Progression of the Biochemical Reactor (BCR) System at the Brule Mine: An Actively Managed Water Treatment System For Selenium and Nitrate Reduction

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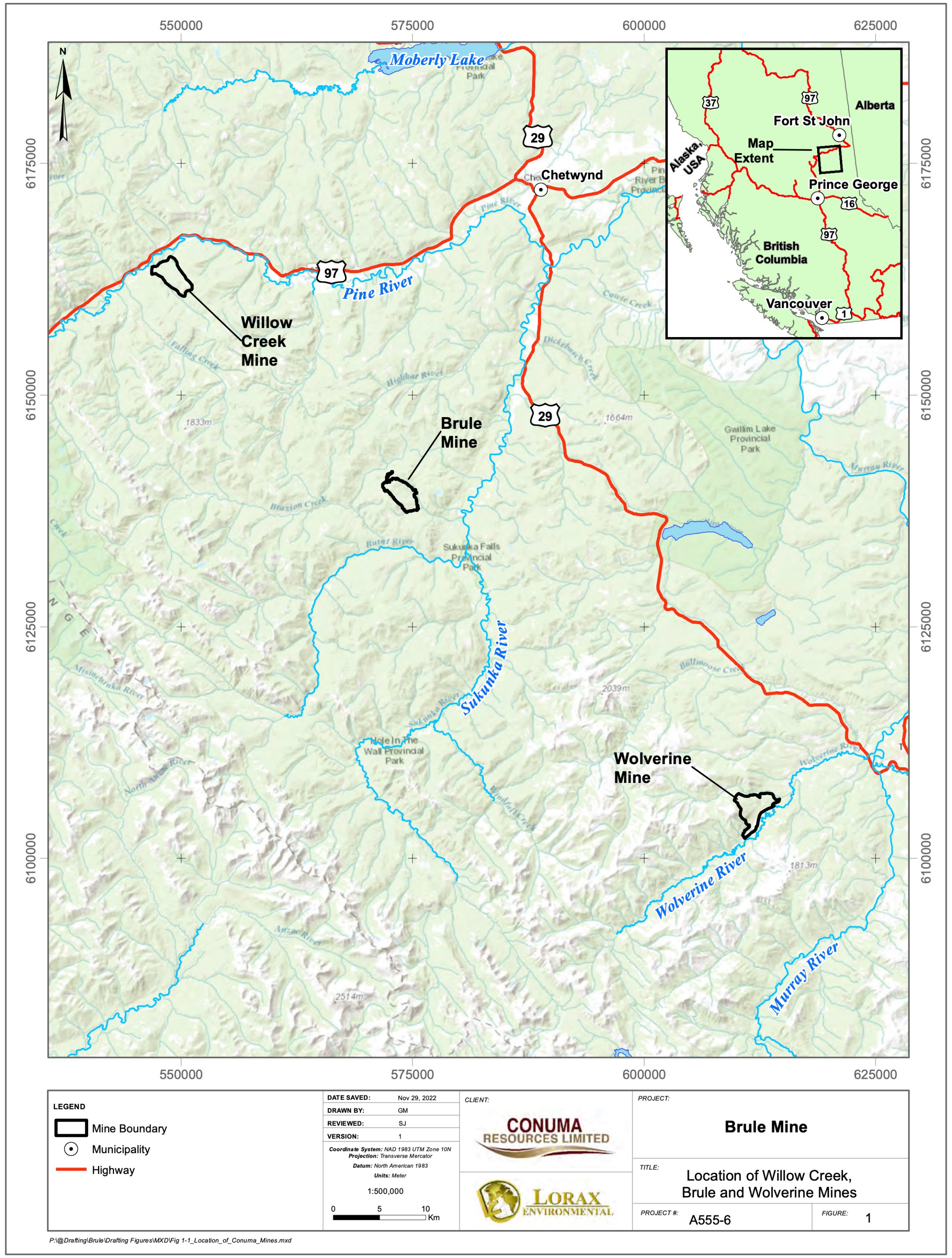
Presentation Outline

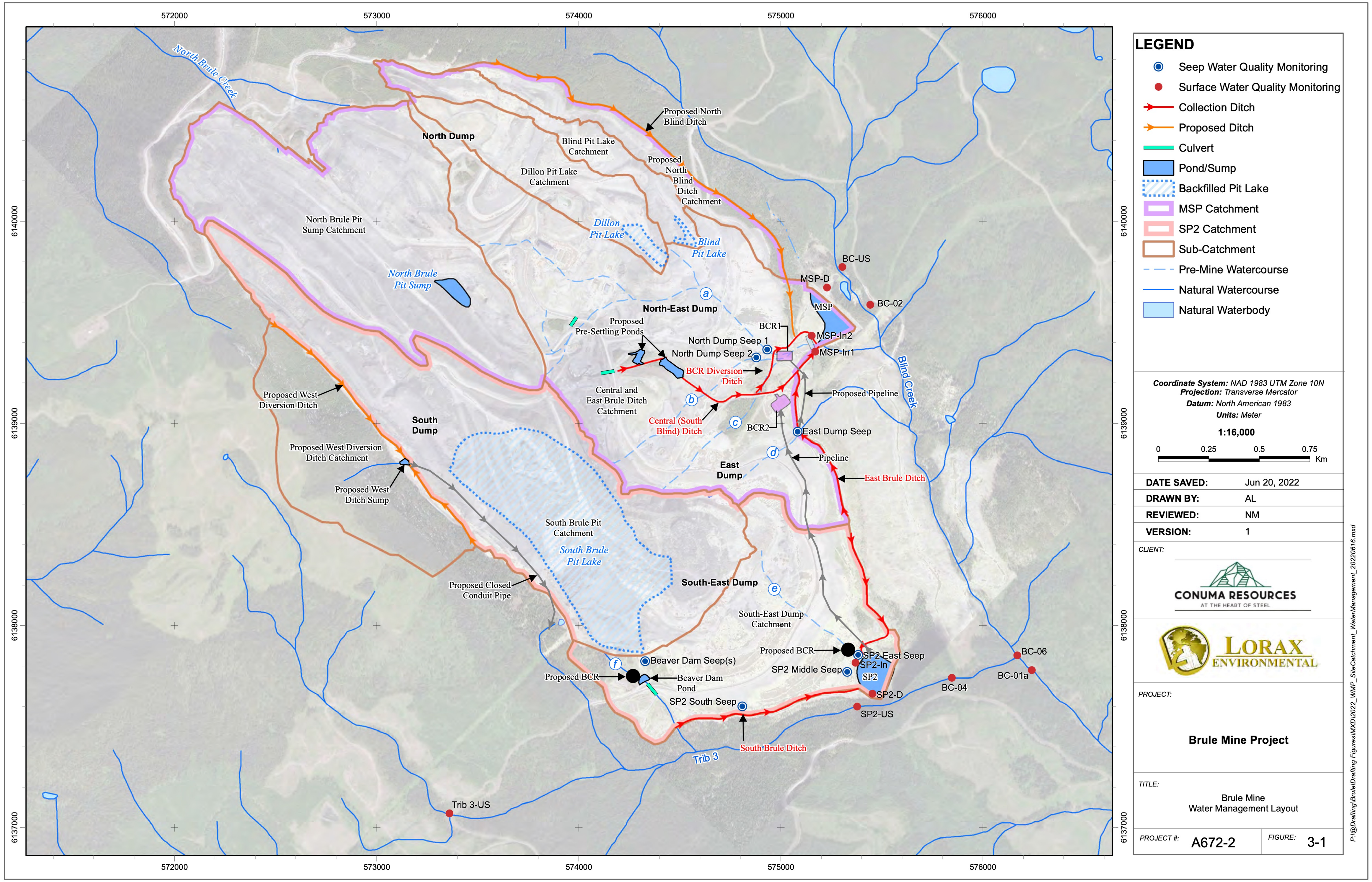
- Conuma
  - Location and Mines
  - Water Treatment
- BCRs and how they work
- BCR Technology Progression
- Treatment Results
- Lessons Learned

Conuma Mines in NE BC

- Three (3) mines acquired in 2016: Wolverine, Brule, Willow Creek
- Near the communities of Tumbler Ridge and Chetwynd
- Steel-making coal production
- Each mine has unique water quality challenges



Brule Mine



LEGEND
Seep Water Quality Monitoring
Surface Water Quality Monitoring
Collection Ditch
Proposed Ditch
Culvert
Pond/Sump
Backfilled Pit Lake
MSP Catchment
SP2 Catchment
Sub-Catchment
Pre-Mine Watercourse
Natural Watercourse
Natural Waterbody
Coordinate System: NAD 1983 UTM Zone 10N
Projection: Transverse Mercator
Datum: North American 1983
Units: Meter
1:16,000
0 0.25 0.5 0.75 Km
DATE SAVED: Jun 20, 2022
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CONUMA RESOURCES
AT THE HEART OF STEEL
LORAX ENVIRONMENTAL
PROJECT:
Brule Mine Project
TITLE:
Brule Mine
Water Management Layout
PROJECT #: A672-2
FIGURE: 3-1
North Brule Creek
North Dump
Blind Pit Lake Catchment
Dillon Pit Lake Catchment
Proposed North Blind Ditch
Proposed North Blind Ditch Catchment
North Brule Pit Sump Catchment
Dillon Pit Lake
Blind Pit Lake
North Brule Pit Sump
BC-US
MSP-D
BC-02
MSP
North-East Dump
Proposed Pre-Settling Ponds
BCR1
North Dump Seep 1
North Dump Seep 2
MSP-In2
MSP-In1
BCR Diversion Ditch
Blind Creek
Proposed Pipeline
Central and East Brule Ditch Catchment
Central (South Blind) Ditch
BCR2
East Dump Seep
Proposed West Diversion Ditch
South Dump
Proposed West Diversion Ditch Catchment
Proposed West Ditch Sump
Pipeline
East Dump
East Brule Ditch
South Brule Pit Catchment
South Brule Pit Lake
South-East Dump
Proposed Closed Conduit Pipe
South-East Dump Catchment
Proposed BCR
SP2 East Seep
SP2-In
SP2 Middle Seep
SP2
BC-06
BC-01a
BC-04
SP2-D
SP2-US
Beaver Dam Seep(s)
Beaver Dam Pond
SP2 South Seep
South Brule Ditch
Trib 3
Trib 3-US
572000
573000
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Types of Water Treatment Systems

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- Chemical, physical and biological treatment systems
- Can be broadly categorized as active and passive technologies
- Trade-off between amount of operation/maintenance and predictability of treatment
- Emerging technologies: semi-passive or enhanced technologies or actively managed systems

Water Treatment

	Active			Semi-Passive		
		Biological			Biological	
	Chemical	Aerobic/ Oxidizing	Anaerobic/ Reducing	Chemical	Aerobic/ Oxidizing	Anaerobic/ Reducing
Ion Exchange	✓					
Membrane (e.g. RO)	✓					
Lime Addition (e.g. HDS plant, limestone bed, lime dosing in situ, etc.)	✓			✓		
Zero Valent Iron				✓		
Biochemical Reactor		✓	✓		✓	✓
Constructed Wetland Treatment System					✓	✓
Anoxic Limestone Drain				✓		✓
In Situ Mine Pool				✓		✓
In Situ Saturated Rock Fill						✓
In Situ Pit Lake				✓	✓	✓
In Situ Tailings Pond				✓	✓	✓

All treatment systems include varying degrees of physical (transfer) treatment processes so these are not noted here.

Conuma and Water Treatment

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- Brule Mine is a steel-making (metallurgical) coal mine in Northeast BC
- Regulations associated with allowable concentrations of selenium and nitrate in water have changed over time (70 to 10 µg/L Se)
- Water treatment utilizes both:
  - Mechanical active water treatment systems (potentially energy intensive)
  - Biochemical reactors (BCRs) - less energy intensive technology
- Conuma's goal is to permit BCRs as primary water treatment system

History of Brule Mine Water Treatment

2005	2006	2014	2015	2016	2017	2020	2021	2022
Permit 17679 was issued	Brule Mine approved in 2006 and was operational until 2014	Brule Mine entered care and maintenance	BCR #1 was constructed under the previous owners Walter Energy.	Conuma took ownership of the mine, and mining recommenced in October 2016	BCR #1 was drained and reconfigured	BCR #2 was Constructed	BCR #1 Flow System was changed from Horizontal to Vertical	BCR #2 Flow System was changed from Horizontal to Vertical

Brule BCR System

What are BCRs

- Engineered treatment systems
- Use an organic substrate to drive natural microbial and chemical reactions to remove contaminants of concern such as selenium and nitrate
- Designed to use solid carbon (food) and nutrient source (wood and hay)
- Currently no amendments or dosing are used
- Actively managed with low maintenance

Target Chemical Species

- Selenium (Se)
- Nitrate (NO_3^{2-})

How Do BCRs Work?

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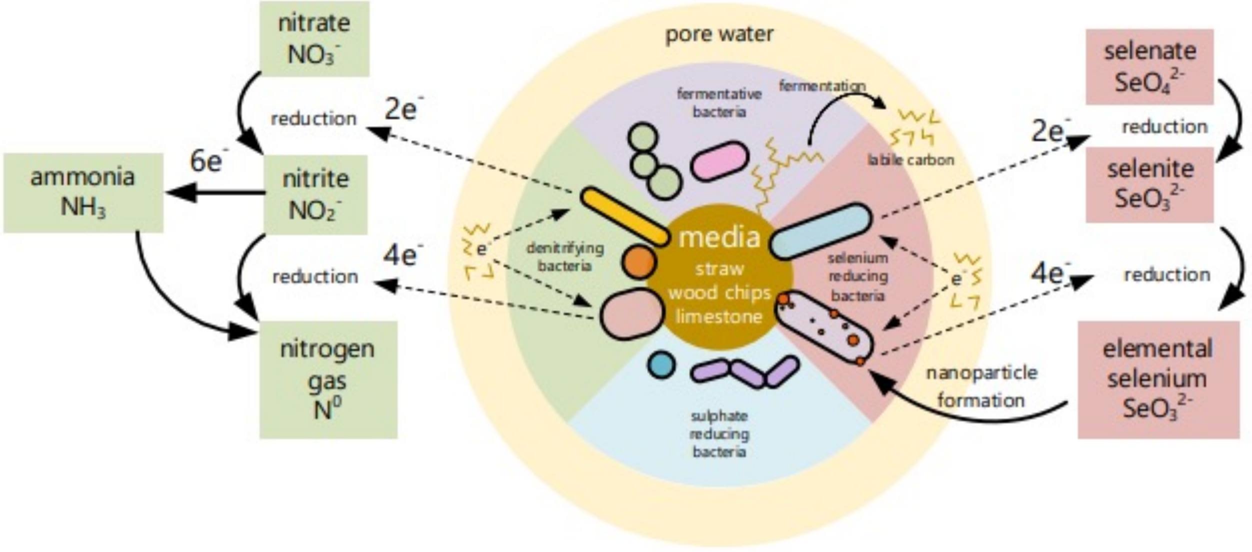
- Saturated mixed media portion supports a microbial community capable of nitrate and selenate reduction
- Dominant biogeochemical processes controlling the removal of key parameters are redox reactions (reduction oxidation)
- Mildly reducing conditions required for Se reduction
- Occurs through anaerobic respiration where microbes use nitrate and selenate instead of oxygen as electron acceptors to gain energy from carbon oxidation
- When selenium and nitrate are reduced, they are removed from water

Denitrification

$4NO_3^- + 5CH_2O \rightarrow N_2 + 5HCO_3^- + 2H_2O + H^+$

Selenate reduction

$2SeO_4^{2-} + 3CH_2O \rightarrow 2Se^0 + 3HCO_3^- + H_2O + OH^-$



Conuma BCR Progression

BCR 1, 2016 → BCR 1, Improvement 2017 → BCR 1, Optimization 2021

BCR 2, 2020 → BCR 2, 2022 → Optimized BCR 2, 2022

Initial Improvements to BCRs

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BCR1

- Changes to inlet water:

  - Source changed to MSP rather than the North Dump seeps

  - Maintains consistent concentrations, less TSS

- Raised edges and improved ditch lines surrounding BCR1 to reduce surface water runoff and sediment load

- Pumping inlet water at a controlled and constant rate rather than gravity feed

- Media density reduction performed 2x/yr

- Direct discharge capabilities

BCR2

- Initial fill/inoculation with BCR1 effluent

- Began flushing with MSP water as soon as the operational water level was met to prevent decreased post treatment water quality

- Changes to design standards for BCR2:

  - Improved mixed media placement to prevent short circuiting

  - Blow-out manifolds to prevent clogging and maintain high flow rates

  - Designed for higher flow rates

  - Direct discharge

BCR Flow Systems

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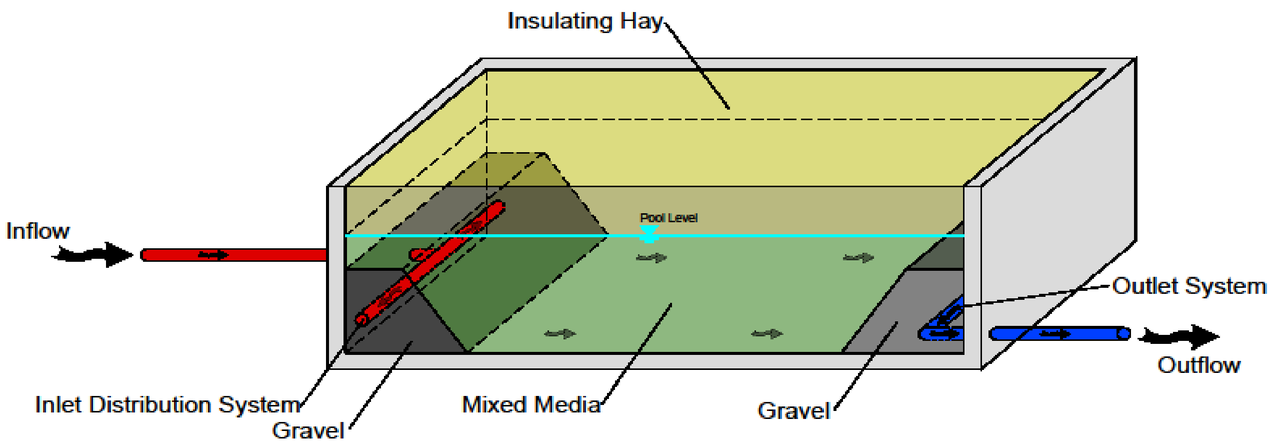
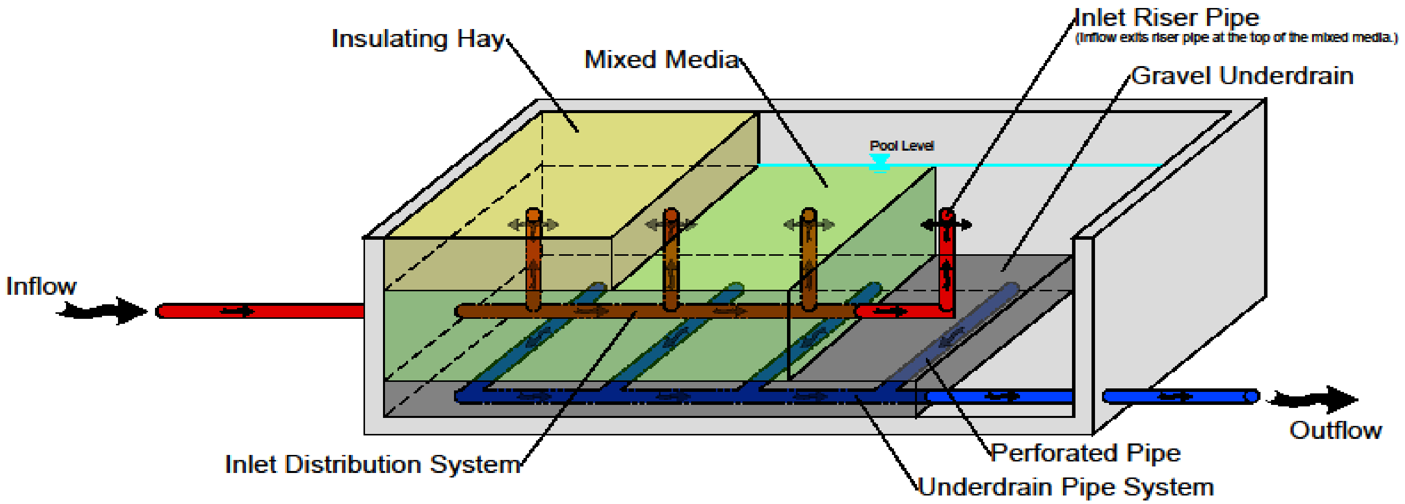
- **Two types of flow systems**: Horizontal and Vertical downflow



Horizontal Flow Bioreactor System



Vertical Flow Bioreactor System

- Provides better hydraulic retention and increased flow capacity
- Greatly reduces the potential and occurrence of preferential flow and short circuiting of the system
- The inlet distribution system consists of a series of riser pipes that uniformly distribute the influent within the treatment area
- Underdrain system allows treated water to be uniformly withdrawn from the entire treatment area
- Insulating hay layer provides temperature stability to maintain biological activity and reduce biological shock to the system during extreme temperature swings

Driver of Progression

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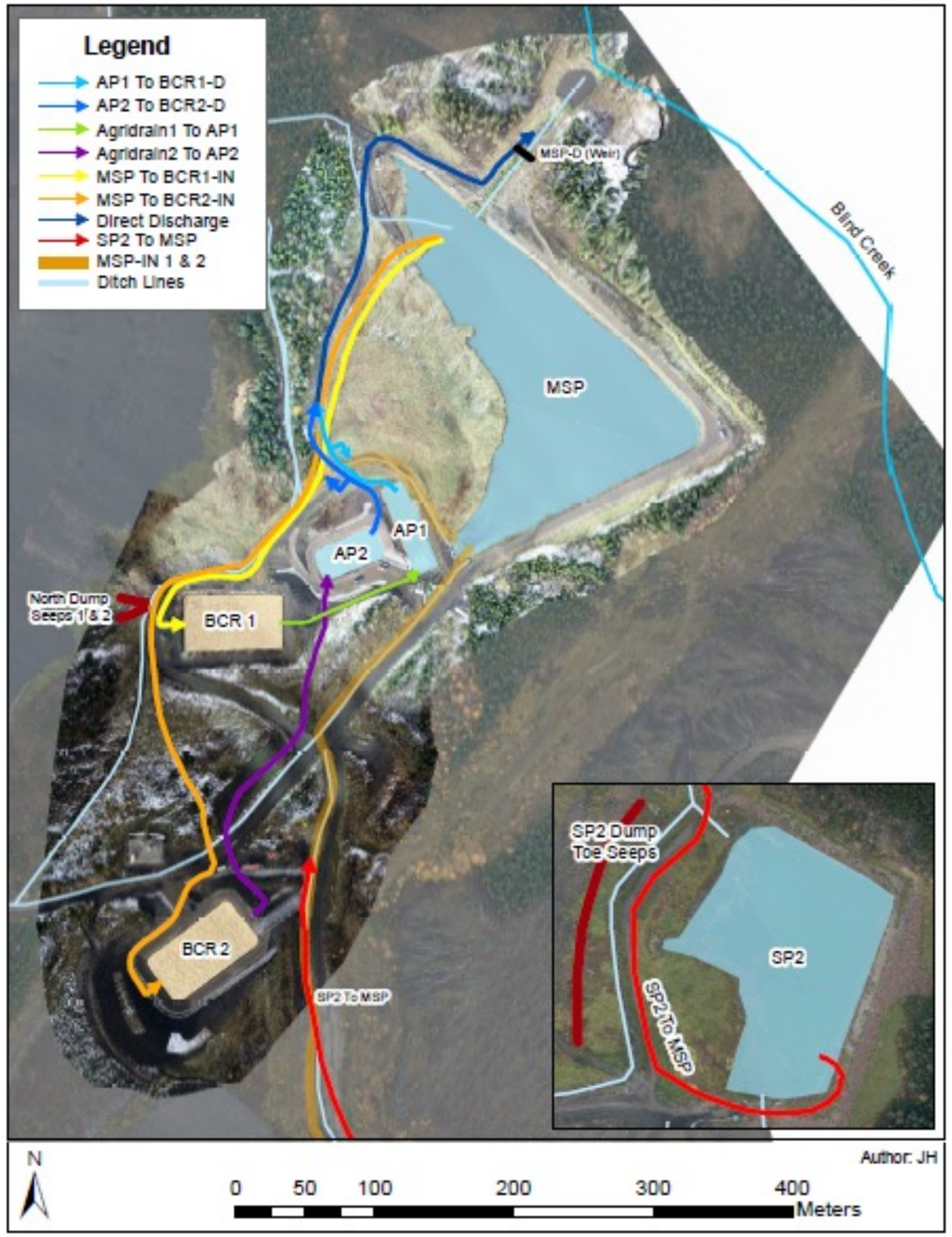
- Ongoing research in BCR Technology
- Need to resolve technical uncertainty at the site level to manage risk
- Advance the BCR Technology in a timely manner
- Goal: better treatment to meet compliance in the receiving environment

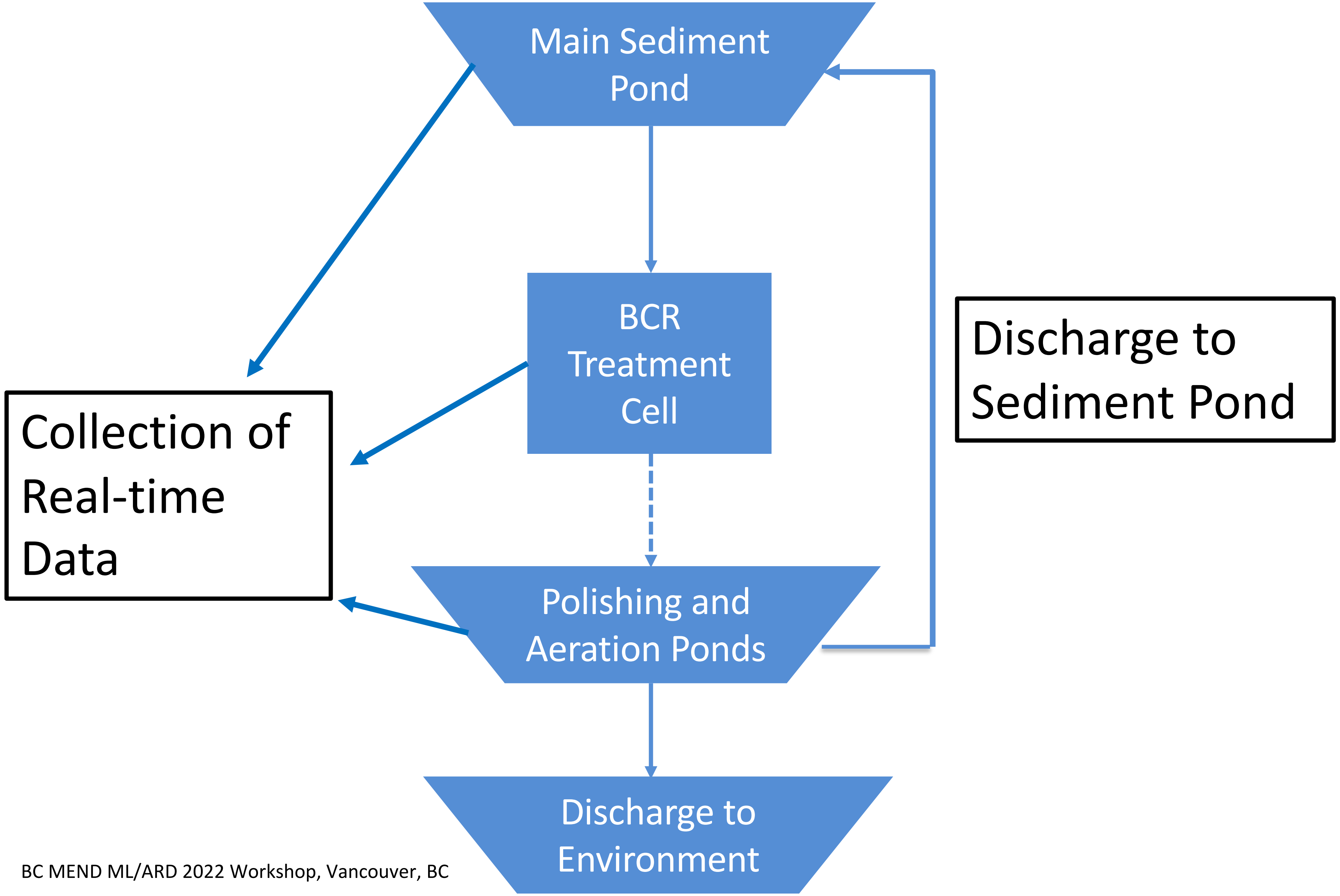
Overview of Brule BCR System

Conuma BCR Configuration



- **Current Biochemical Reactor Flow Paths**
  - Sediment Pond 2 (SP2) → Main Sediment Pond (MSP)
  - High selenium water (100-200 ppb) from SP2 is pumped to MSP for BCR treatment
  - **BCR1:** MSP → BCR1 → Aeration Pond 1 → MSP Discharge→ Blind Creek Compliance Point
  - **BCR2:** MSP → BCR2 → Aeration Pond 2 → MSP Discharge→ Blind Creek Compliance Point

Actively-Managed Conuma BCRs



Actively Managed BCRs – Automation

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- **Key components:**
  - Installation of VFDs on all pumps to improve influent and effluent flow
  - Installation of valve actuators to improve flow control
  - Connection to system flowmeters to monitor and log flow
  - Water quality probes will be installed to continuously monitor influent, effluent and discharge water
- **Outcome:**
  - Real time data on water quality and equipment functions
  - Constant and consistent data access allows for improved performance of the system
  - Off site access will allow operators to remotely access the system and make changes if required
  - System notification of key water quality indicators
  - Advanced notifications of potential system to prevent lengthy downtime periods

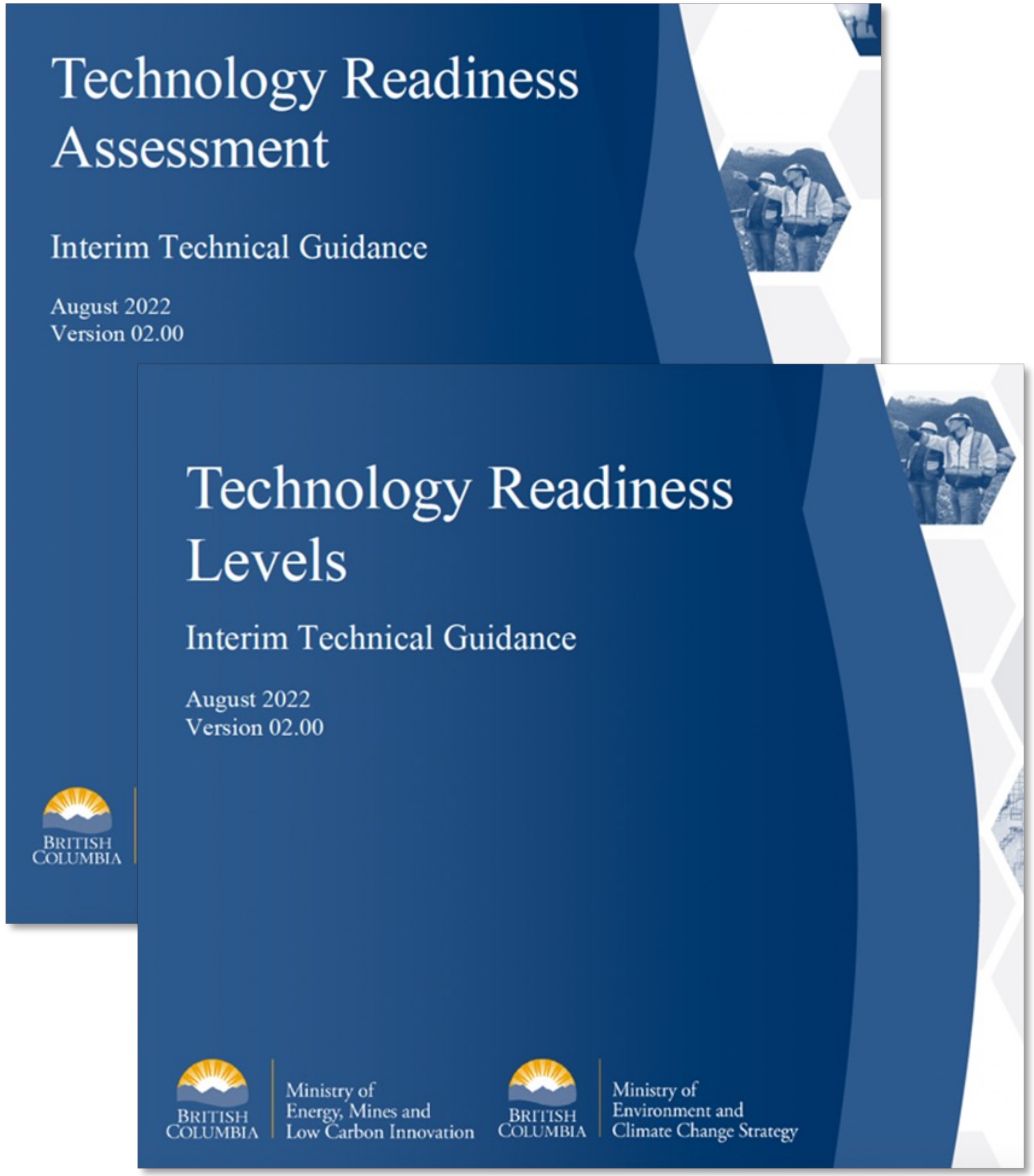
What is Next

BC Interim Technical Guidance

CONUMA RESOURCES

- TRL (level of readiness) and TRA (assessment of readiness level) Guidance documents released by BC EMLI/ENV
- Address **source control measures and effluent water treatment systems for major mines in BC**
- Bridge gaps in TRLs and permitting in the mining sector

Conuma is currently reviewing the Guidance documents to assess and advance BCRs as permittable water treatment systems for the mining sector



Technology Readiness Assessment

Interim Technical Guidance

August 2022
Version 02.00

BRITISH COLUMBIA

Technology Readiness Levels

Interim Technical Guidance

August 2022
Version 02.00

BRITISH COLUMBIA | Ministry of Energy, Mines and Low Carbon Innovation

BRITISH COLUMBIA | Ministry of Environment and Climate Change Strategy

TRL6

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Technology Readiness Level (TRL)	Criteria	Connection to regulatory processes
TRL6: Prototype demonstration in a simulated environment (Demonstration system operating under relevant site-specific conditions)	○ Development of a prototype that represents or nearly represents the final configuration ○ Testing in a laboratory or simulated environment ○ Collection of empirical data	• Research and development conducted by a proponent. • Activity may be conducted on-site and may require authorization under MA and/or EMA. • Reclamation security is required for the removal of the prototype and reclamation of the disturbed area.

TRL7

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Technology Readiness Level (TRL)	Criteria	Connection to regulatory processes
TRL7: Prototype ready for demonstration in site-specific environment (Demonstration system operating at near full-scale under relevant site-specific conditions)	○ Development of a prototype representative of the final configuration ○ Testing in the actual field setting ○ Empirical data supports the implementation of the technology to meet receiving environment requirements under a range of conditions representative of the expected life and application of the technology ○ A risk management approach and risk register have been developed/updated. Identified risks have proposed mitigations through operational and management actions ○ MA and EMA Joint Application Information Requirements for the technology, excluding capital and operating costs, that are technology-specific can be met (JAIR section 5.6.4). An independent peer review may be used in lieu of literature and analogue data.	• Research and development conducted by a proponent. • Activity may be conducted on-site and may require authorization under MA and/or EMA. • The technology may be proposed for use in MA and/or EMA planning processes. • The technology may be included in EAC applications. • Reclamation security is required for the removal of the prototype and reclamation of the disturbed area. • Reclamation security may be required for the provision of an alternative, proven, technology

TRL8

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Technology Readiness Level (TRL)	Criteria	Connection to regulatory processes
TRL8: Actual technology completed and qualified through tests and demonstrations (First-of-a-kind system complete and proven at full-scale)	○ A risk management approach and risk register have been developed. Identified risks have proposed mitigations through operational and management actions ○ The technology is transferable and can conceptually be implemented at any site, subject to site-specific conditions ○ The operational and replacement costs of the technology can be calculated for bonding requirements ○ MA and EMA Joint Application Information Requirements are fully met (JAIR Section 5.4.6.), using an appropriate combination of literature, analogue, and empirical data for the technology.	• The technology may be proposed for use in MA and/or EMA planning processes. • The technology may be included in EAC applications. • The technology may be included in MA and/or EMA permit applications as a proven technology. • MA/EMA Joint Application Information Requirements can be met with empirical data. • Reclamation security is required for the technology's capital and operating costs and reclamation of the disturbed area.

TRL 9

CONUMA RESOURCES

Technology Readiness Level (TRL)	Criteria	Connection to regulatory processes
TRL9: Actual technology proven through successful deployment in operational settings (System complete and proven at full-scale in multiple settings)	○ MA and EMA Joint Application Information Requirements are fully met (JAIR Section 5.4.6.), using an appropriate combination of literature and analogue data for the technology. Empirical data may not be required	• The technology may be proposed for use in MA and/or EMA planning processes. • The technology may be included in EAC applications. • The technology may be included in MA and/or EMA permit applications as a proven technology. • MA/EMA Joint Application Information Requirements can be met without empirical data. • Reclamation security is required for the technology's capital and operating costs and removal and reclamation of the disturbed area.

Sample BCR Operational Results

Hydrochemistry

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Historical hydrochemistry of influent, effluent and receiving waters

	DO (mg/L)	ORP (mg/L)	pH	Se (mg/L)	Nitrate (mg/L)	Sulphate (mg/L)	Ammonia (mg/L)
BCR1-In	0 -15	0 - 176	6 – 8	0.009 - 0.199	0.013 – 49.2	317 - 712	246 - 605
Agridrain	<0 - 5	-482 – 39	6 – 8	0.002 - 0.1	0.001 - 28	306 - 721	288 - 732
BCR1-D	<0 - 18	-187 – 169	7 – 9	0.006 - 0.089	0.001 – 28.7	322 - 728	294 - 802
BC-01a	0 -124	0 -169	8 -9	0.001 – 0.061	1.01 – 47.9	41 - 618	116 - 530

Definitions:

BCR1-In = Influent
Agridrain = Effluent
BCR1-D = Discharge to Environment
BC-01a = Compliance Location

Selenium Removal

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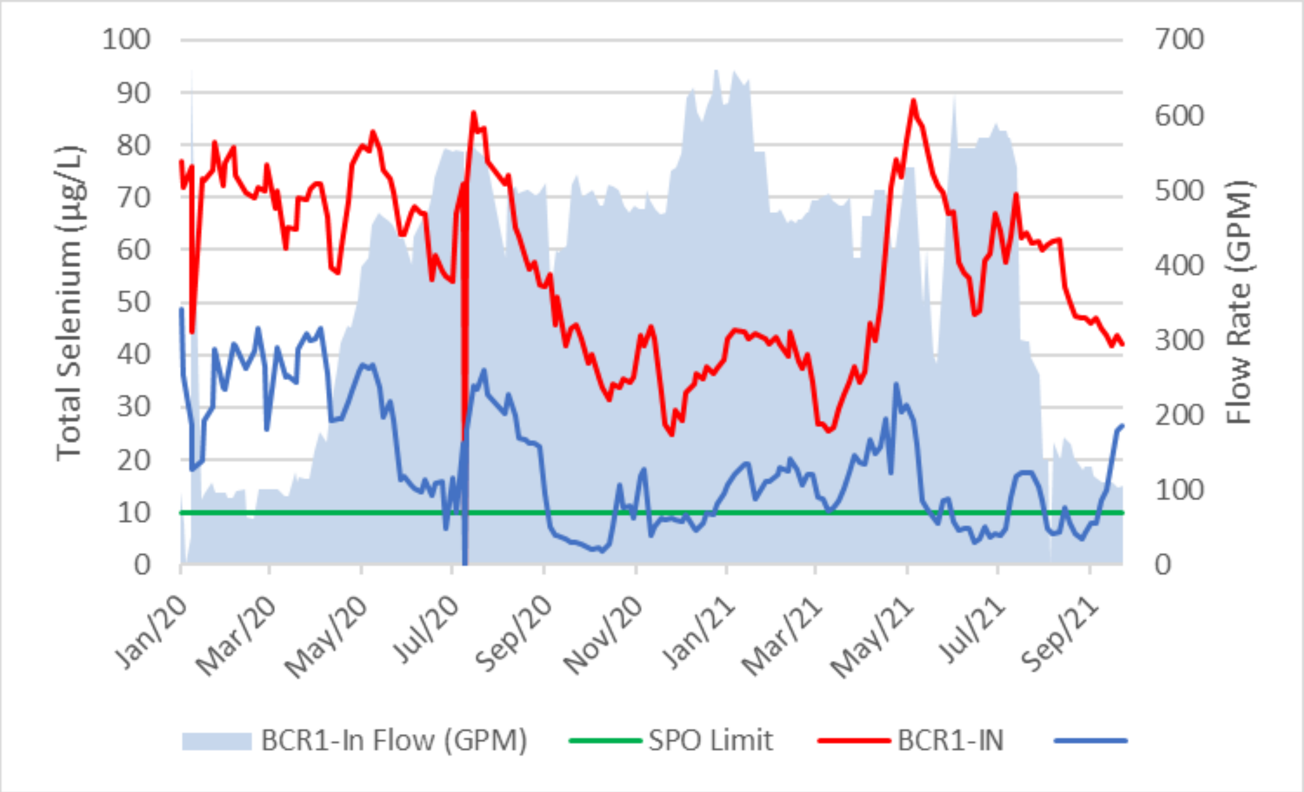
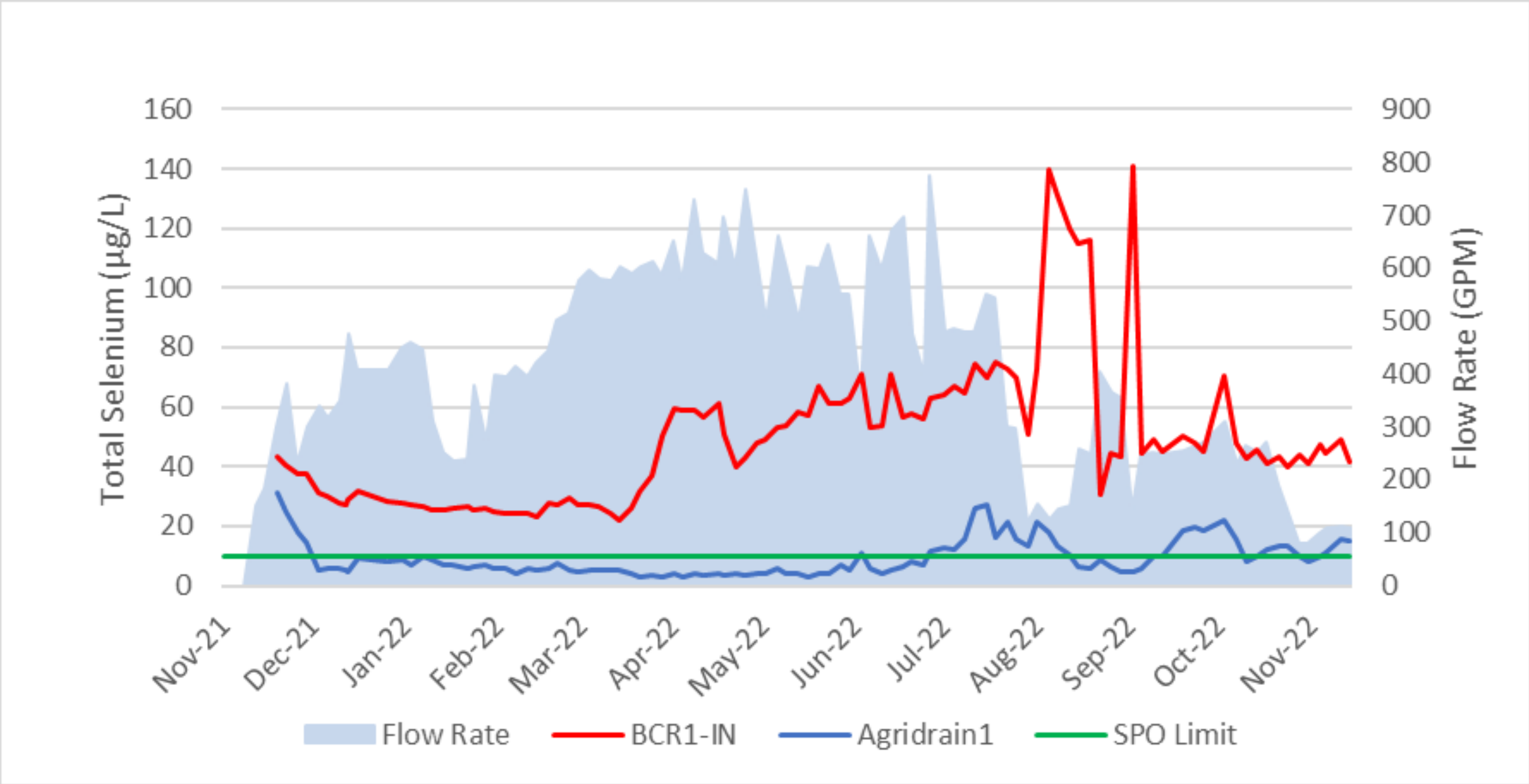
Horizontal Flow



Vertical Flow

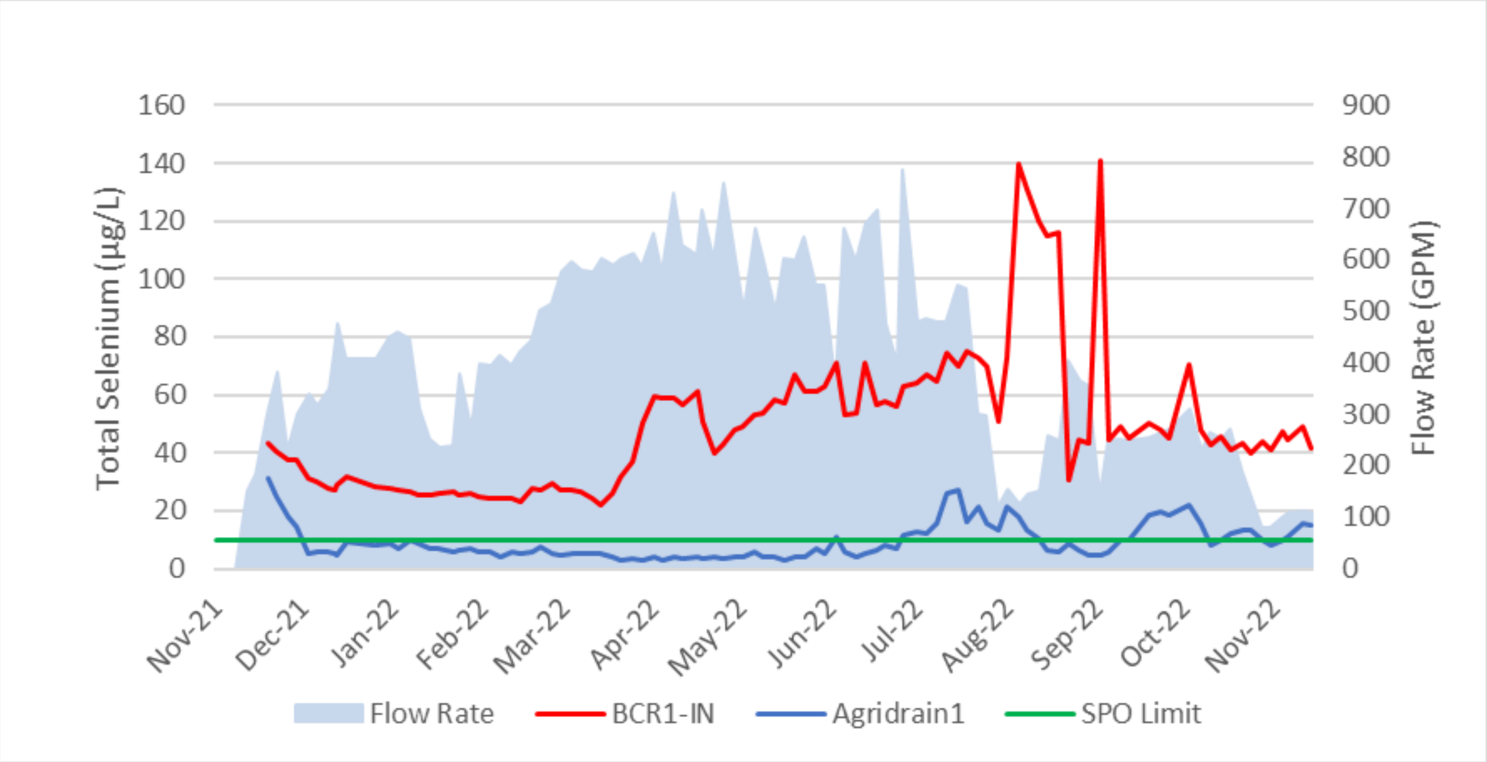


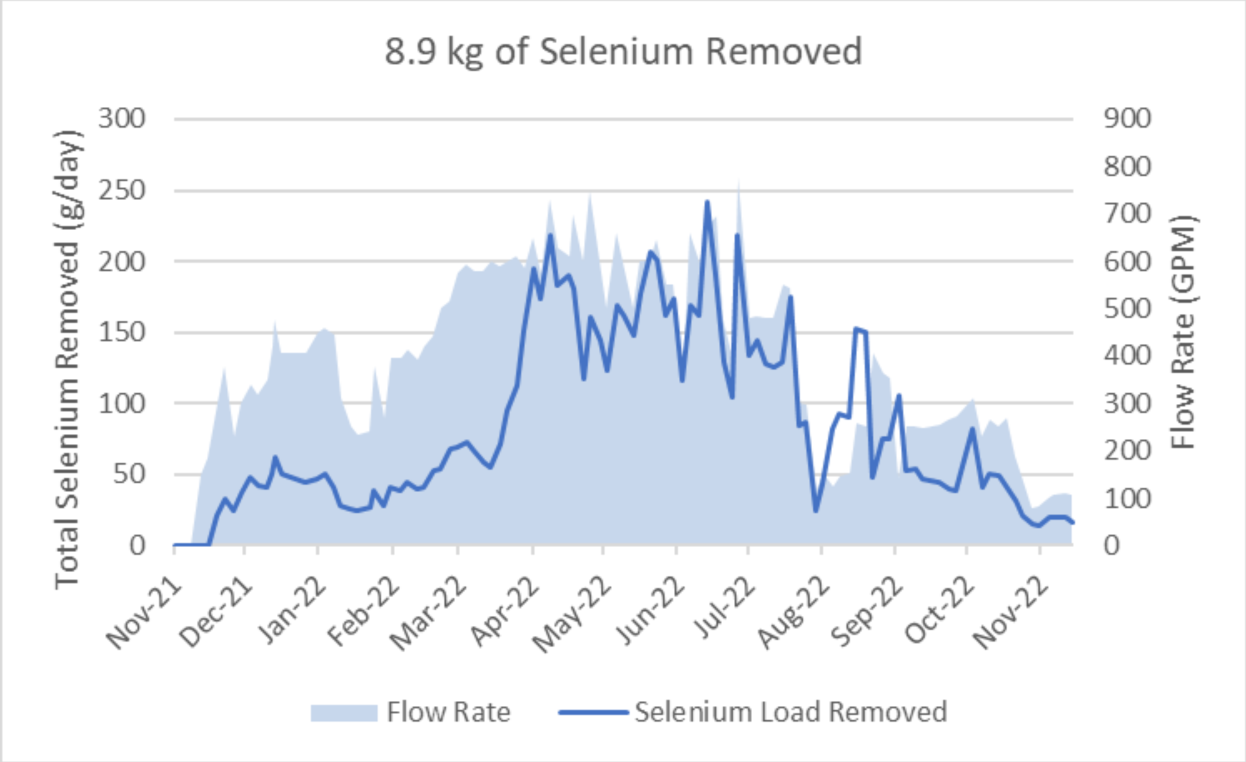
- Up to 50 – 90% removal efficiency for Se
- Sporadically below the SPO limit

- Up to 90 - 95% removal efficiency for Se
- Consistently below the SPO limit after the initiation phase

Selenium Removal

CONUMA RESOURCES



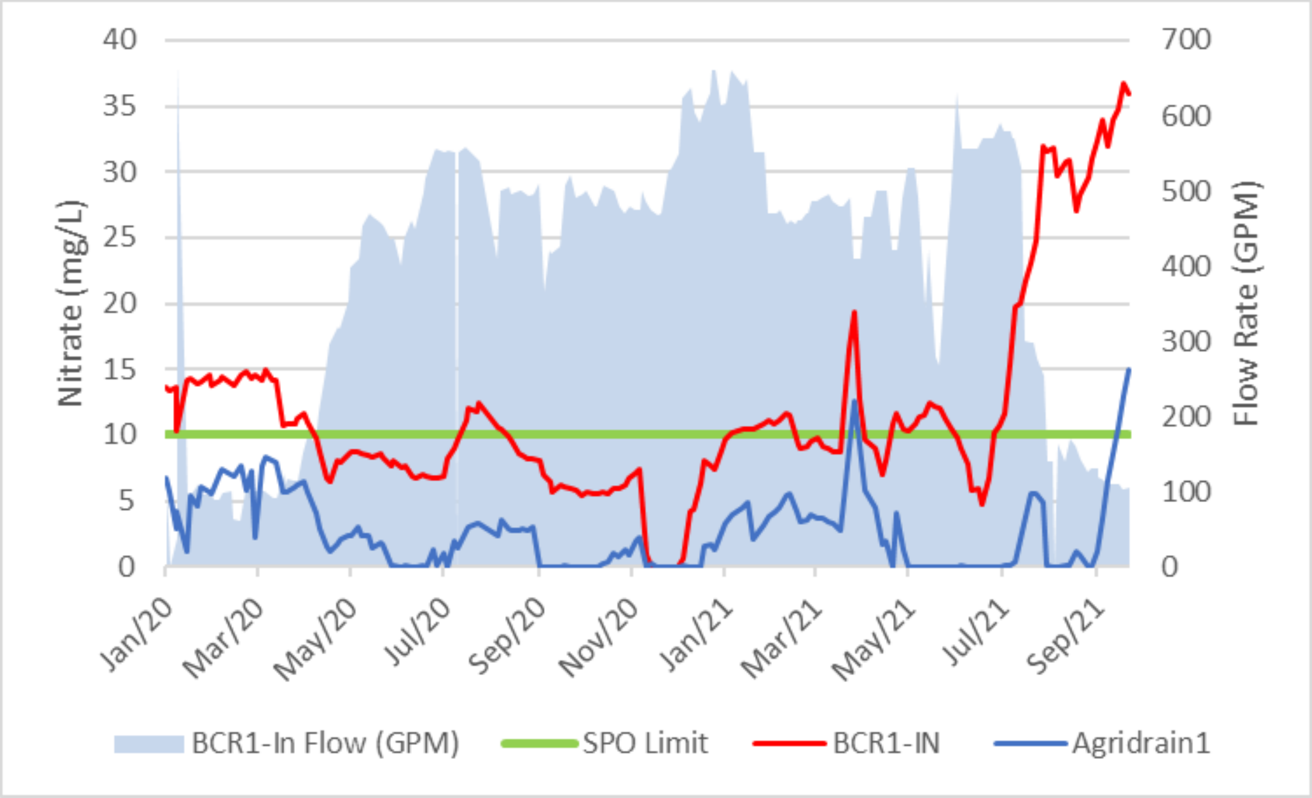


- Up to 8.9 kg of selenium removed for a period of approximately 1 year

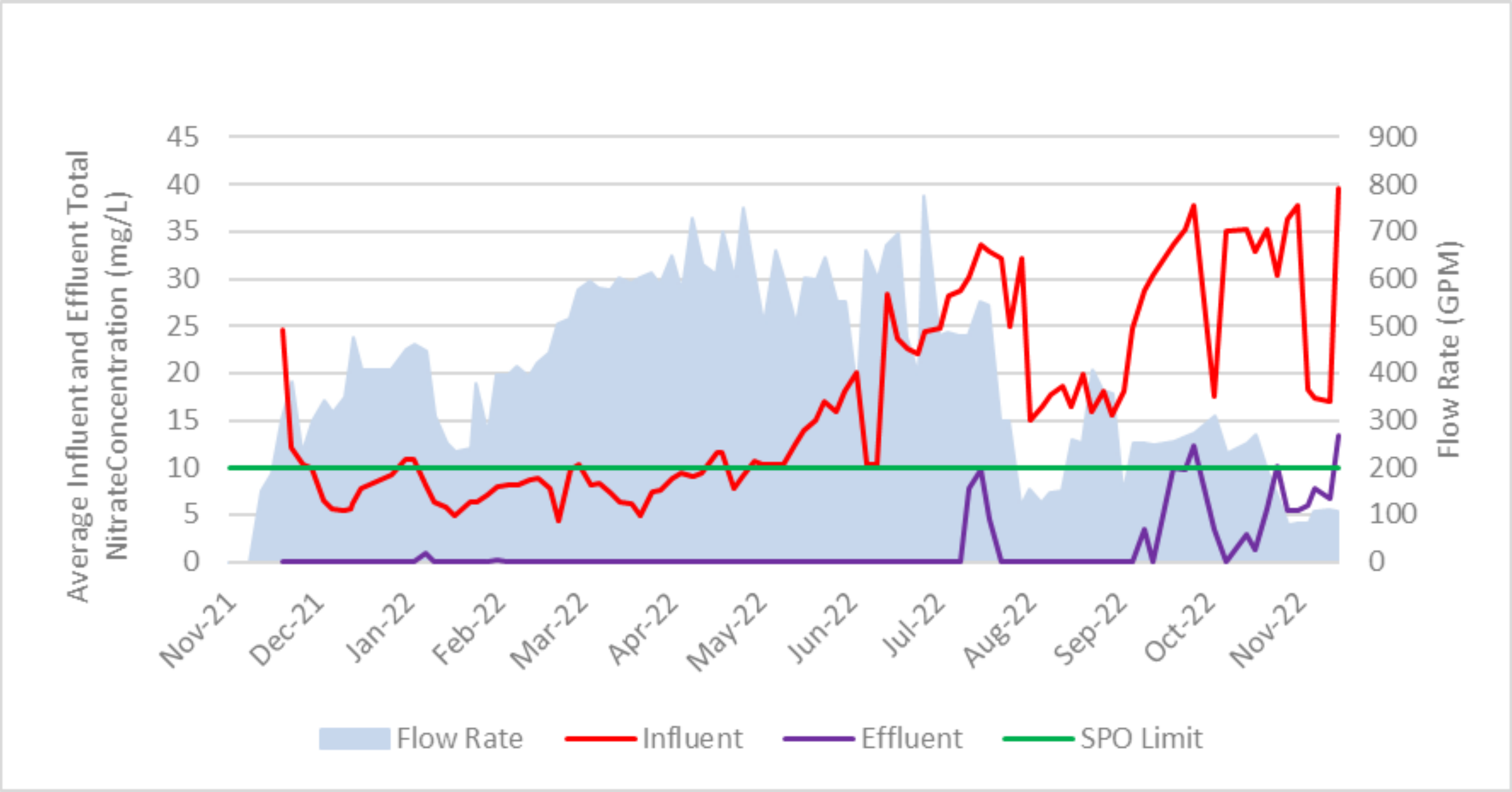
Nitrate Removal

CONUMA RESOURCES

Horizontal Flow



Vertical Flow

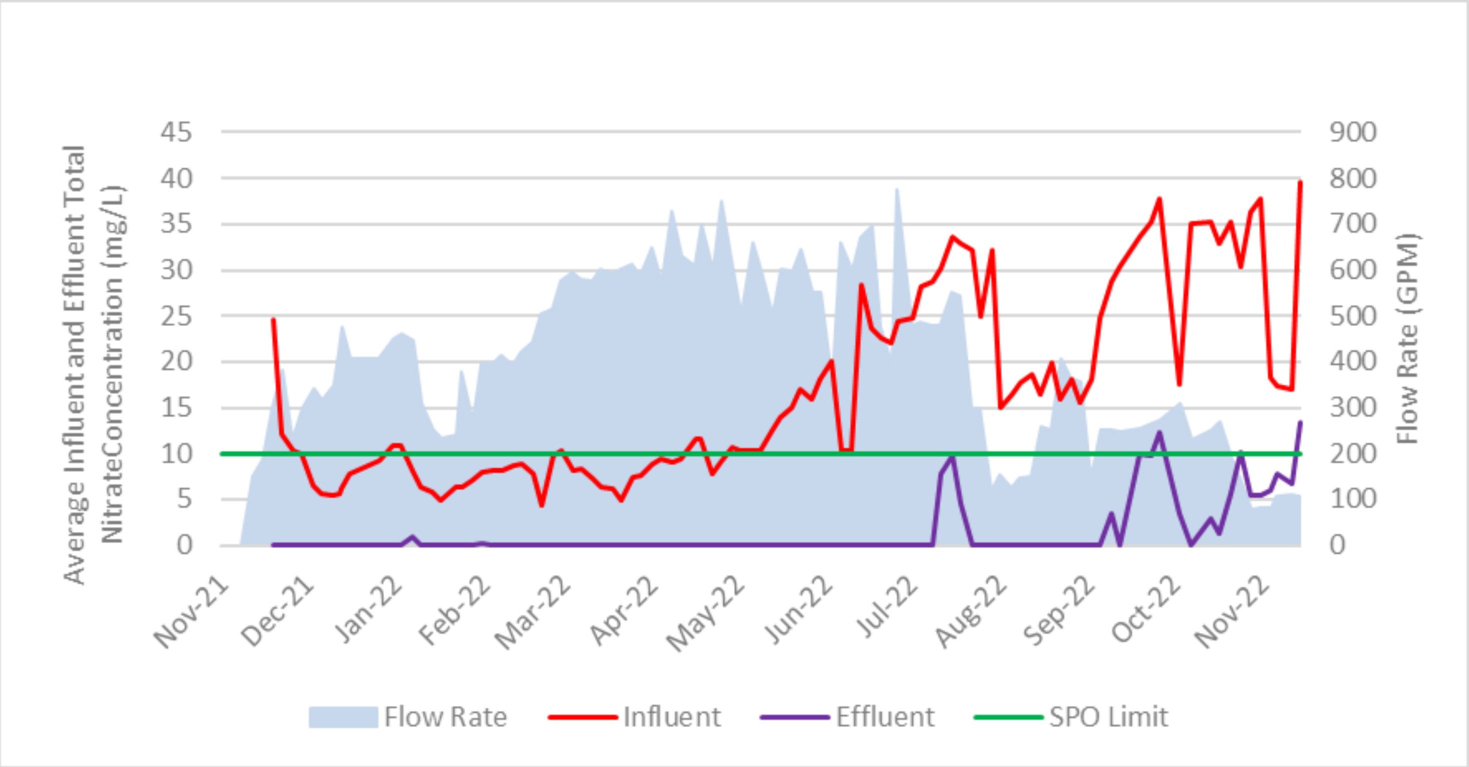


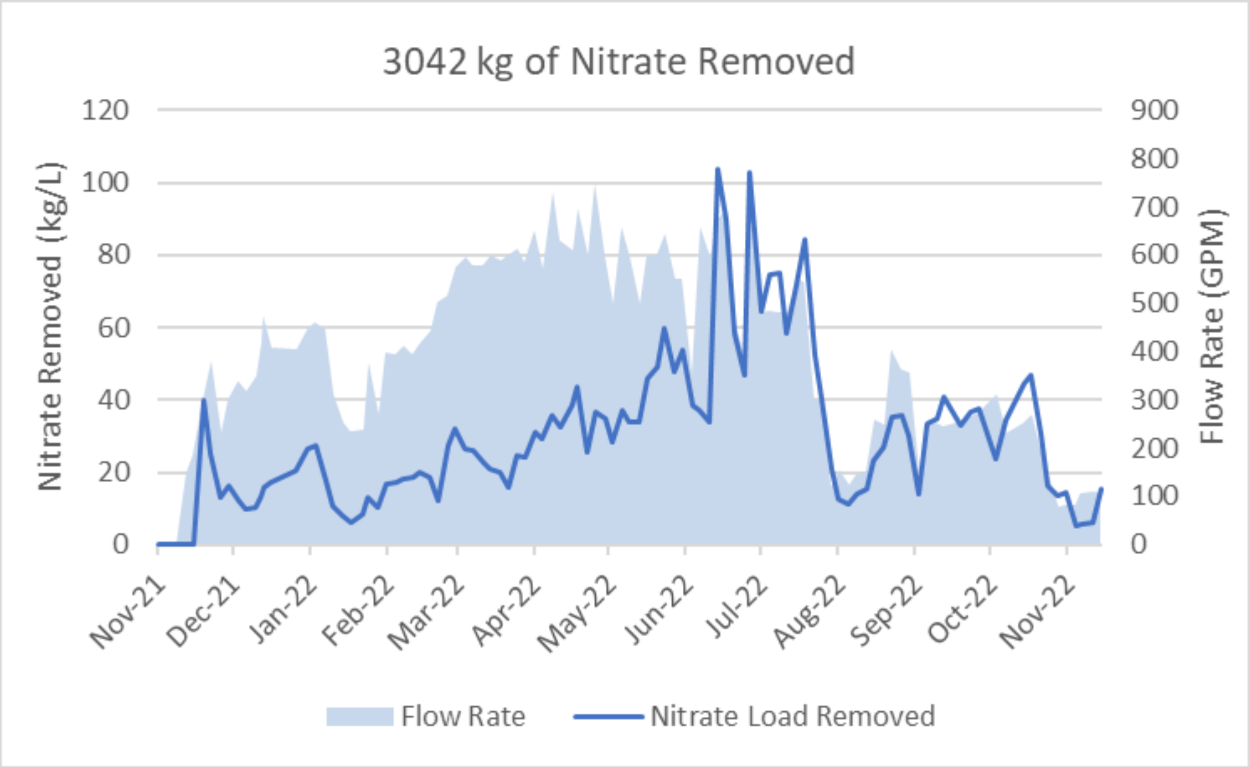
- Rarely up to 100% removal of nitrate

- Up to 100% removal of nitrate for a long time
- Influence

Nitrate Removal

CONUMA RESOURCES

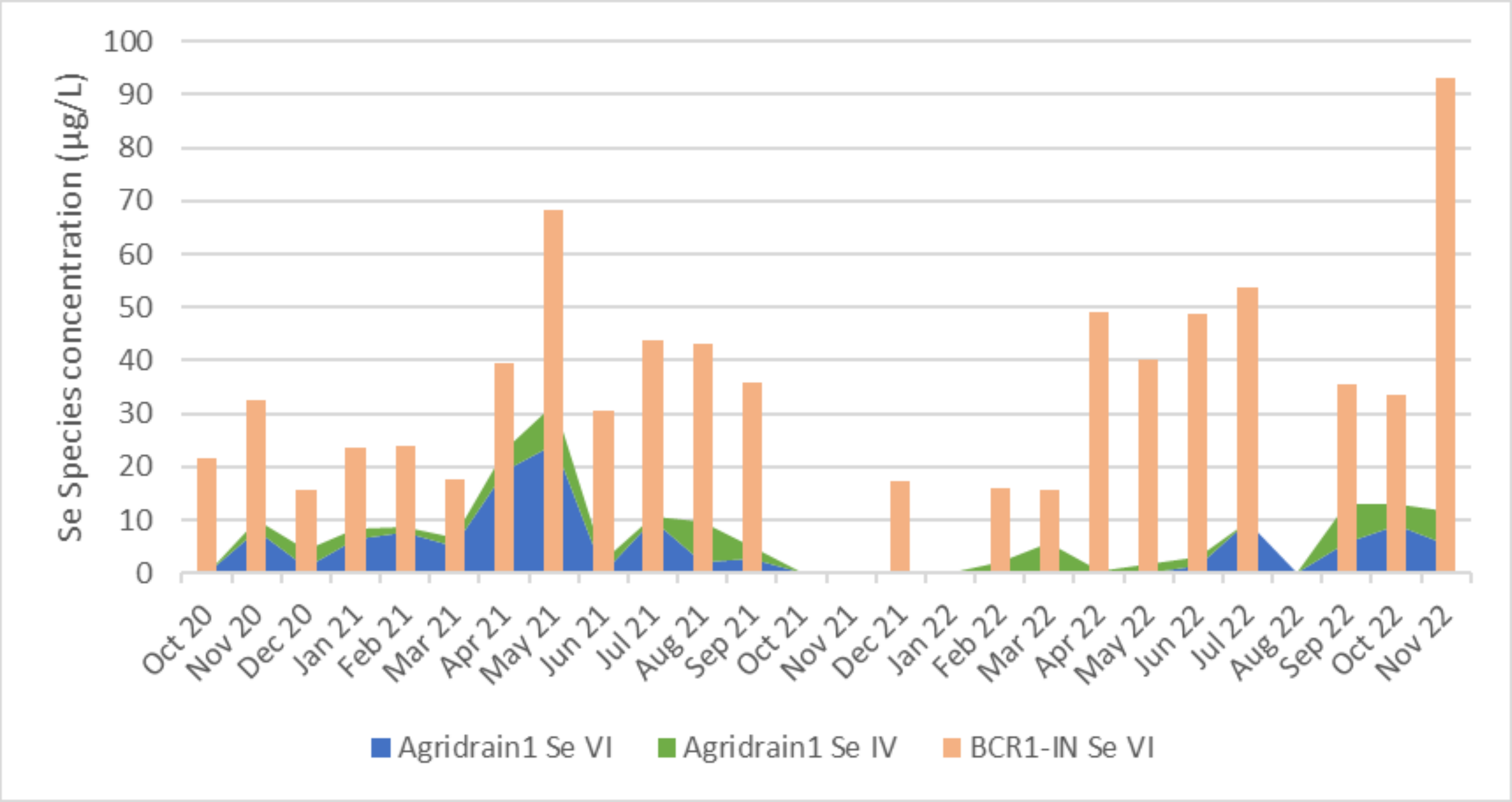




- Up to 3042 kg of nitrate removed in 1 year

Selenium Speciation

CONUMA RESOURCES

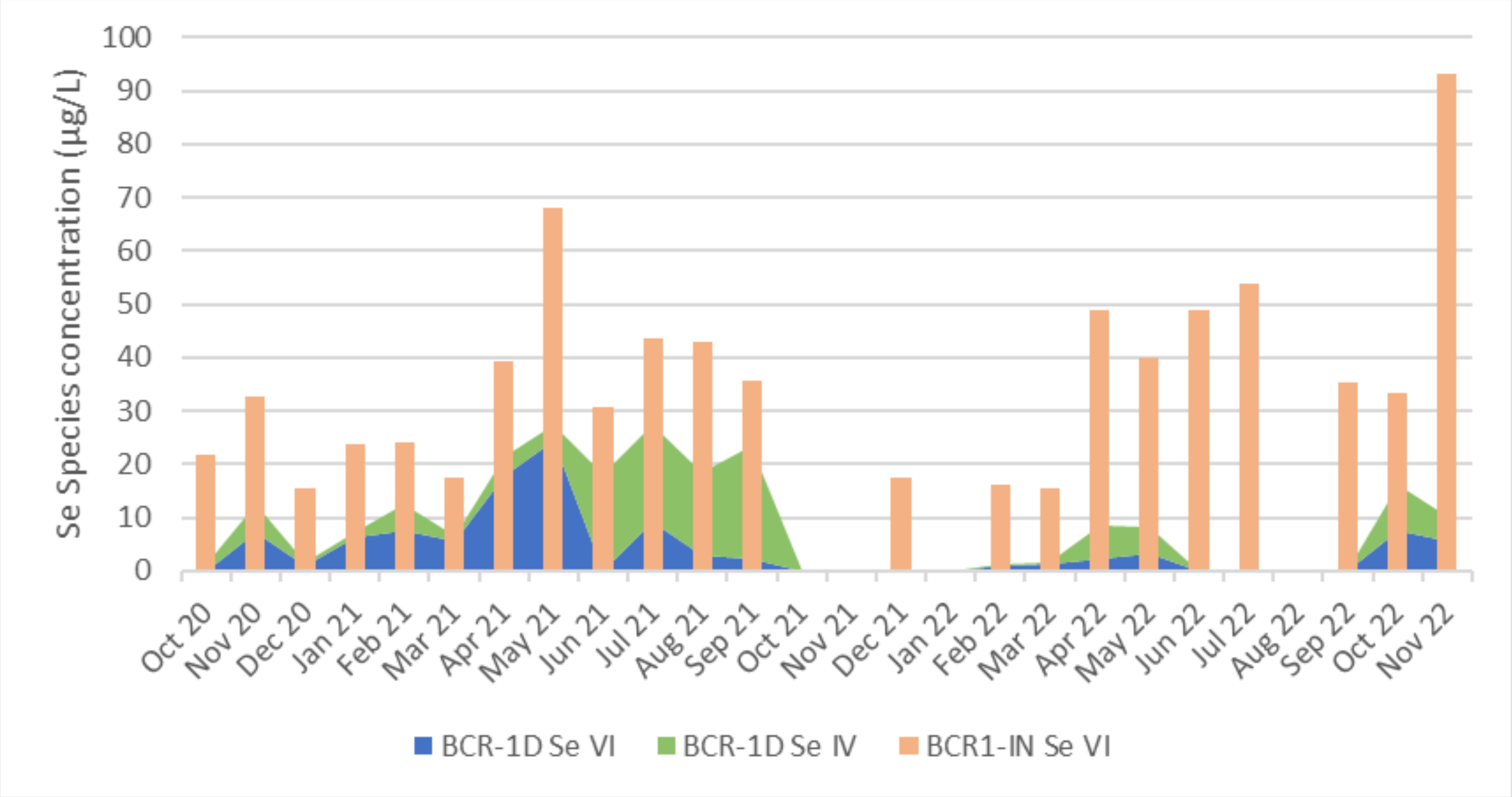


- Significant shift from selenate to selenite and/or insoluble elemental selenium

BCR1-IN = Influent
Agridrain1 = Effluent

Selenium Speciation

CONUMA RESOURCES



BCR1-IN = Influent
BCR1-D = Discharge to Environment

- Similar significant shift from selenate to selenite and/or insoluble elemental selenium

Lessons Learned

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- Improper media placement and compaction can cause preferential flow paths decreasing the hydraulic retention time and treatment efficiency of the BCR
- Rapid changes in inflow parameters can impact BCR performance.
- Wide knowledge base is critical in the progression of the BCR Technology
- There is no universal single solution to water treatment at a mine
- Additional treatment capacity is required to achieve and maintain compliance

Thank You