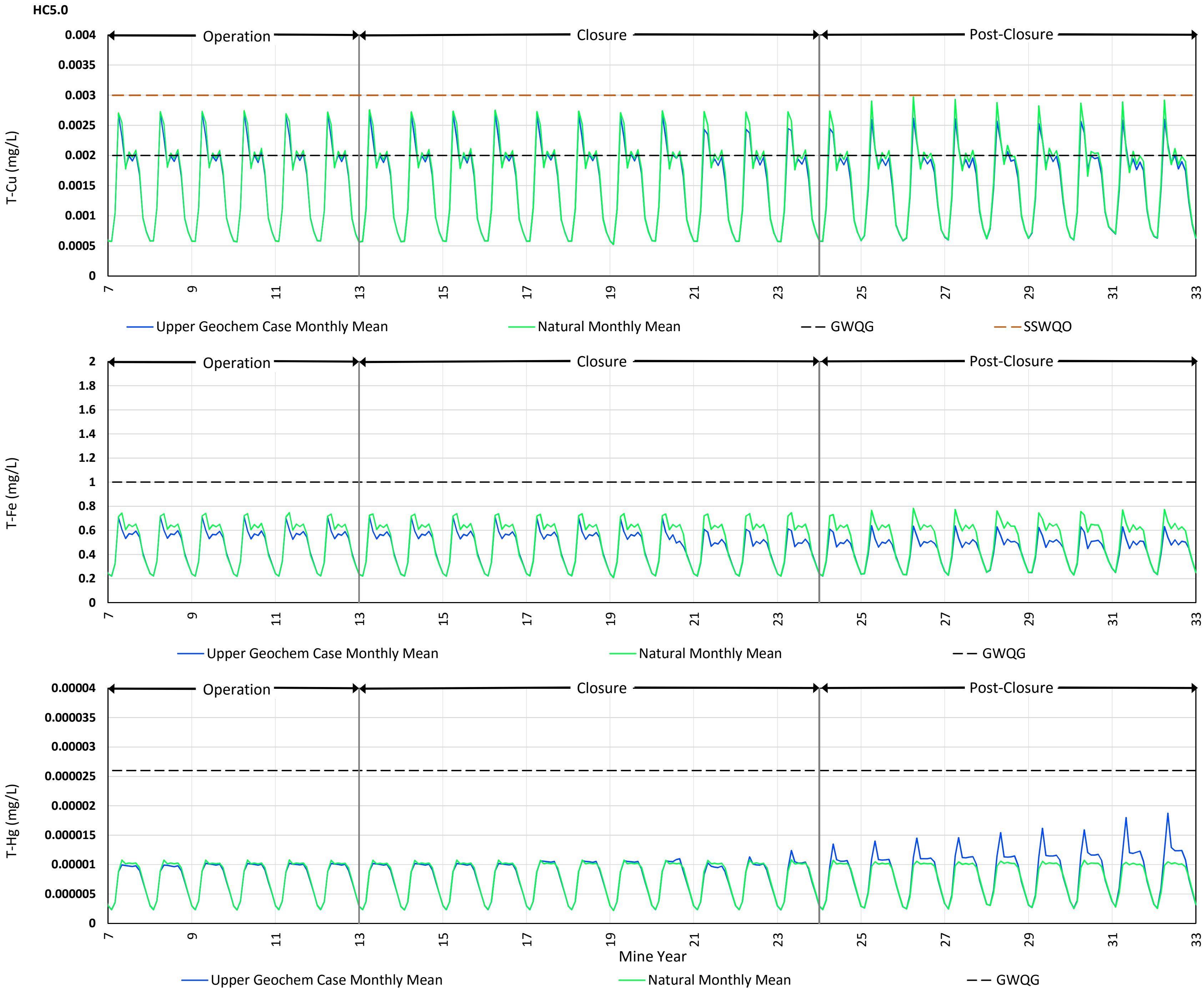


HC5.0
Operation
Closure
Post-Closure
D-Al (mg/L)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Ag (mg/L)
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
T-As (mg/L)
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
Mine Year

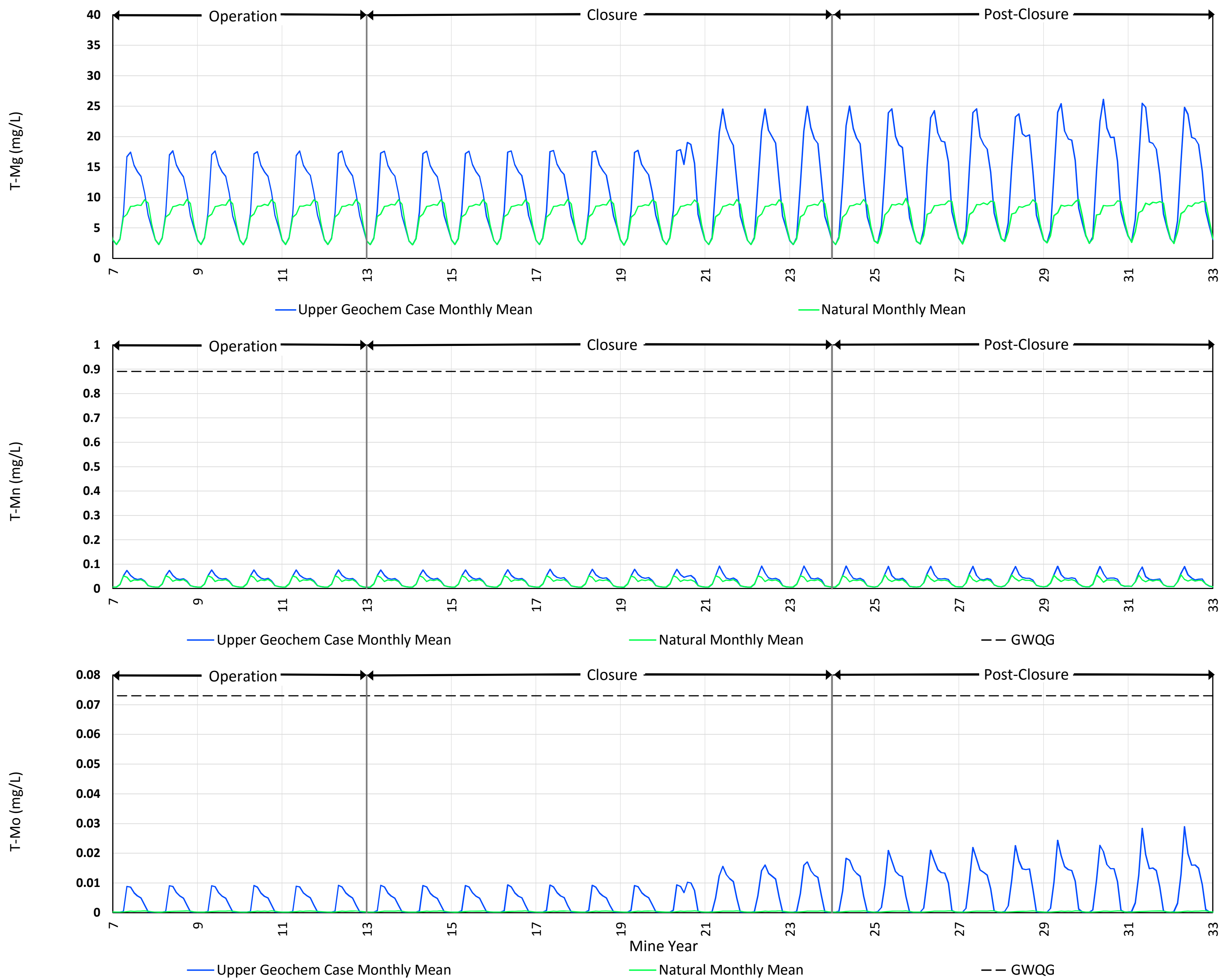
HC5.0



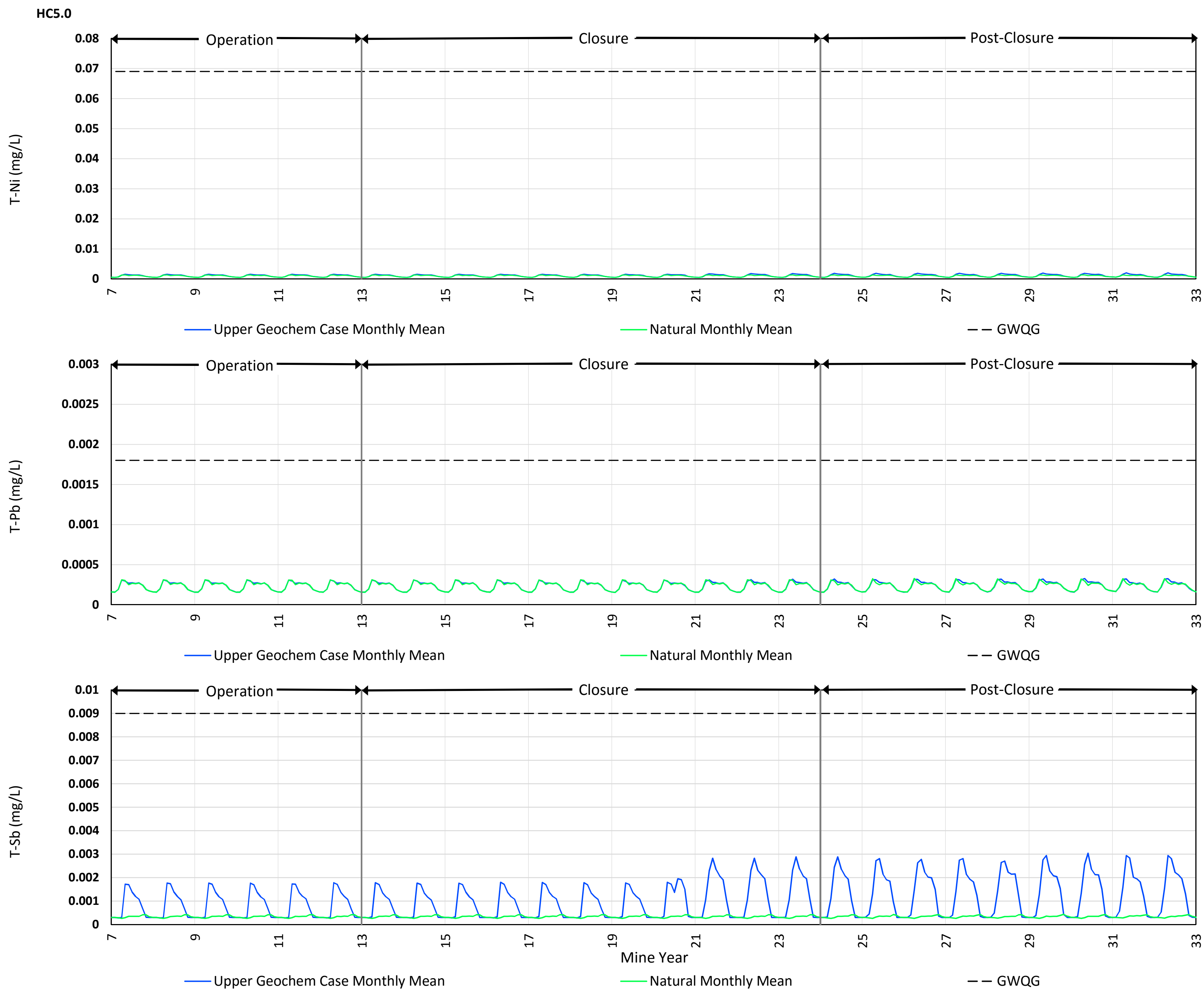
Operation
Closure
Post-Closure
T-Ca (mg/L)
70
60
50
40
30
20
10
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Cd (mg/L)
0.0002
0.00018
0.00016
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
GWQG
T-Cr (mg/L)
0.002
0.0018
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
Mine Year

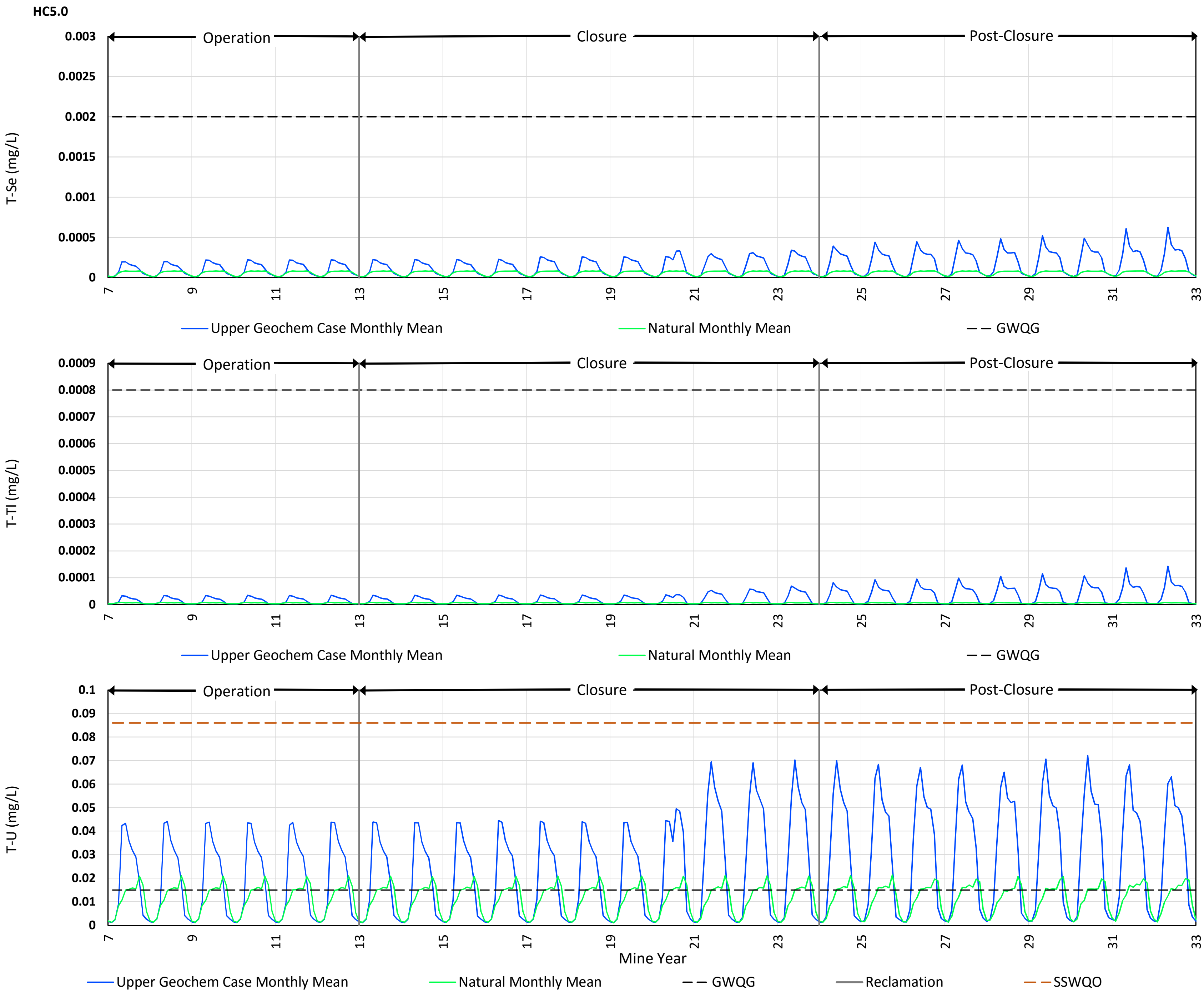

HC5.0
Operation
Closure
Post-Closure
T-Cu (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Fe (mg/L)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
T-Hg (mg/L)
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
Mine Year

HC5.0

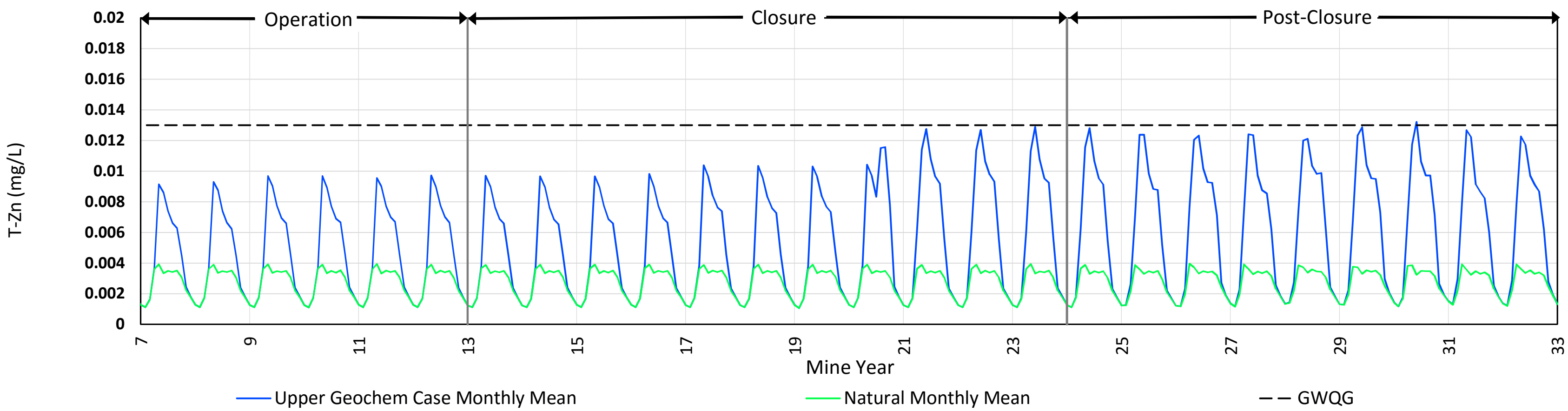


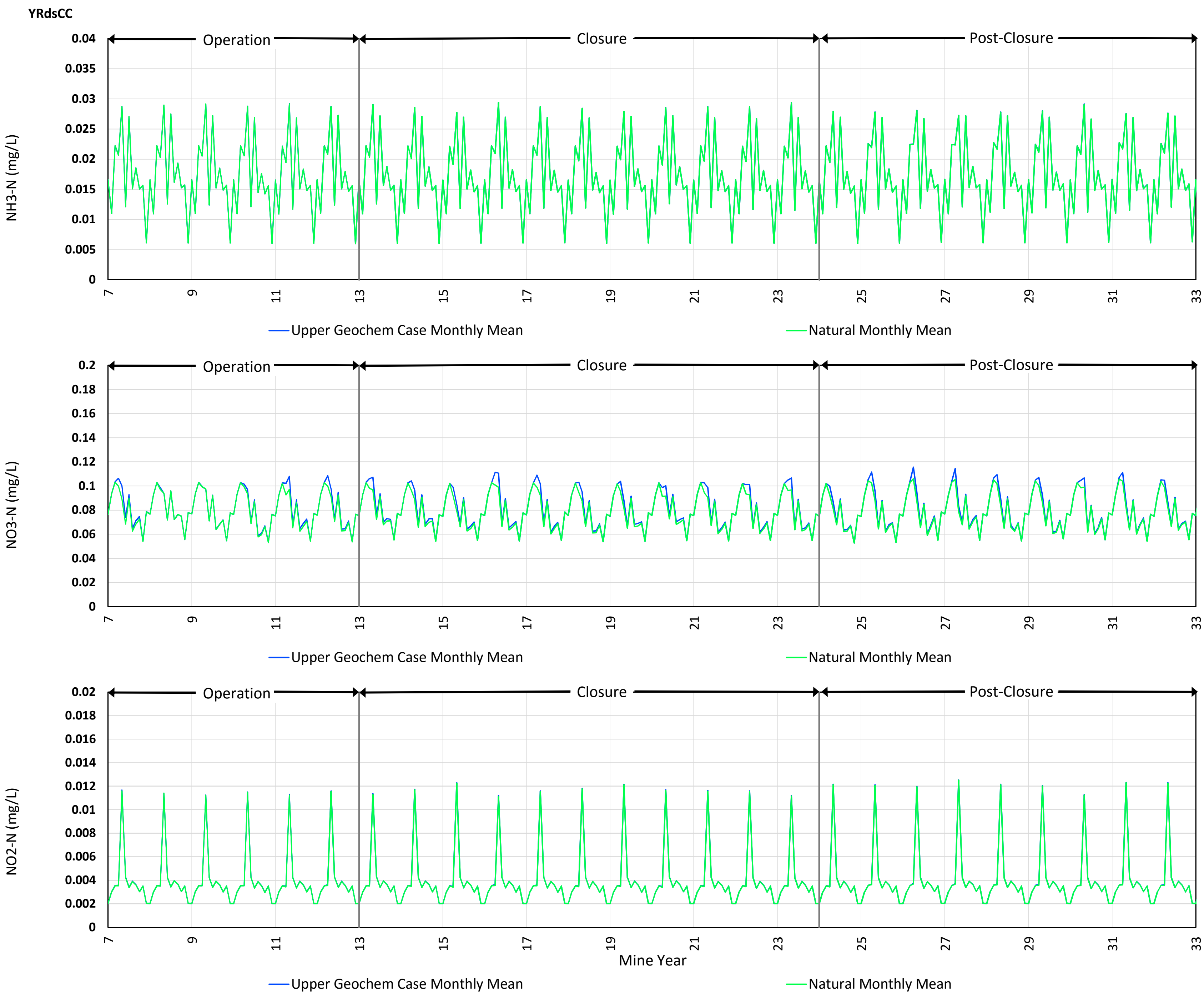
Operation
Closure
Post-Closure
T-Mg (mg/L)
40
35
30
25
20
15
10
5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Mn (mg/L)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
GWQG
T-Mo (mg/L)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Mine Year

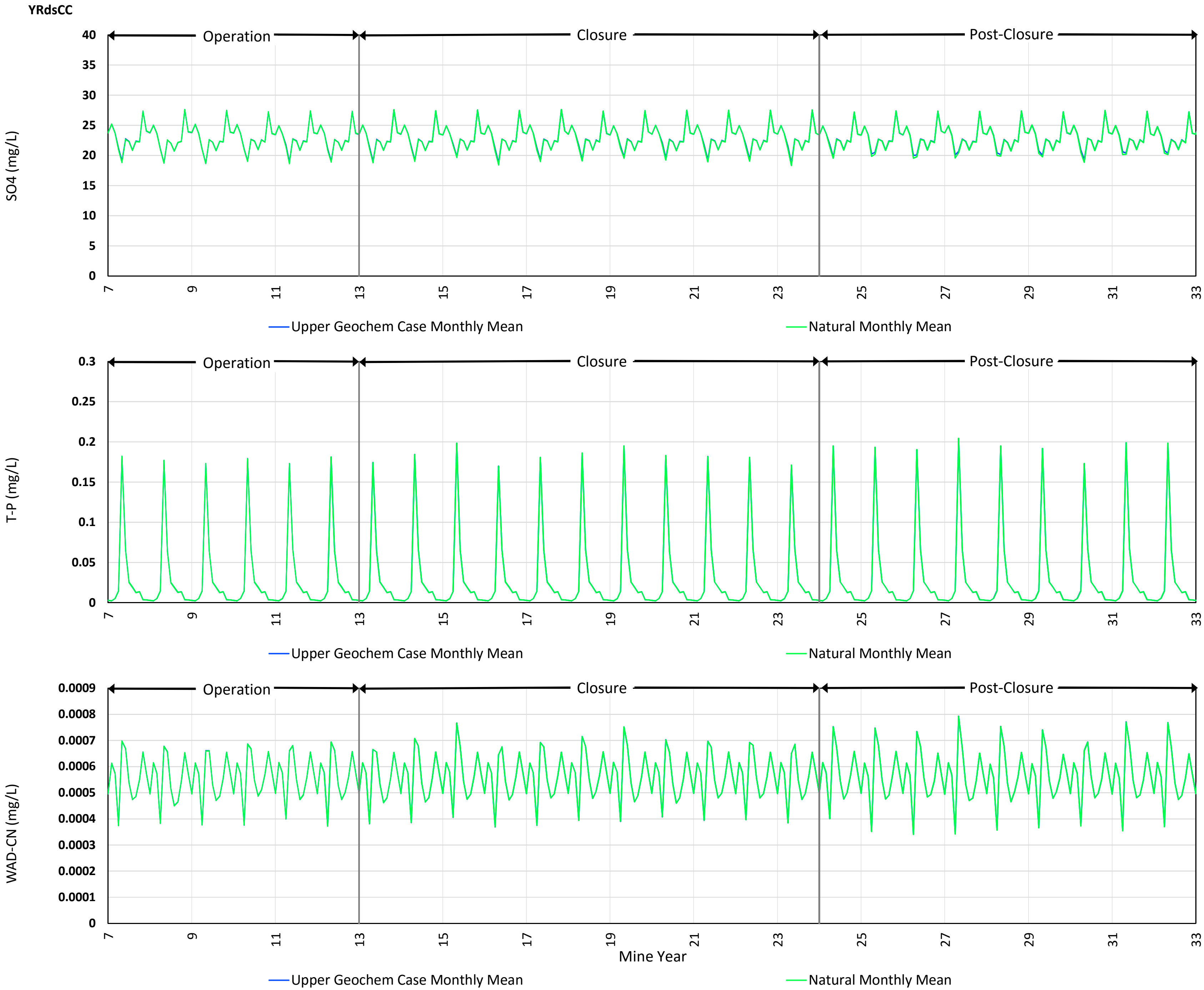

HC5.0
Operation
Closure
Post-Closure
T-Ni (mg/L)
T-Pb (mg/L)
T-Sb (mg/L)
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG

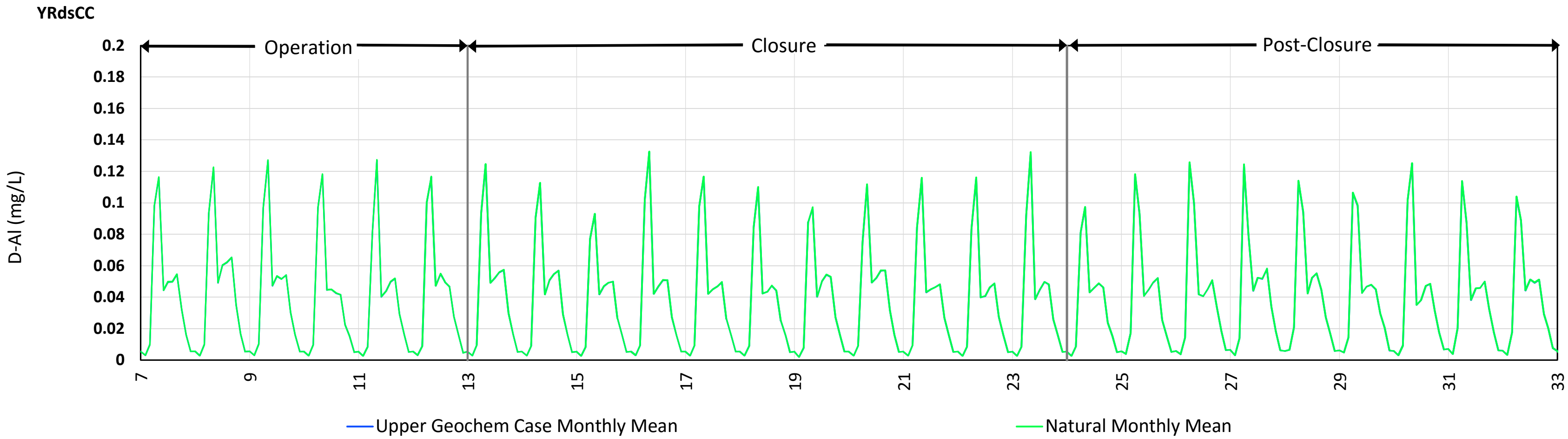

HC5.0
Operation
Closure
Post-Closure
T-Se (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
T-Tl (mg/L)
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
T-U (mg/L)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Reclamation
SSWQO

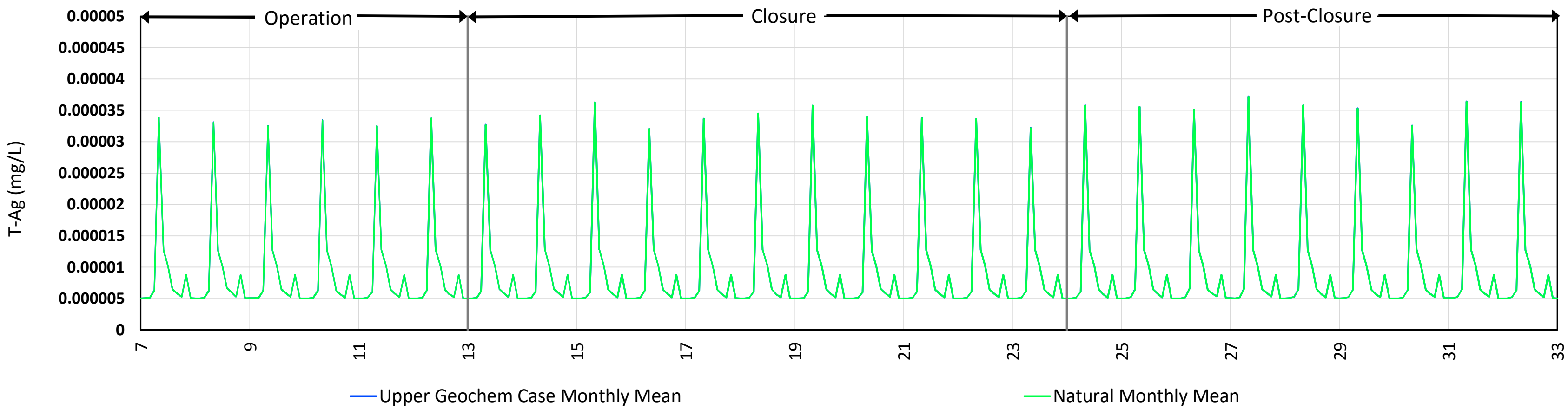
HC5.0

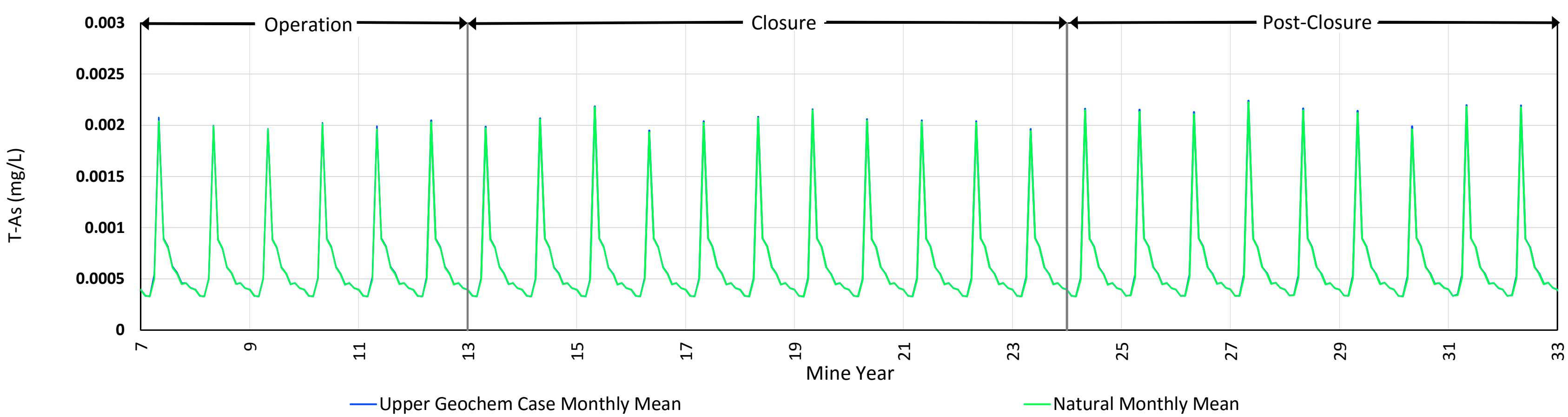

Operation
Closure
Post-Closure
T-Zn (mg/L)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG


YRdsCC
Operation
Closure
Post-Closure
NH3-N (mg/L)
NO3-N (mg/L)
NO2-N (mg/L)
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean

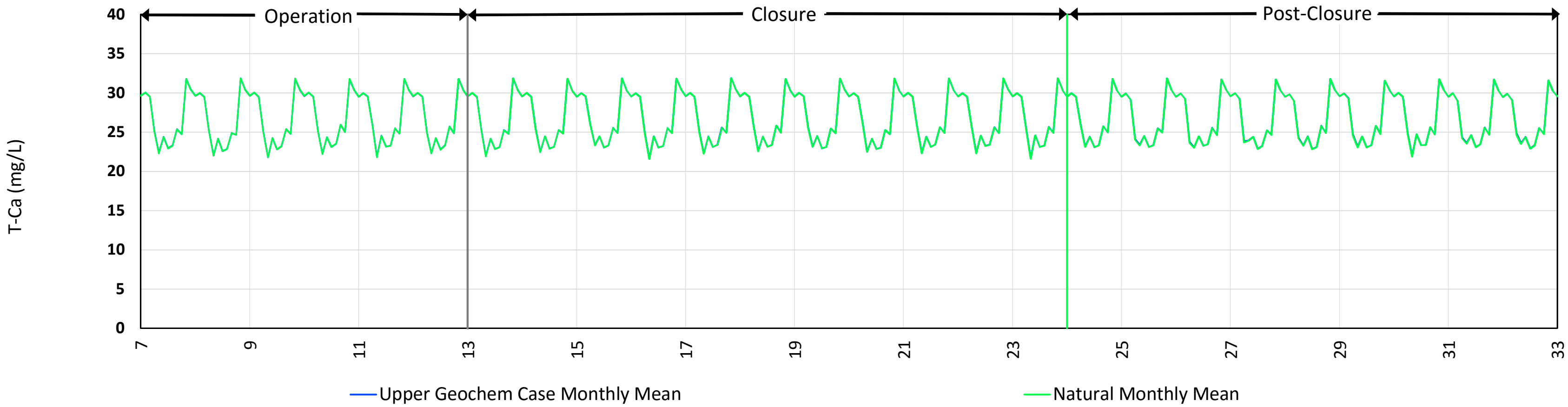

YRdsCC
Operation
Closure
Post-Closure
SO4 (mg/L)
T-P (mg/L)
WAD-CN (mg/L)
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean

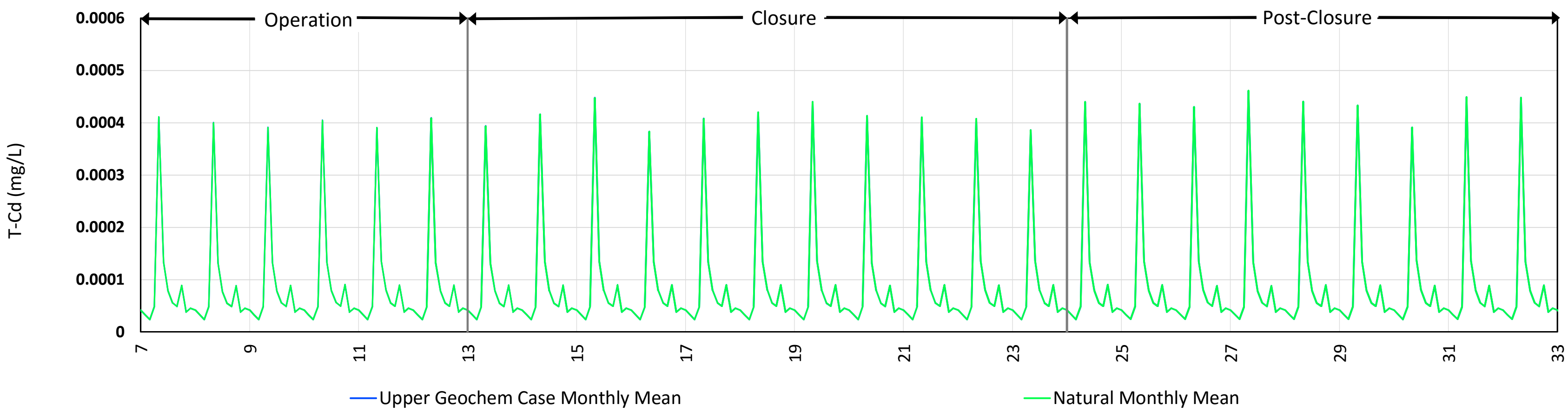

YRdsCC
Operation
Closure
Post-Closure
D-Al (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean

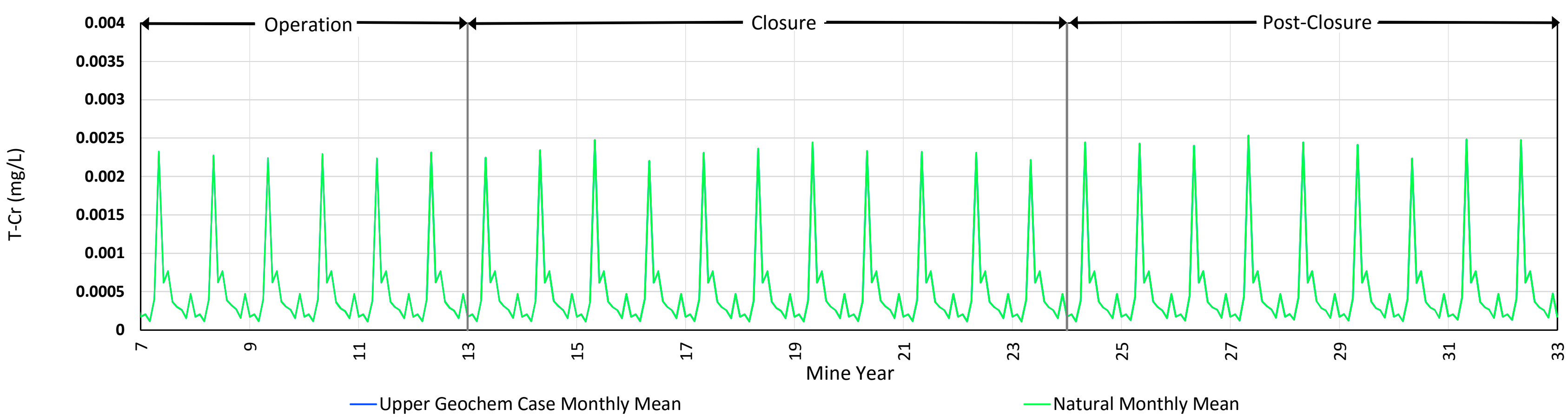

Operation
Closure
Post-Closure
T-Ag (mg/L)
0.00005
0.000045
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean

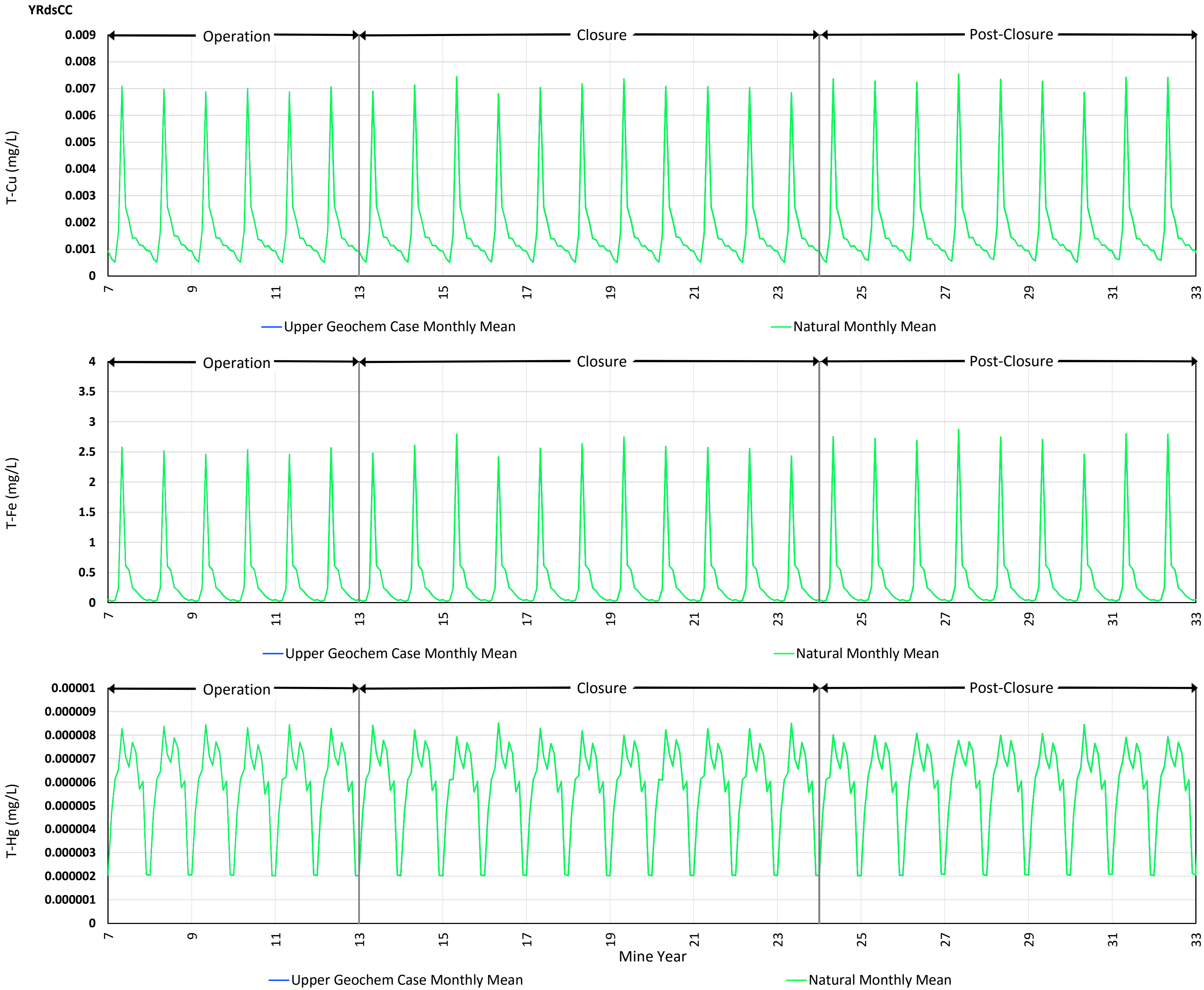

Operation
Closure
Post-Closure
T-As (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean

YRdsCC

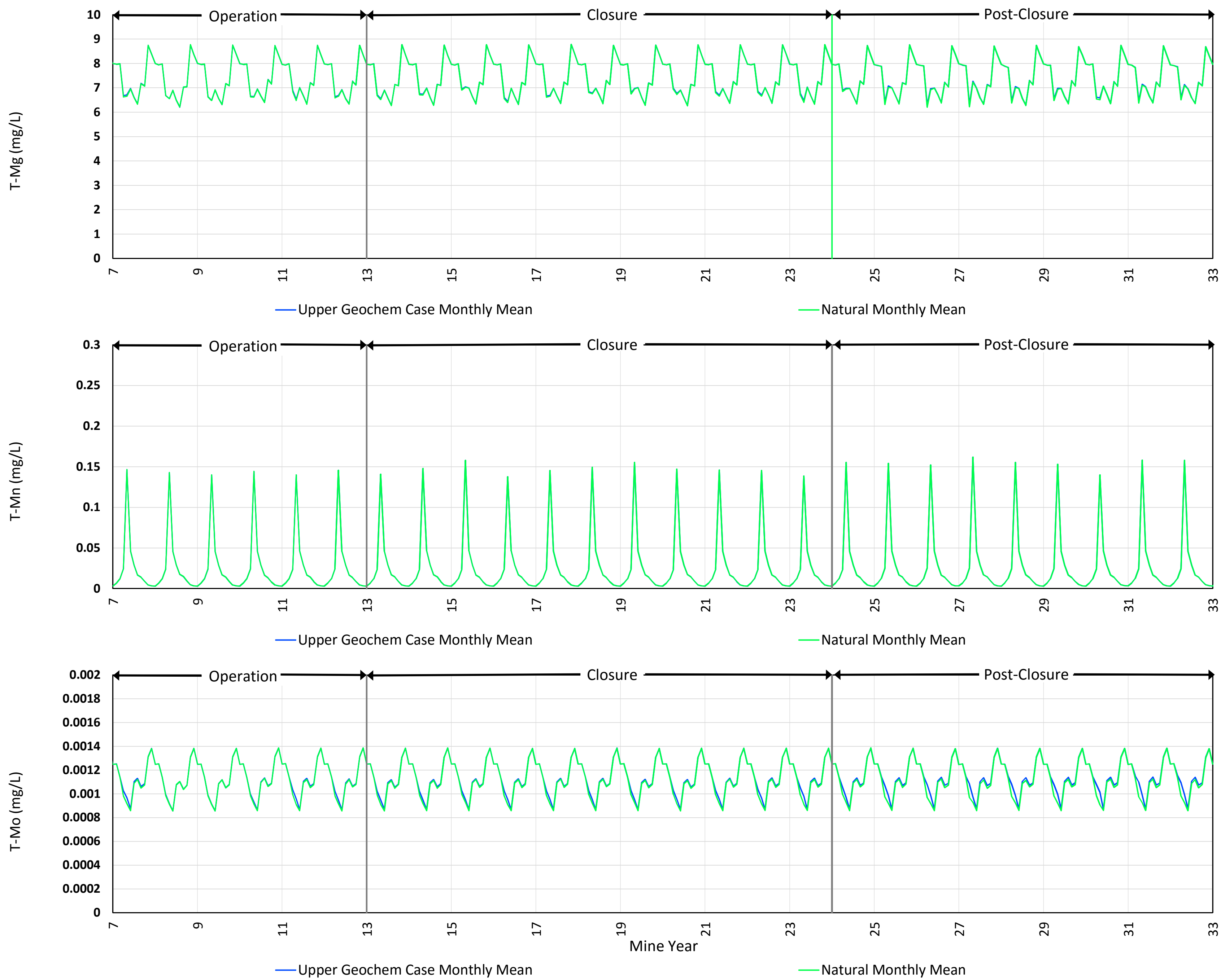

Operation
Closure
Post-Closure
T-Ca (mg/L)
40
35
30
25
20
15
10
5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean


Operation
Closure
Post-Closure
T-Cd (mg/L)
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean

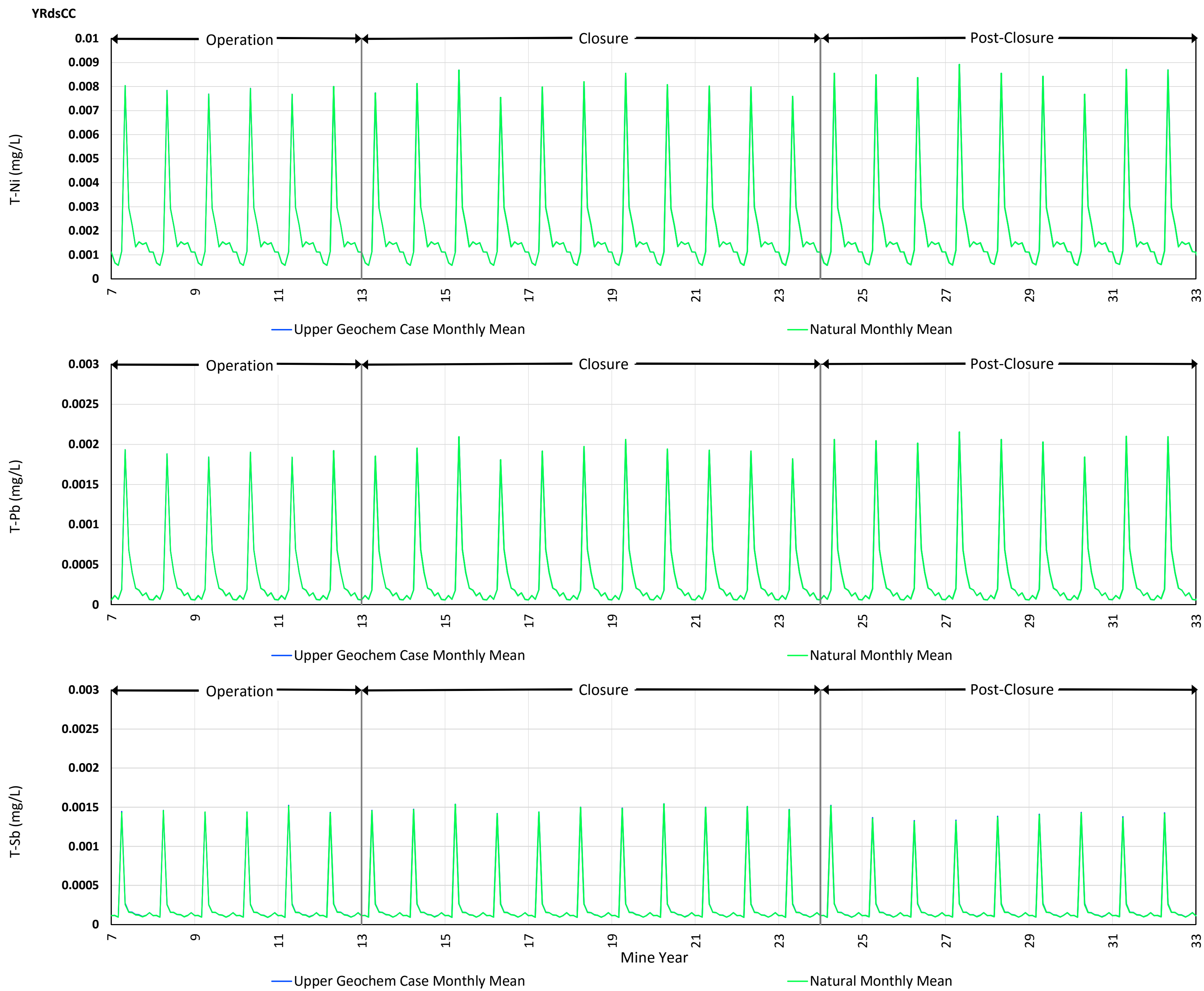

Operation
Closure
Post-Closure
T-Cr (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean

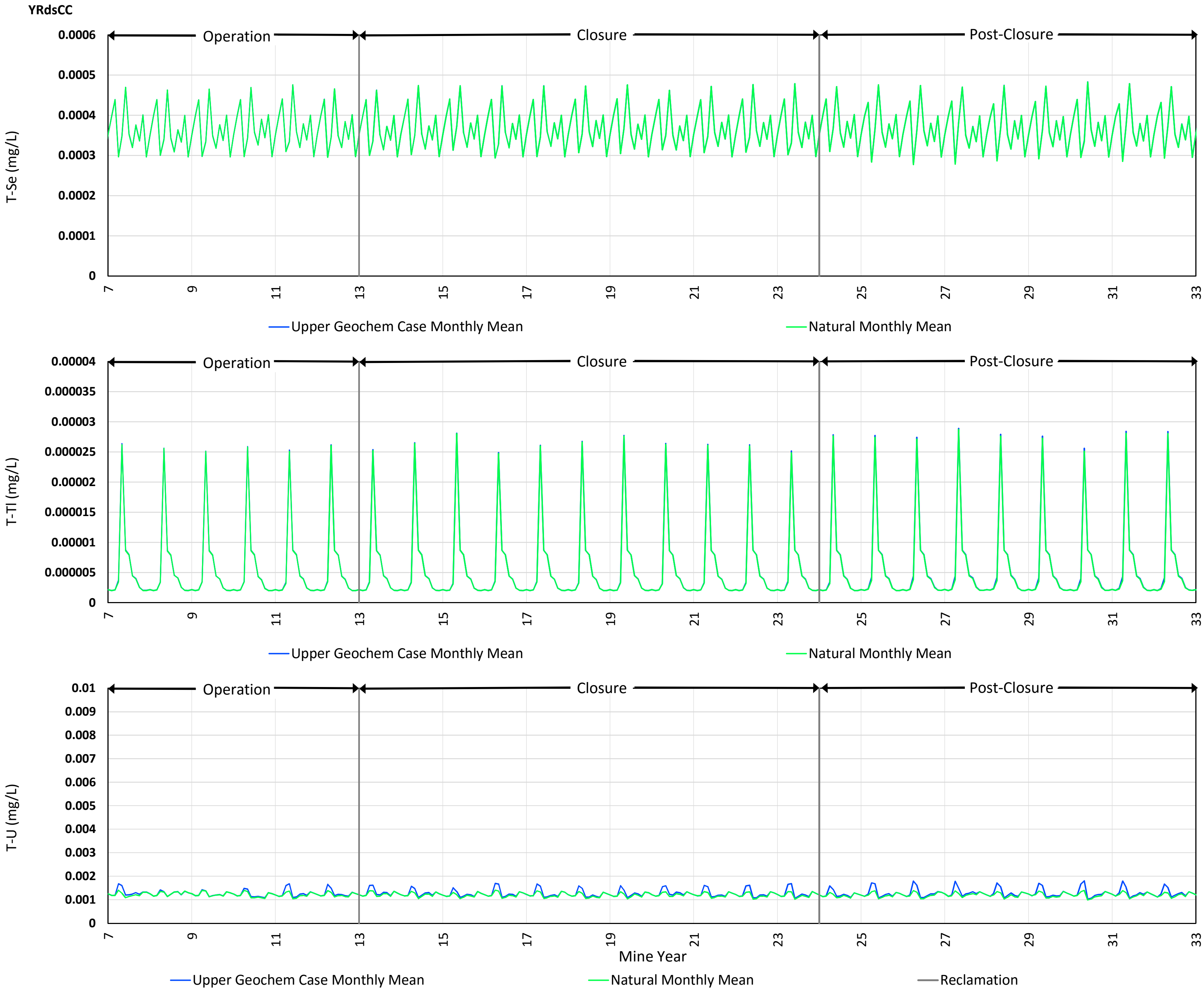

YRdsCC
T-Cu (mg/L)
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
Operation
Closure
Post-Closure
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Fe (mg/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
T-Hg (mg/L)
0.00001
0.000009
0.000008
0.000007
0.000006
0.000005
0.000004
0.000003
0.000002
0.000001
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year

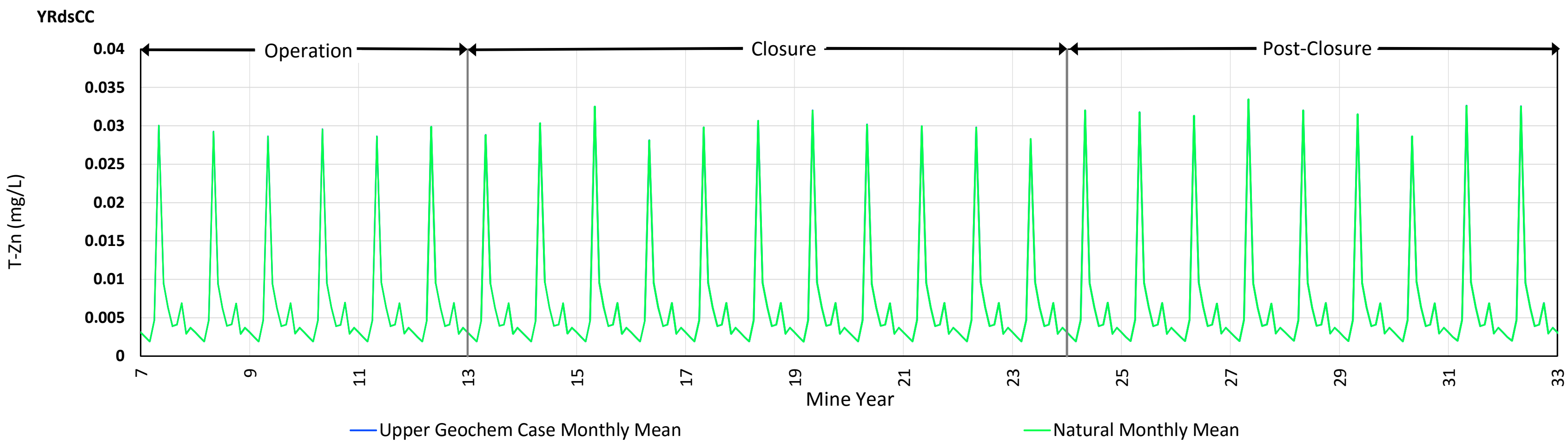
YRdsCC



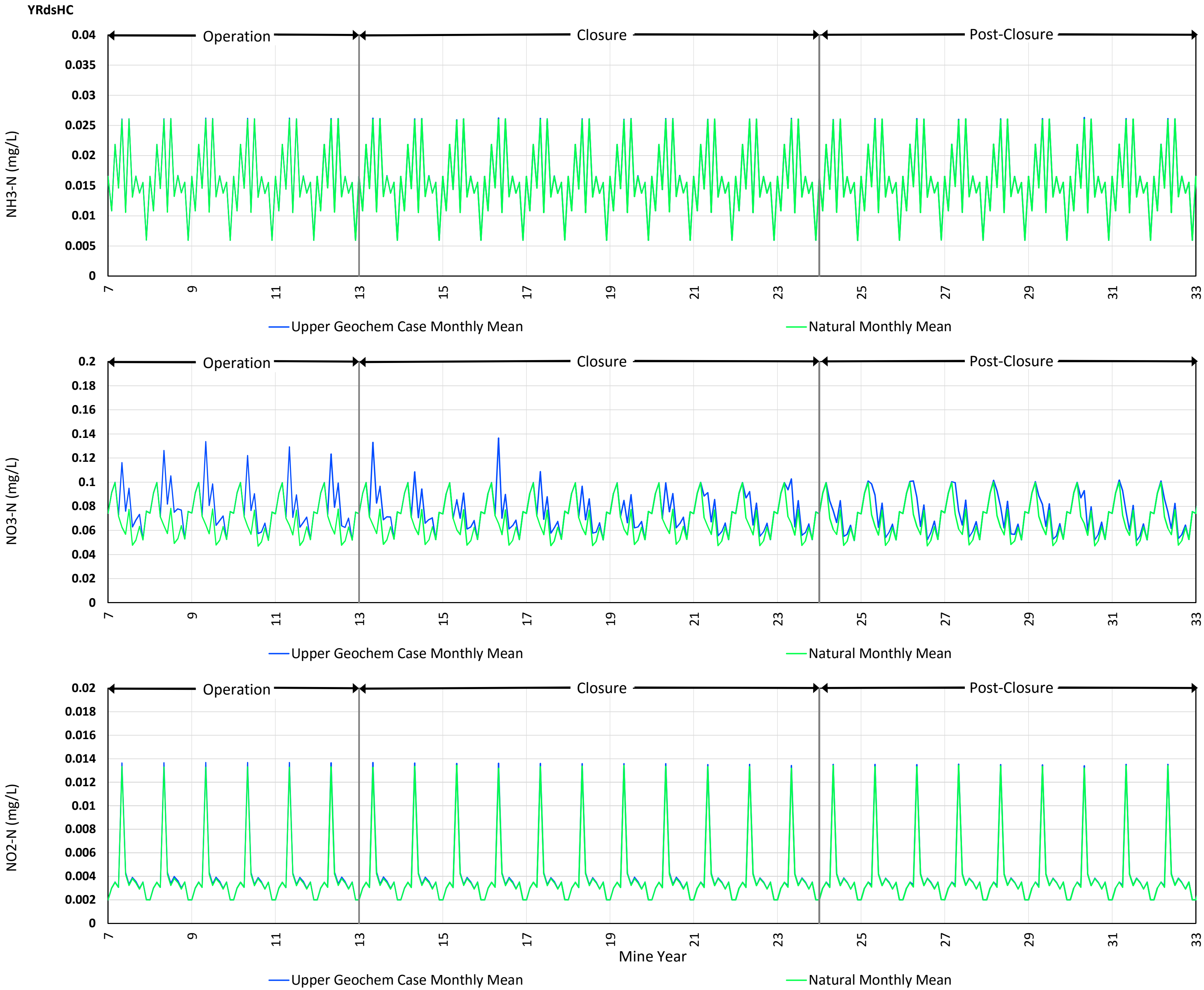
Operation
Closure
Post-Closure
T-Mg (mg/L)
T-Mn (mg/L)
T-Mo (mg/L)
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean


YRdsCC
Operation
Closure
Post-Closure
T-Ni (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Pb (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
T-Sb (mg/L)
Mine Year

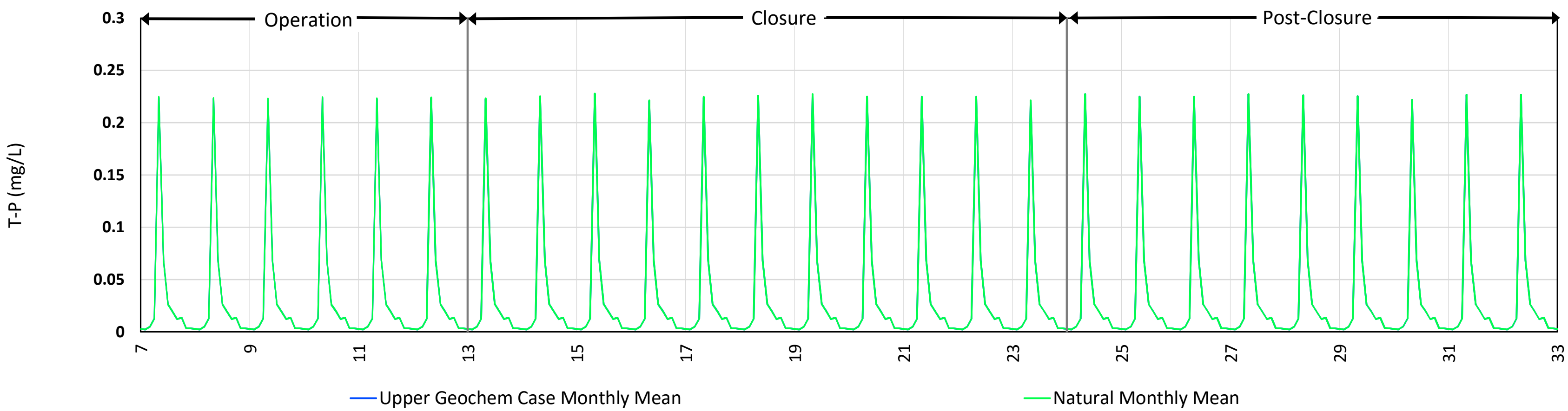

YRdsCC
Operation
Closure
Post-Closure
T-Se (mg/L)
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Tl (mg/L)
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
T-U (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
Mine Year
Reclamation

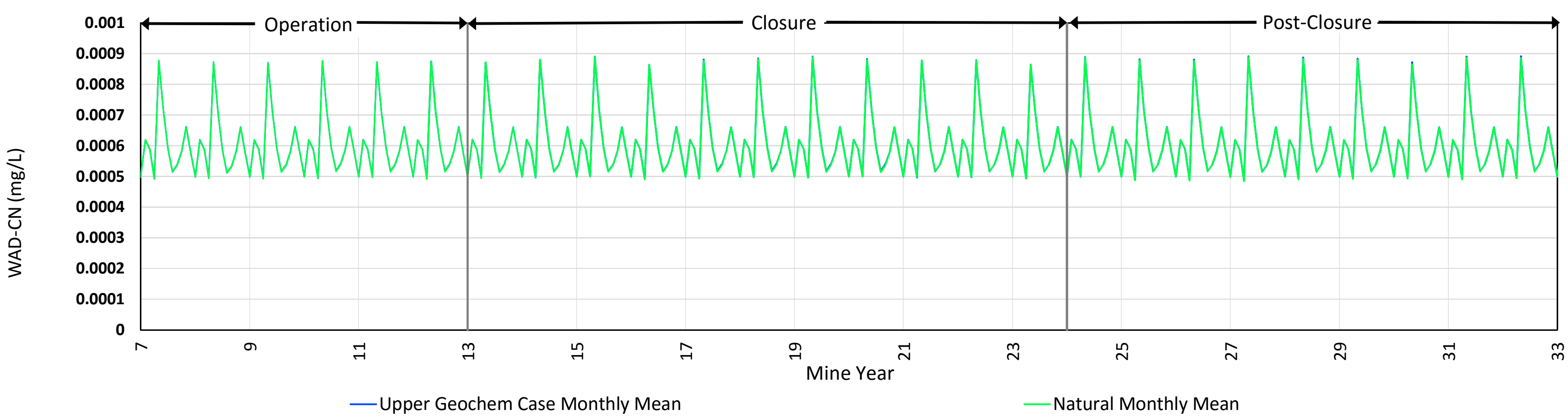


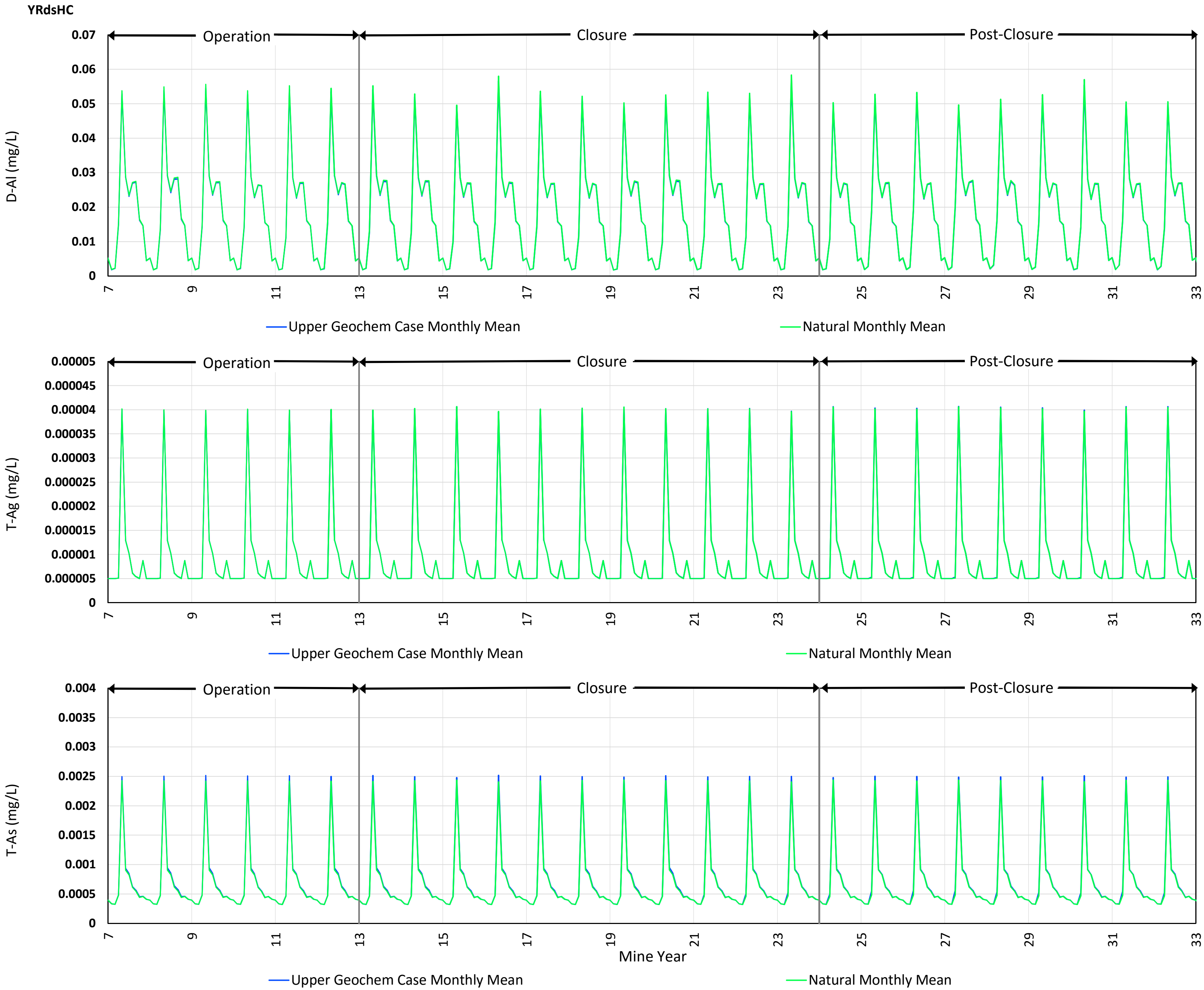
YRdsCC
Operation
Closure
Post-Closure
T-Zn (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean

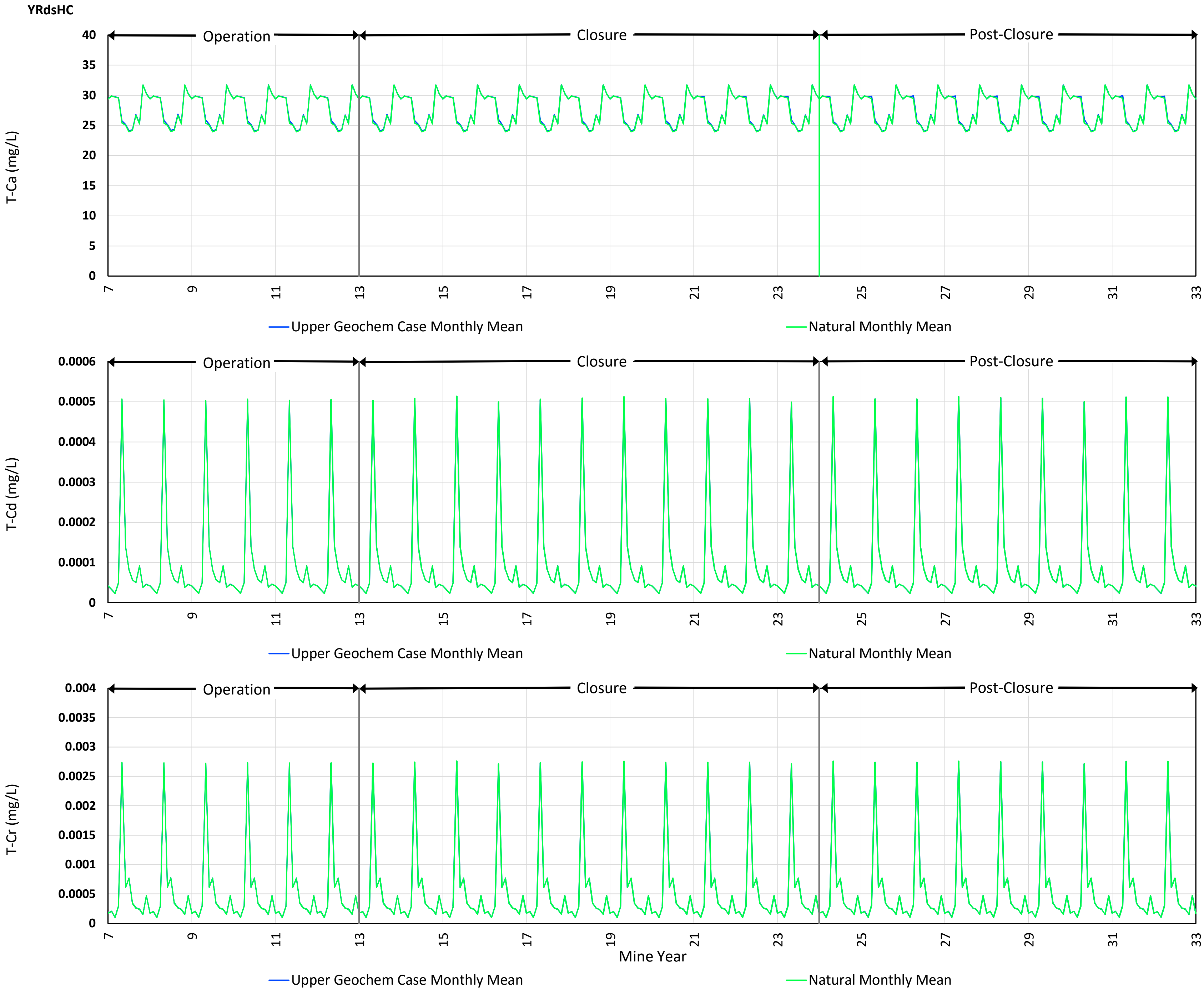

YRdsHC
Operation
Closure
Post-Closure
NH3-N (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
NO3-N (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
NO2-N (mg/L)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
Mine Year

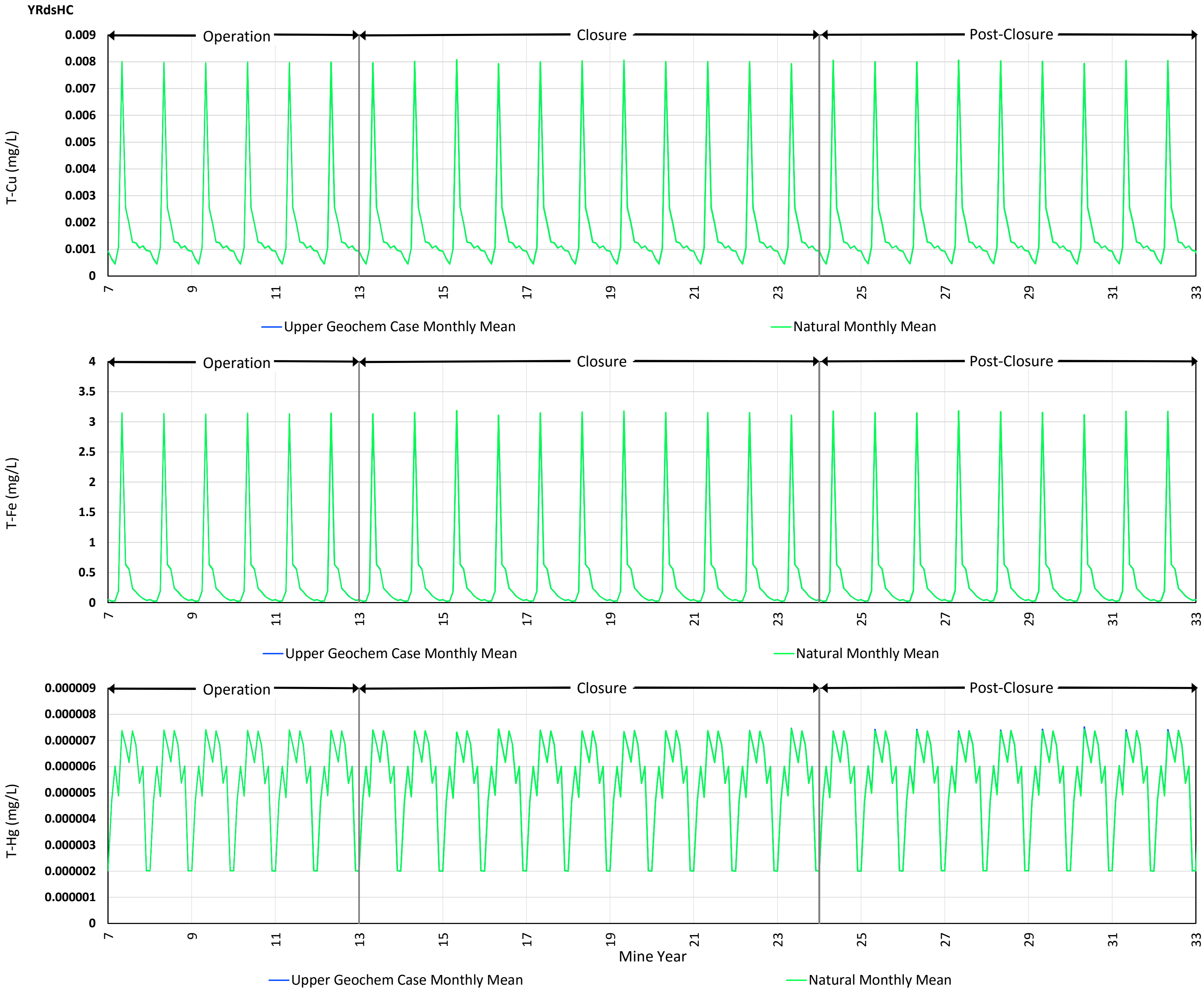

YRdsHC
Operation
Closure
Post-Closure
SO4 (mg/L)
0
5
10
15
20
25
30
35
40
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean


Operation
Closure
Post-Closure
T-P (mg/L)
0
0.05
0.1
0.15
0.2
0.25
0.3
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean

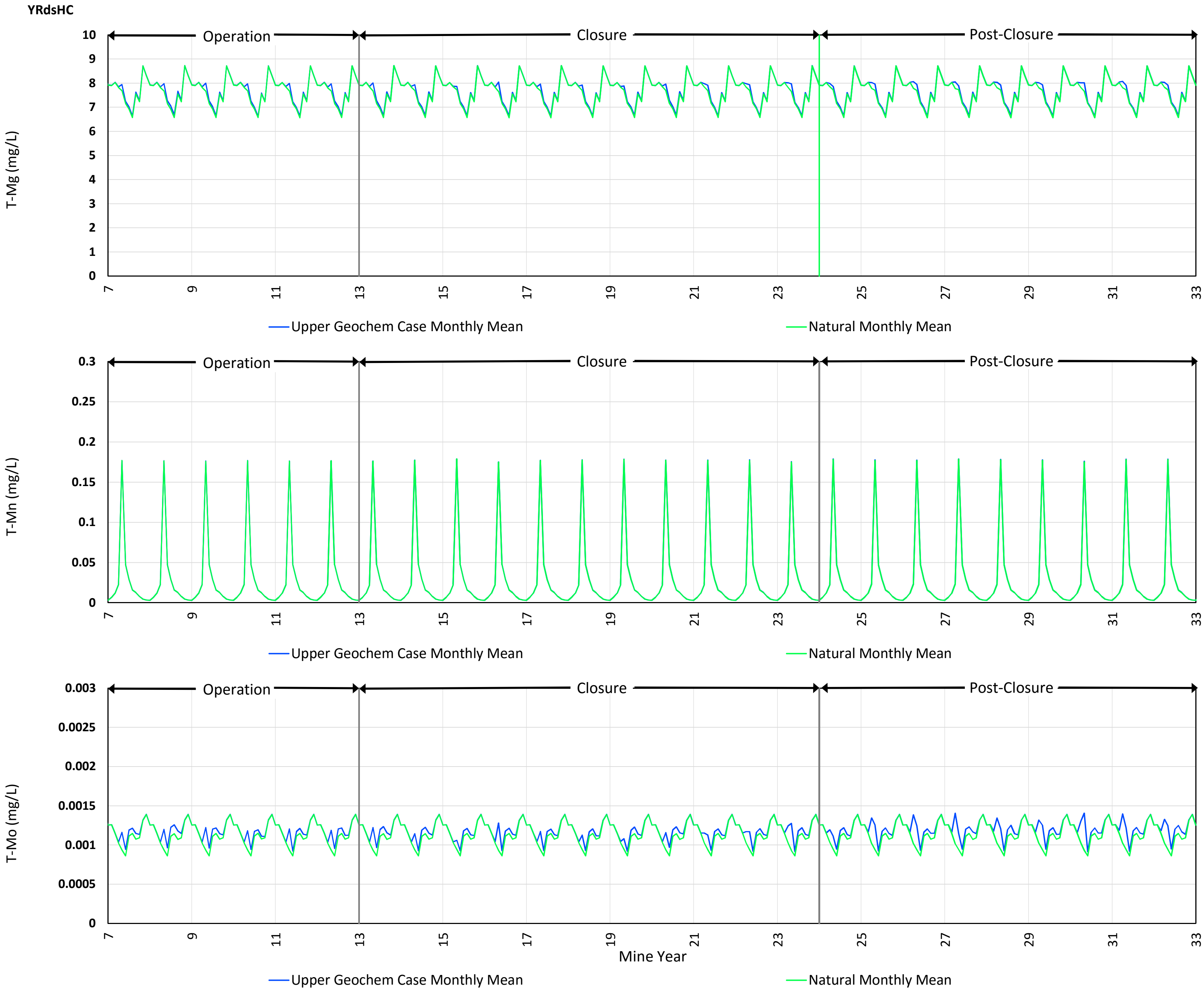

Operation
Closure
Post-Closure
WAD-CN (mg/L)
0
0.0001
0.0002
0.0003
0.0004
0.0005
0.0006
0.0007
0.0008
0.0009
0.001
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean


YRdsHC
Operation
Closure
Post-Closure
D-Al (mg/L)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Ag (mg/L)
0.00005
0.000045
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
0
T-As (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
Mine Year

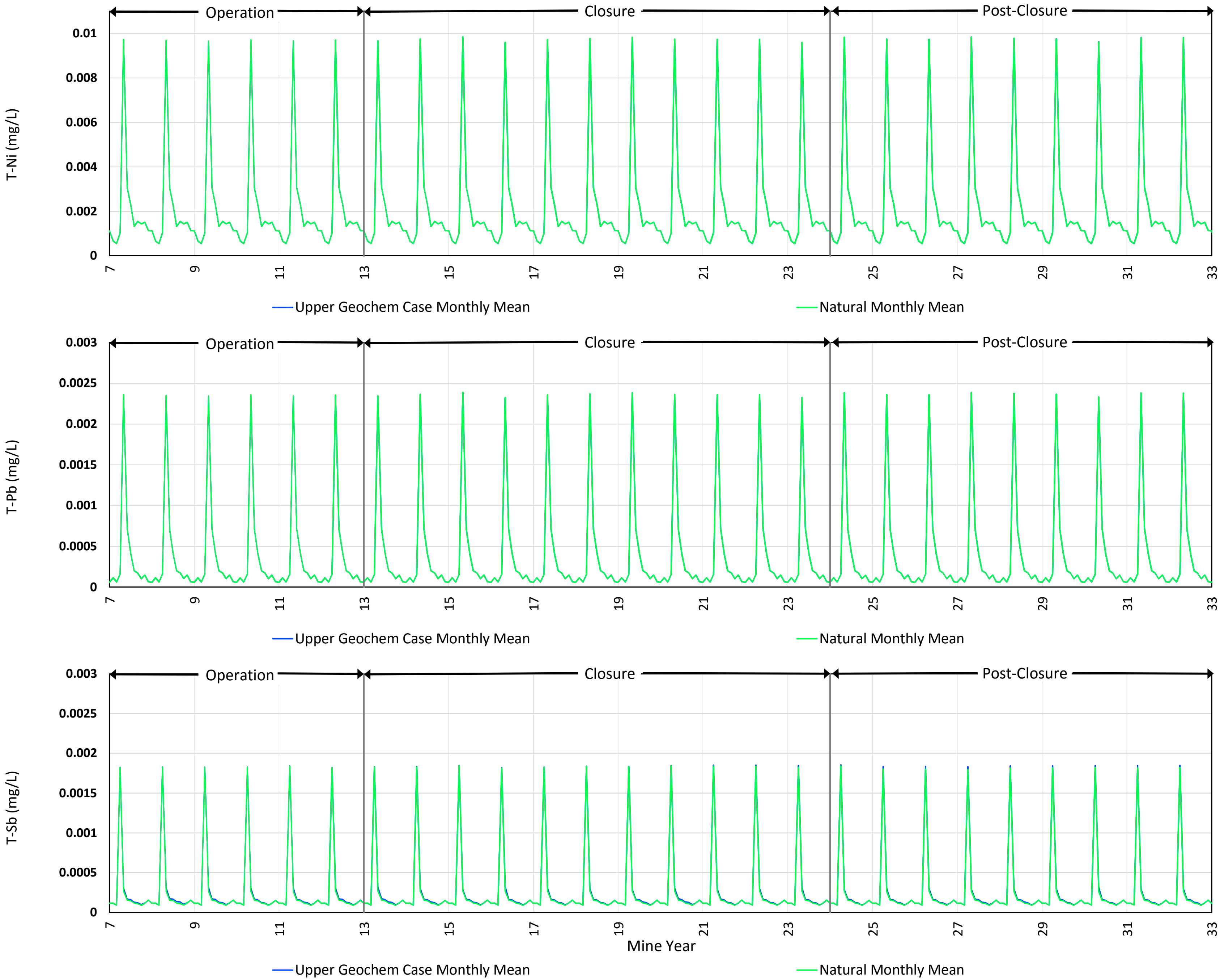

YRdsHC
Operation
Closure
Post-Closure
T-Ca (mg/L)
40
35
30
25
20
15
10
5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Cd (mg/L)
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
T-Cr (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
Mine Year

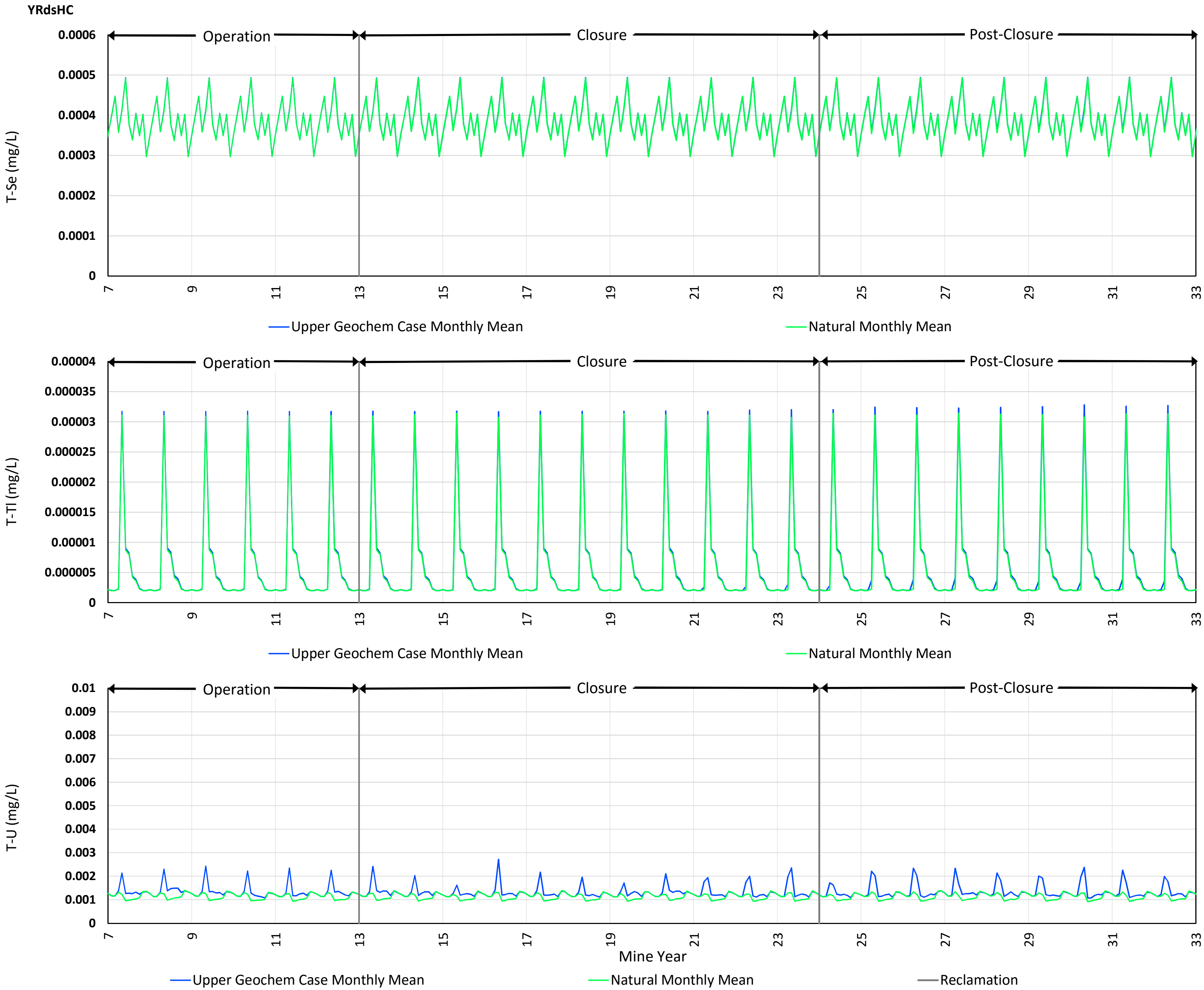


YRdsHC
Operation
Closure
Post-Closure
T-Cu (mg/L)
T-Fe (mg/L)
T-Hg (mg/L)
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean

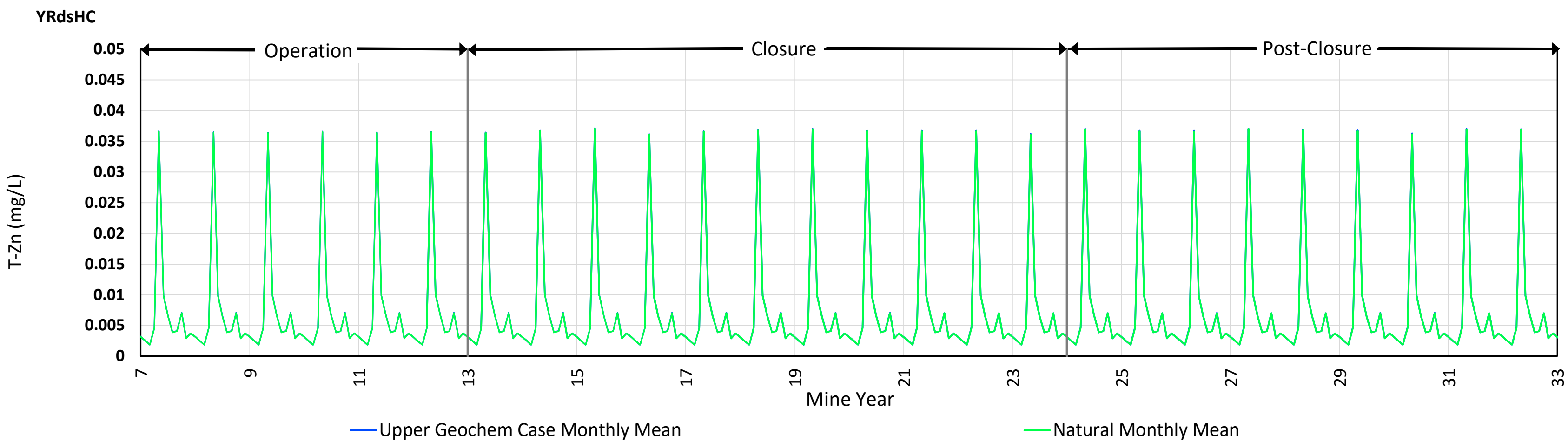

YRdsHC
Operation
Closure
Post-Closure
T-Mg (mg/L)
T-Mn (mg/L)
T-Mo (mg/L)
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean

YRdsHC

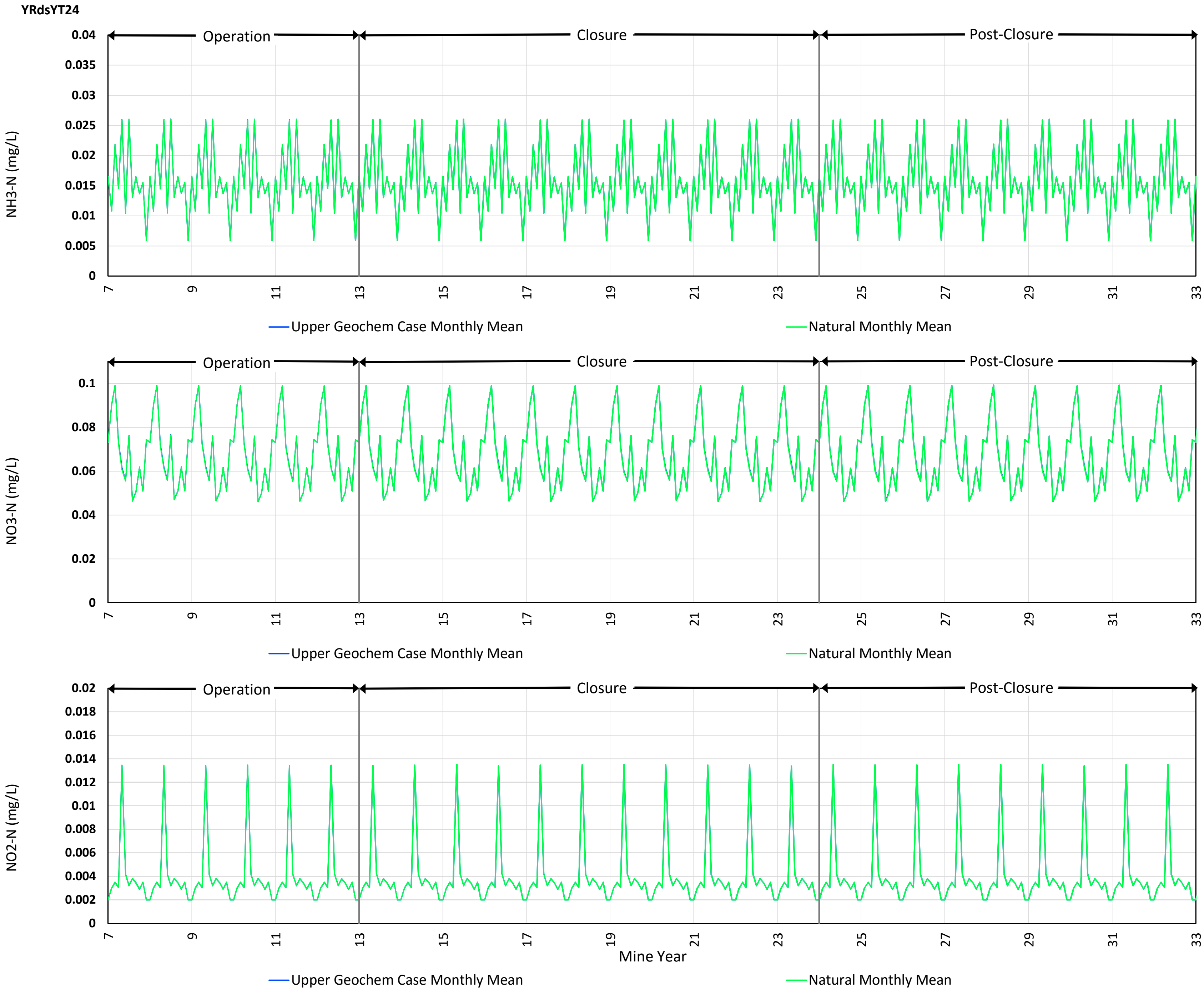

Operation
Closure
Post-Closure
T-Ni (mg/L)
0.01
0.008
0.006
0.004
0.002
0
T-Pb (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
T-Sb (mg/L)
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean

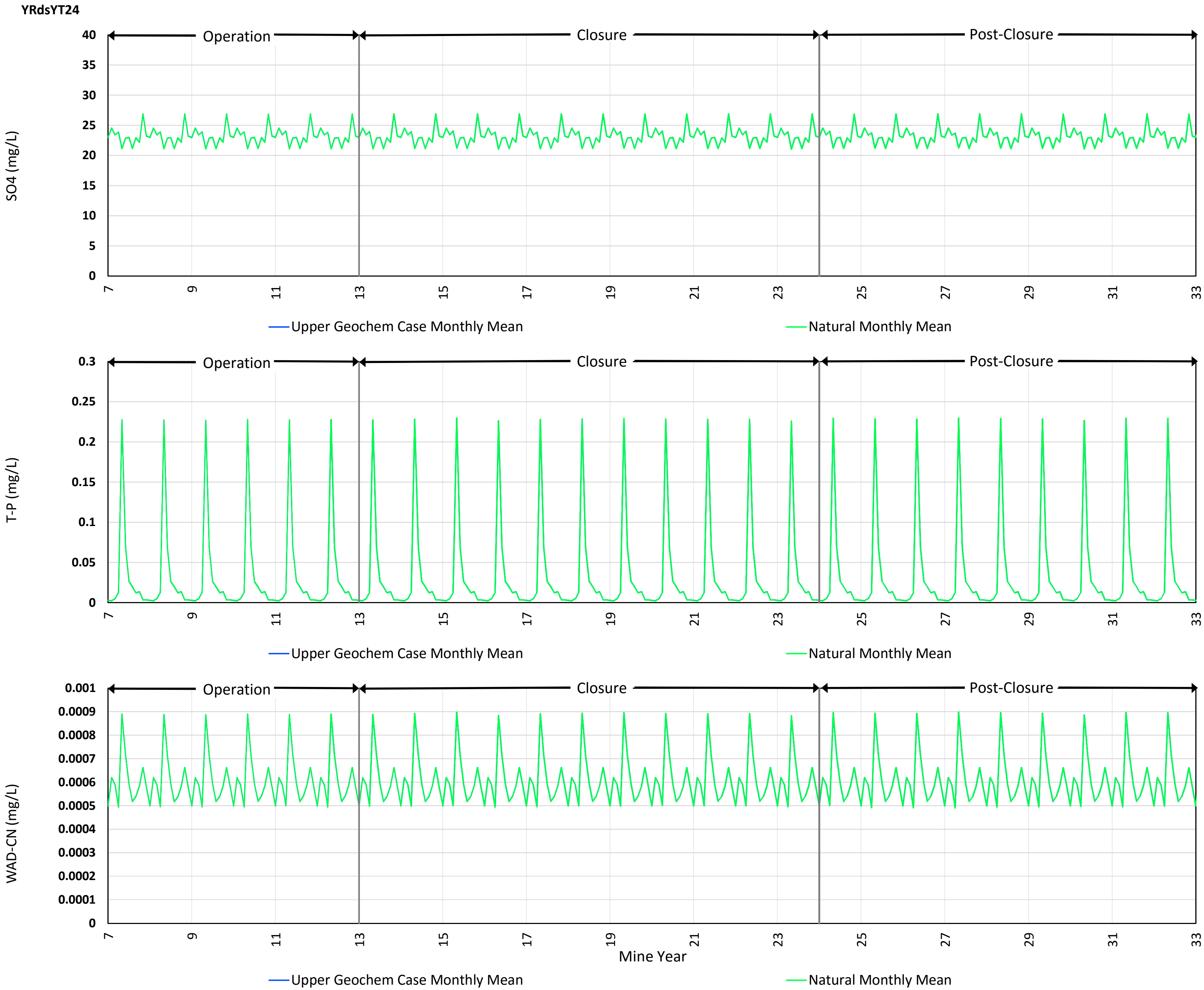


YRdsHC
Operation
Closure
Post-Closure
T-Se (mg/L)
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Tl (mg/L)
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
T-U (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
Mine Year
Reclamation



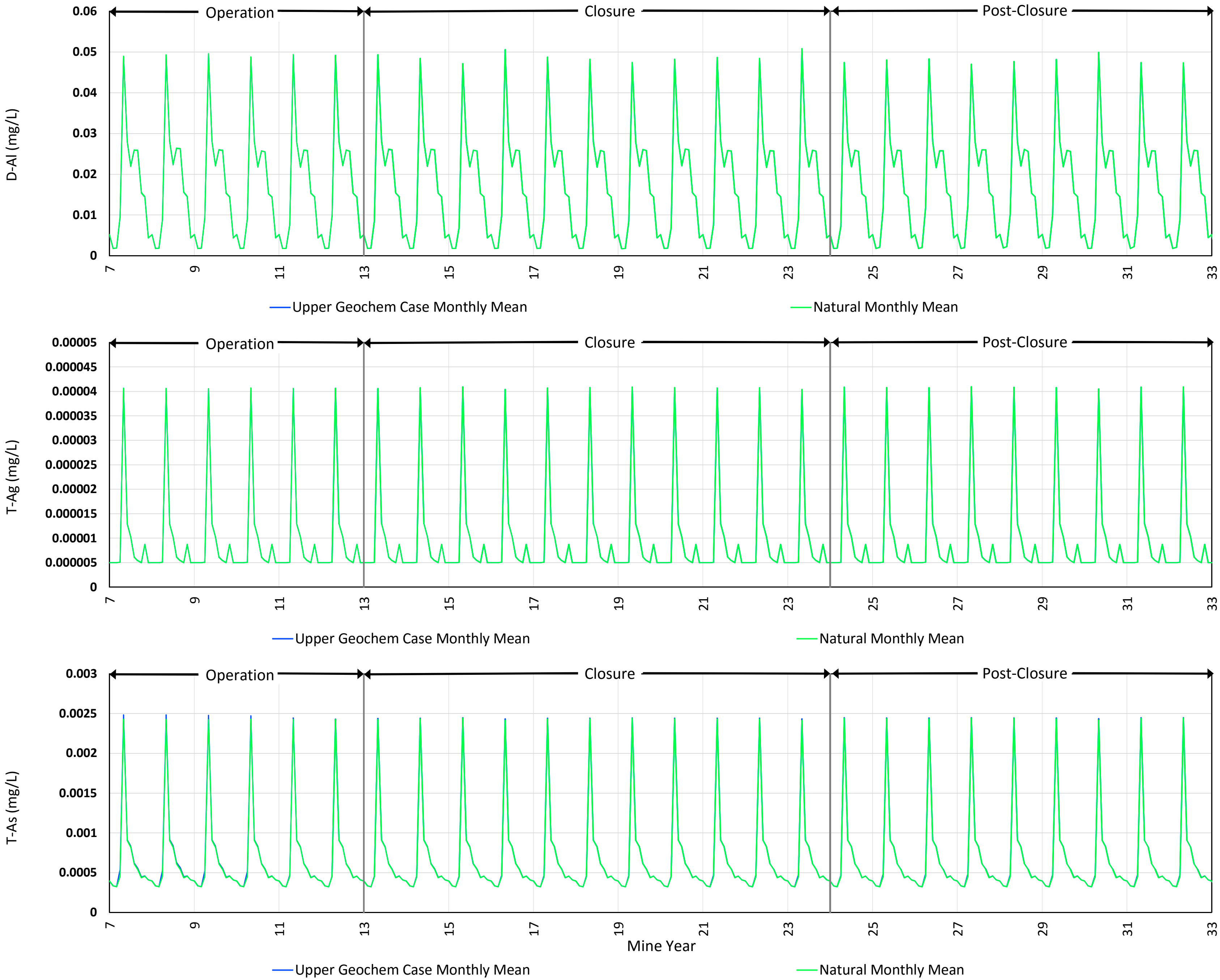
YRdsHC
Operation
Closure
Post-Closure
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
T-Zn (mg/L)
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean


YRdsYT24
Operation
Closure
Post-Closure
NH3-N (mg/L)
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
NO3-N (mg/L)
0.1
0.08
0.06
0.04
0.02
0
NO2-N (mg/L)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
Mine Year



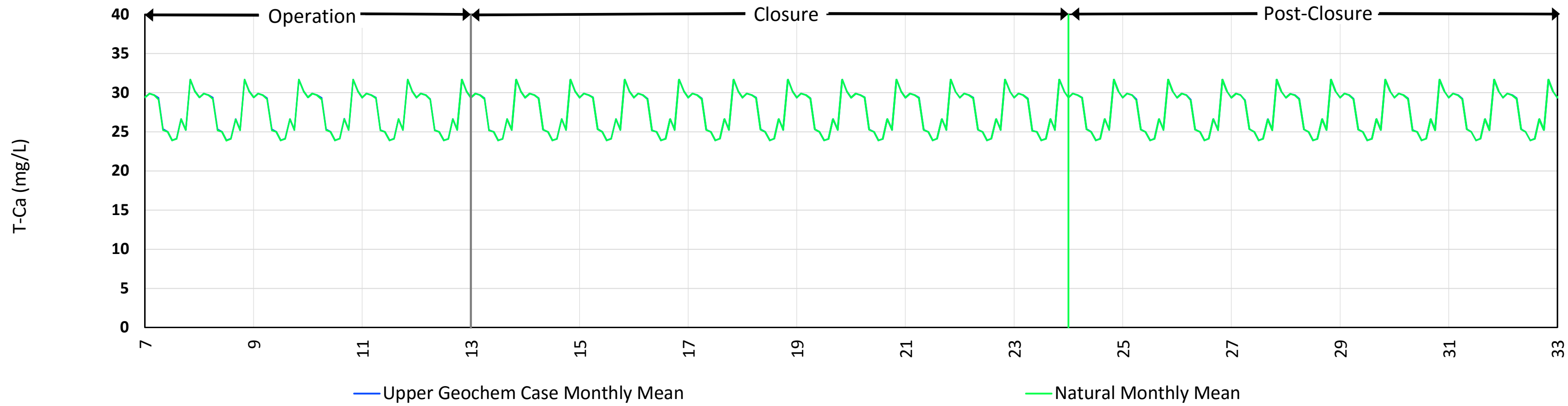
YRdsYT24
Operation
Closure
Post-Closure
SO4 (mg/L)
40
35
30
25
20
15
10
5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
Operation
Closure
Post-Closure
T-P (mg/L)
0.3
0.25
0.2
0.15
0.1
0.05
0
Upper Geochem Case Monthly Mean
Natural Monthly Mean
Operation
Closure
Post-Closure
WAD-CN (mg/L)
0.001
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean

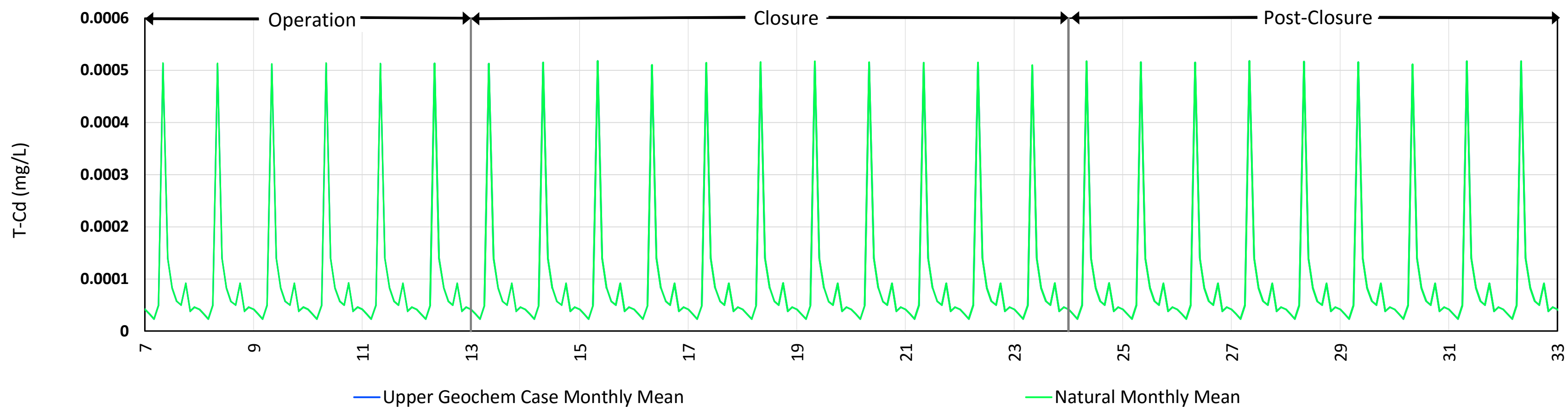
YRdsYT24

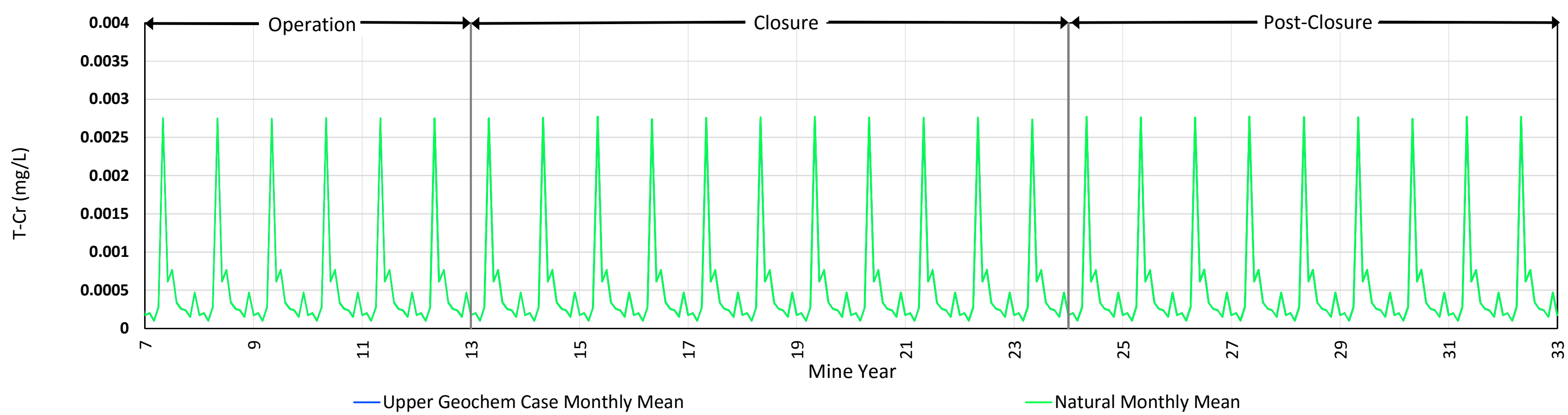


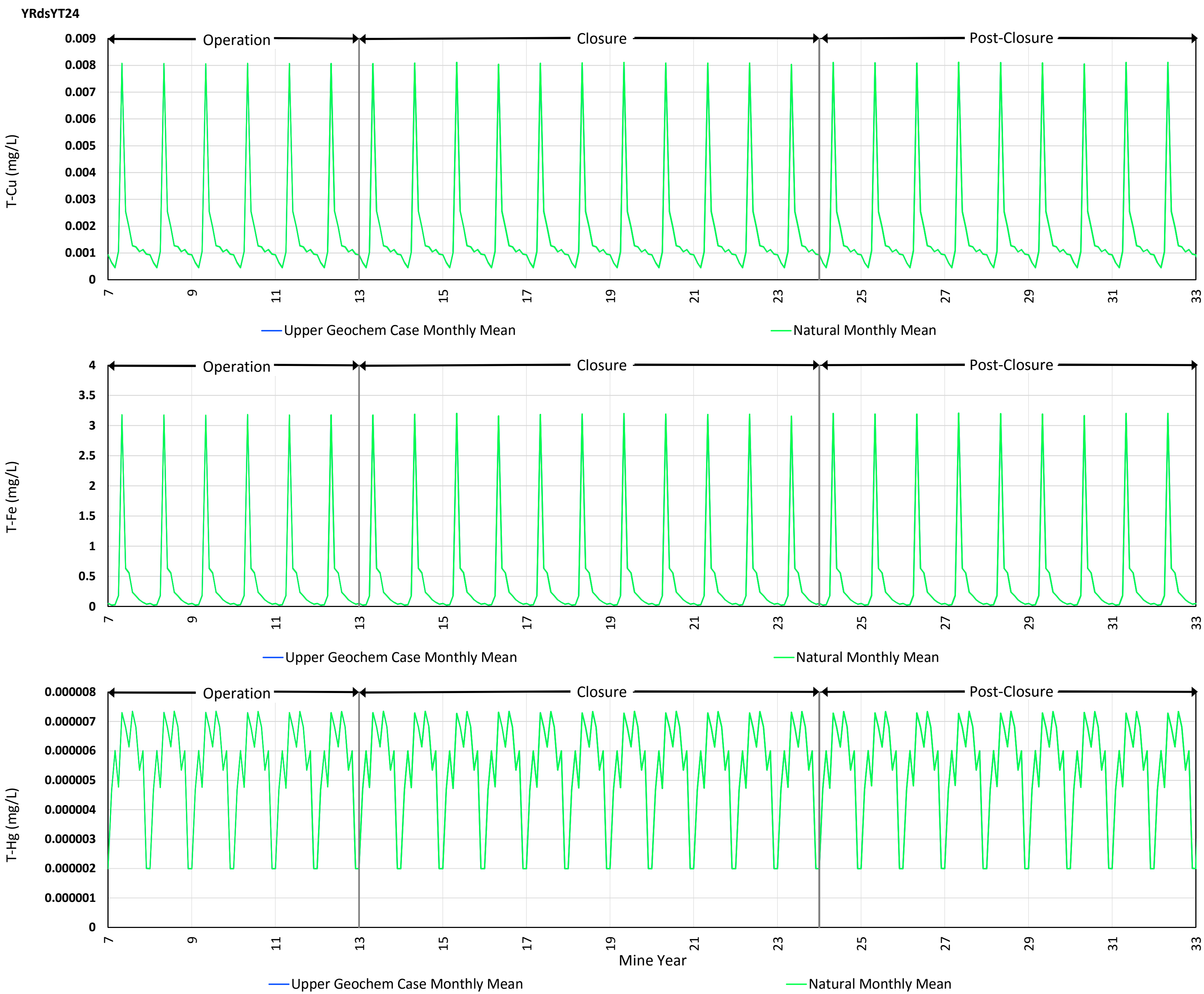
Operation
Closure
Post-Closure
D-Al (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
Operation
Closure
Post-Closure
T-Ag (mg/L)
0.00005
0.000045
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
0
Upper Geochem Case Monthly Mean
Natural Monthly Mean
Operation
Closure
Post-Closure
T-As (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean

YRdsYT24

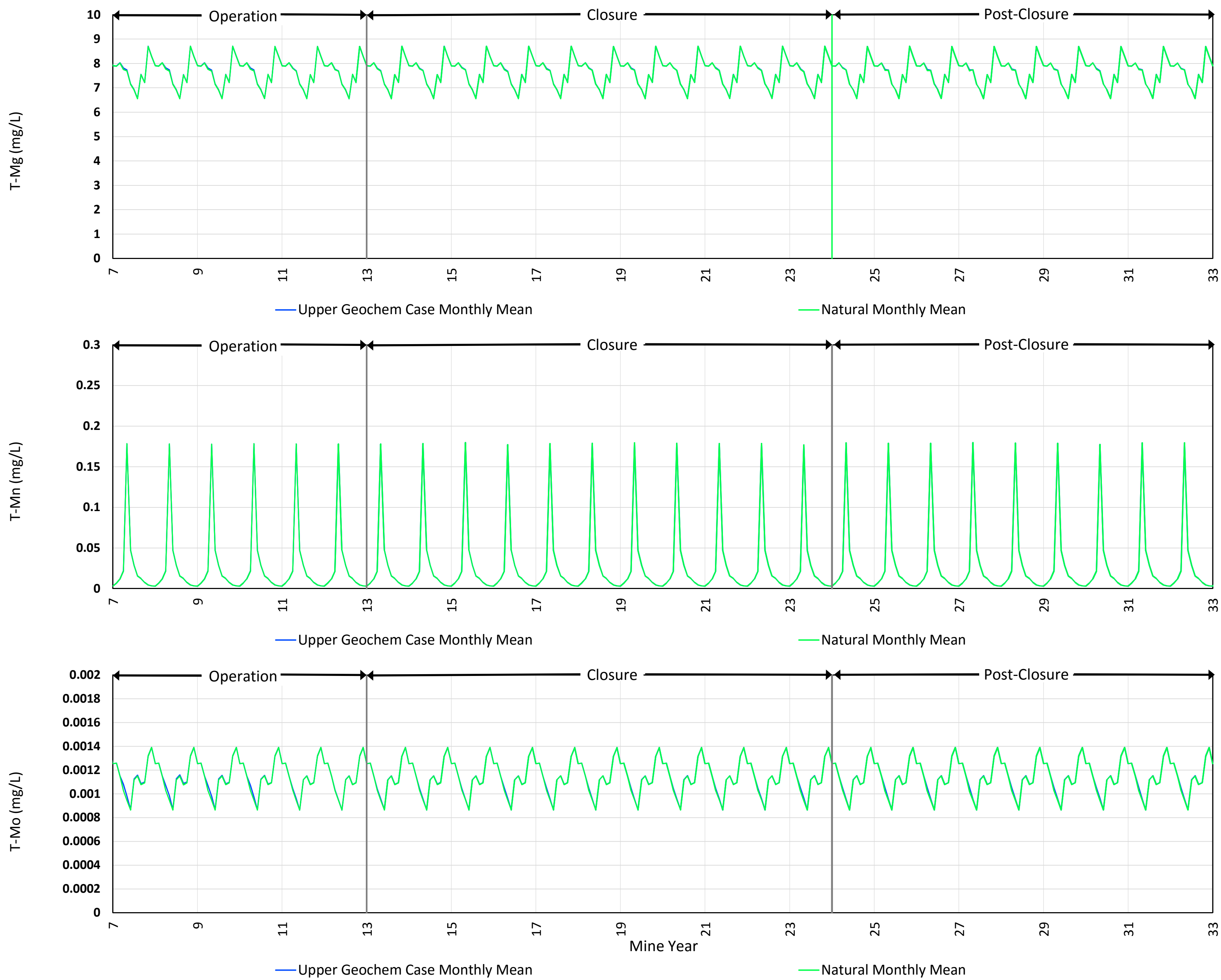

Operation
Closure
Post-Closure
T-Ca (mg/L)
40
35
30
25
20
15
10
5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean


Operation
Closure
Post-Closure
T-Cd (mg/L)
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean


Operation
Closure
Post-Closure
T-Cr (mg/L)
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean

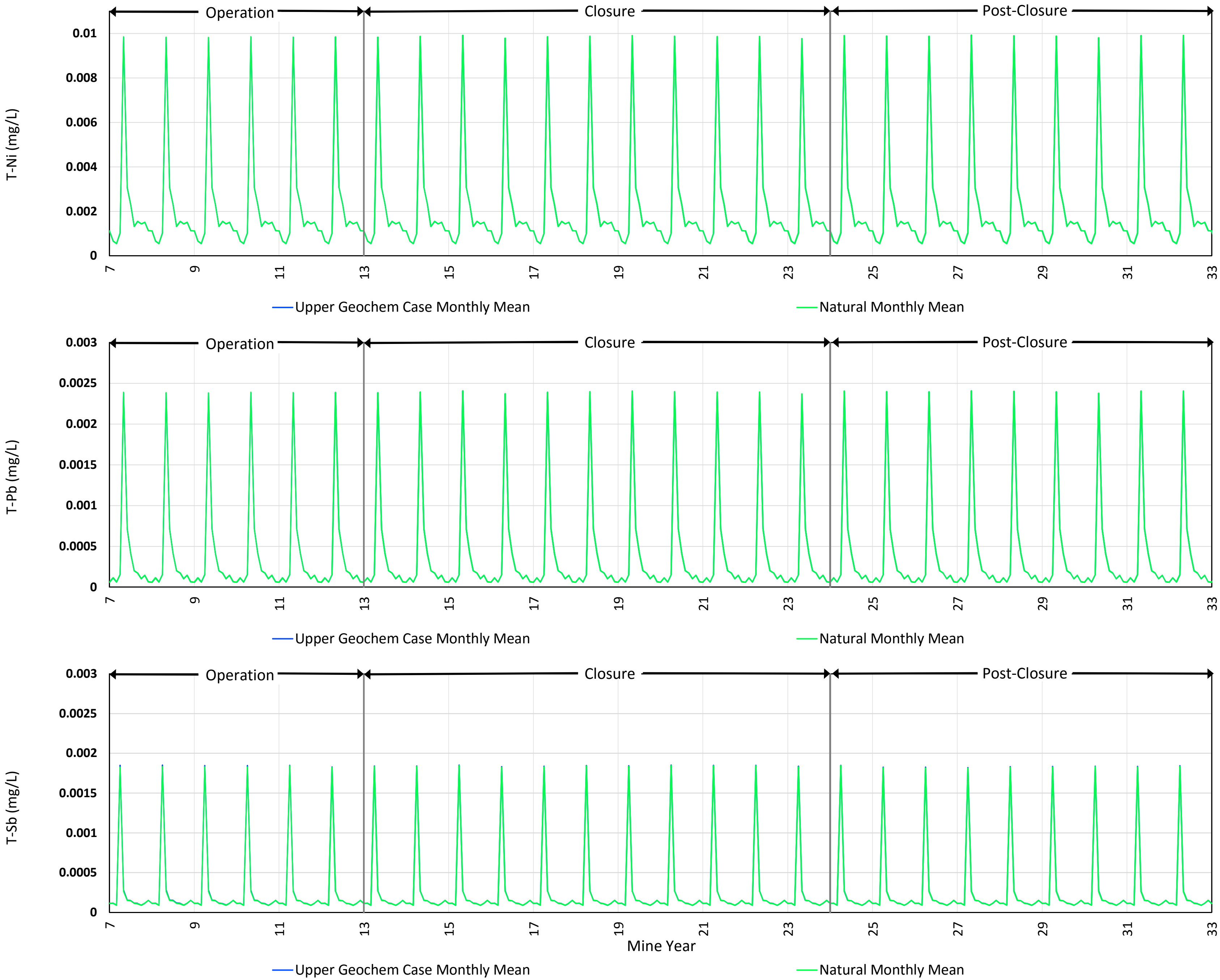

YRdsYT24
Operation
Closure
Post-Closure
T-Cu (mg/L)
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Fe (mg/L)
4
3.5
3
2.5
2
1.5
1
0.5
0
T-Hg (mg/L)
0.000008
0.000007
0.000006
0.000005
0.000004
0.000003
0.000002
0.000001
0
Mine Year

YRdsYT24

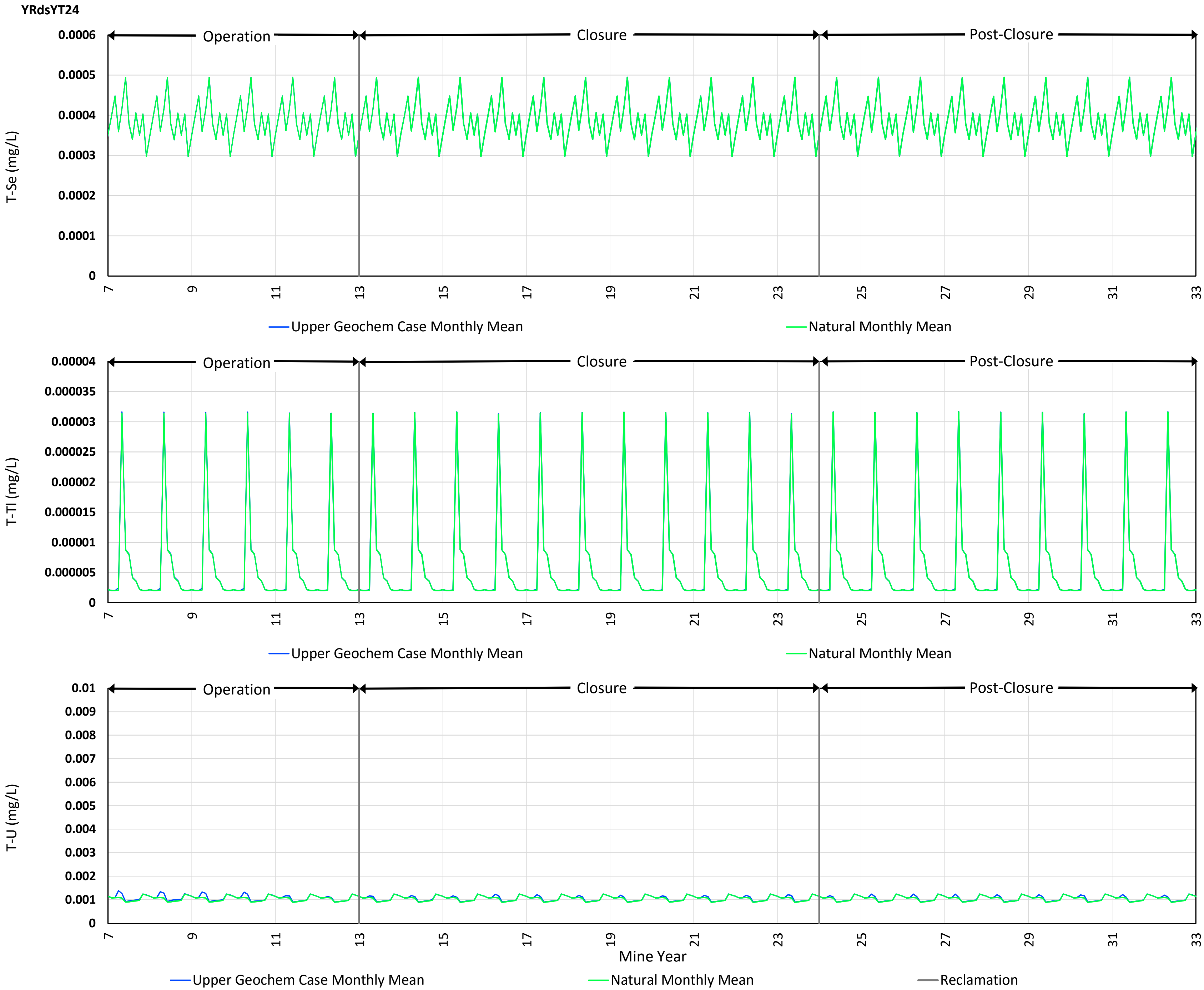


Operation
Closure
Post-Closure
T-Mg (mg/L)
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Mn (mg/L)
T-Mo (mg/L)
Mine Year

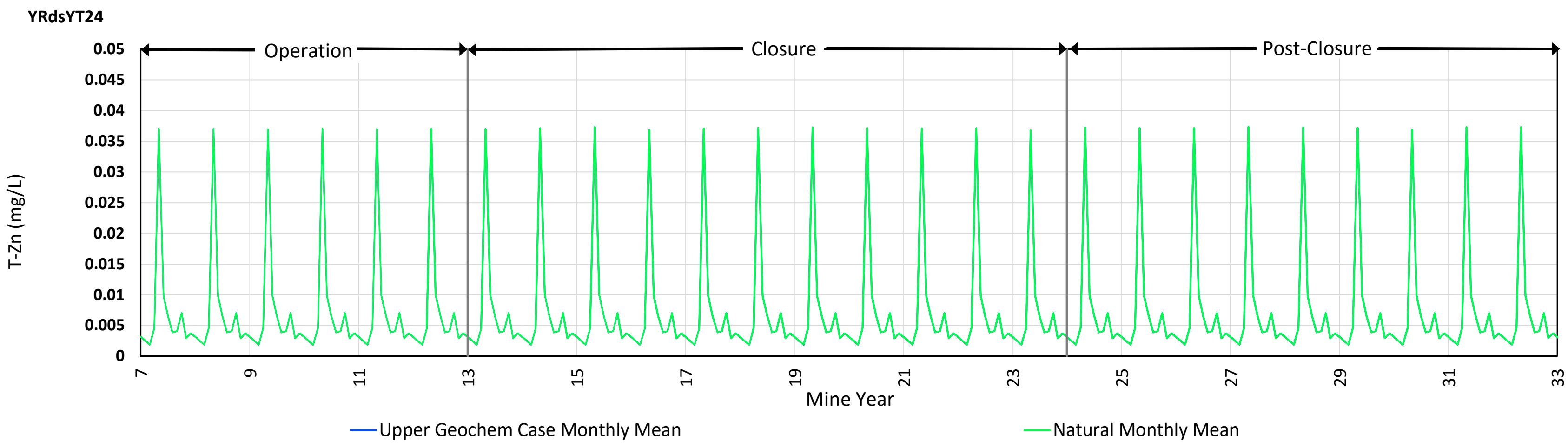
YRdsYT24



Operation
Closure
Post-Closure
T-Ni (mg/L)
0.01
0.008
0.006
0.004
0.002
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Pb (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
T-Sb (mg/L)
Mine Year

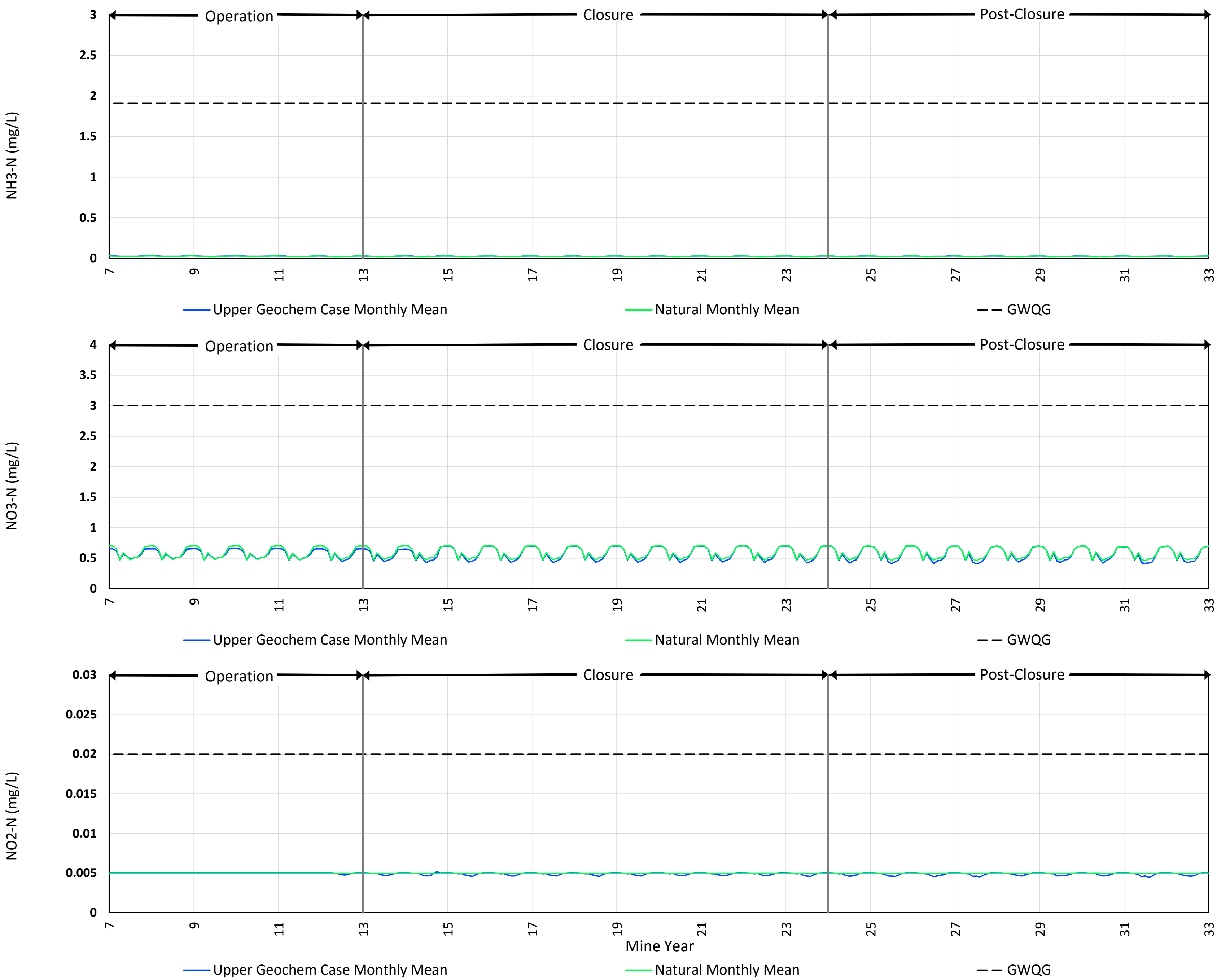


YRdsYT24
Operation
Closure
Post-Closure
T-Se (mg/L)
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Tl (mg/L)
0.00004
0.000035
0.00003
0.000025
0.00002
0.000015
0.00001
0.000005
T-U (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
Mine Year
Reclamation

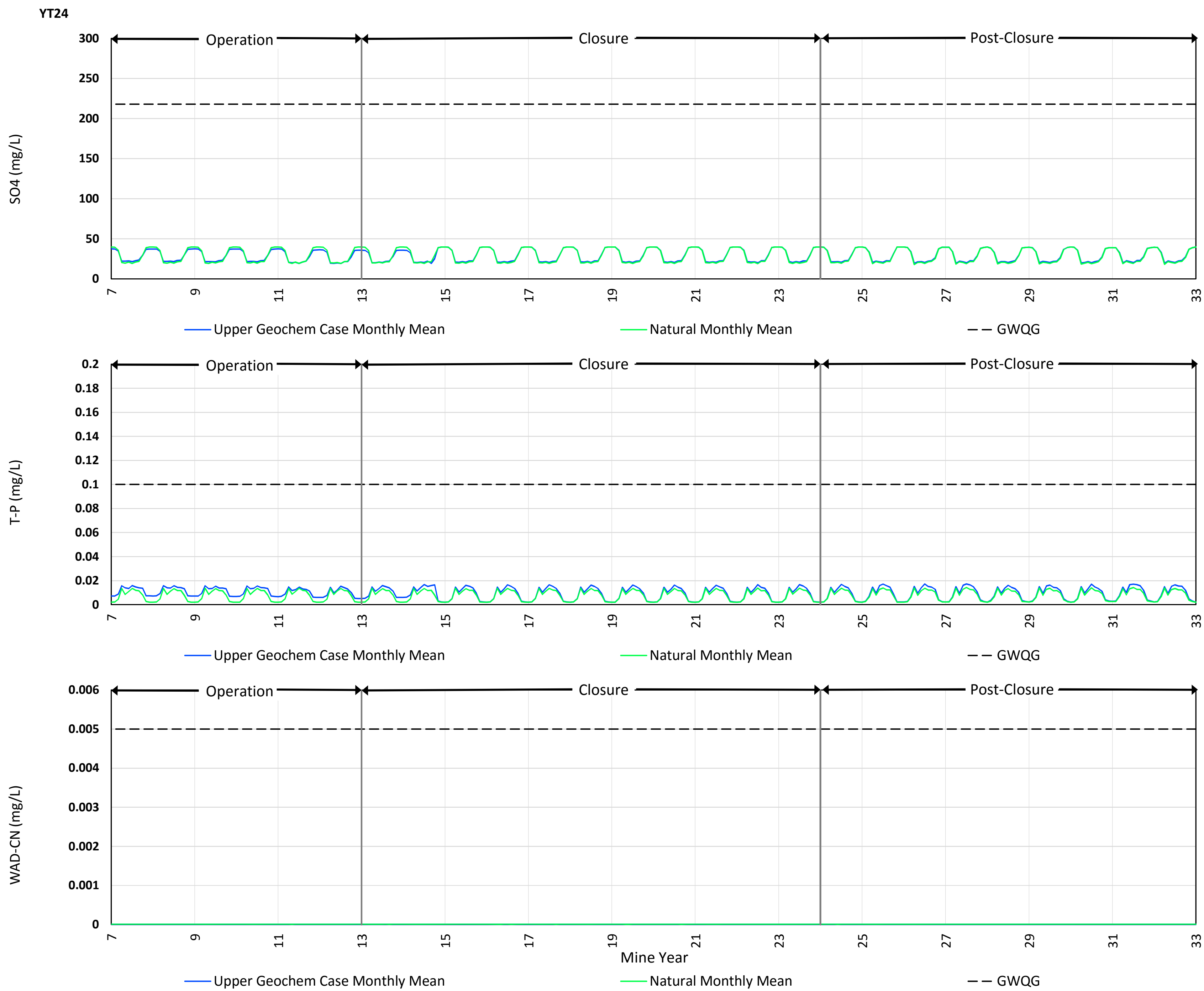


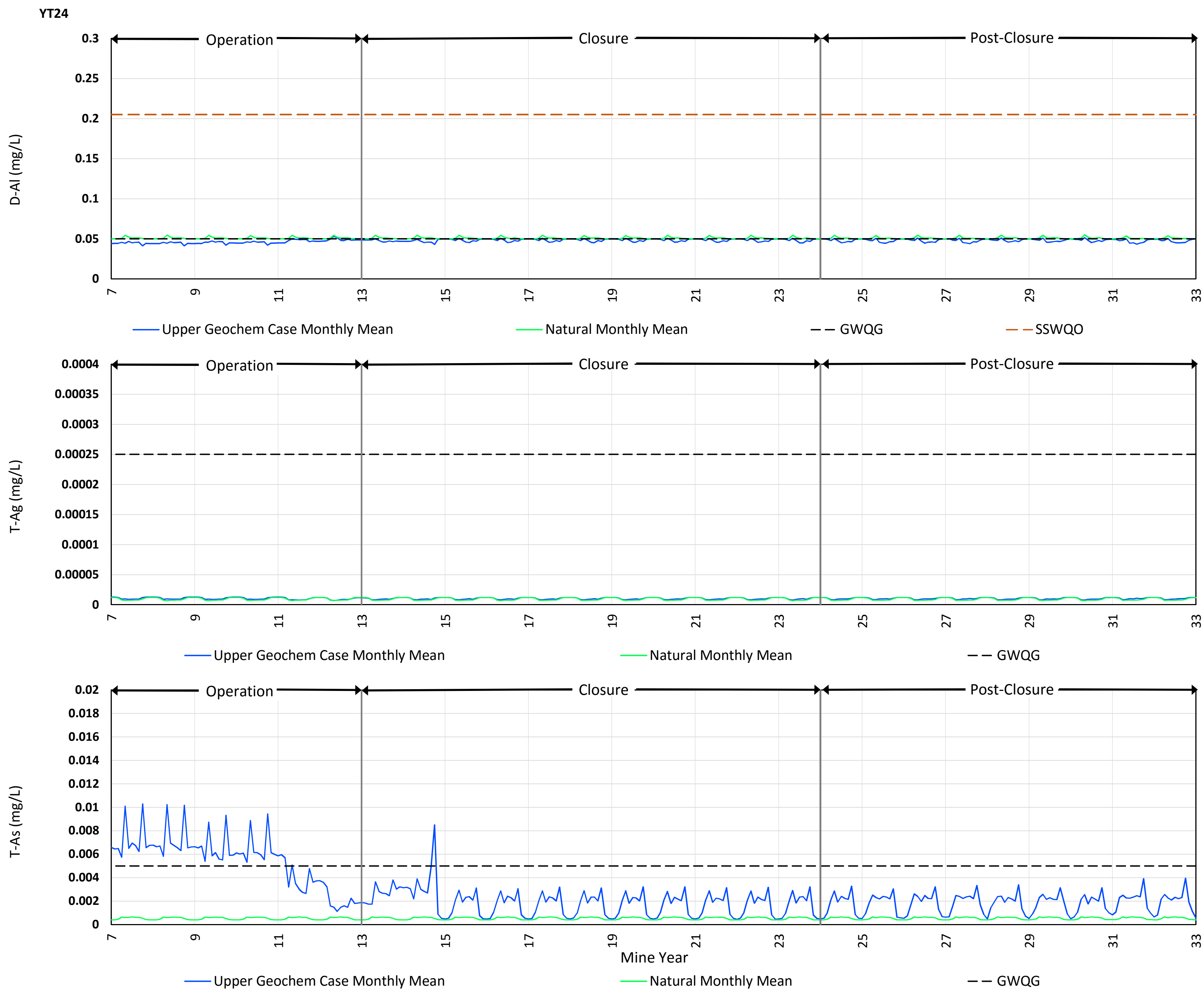
YRdsYT24
Operation
Closure
Post-Closure
T-Zn (mg/L)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean

YT24

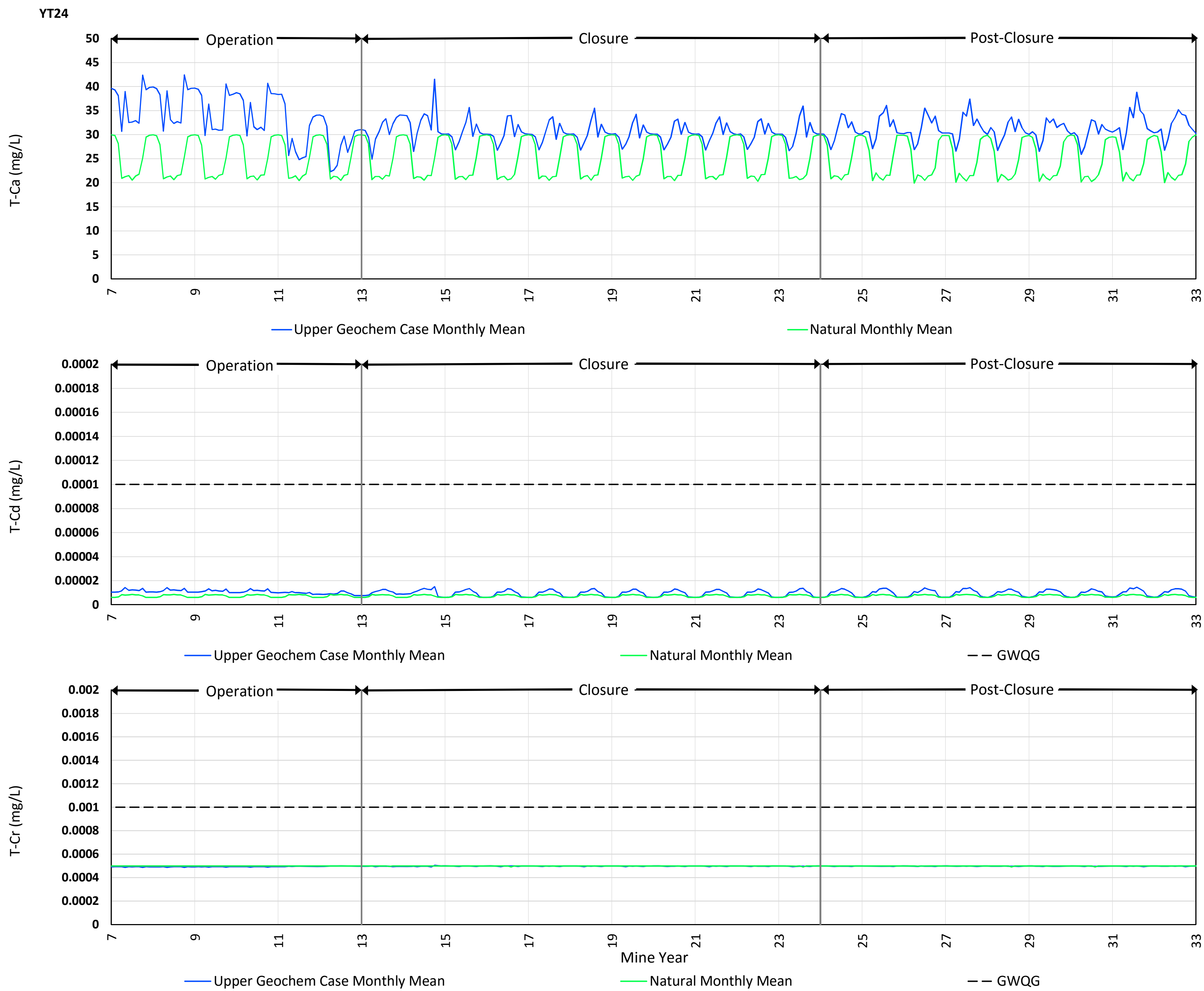


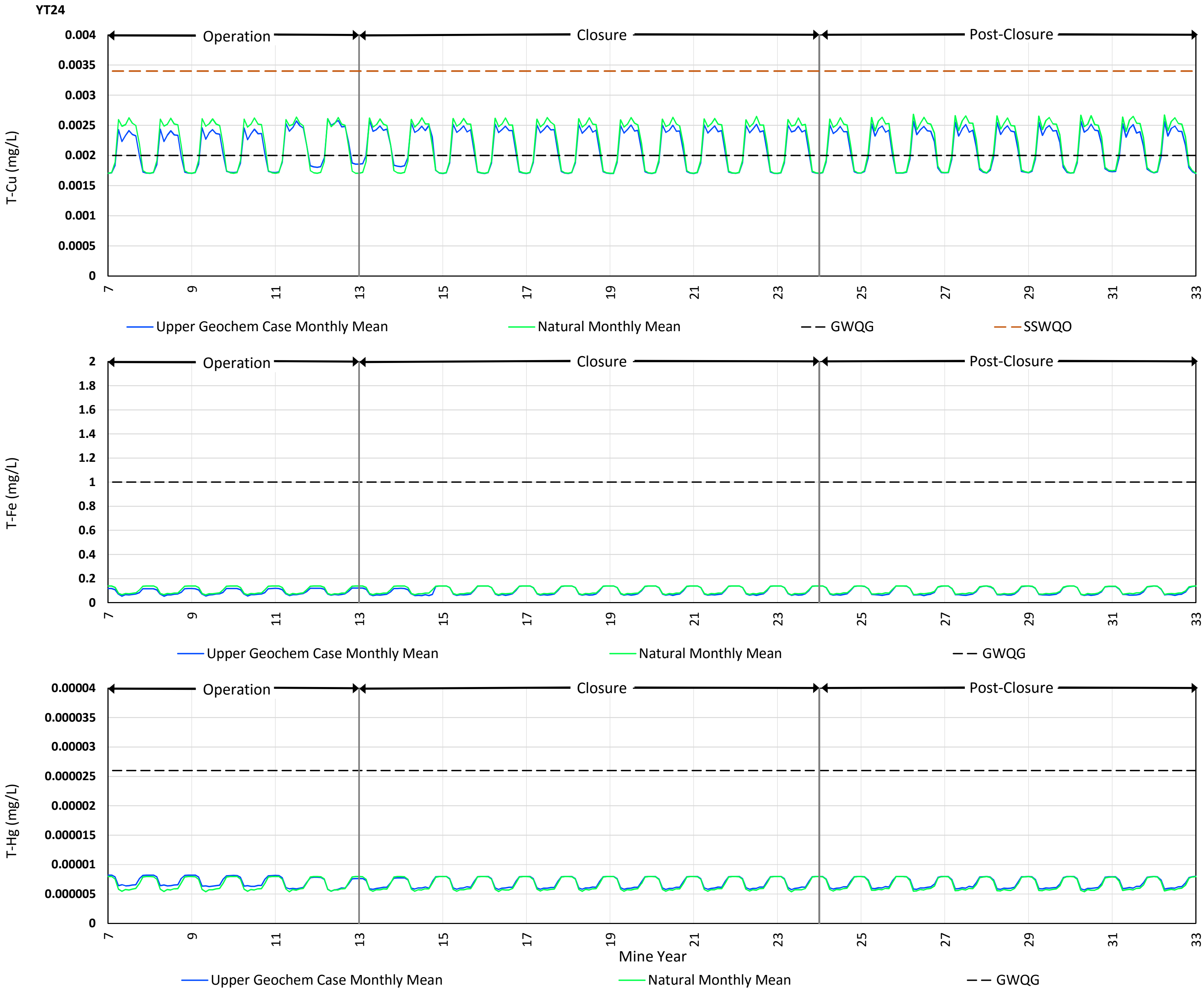
Operation
Closure
Post-Closure
NH3-N (mg/L)
NO3-N (mg/L)
NO2-N (mg/L)
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG


YT24
Operation
Closure
Post-Closure
SO4 (mg/L)
300
250
200
150
100
50
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
T-P (mg/L)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
WAD-CN (mg/L)
0.006
0.005
0.004
0.003
0.002
0.001
0
Mine Year

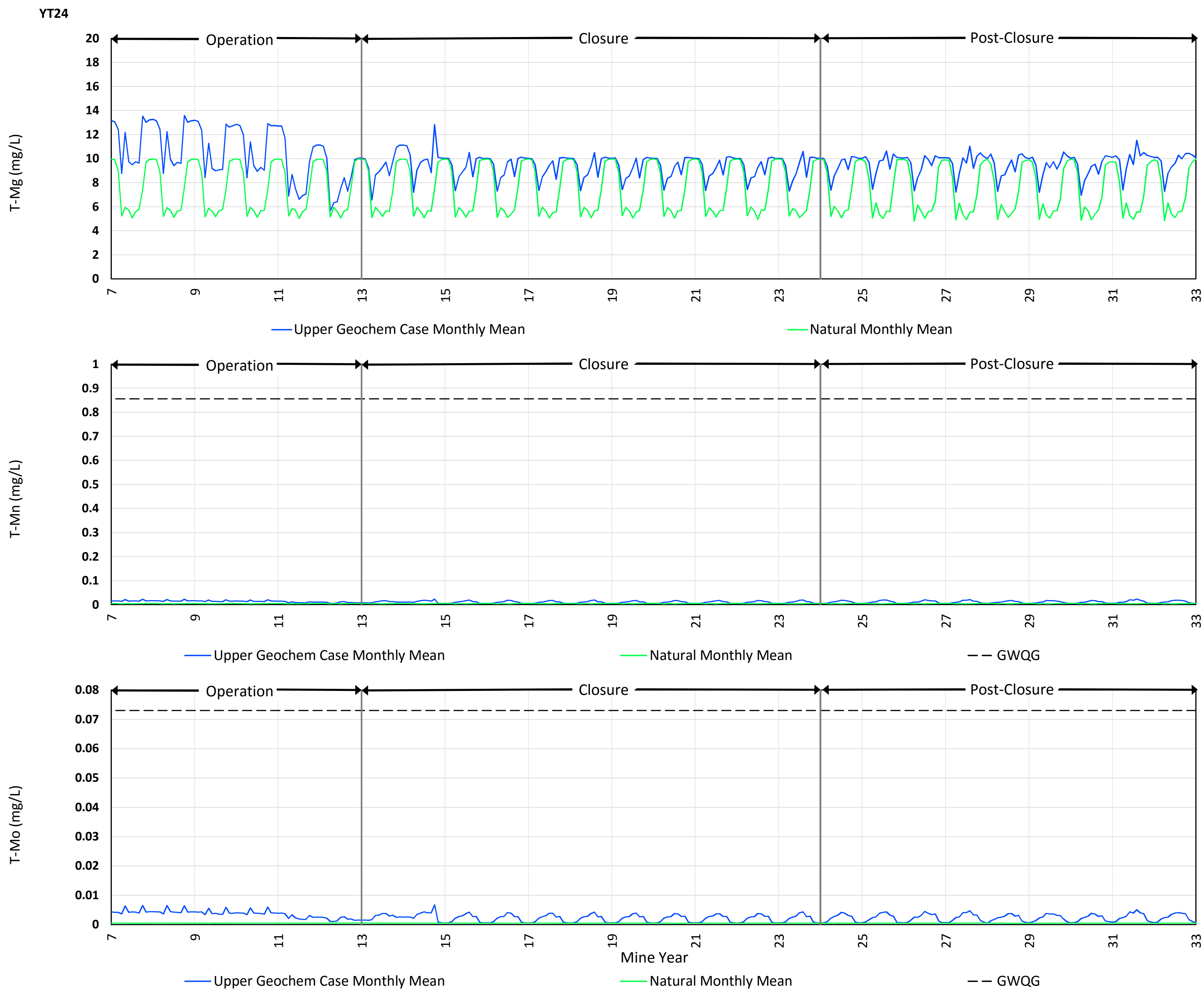


YT24
Operation
Closure
Post-Closure
D-Al (mg/L)
0.3
0.25
0.2
0.15
0.1
0.05
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Ag (mg/L)
0.0004
0.00035
0.0003
0.00025
0.0002
0.00015
0.0001
0.00005
0
T-As (mg/L)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Mine Year

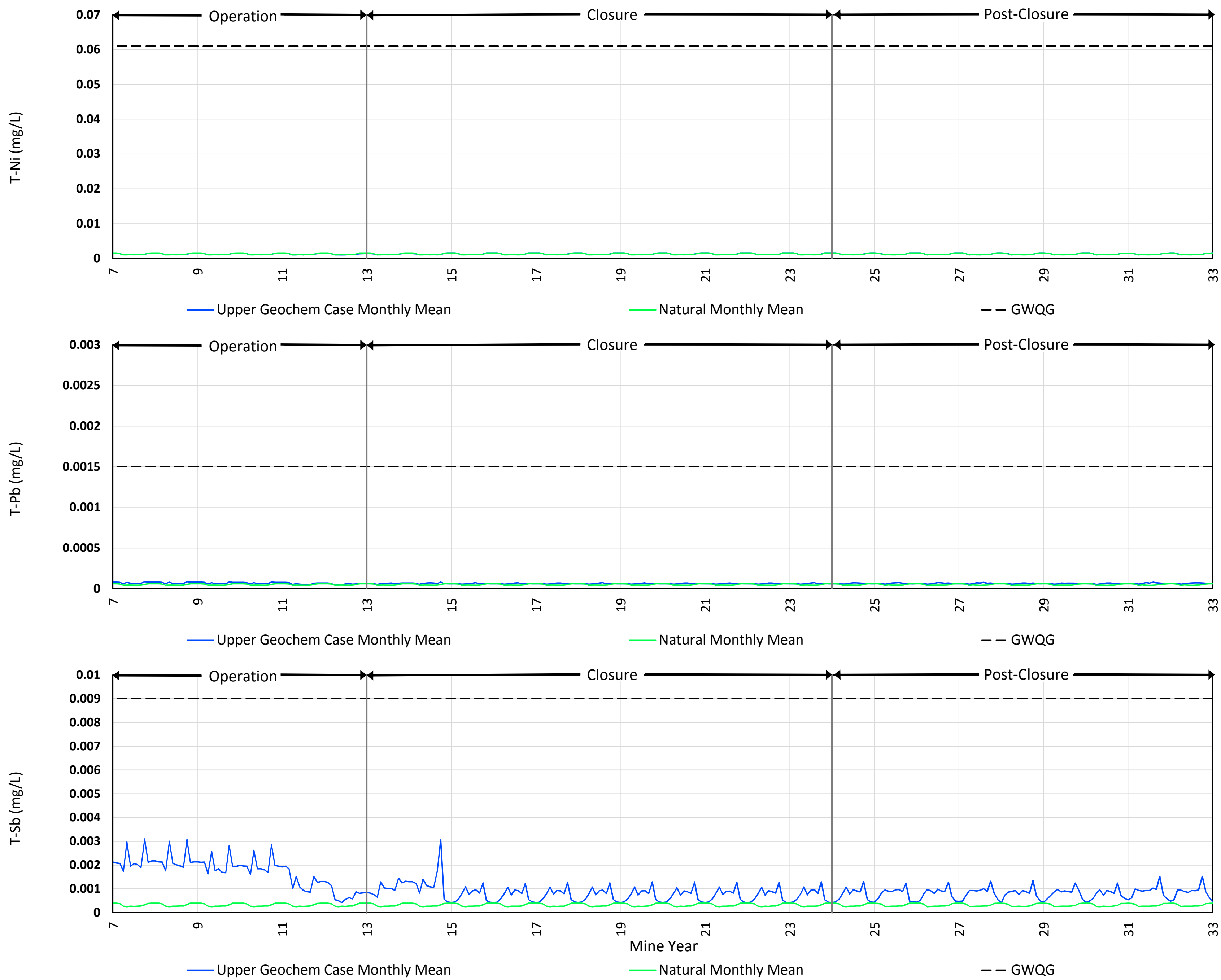

YT24
Operation
Closure
Post-Closure
T-Ca (mg/L)
50
45
40
35
30
25
20
15
10
5
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Cd (mg/L)
0.0002
0.00018
0.00016
0.00014
0.00012
0.0001
0.00008
0.00006
0.00004
0.00002
0
GWQG
T-Cr (mg/L)
0.002
0.0018
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
Mine Year



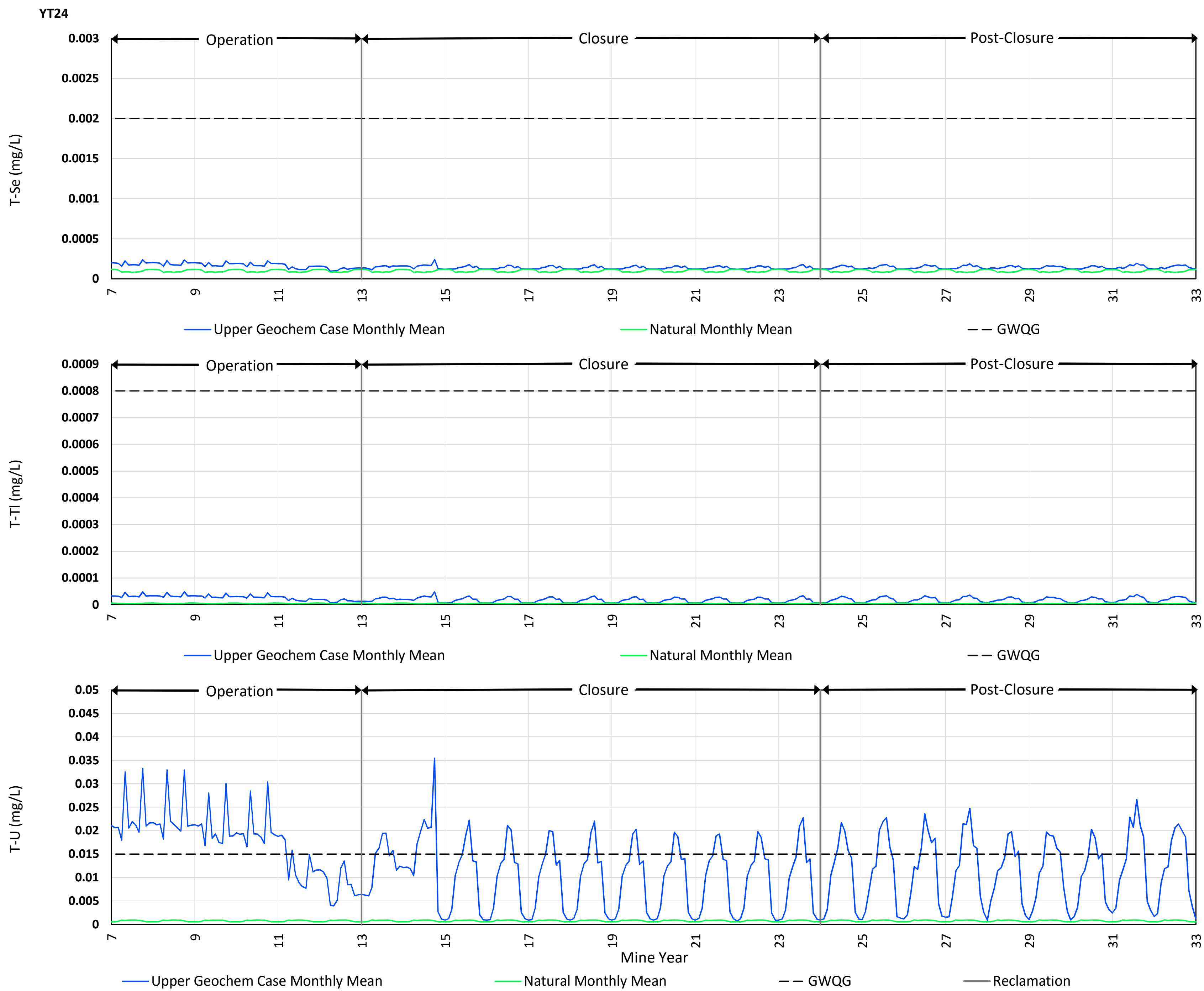
YT24
Operation
Closure
Post-Closure
T-Cu (mg/L)
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
SSWQO
T-Fe (mg/L)
T-Hg (mg/L)
Mine Year

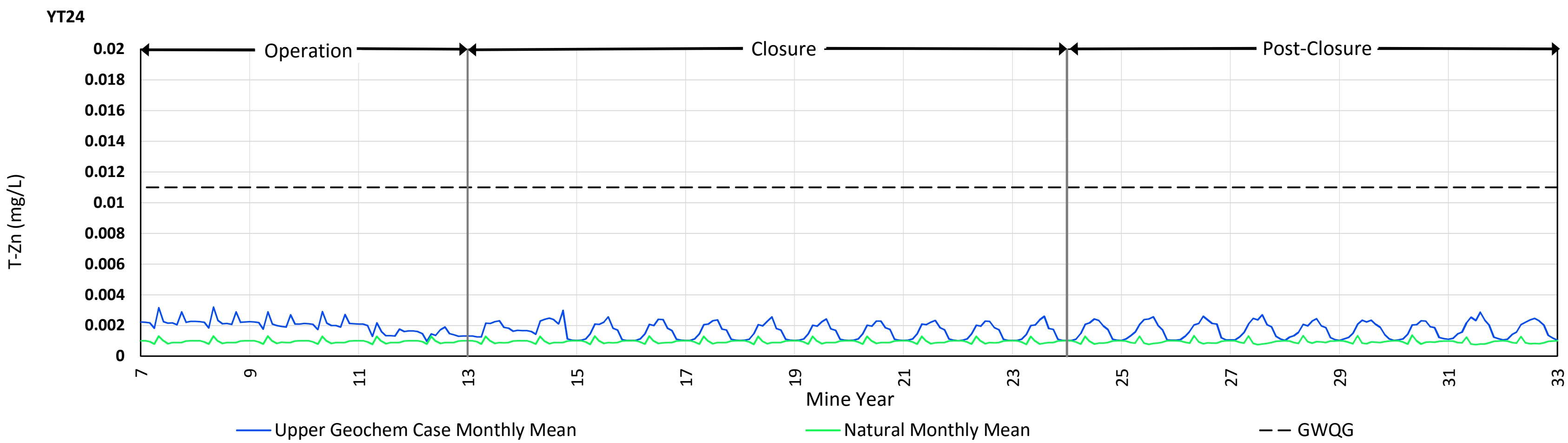

YT24
Operation
Closure
Post-Closure
T-Mg (mg/L)
Upper Geochem Case Monthly Mean
Natural Monthly Mean
T-Mn (mg/L)
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
T-Mo (mg/L)
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG

YT24



Operation
Closure
Post-Closure
T-Ni (mg/L)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
T-Pb (mg/L)
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
Operation
Closure
Post-Closure
T-Sb (mg/L)
0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG


YT24
Operation
Closure
Post-Closure
T-Se (mg/L)
T-Tl (mg/L)
T-U (mg/L)
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG
Reclamation


YT24
Operation
Closure
Post-Closure
T-Zn (mg/L)
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
7
9
11
13
15
17
19
21
23
25
27
29
31
33
Mine Year
Upper Geochem Case Monthly Mean
Natural Monthly Mean
GWQG