Snap Lake Water Licence Amendment Application Overview

Erica Bonhomme, Manager Environment
April 15, 2014

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Snap Lake Mine Water Management Infrastructure

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Water Licence Amendment Application

- Submitted December 2013
- De Beers is applying to change the quality of water allowed to be discharged to Snap Lake
- Water modeling and studies of the aquatic life in Snap Lake show that previous benchmarks are overly protective
- Application also proposes minor regulatory and administrative changes
- Proposed amendments will improve mine operational efficiency and reduce costs while ensuring that the water in Snap Lake remains safe to drink, and that the fish and the food they depend on remain healthy.

Technical and Community Engagement

- Updates on site-specific water quality studies in 2013
- Spring freshet visits May-June 2013
- Snap Lake community site visits July 2013
- Annual Fish Tasting September 2013
- Presentations on modeling, site-specific toxicity studies at Canadian Council for Fisheries Research Conference, January 2014
- Information session on water licence application January 6, 2014
- Snap Lake Site Visit (government), March 11, 2014
- 2014 Snap Lake Activities update March 20, 2014
- Community visits, site visits and fish tasting will take place again in 2014

Application Supporting Documents

Models

- Groundwater Flow Model for Snap Lake Mine
- Snap Lake Site Water Balance Model Report
- Site Water Quality Report
- Snap Lake Hydrodynamic and Water Quality Model Report

Establishment of Chronic Effects Benchmarks and Site Specific Water Quality Objectives (SSWQOs)

- Development of TDS Chronic Effects Benchmark for Aquatic Life in Snap Lake Report
- Development of Fluoride Chronic Effects Benchmark for Aquatic Life in Snap Lake Report
- Development of Nitrate Chronic Effects Benchmark for Aquatic Life in Snap Lake Report
- Development of Strontium Chronic Effects Benchmark for Aquatic Life in Snap Lake Report

Development of Effluent Quality Criteria (EQCs)

- Evaluation of Effluent Quality Criteria Report

Application Supporting Documents

Response Plans

- TDS Response Plan
- Nitrogen Response Plan
- Strontium Response Plan

Supplemental Information Related to SSWQOs

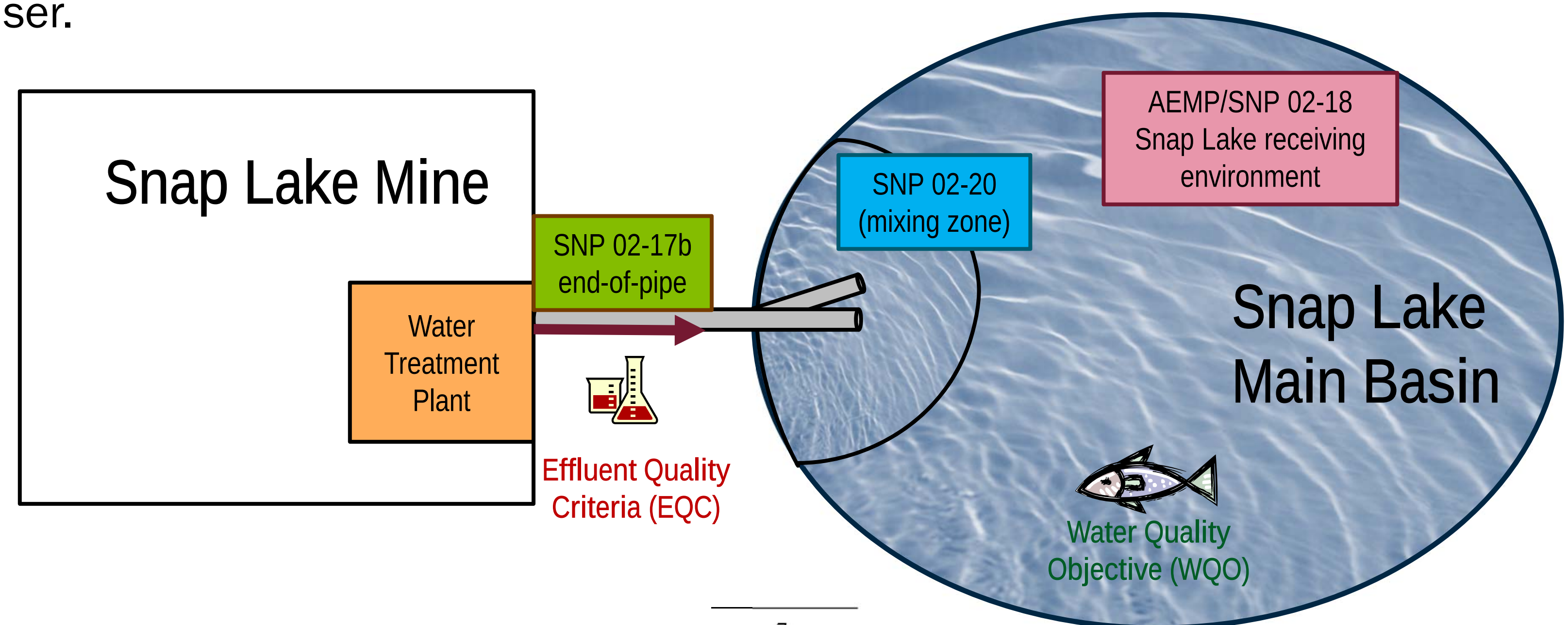
- Technical Memo: Revision of Site Specific Water Quality Objective for Strontium
- Technical Memo: Second *Daphnia magna* 21-day TDS Toxicity Test Results

Supplemental Information, s.117 Related to Proposed Change in TDS Limit

- Cumulative Effects
- Accidents and Malfunctions
- Alternatives

Key Terminology Used in Application

- Site-specific Water Quality Objectives (SSWQOs) apply in the lake and are protective of aquatic life - a specific concentration of a substance in water beyond which detrimental effects to aquatic health may occur.
- EQCs are concentrations that can be discharged to the lake without exceeding the SSWQOs in the lake.
- EQCs are measured "end-of-pipe"
- Effluent is all water discharged from the water treatment plant to Snap Lake through the diffuser.

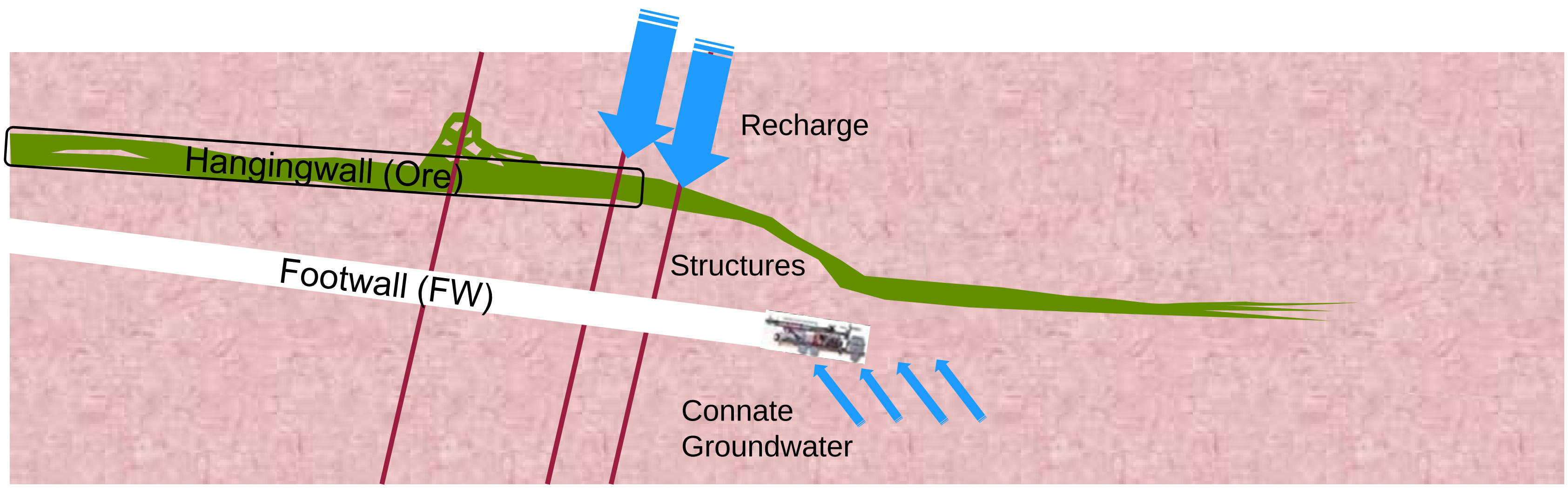


Proposed changes to the water licence EQCs

Parameter	Average Monthly Limit (AML) (mg/L)		Max Grab (mg/L)	
	current	proposed	current	proposed
Total Suspended Solids	7	7	14	14
Ammonia as N	10	10	20	20
Nitrite as N	0.5	1	1	3
Nitrate as N	22	14	44	32
Nitrate as N (January 1, 2015)	4	14	8	32
Chloride	310	378	620	607
Fluoride Jan1 2015	0.15	2.43	0.3	3.73
Sulphate	75	427	150	640
Metals	trace	remove	trace	remove
TDS	Propose removing current whole-lake average TDS Water Licence limit of 350 milligrams per litre (mg/L) and replacing with end-of-pipe AML of 684 mg/L and max grab of 1,003 mg/L.			

Introduction to Groundwater and Site Models

- As mining proceeds, loadings of Total Dissolved Solids (TDS) and Nitrogen to Snap Lake are predicted to increase
- During development of footwall, higher TDS connate groundwater is released underground.
- Connate water is the largest contributor of TDS loadings to Snap Lake. Nitrogen originates from explosives used during footwall and ore development.

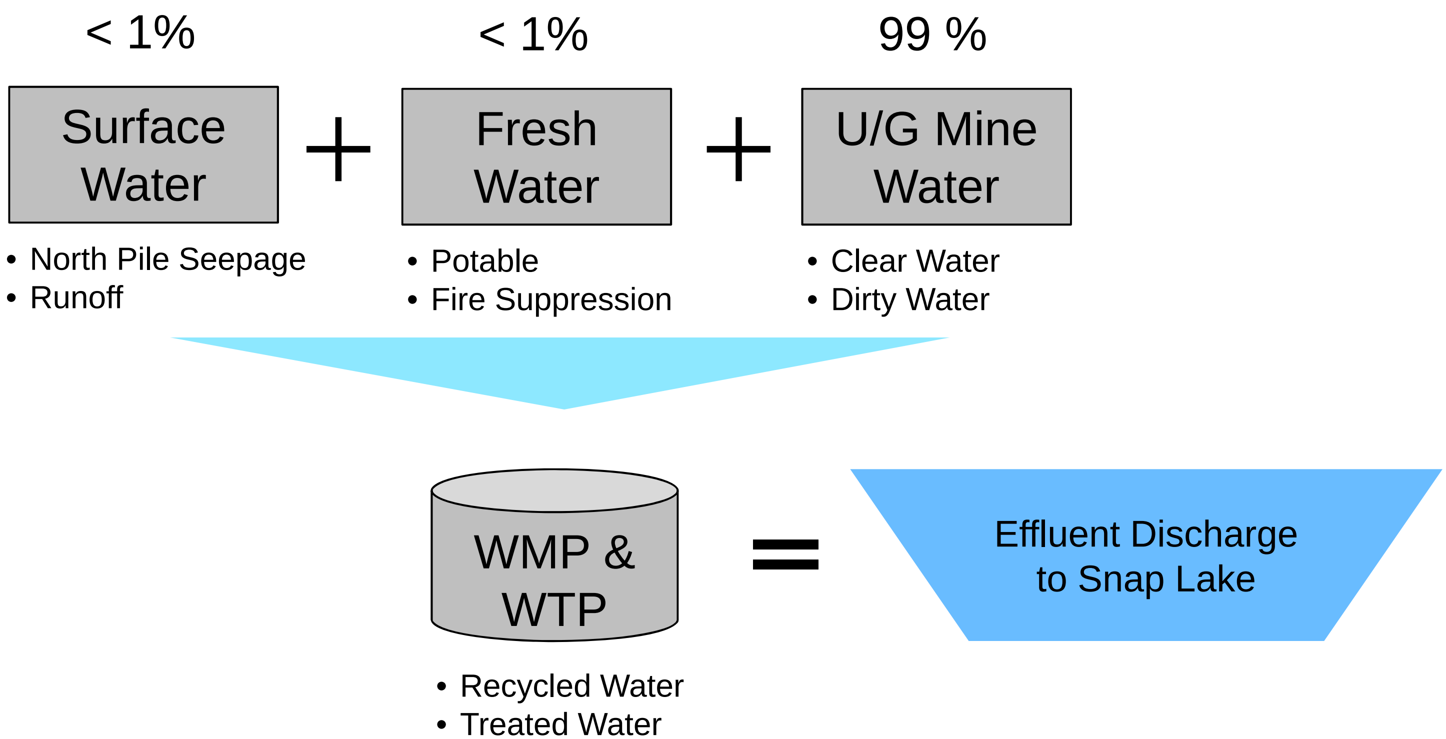


Introduction to Groundwater and Site Models

- Snap Lake's Water Treatment Plant treats for sediment (TSS – total suspended solids) and adjusts pH of water – it does not treat for TDS, ammonia or nitrates
- "Clear Water" refers to water pumped from underground that has trace amounts of TSS
- "Dirty Water" refers to water pumped from underground that is high in TSS. It also includes high TDS connate water.
- Currently, Snap Lake Mine treats and discharges up to 43,000 m^3 water per day
- Mine effluent quality and quantity monitored at SNP Station 02-17b (in-line)

Introduction to Groundwater and Site Models

Generalized Water Balance Snap Lake Mine



Snap Lake
Groundwater Flow Model

Houmao Liu, Ph.D. P.E.
Principal Hydrogeologist
Itasca Denver, Inc.

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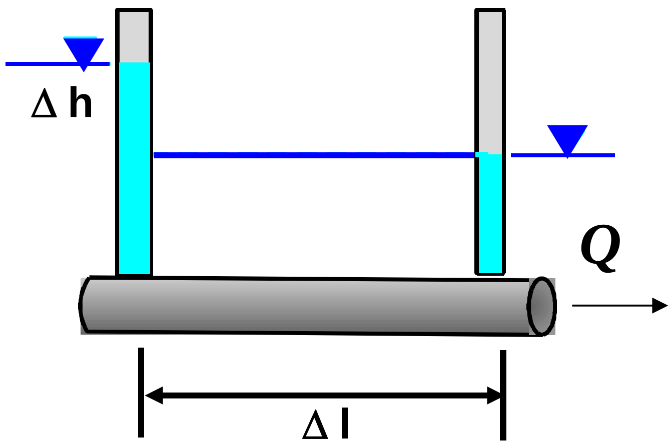
Basis Of Model

- Nine years of operational data:
  - Continuous understanding and mapping of structures
  - Continuous measurement of the underground mine discharge rate
  - Continuous measurement of total dissolved solids (TDS) in the underground mine discharge

- Itasca's accumulated knowledge since 2001.

Basic Concept of Groundwater Flow

Darcy's Law (developed in 1856):

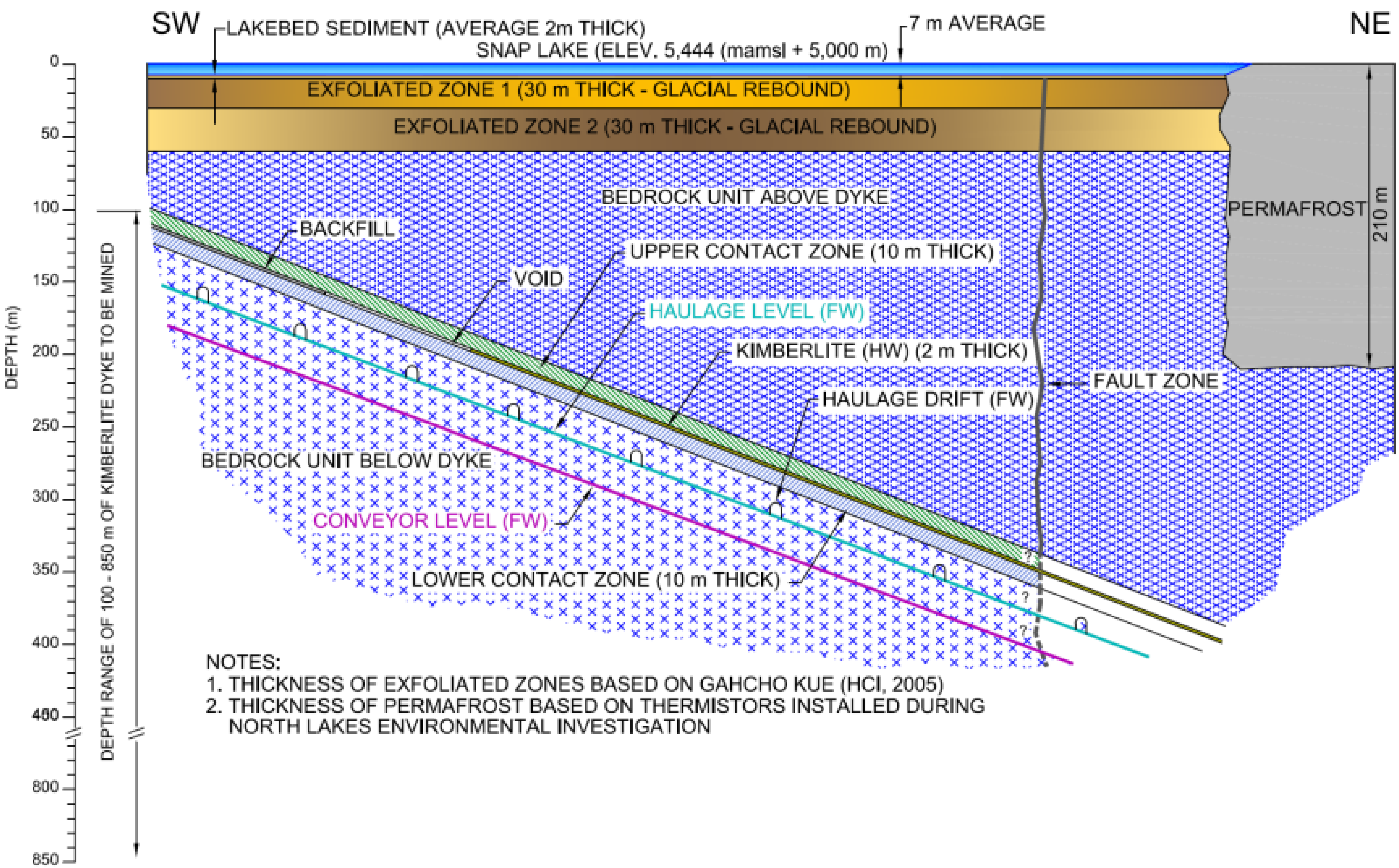


$$Q = K \times A \times \left(\frac{\Delta h}{\Delta l} \right)$$

Definition:

Hydraulic Conductivity ***K*** = Discharge Rate per Unit Area under Hydraulic Gradient of 1

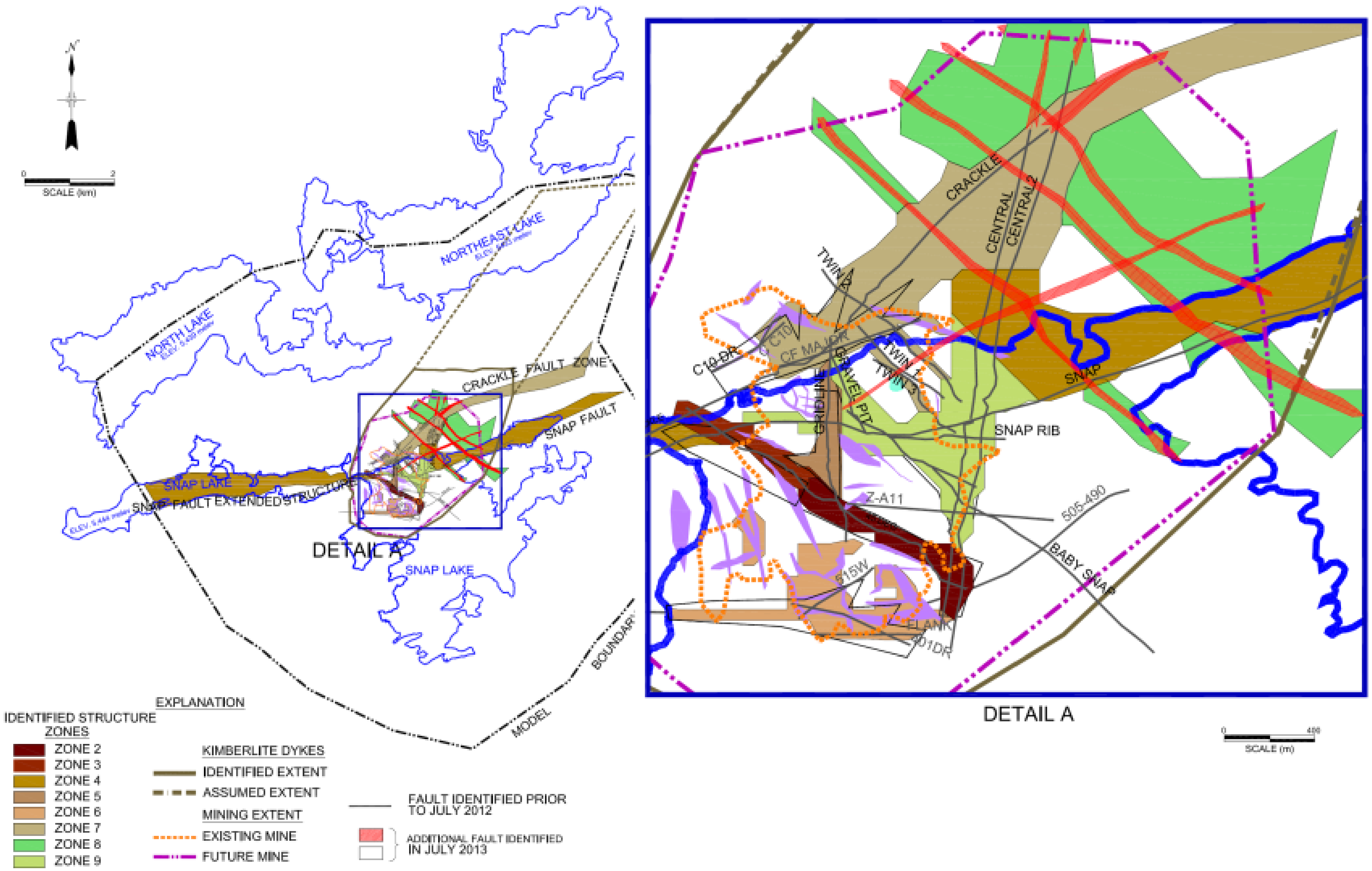
Generalized Hydrogeologic Model of Mine Area



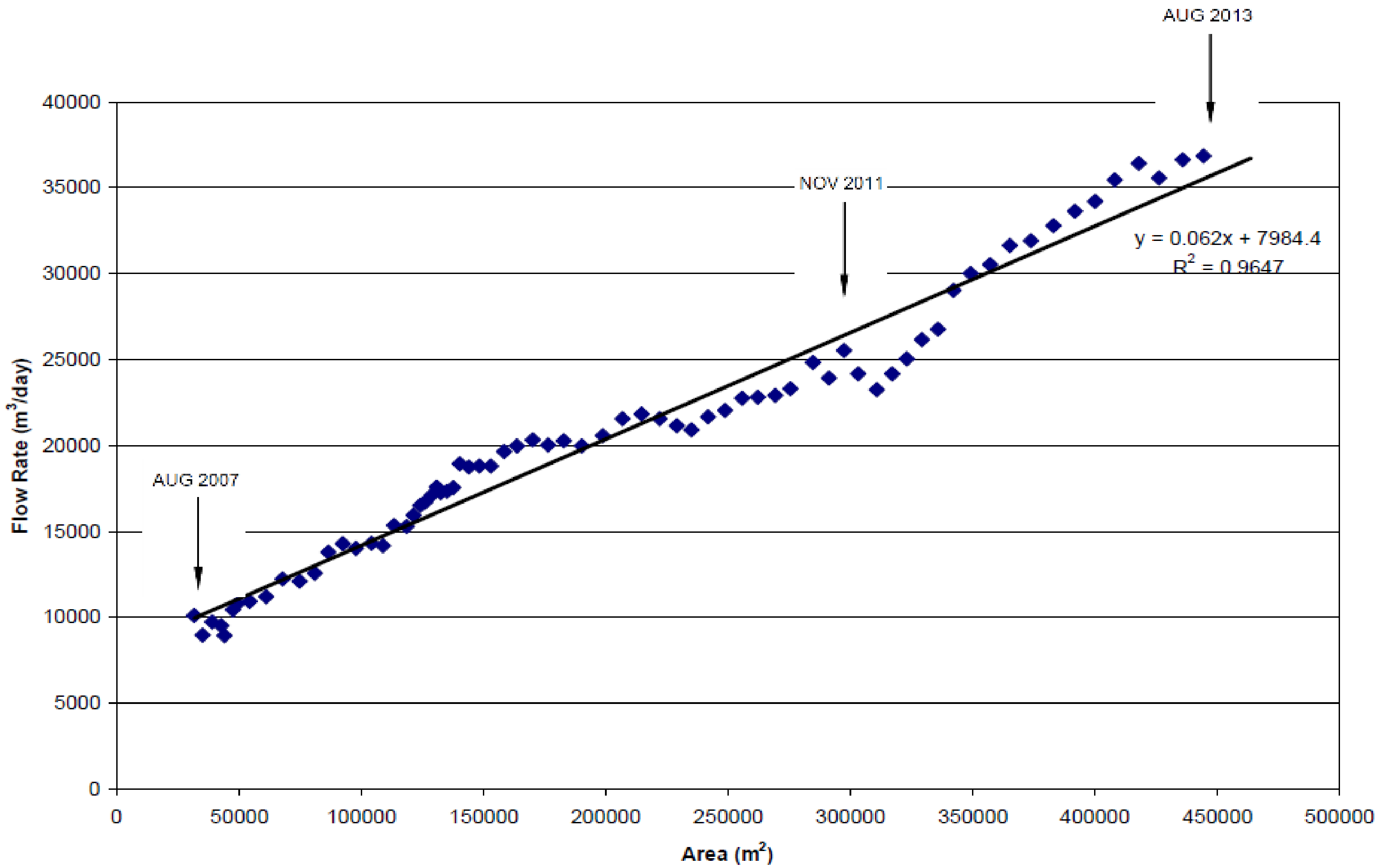
Current Status of Knowledge of Underground Mine Discharge

- The following is known about mining beneath Snap Lake and the permafrost:
  - Most of the underground mine discharge originates from Snap Lake.
  - Permafrost is the frozen rock outside of the lakes, which is about 210 m thick. Permafrost is considered to be impermeable.
- Extensive geological structures have been identified.
- Most of the groundwater that seeps to the mine workings is through structures, based on nine years of observation.

Extensive Faults Identified for Both Current and Future Mining



Measured Total Underground Mine Discharge vs. Mined Area (mostly under Snap Lake)



The measured underground mine discharge increases as the mined area increases (current mining under Snap Lake).

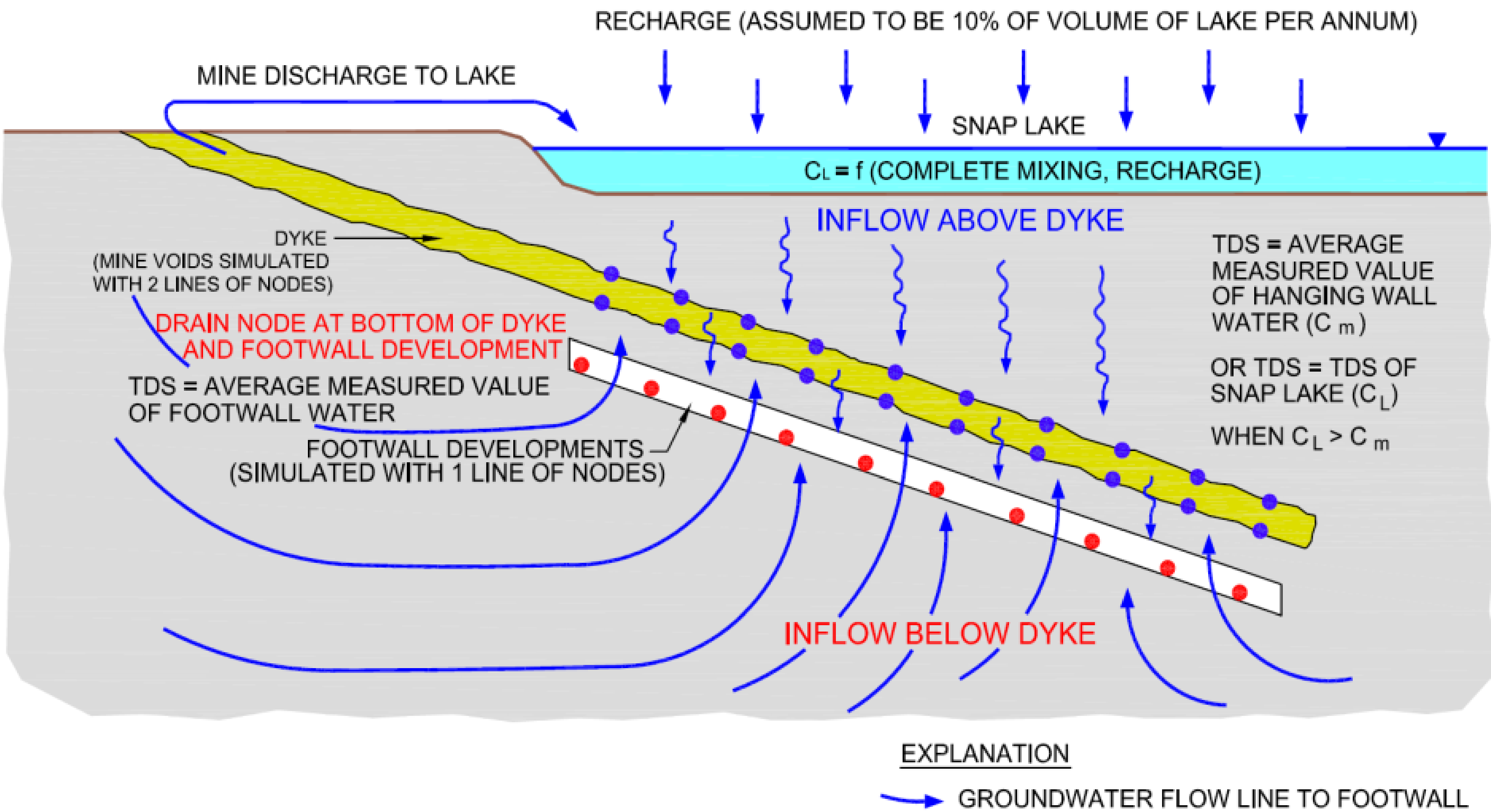
Current Status of Knowledge of TDS in the Underground Mine Discharge

- There are two different groundwater sources of TDS:
  - Hanging Wall (HW): Monitored TDS values range from 150 to 500 mg/L..
  - Footwall (FW): Monitored TDS values range from 100 to 20,000 mg/L.

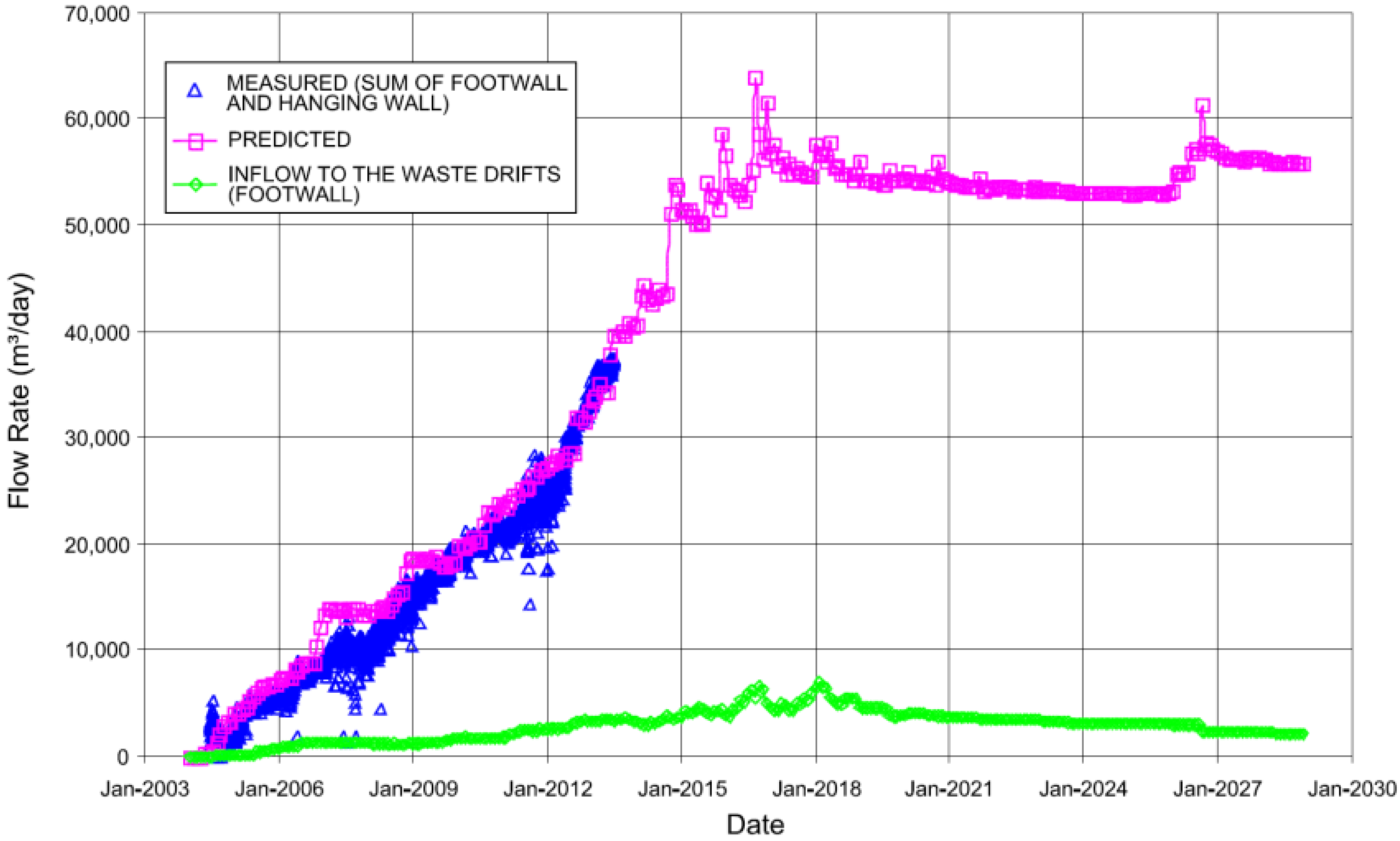
- TDS concentrations have been monitored in seeps to both the HW and FW during operation.
  - Monitored TDS values in seeps to both the HW and FW, observed during current operations, do not show a trend along depth.

- TDS concentrations in the underground mine discharge depend on the ratio of seepage rates to the HW over the FW mine workings.

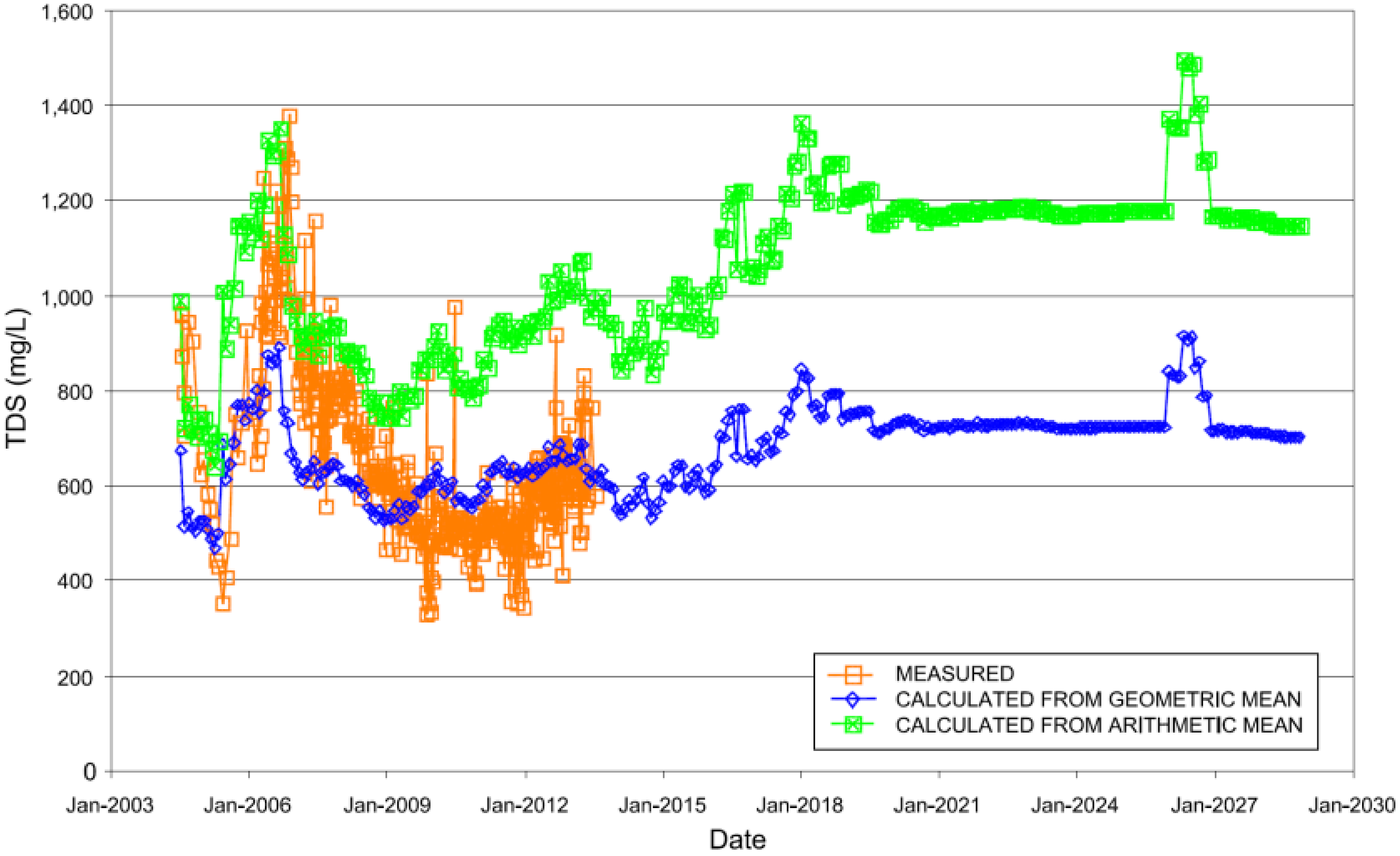
Conceptual Model for TDS Calculations



Measured and Simulated Total Underground Mine Discharge Rate and Simulated Seepage Rate to Footwall



Calculated and Measured TDS Concentrations in Underground Mine Discharge



Simulated TDS Concentrations

- The monitored TDS concentrations show two modes:
  - High values during the initial stage of FW development
  - Decreasing trend following the initial surge

- Two TDS concentrations were assumed for HW and FW groundwater to capture such variations:
  - Higher bound of TDS concentrations: HW, 229 mg/L; FW, 5,728 mg/L
  - Lower bound of TDS concentrations: HW, 215 mg/L; FW, 3,490 mg/L

- Predicted TDS concentrations capture the possible range of future TDS concentrations in the underground mine discharge.

High Certainty

- The model is calibrated to nine years of monitoring data related to:
  - Underground mine discharge rate
  - TDS values in the underground mine discharge
- The model incorporates updated structural data into the future mining.

Snap Lake Mine
Site Water Balance and Water Quality Model Predictions

Alison Snow, M.A.Sc.
Water Quality Modeller
Golder Associates Ltd.

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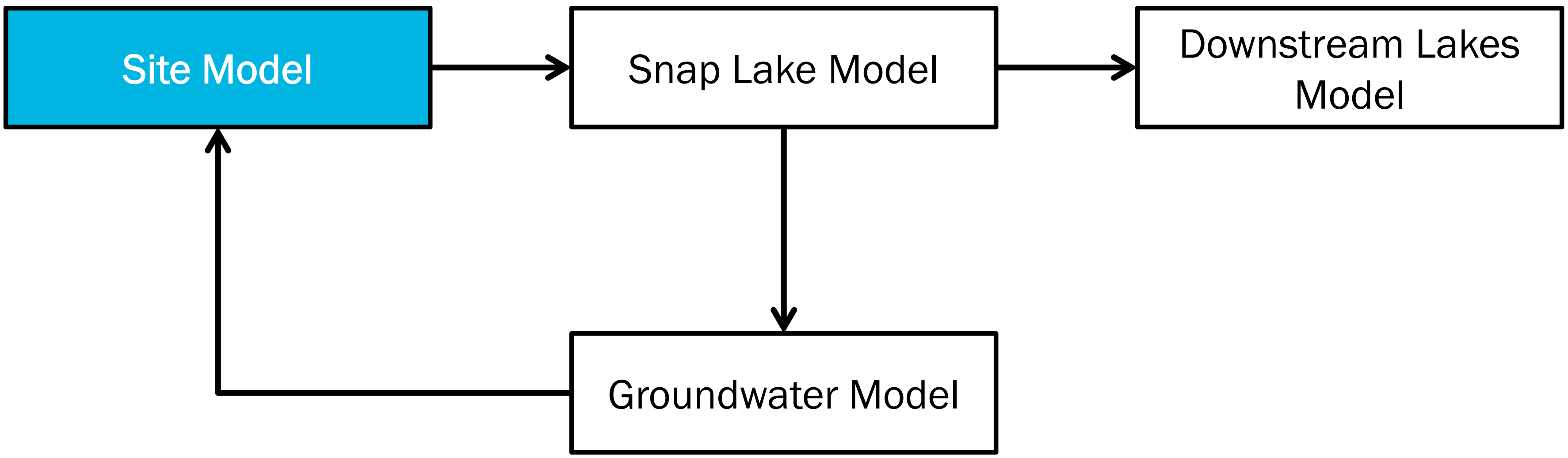
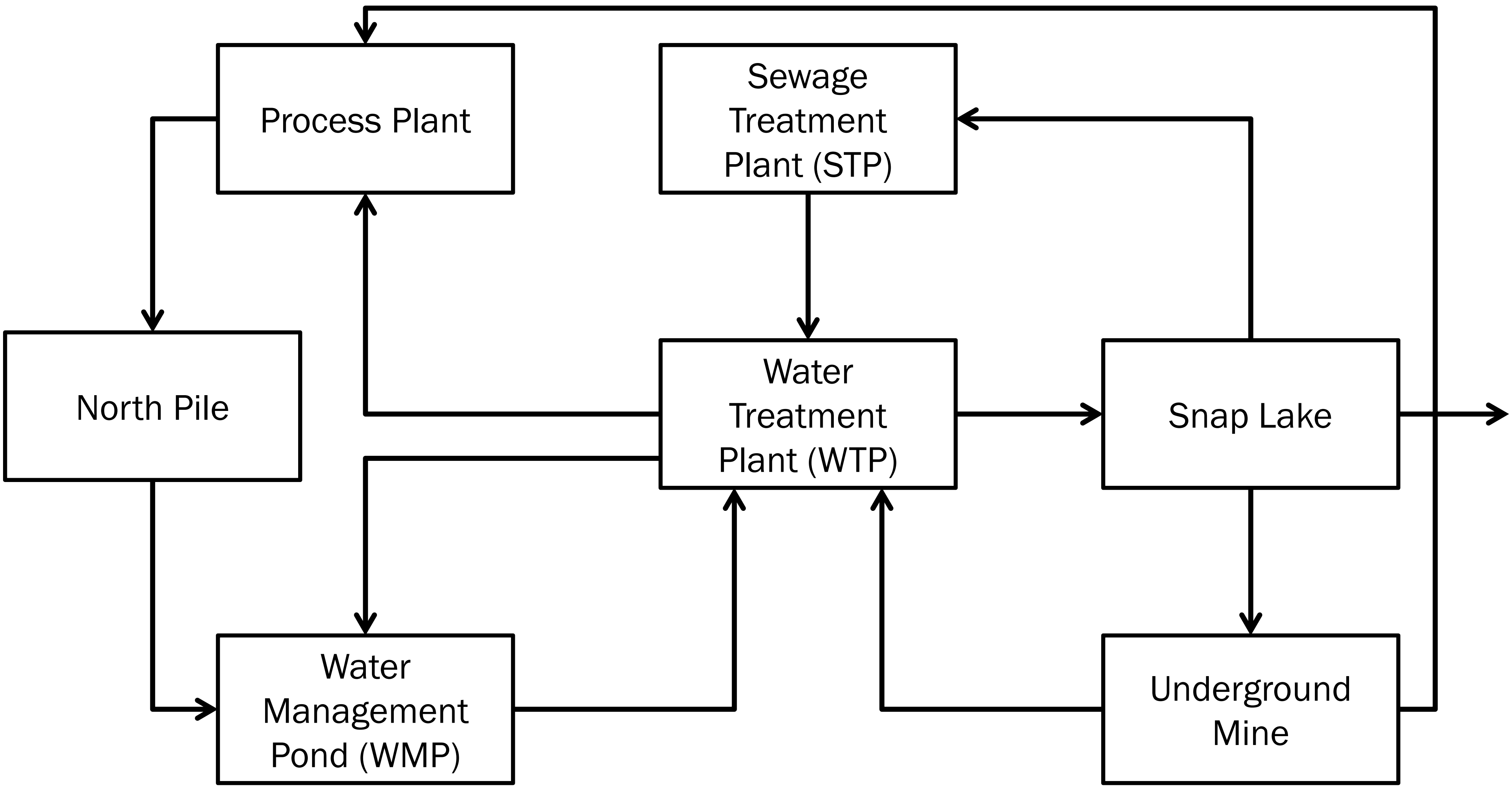
Model Linkages



- The purpose of the Site Model is to predict the quantity and quality of water discharged from the Mine site to Snap Lake
- The Site Model was developed in GoldSim

Mine Site Components



Water Quality Constituents

Group	Constituent
Solids	Total dissolved solids
Major Ions	Chloride
	Fluoride
	Sulphate
Nutrients	Nitrate

- Nitrite was not simulated in either the Site Model or the Snap Lake Model.

Model Scenarios

<u>Minewater Discharge</u>

1) Lower Bound
   - Hydraulic conductivities of structure zones were derived from model calibration
   - Predicted maximum minewater discharge rate of approximately 60,000 m^3/d
2) Upper Bound
   - Hydraulic conductivities of structure zones related to the Crackle and Snap Faults were increased by an order of magnitude
   - Predicted maximum minewater discharge rate of approximately 96,000 m^3/d

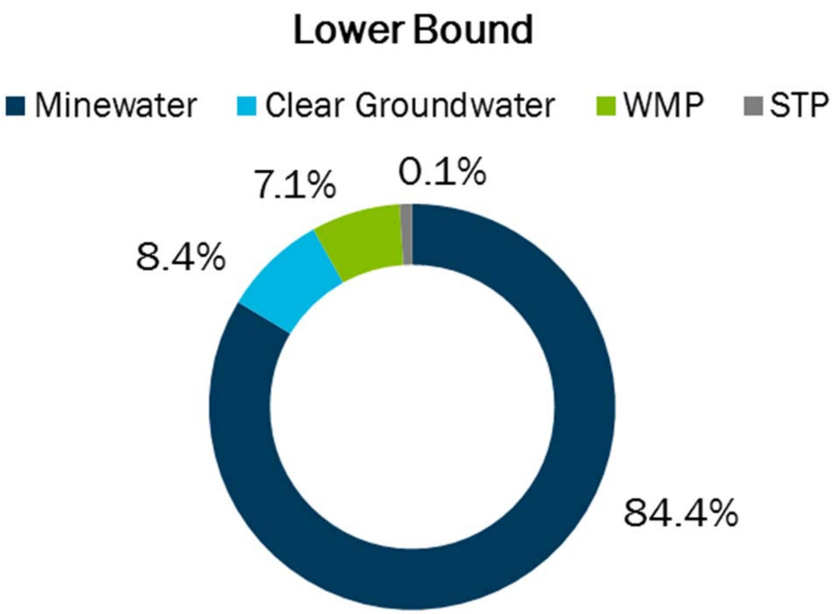
<u>Footwall Total Dissolved Solids Concentration</u>

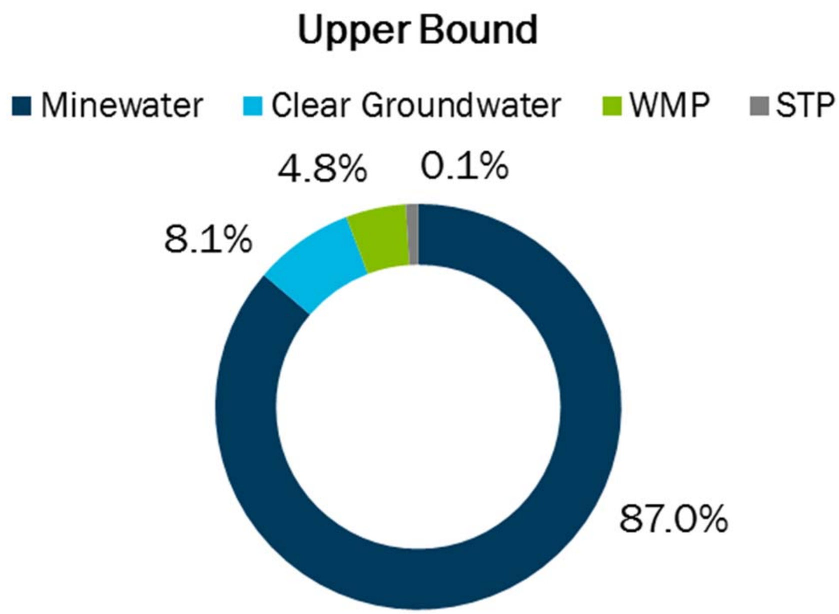
1) Scenario A = arithmetic mean = 5,728 mg/L
2) Scenario B = geometric mean = 3,490 mg/L

	Footwall Total Dissolved Solids Concentration	
Minewater Discharge	Scenario A	Scenario B
Upper Bound	Upper Bound Scenario A	Upper Bound Scenario B
Lower Bound	Lower Bound Scenario A	Lower Bound Scenario B

Key Findings - Inflows to the Water Treatment Plant

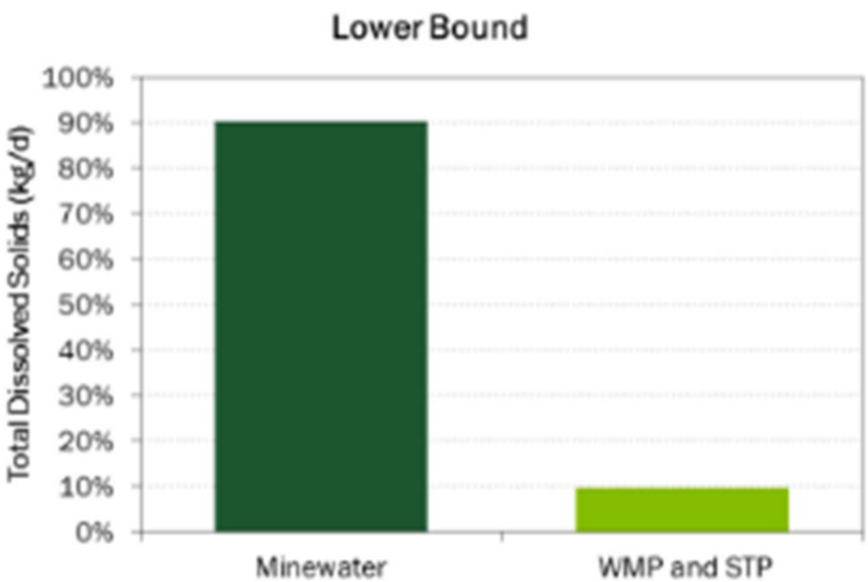
- Minewater discharge accounts for the majority of flows to the WTP
- Water pumped from the North Pile sumps and site runoff captured in the WMP peaks during freshet

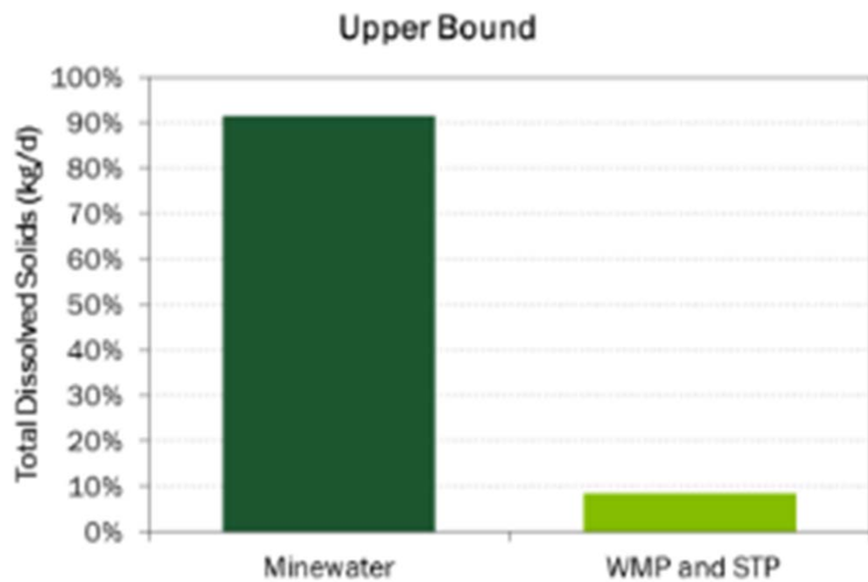




Key Findings – Total Dissolved Solids Loading to the Water Treatment Plant

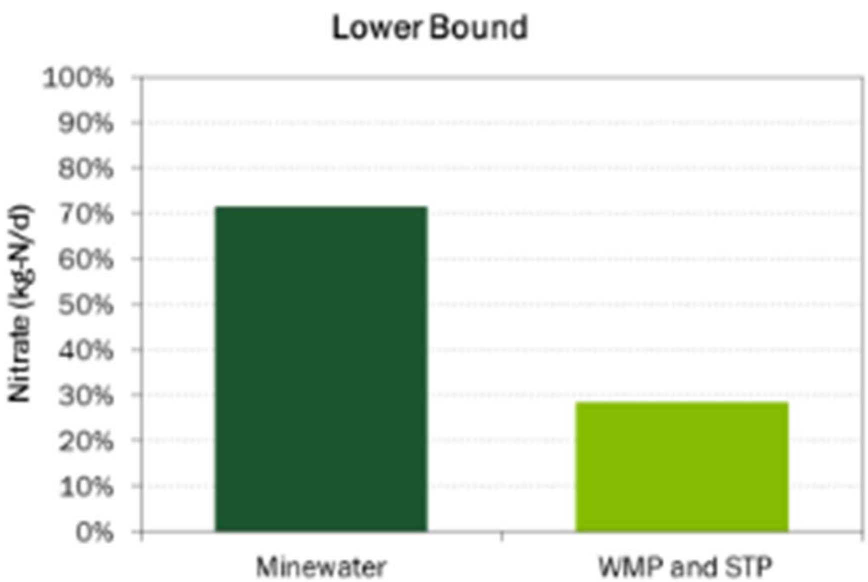
- Minewater accounts for the majority of loading to the WTP especially for TDS and major ions
- Loadings from the North Pile sumps and from site runoff captured in the WMP peak during freshet

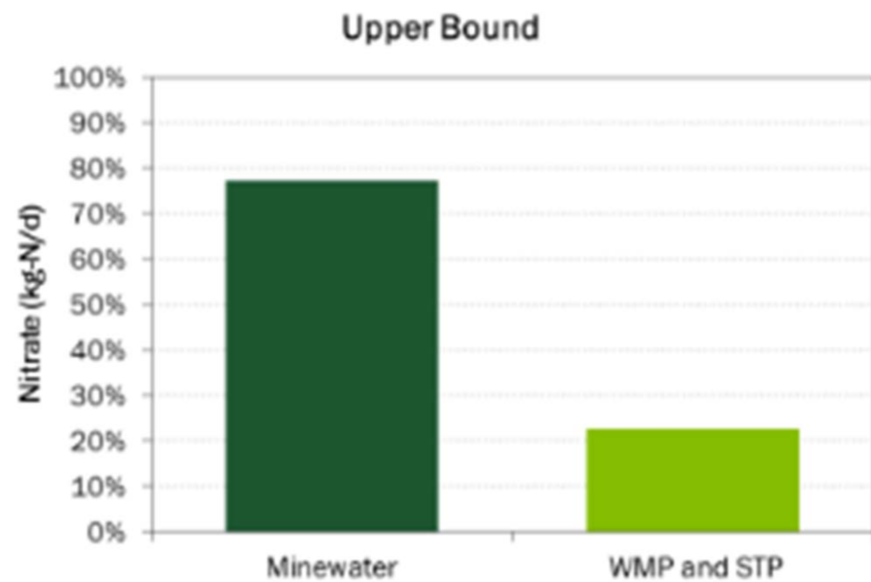




Key Findings – Nitrogen Loading to the Water Treatment Plant

- Loadings from the North Pile and from site runoff captured in the WMP make up a larger percentage of the loading to the WTP for nitrogen parameters





Snap Lake Mine Hydrodynamic and Water Quality Model Predictions

Alison Snow, M.A.Sc.
Water Quality Modeller
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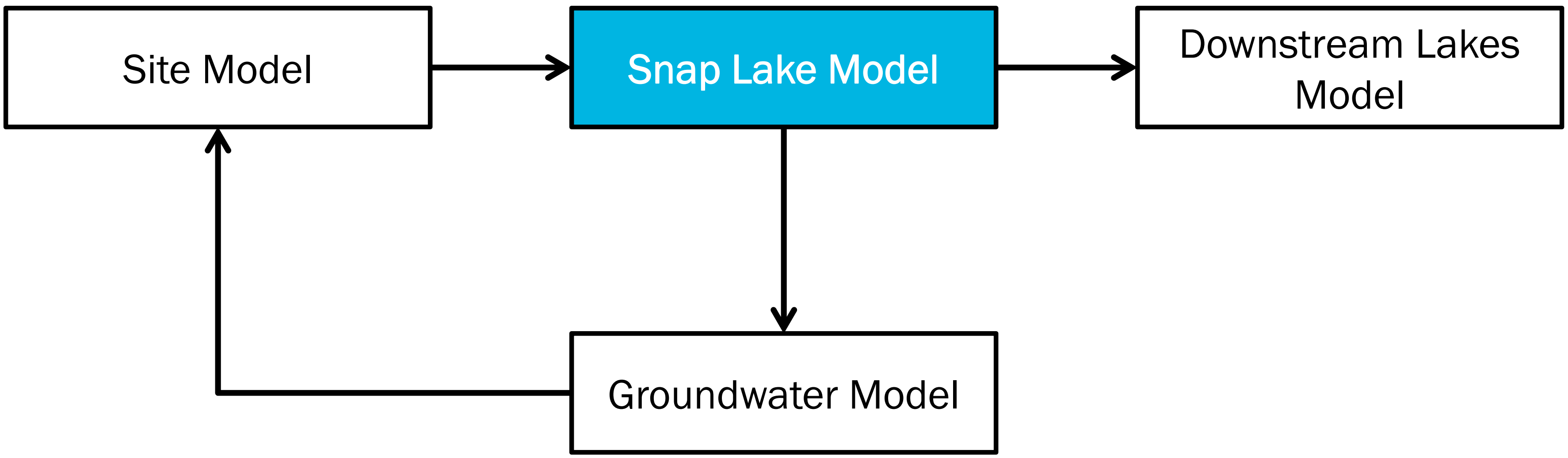
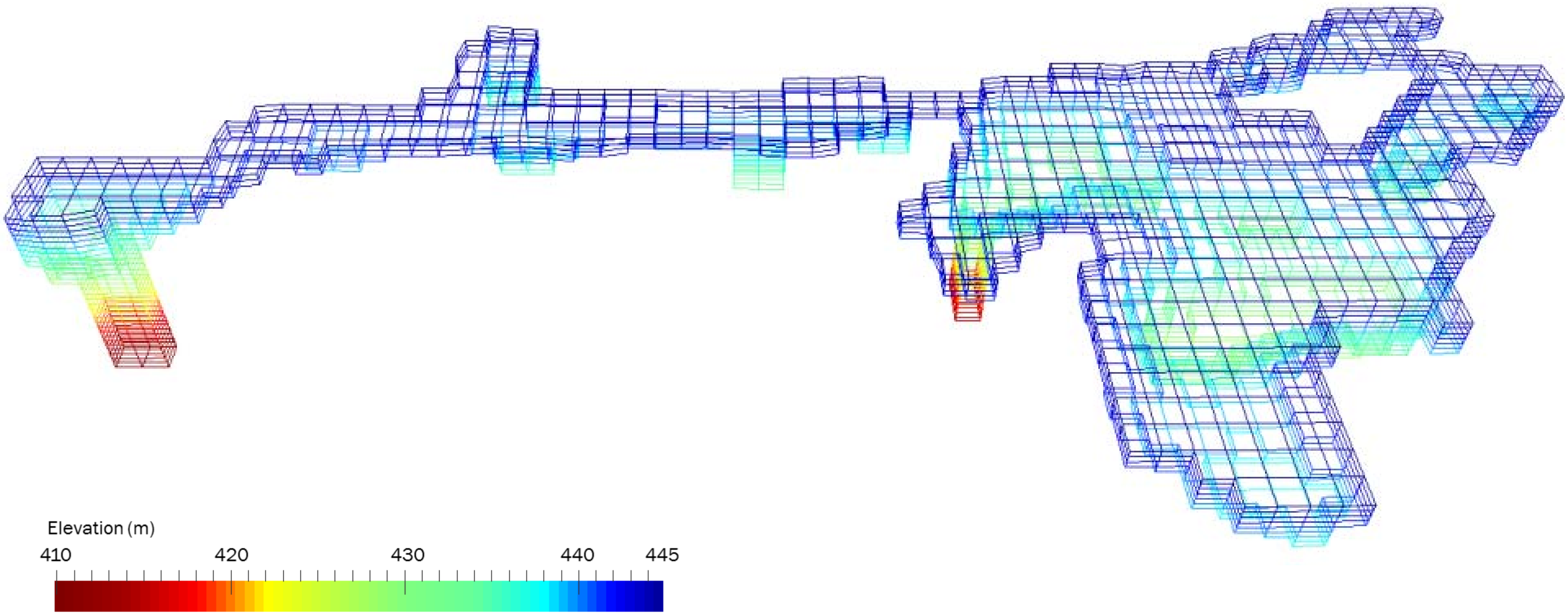
Model Linkages



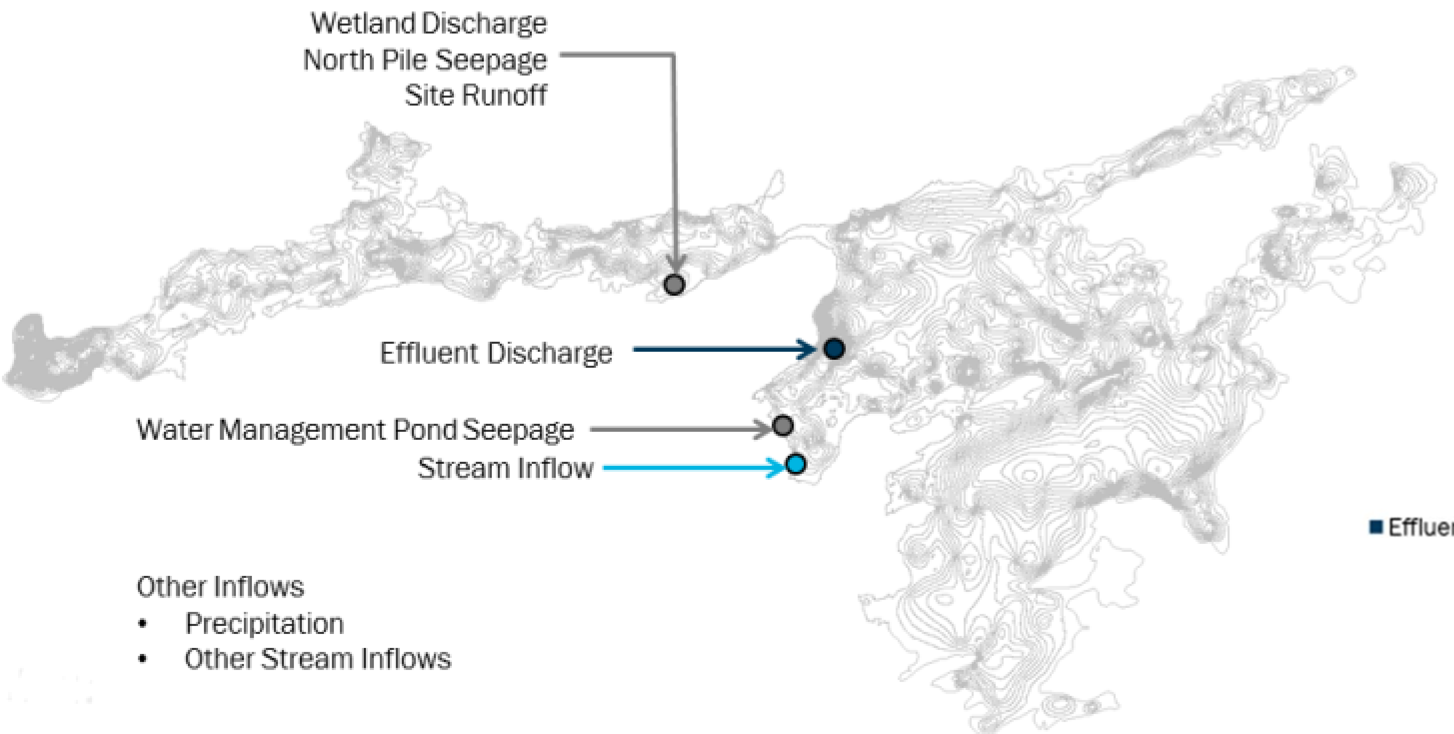
- The purpose of the Snap Lake Model is to predict concentrations of TDS, major ions, nutrients, and metals in Snap Lake
- The Snap Lake Model was developed in GEMSS

Snap Lake Model Grid

- Grid resolution: 200 metres x 200 metres x 1 metre

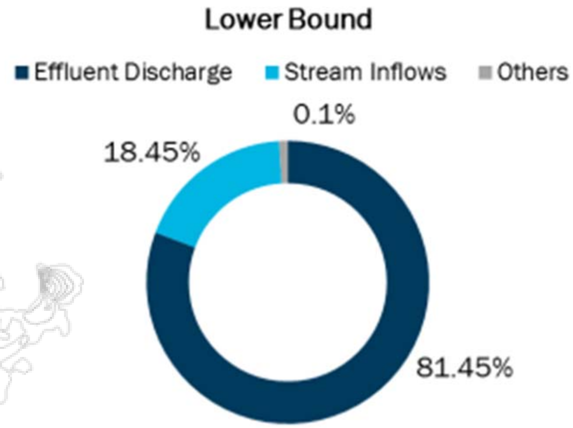


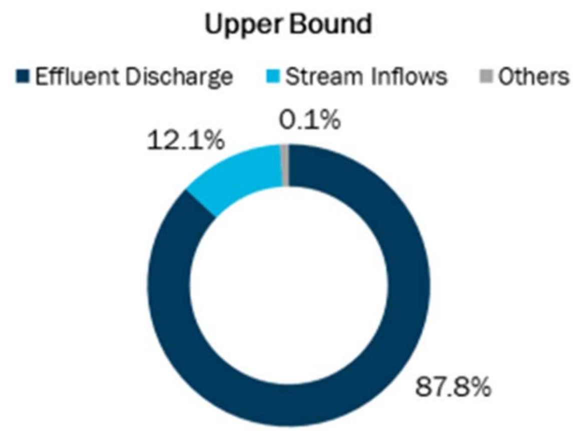
Model Inputs – Inflows to Snap Lake



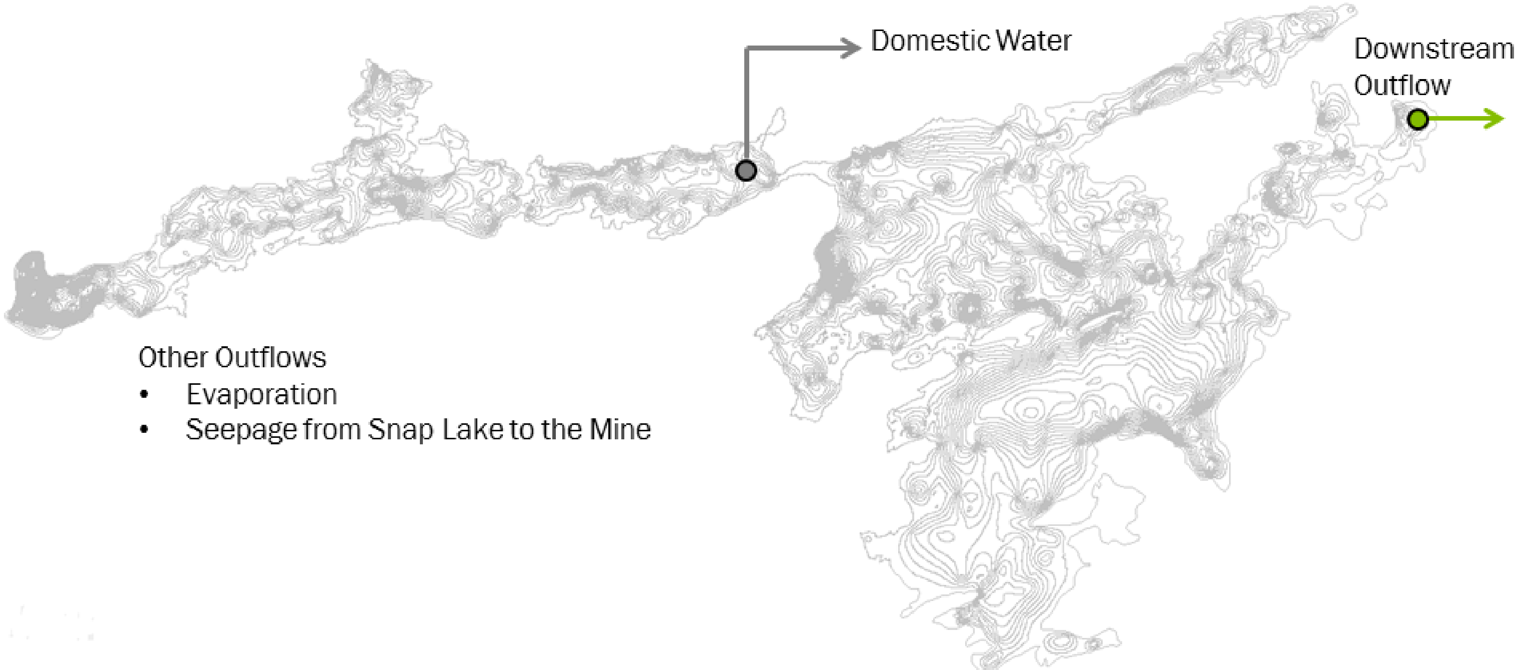
Other Inflows

- Precipitation
- Other Stream Inflows



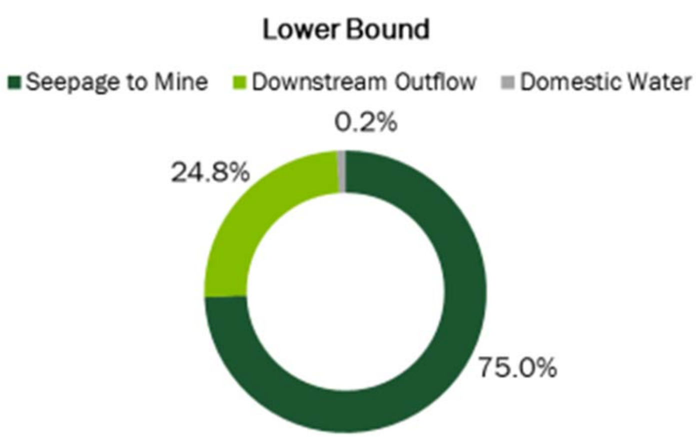


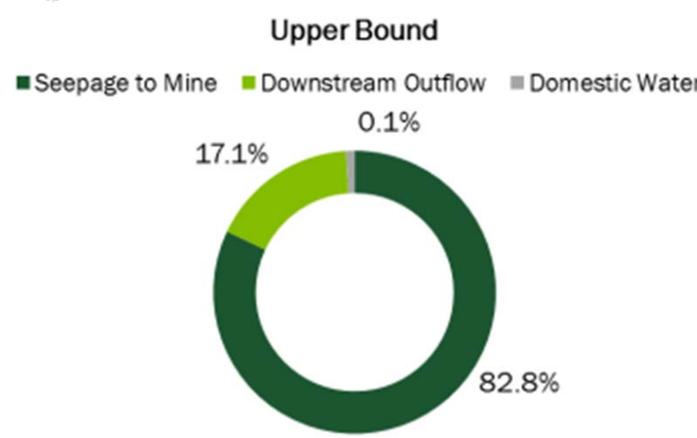
Model Inputs – Outflows from Snap Lake



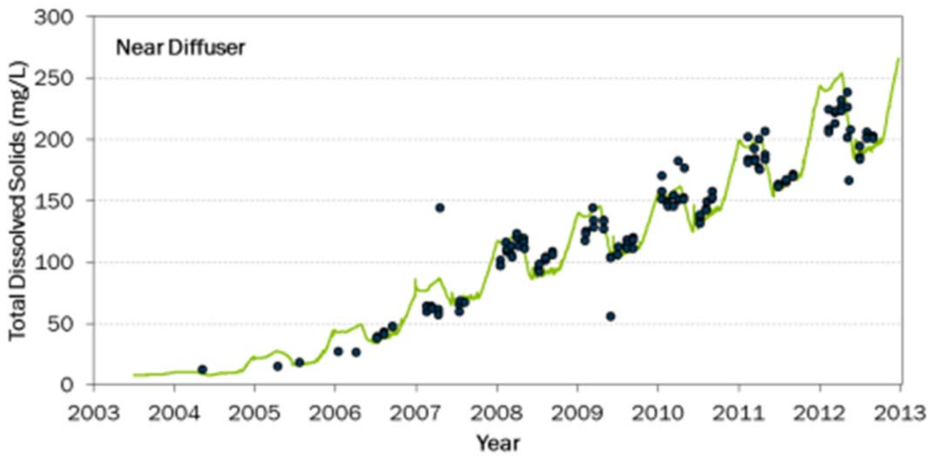
Other Outflows

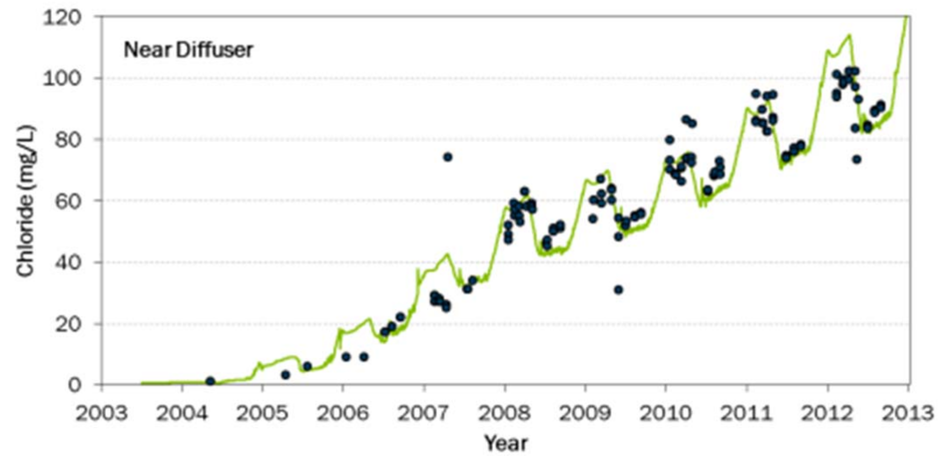
- Evaporation
- Seepage from Snap Lake to the Mine

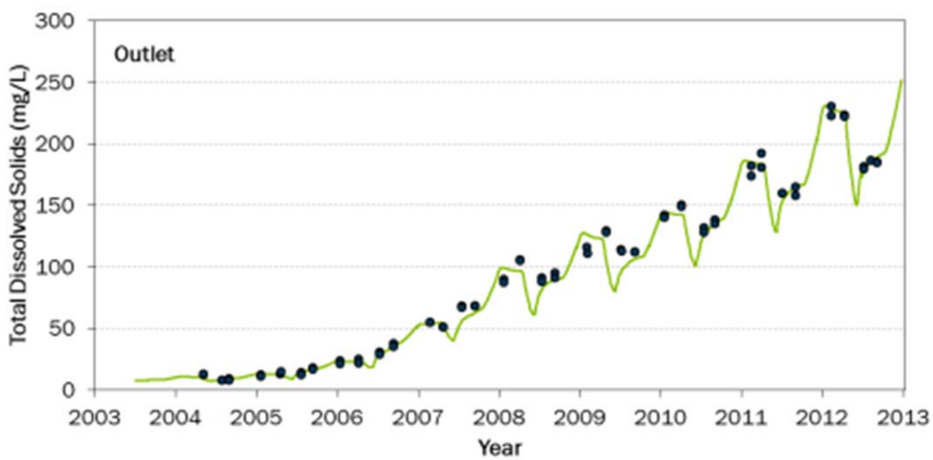


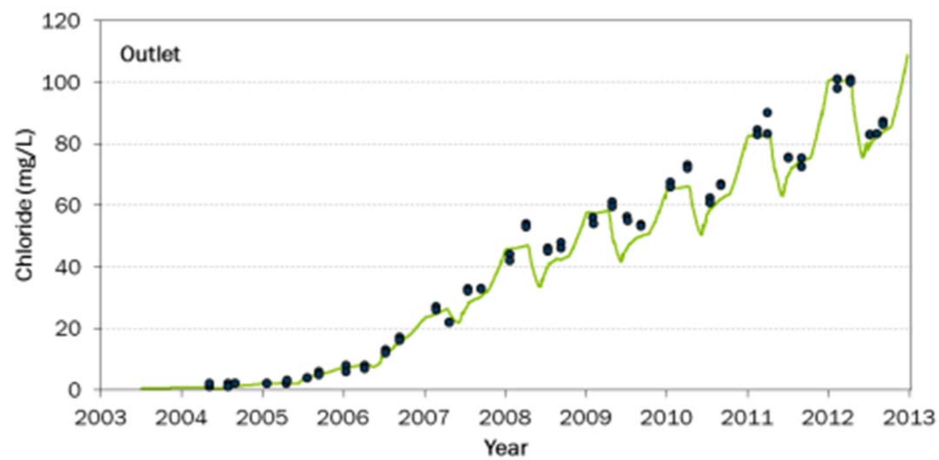


Model Calibration – Total Dissolved Solids and Chloride









Model Scenarios

	Footwall Total Dissolved Solids Concentration	
Minewater Discharge	Scenario A (5,728 mg/L)	Scenario B (3,490 mg/L)
Upper Bound (96,000 m^3/d)	Upper Bound Scenario A	Upper Bound Scenario B
Lower Bound (60,000 m^3/d)	Lower Bound Scenario A	Lower Bound Scenario B

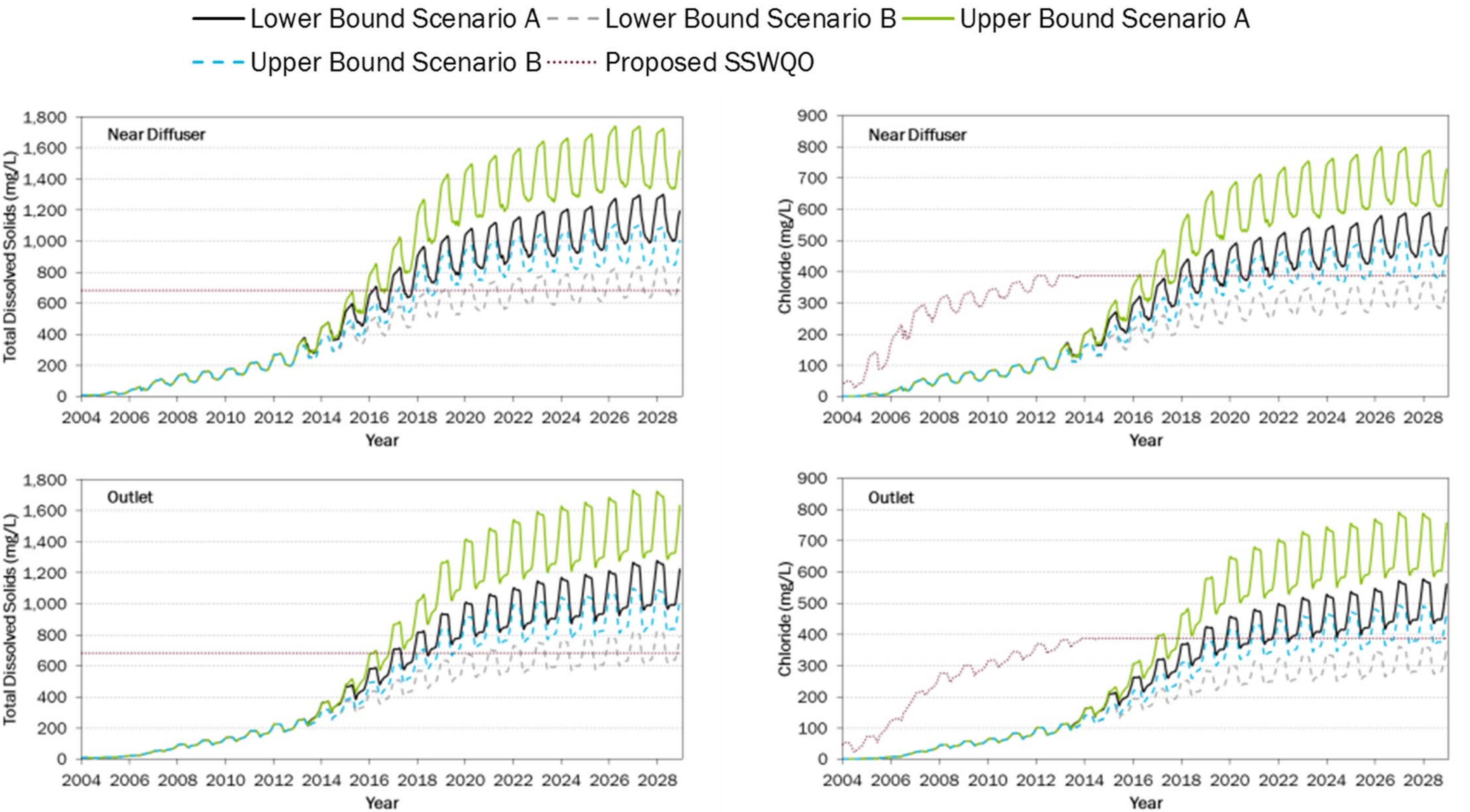
Maximum Predicted Concentrations during Operations

Constituent	Proposed SSWQO	Units	Maximum Concentrations at Diffuser Stations			
			Lower Bound Scenario A	Lower Bound Scenario B	Upper Bound Scenario A	Upper Bound Scenario B
TDS	684	mg/L	**1,311**	**845**	**1,753**	**1,117**
Chloride	388	mg/L	**594**	375	**808**	**511**
Fluoride	2.46	mg/L	0.47	0.47	0.48	0.48
Sulphate	429	mg/L	90	59	120	78
Nitrate	16	mg-N/L	9	9	10	10

Site-specific water quality objectives (SSWQOs) apply in the lake and are protective of aquatic life – a specific concentration of a substance in water beyond which detrimental effects to aquatic life may occur

Bolded values indicate predicted exceedances of SSWQO

Predicted Depth-Averaged Total Dissolved Solids and Chloride Concentrations



Key Findings

- In all four scenarios, TDS concentrations are predicted to exceed the proposed SSWQO of 684 mg/L. TDS concentrations near the diffuser stations and at the outlet of Snap Lake are predicted to range from approximately 800 to 1,700 mg/L in 2028

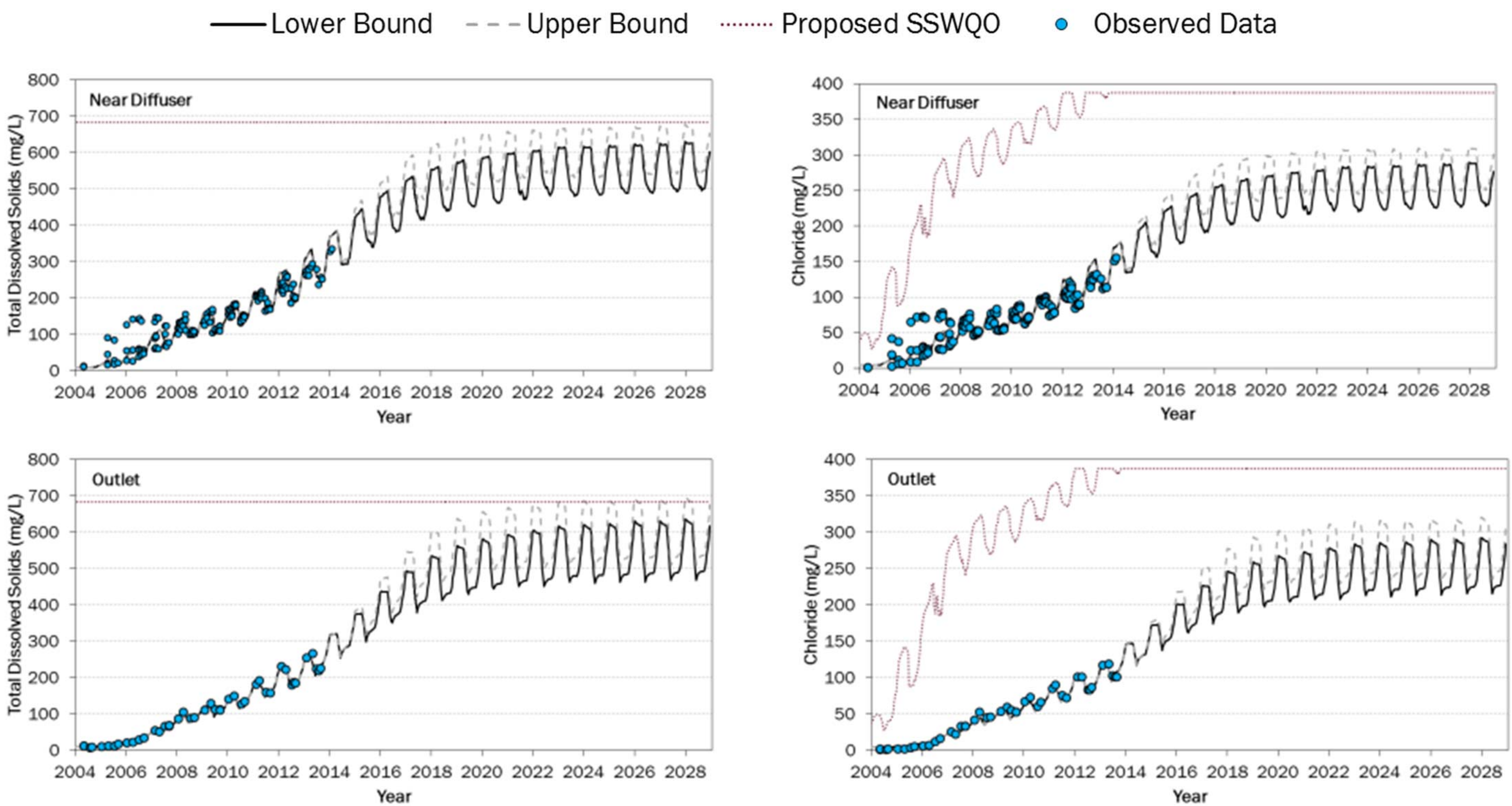
- Chloride concentrations are predicted to exceed the proposed SSWQO of 388 mg/L near the diffuser stations and at the outlet of Snap Lake in Upper Bound Scenarios A and B and Lower Bound Scenario A. In Upper Bound Scenarios A and B and Lower Bound Scenario A, chloride concentrations are predicted to increase to approximately 800, 500, and 600 mg/L in 2028, respectively

- Concentrations of all nutrients, other ions, and total metals and metalloids in Snap Lake are predicted to remain below proposed SSWQOs

Model Scenarios – Proposed Effluent Quality Criteria are Met

Name	Effluent Discharge Rate	Effluent Discharge TDS Concentration as of January 1, 2015 (mg/L)
Base Case A	Lower Bound	$\leq$ 684
Base Case B	Upper Bound	$\leq$ 684

Predicted Depth-Averaged Total Dissolved Solids and Chloride Concentrations (Proposed EQC are Met)



Snap Lake Mine
Downstream Lakes Total Dissolved Solids Model Predictions

Alison Snow, M.A.Sc.
Water Quality Modeller
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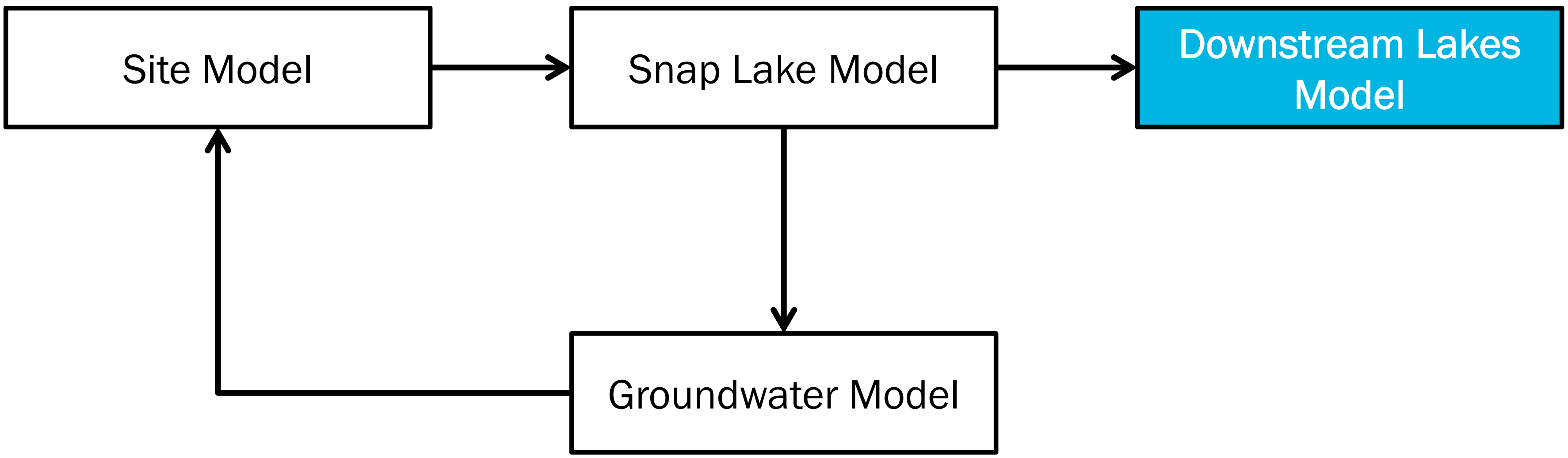
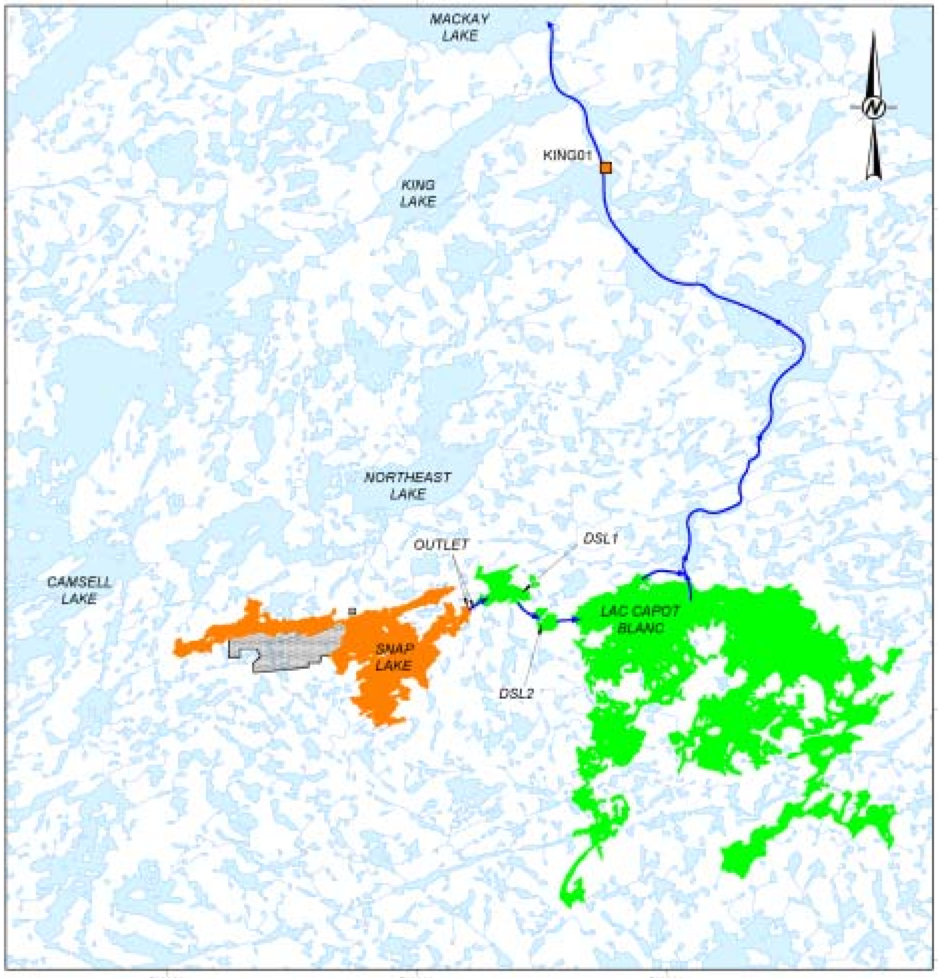
Model Linkages



- The purpose of the Downstream Lakes Model is to predict concentrations of TDS in lakes downstream of Snap Lake

Downstream Lakes Current Monitoring

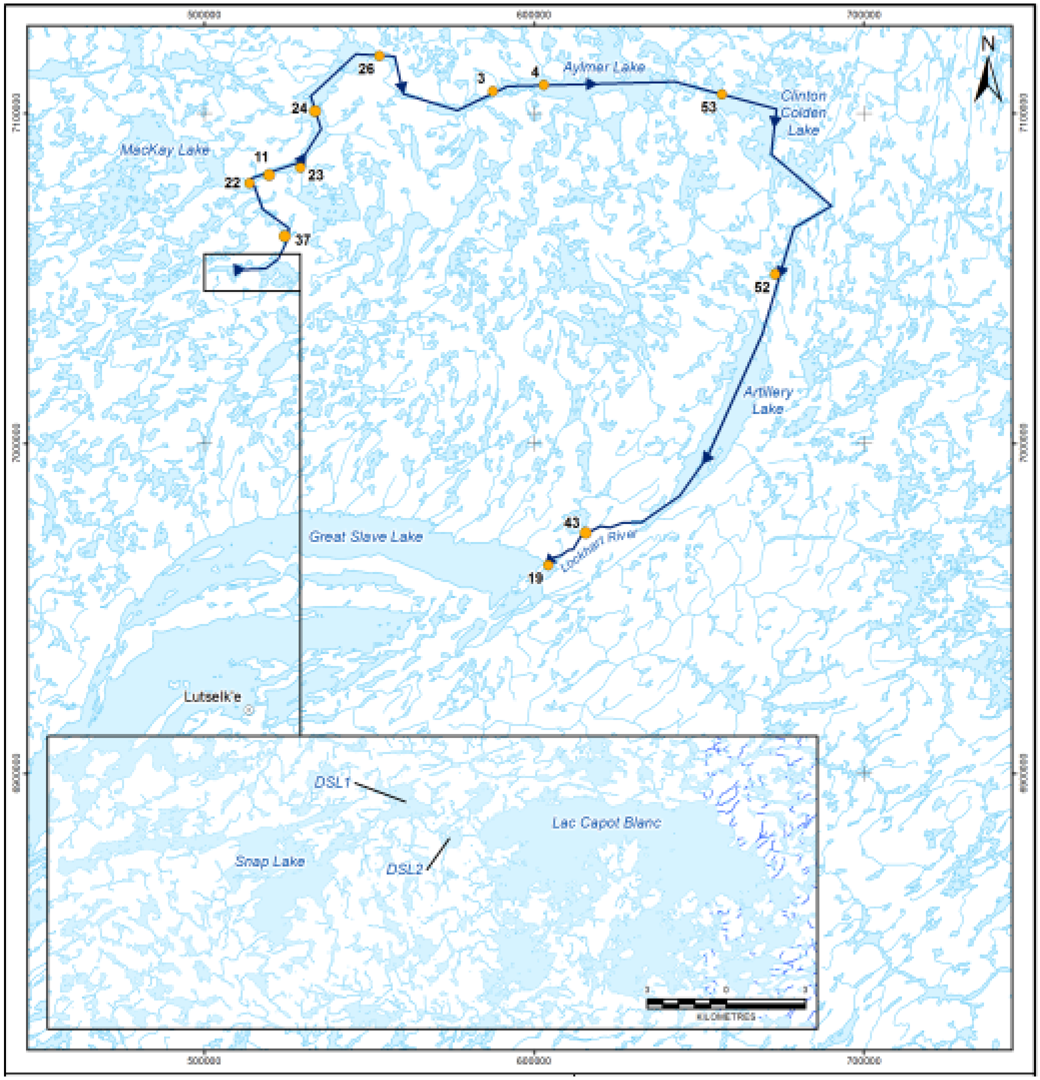


Downstream Lakes Models

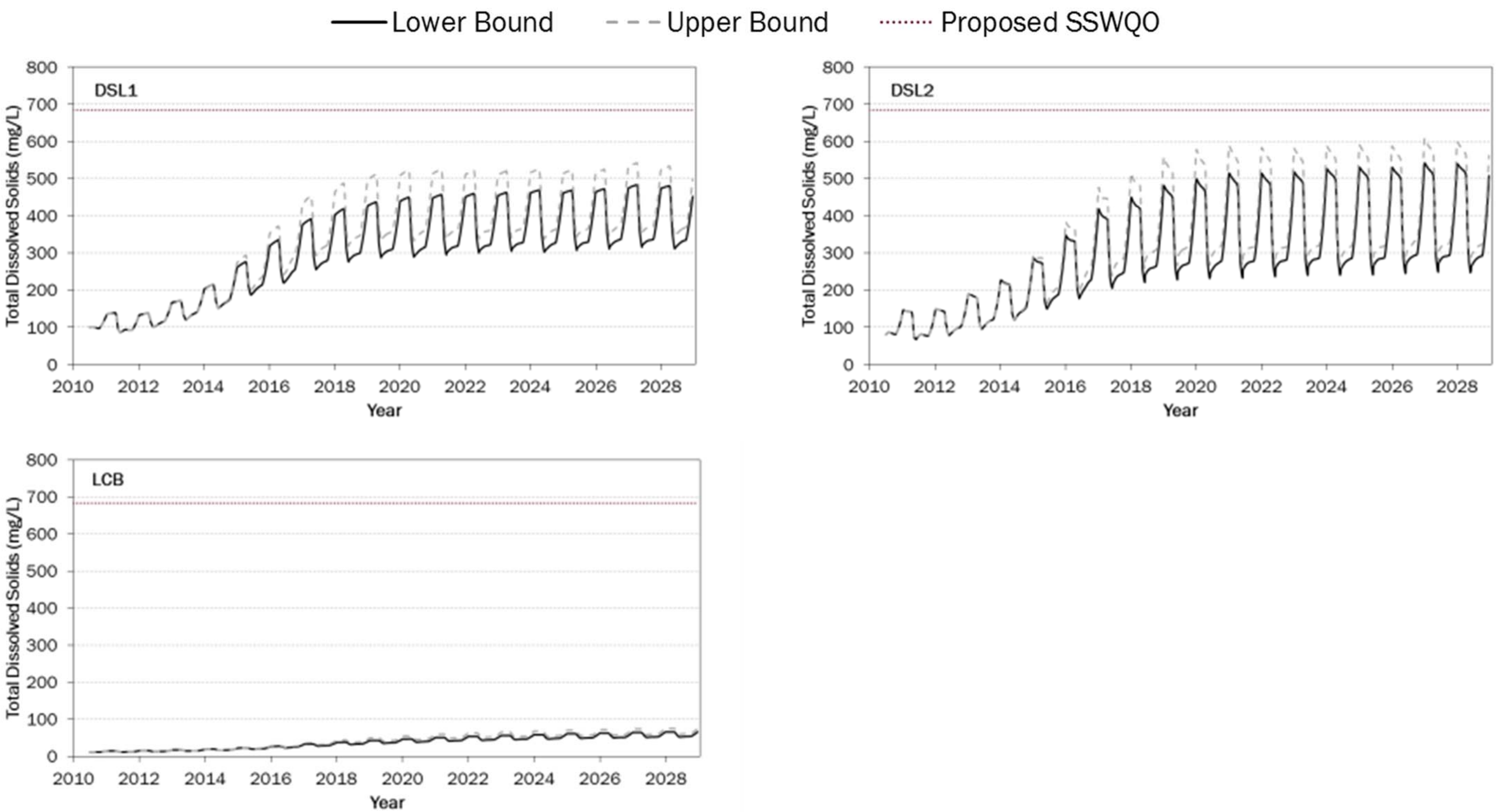
1) Mass-balance Model
   - Downstream Lake 1 (DSL1)
   - Downstream Lake 2 (DSL2)
   - Lac Capot Blanc (LCB)

2) Hydrodynamic Model
   - LCB

3) Mass-balance Model
   - Lakes downstream of LCB



Model Results - Whole-lake Average Total Dissolved Solids Concentrations



Maximum Predicted Total Dissolved Solids Concentrations in Lakes Downstream of Lac Capot Blanc

Downstream Site	Distance Downstream from Snap Lake (km)	Baseline TDS (mg/L) (Range = 10 to 53)	Maximum TDS Concentrations (mg/L)		
			EAR Predictions	2013 Model Predictions	
				Base Case A	Base Case B
37 (U/S of King Lake)	24	17	119	66	74
22 (Mackay Lake)	44	20	41	37	39
11 (Mackay Lake)	54	12	16	16	16
23 (Mackay Lake)	65	10	13	13	13
24 (Mackay Lake)	81	14	16	17	17
26 (Mackay Lake)	109	17	19	19	20
3 (Inlet of Aylmer Lake)	155	20	22	22	22
4 (Aylmer Lake)	172	24	22	26	26
53 (Clinton Colden Lake)	227	35	36	36	36
52 (Ptarmigan Lake)	310	24	25	25	25
43 (Lockhart River)	419	53	54	54	54
19 (Lockhart River)	434	14	14	14	14

Note: Shaded cells indicate where TDS concentrations are predicted to be outside of the baseline range

Key Findings

With TDS in the effluent discharge to Snap Lake less than or equal to the proposed EQC of 684 mg/L

- TDS concentrations were predicted to decrease with distance downstream of Snap Lake
- TDS concentrations in DSL1, DSL2, and LCB were predicted to remain below the proposed SSWQO of 684 mg/L
- TDS concentrations downstream of LCB were predicted to be within EAR predictions and the baseline range at Site 22 (MacKay Lake), which is approximately 44 km downstream of Snap Lake

TDS Response Plan

Erica Bonhomme, Manager, Environment Snap Lake Mine

De Beers
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TDS Response Plan

- Licence required Plan to be submitted for approval by December 31, 2013
- To include items 3.a)-d) of Schedule 5, Part F of licence
- Notably, the requirements to recommend:
  - *"...appropriate Water Quality Objectives for TDS, Chloride and Fluoride in Snap Lake derived from toxicity testing..."; and,*
  - *"...EQCs for TDS, Chloride and Flouride, to be applied at SNP station 02-17 that would ensure protection of aquatic life in Snap Lake."*
- There are no national water quality guidelines for TDS
- The conclusions of these required toxicity studies has led De Beers' to recommend site-specific water quality objectives (SSWQOs) for Snap Lake, and new (higher) EQCs for TDS, Chloride and Fluoride
- The recommended SSWQOs and EQCs are the foundation of the amendment application.

TDS Response Plan

- The full results of the studies are provided in the following reports:
  - Development of Total Dissolved Solids Chronic Effects Benchmark for Aquatic Life in Snap Lake
  - Development of Fluoride Chronic Effects Benchmark for Aquatic Life in Snap Lake
- Recent supplemental toxicity testing (*Daphnia magna*) suggests that an even higher SSWQO for TDS than proposed may be appropriate
  - Technical Memo: Results of 2nd *Daphnia magna* Toxicity Test Results
- A TDS EQC which is inclusive of chloride, fluoride and sulphate would be protective of the aquatic environment
- De Beers has high confidence that the current proposal is protective of the aquatic environment, however requests the opportunity to present additional evidence specific to TDS as part of the MVLWB review process

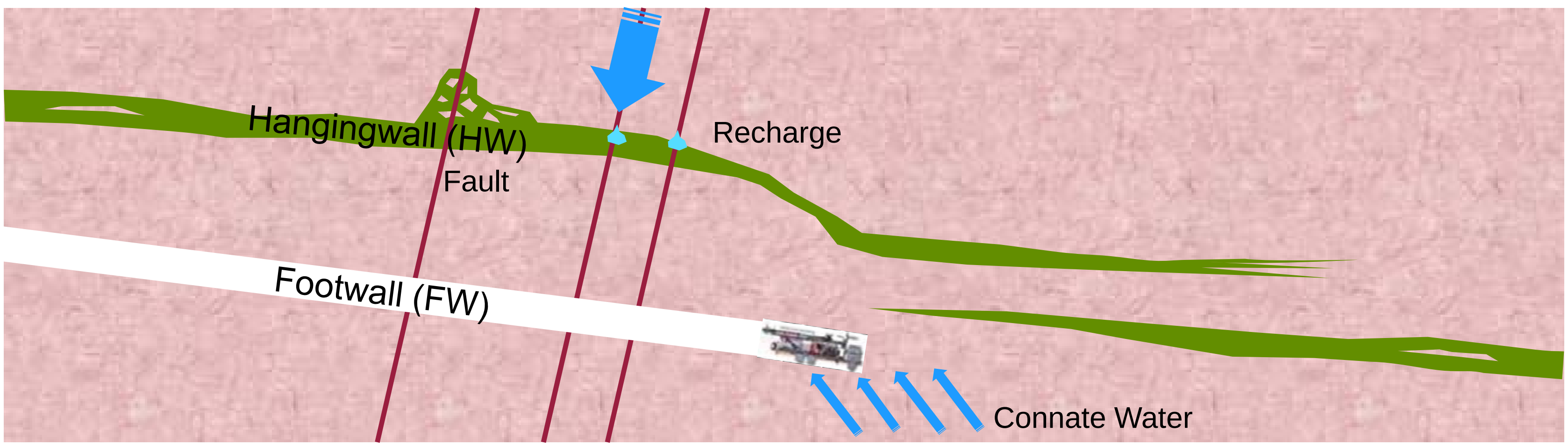
TDS Sources and Management

Assessment and quantification of sources of TDS loading in minewater:

- Based on results from Snap Lake Site Water Quality Model Report and Groundwater Model Scenarios
- Models updated annually based on field monitoring data
- ~90% TDS loading is from underground (as measured at SNP 02-01)
- Most TDS is released during footwall development

Current practices for minimizing groundwater seepage to the underground:

- Cover hole drilling minimizes risk of encountering high flow zone
- Grouting provides temporary and partial reduction in flow only



TDS Sources and Management

Summary of investigations into minimizing TDS loadings to the environment:

- Pre-feasibility comparison of effluent treatment technologies (RO, IX, EDR, distillation, activated alumina, lime precipitation)
- Pre-feasibility screening of conceptual ultrafiltration/RO/Crystallization system for treatment of footwall water
- In-line and handheld monitoring of minewater and effluent to improve understanding of flows, loadings and variability

Options for reducing TDS in effluent:

- Evaluation of pre-feasibility studies concludes that micro-filtration, RO, IX and evaporation/crystallization processes are potentially feasible for Snap Lake
- Treatment of full mine effluent is not cost-effective
- Reducing TDS in effluent in order to maintain whole-lake average below 350 mg/L is not economically feasible, nor necessarily practicable for Snap Lake Mine
- Currently in Concept Pilot Testing stage to evaluate options for treating effluent to meet proposed SSWQOs for TDS that are both practicable and protective of the environment

TDS Treatment Pilot Testing and Feasibility

- Concept Pilot Testing underway; feasibility decision Q4 2014
- Feasibility will be based on detailed cost-benefit analysis and decision on SSWQOs

↑ TDS removal = ↑

Waste Generation
Energy Consumption
GHG Emissions
Operating Cost
Infrastructure

<u>Other Considerations</u>
Reliability
Scalability
Effectiveness
Temporary Brine Storage
Seasonality of Road

- Initial Findings:
  - Treatment can be more than 90% effective at removing TDS from minewater
  - No need to target specific ions, but rather TDS as a whole
  - Targeted footwall treatment is not practicable under current mine operating conditions
  - May be most practicable to treat a percentage of minewater.

TDS Treatment Pilot Testing and Feasibility

Treated Parameters:

- TDS, Nitrate (NO3-) and Nitrite (NO2-), Chloride (Cl-) and Fluoride (F-) Ions

Potentially Feasible at Snap Lake Mine:

  - Membrane Filtration Micro-filtration and Reverse Osmosis
  - Ion Exchange for Water Softening
  - Evaporation/Crystallization
  - Partial Treatment for Blending

- Initial treatability involves performing numerical simulation
- Pilot Testing proposes a physical simulation off-site
- Reduced-scale treatment plant will be used to:
  - Evaluate treatment
  - Obtain critical design parameters, and
  - Predict system performance

Pilot Test Facility and Treatment Units

Clarifier Gravity Settling

Microfiltration/Reverse Osmosis Skids

Ion Exchange/Chemical Softening

Treatment Units – Pilot Test

Microfiltration (MF)
- Filter Suspended Solids down to 0.1 Micron

Reverse Osmosis (RO)
- Mechanical process to filter out all dissolved ions

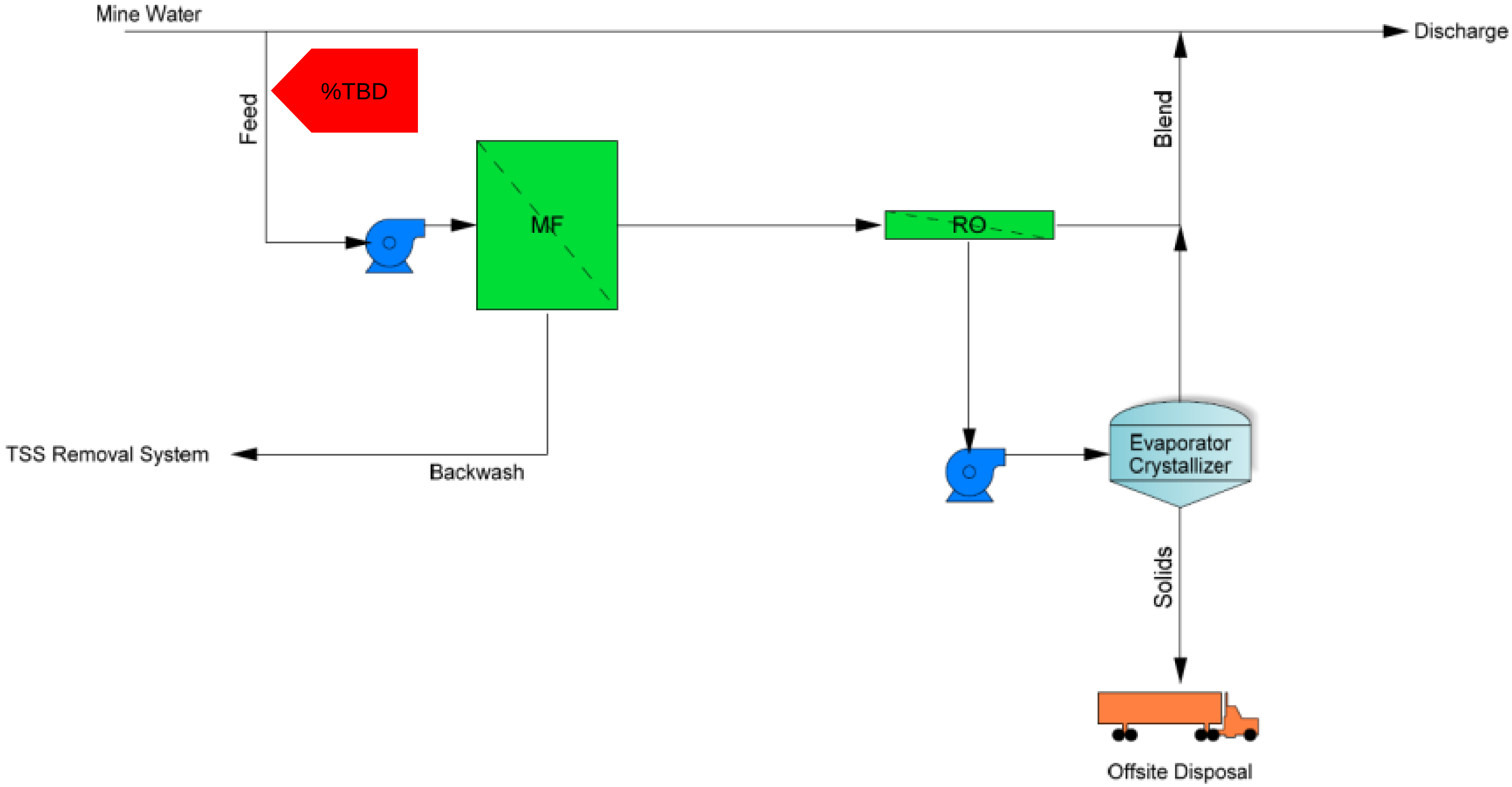
Ion Exchange (IX)
- Chemical process to remove specific ions (cations or anions or both)

Evaporator/Crystallizer
- Remove water from concentrated brine to generate solid salts

Treatment Flow Diagram - 4 Pilot Test Options

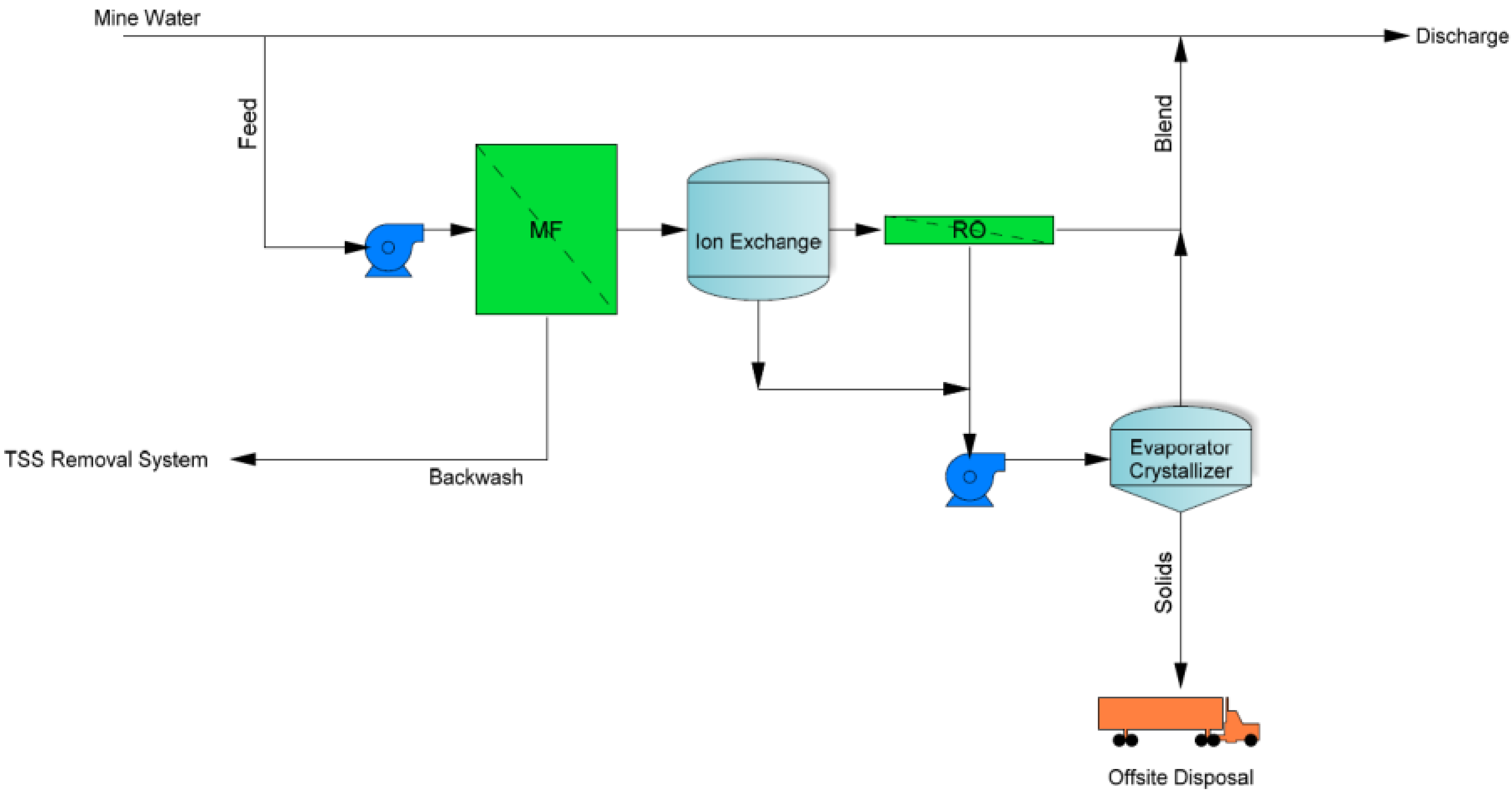
- Numerical Simulation used to inform initial Treatability Studies
- Physical Simulation – Pilot Testing Proposed

Option 1: MF/RO/Evap/Crystallizer Concept



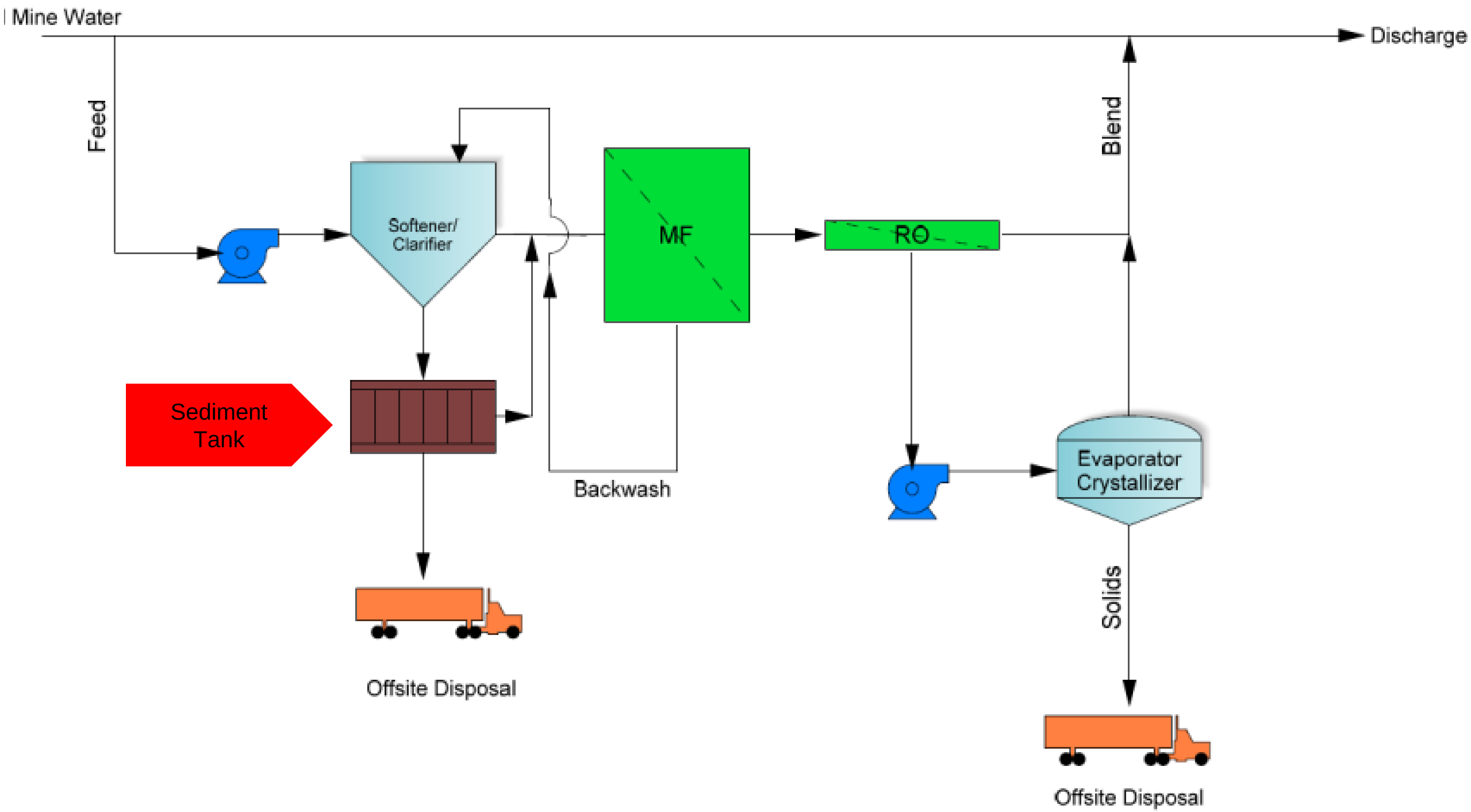
Treatment Flow Diagram - 4 Pilot Test Options

Option 2: MF/IX/RO/Evap/Crystallizer Concept



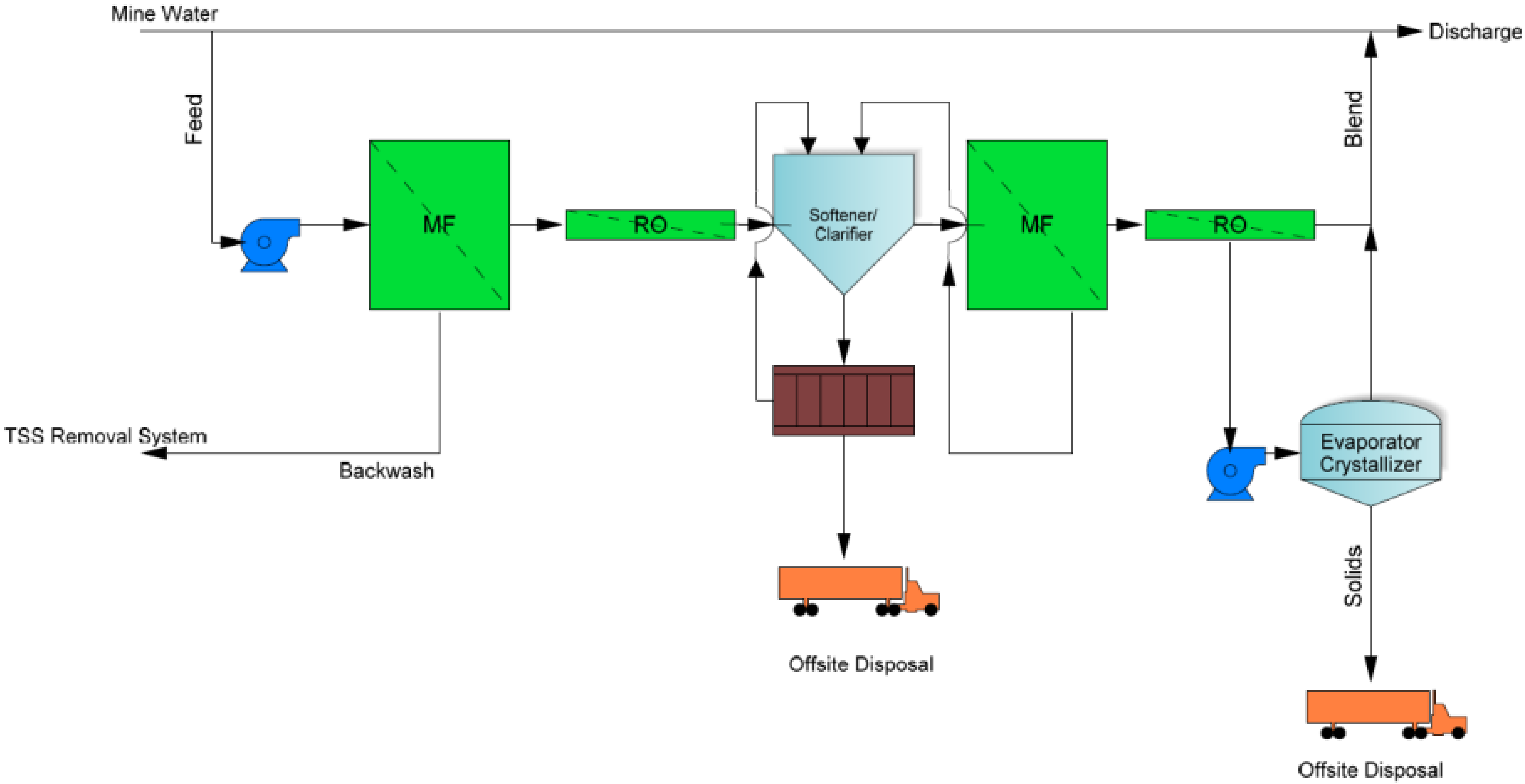
Treatment Flow Diagram- 4 Option Pilot Tests

Option 3: Softening/MF/RO/Evap/Crystallizer Concept



Treatment Flow Diagram - 4 Option Pilot Tests

Option 4: MF/RO/Softening/MF/RO/Evap/Crystallizer Concept



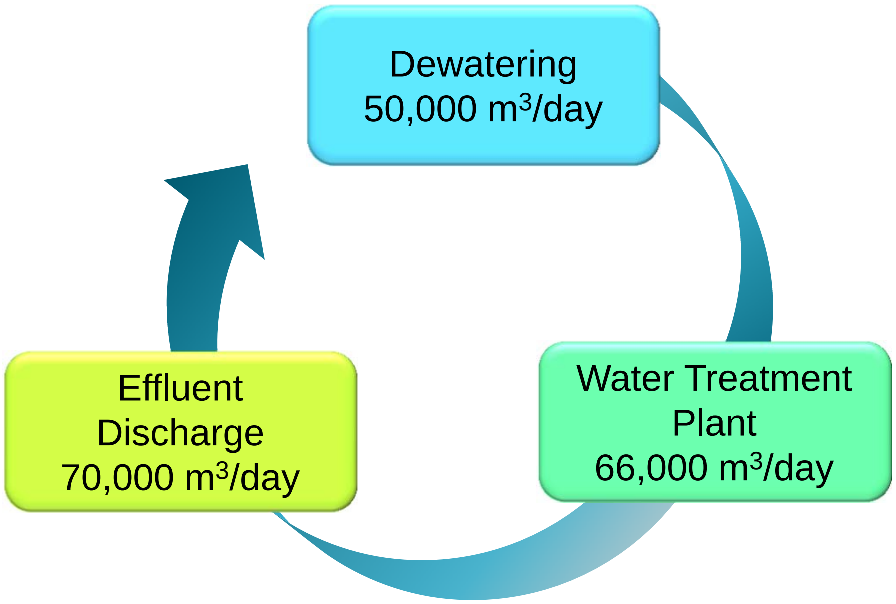
TDS Treatment Concept - Timeline

current

Pre-Feasibility • Evaluation of treatment options • Evaluation of grouting	Q1 2014
Pilot Concept Testing • Representative testing of 4 treatment processes	Q3 2014
Feasibility & Design Decision • Review of Pilot concept results • Development of capital and operating costs	Q4 2014
Design • Detailed Design • Long lead time materials procurement	Q4 2014
Approvals • Regulatory Approvals	Q1 2015
Implementation • Materials Supply and Construction • Commissioning & testing	Q2 2015+

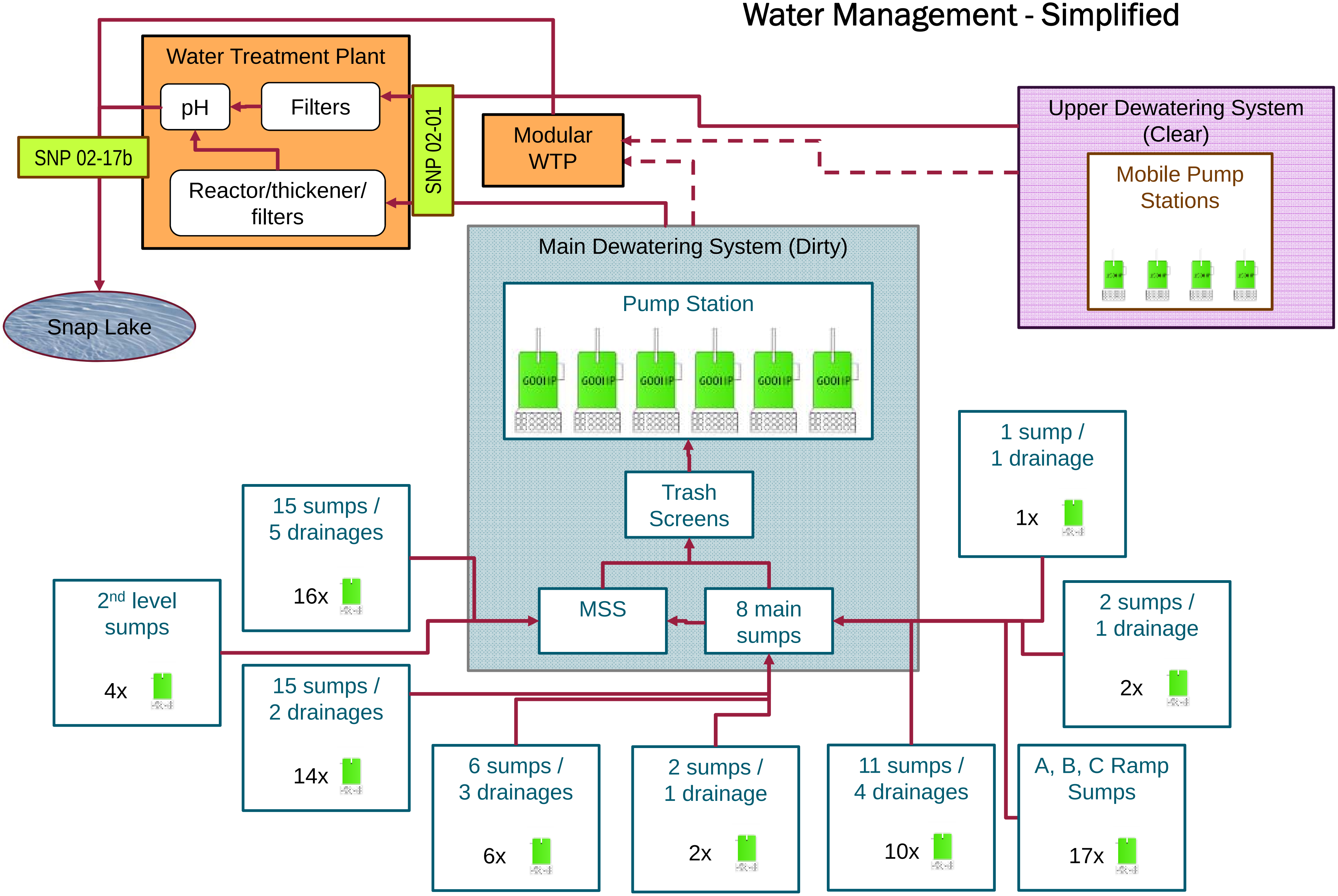
Life of Mine Water Management

- Improve understanding of structural influences on hydrogeological model
- Improve understanding of underwater flow rates, variability and influencing factors
- Phase I: Increase water management capacity by Q3 2014



- Phase II: Improve pumping system reliability and infrastructure in support of LOM plan
- Phase III: Complete LOM dewatering design and implementation
- Commissioning of Modular Water Treatment Plant to add 25,000m^3 total (10,000 m^3/day dirty and 15,000m^3 clean water)

Water Management - Simplified



Snap Lake Mine: Addressing Water License Requirements for Fluoride, Chloride, and TDS Water Quality Benchmarks

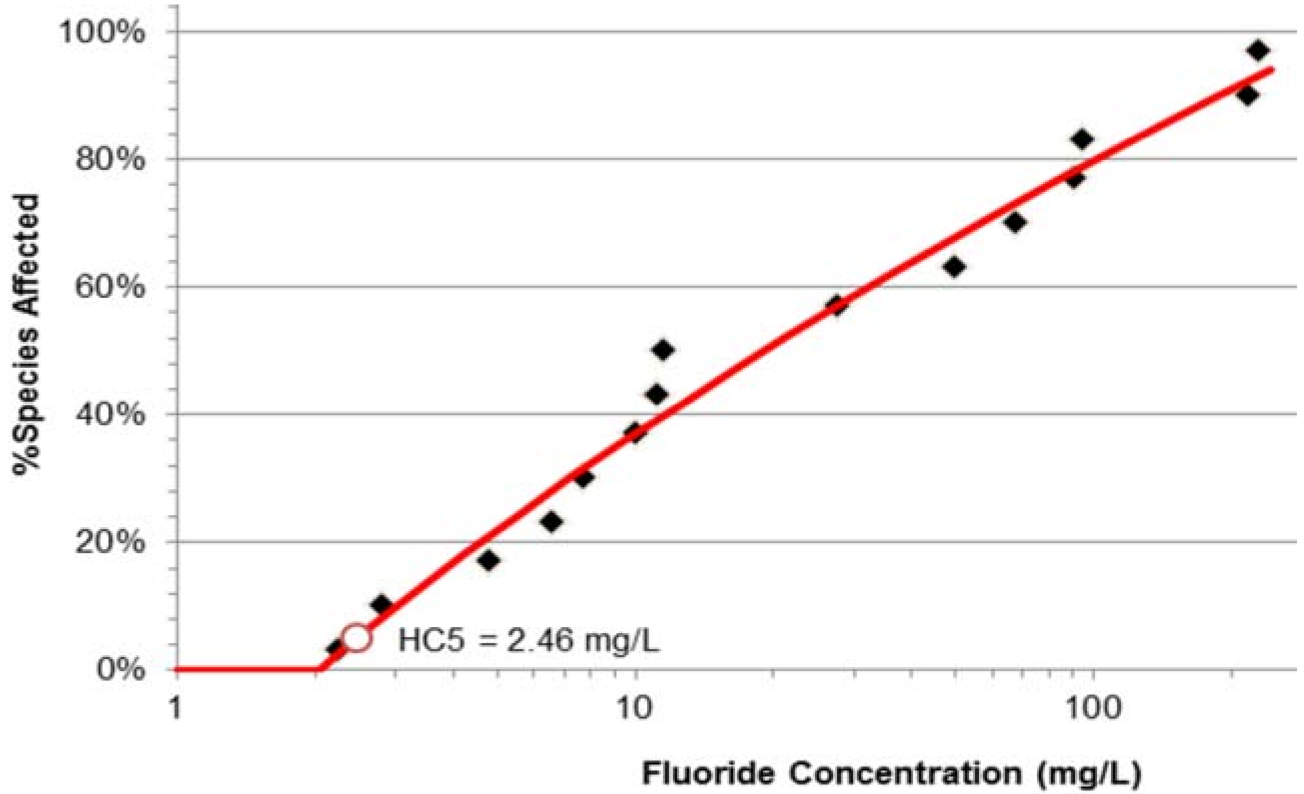
De Beers
Group of Companies

Goal: Protect Fish Stocks/Lake Function

Fluoride

- Fluoride makes up ~0.1% of Snap Lake TDS
- Species Sensitivity Distribution (SSD) considering BCMoE (1995) and CCME (2002) WQGs and most recent published data on effects of fluoride to aquatic life

Fluoride SSWQO = 2.46 mg/L



Chloride

- EKATI has developed chloride site specific water quality objective (SSWQO) based on varying hardness concentrations
- EKATI chloride SSWQO accepted by the WLWB and now part of the EKATI renewed Water Licence
- EKATI nitrate SSWQO also applicable to other waters including Snap Lake (published in the primary literature)

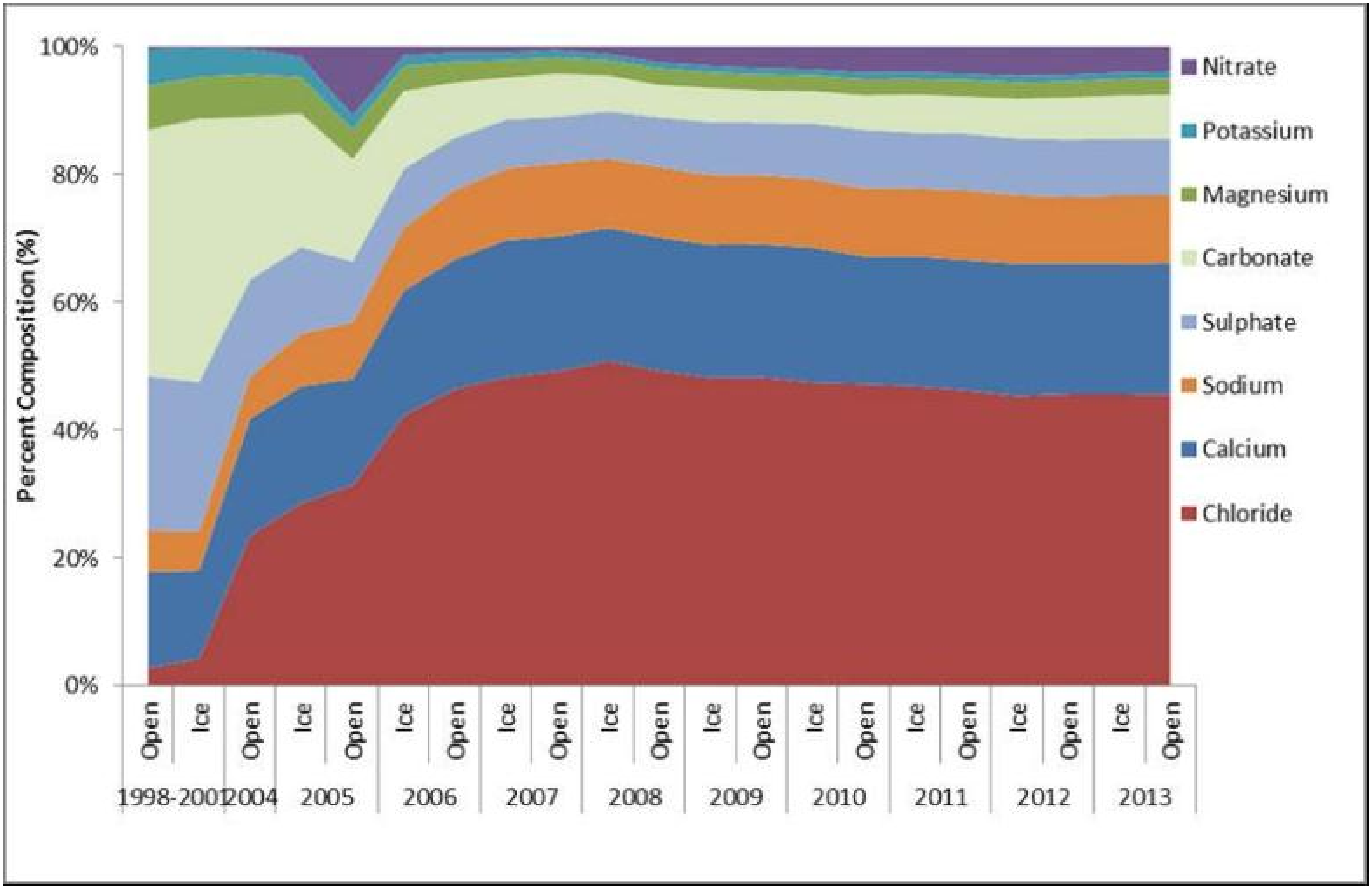
- Using hardness-dependent SSWQO from EKATI at hardness of 160 mg/L: 388 mg/L Cl

Chloride SSWQO = 388 mg/L

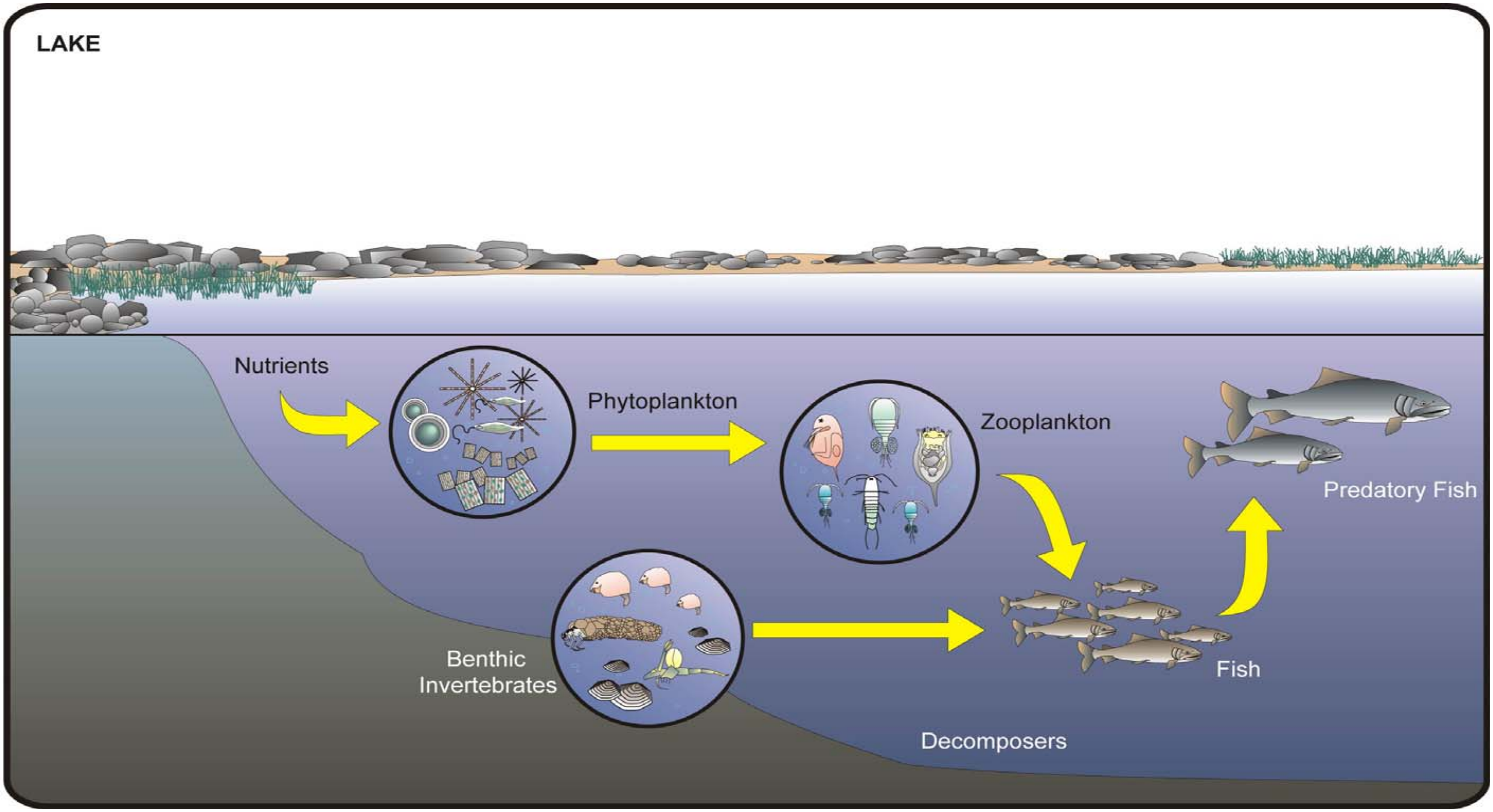
TDS

- Technically defensible studies conducted to determine by how much the dissolved salts in Snap Lake can safely increase without harming the fish or the food chain on which they depend
- Snap Lake TDS composition relatively stable: primarily chloride (45-46%), calcium (20-21%), sodium (10-11%), sulphate (9%), magnesium (3%), nitrate (1%), other minor ions including carbonate, potassium, fluoride

TDS Composition



Snap Lake Aquatic Food Web

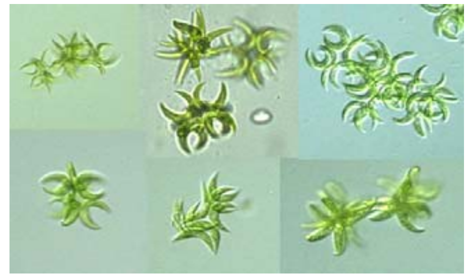


TDS Testing Purpose

- Maintain lake productivity supporting fish:
  - Representative freshwater phytoplankton and zooplankton
  - *[Protect fish from indirect effects on their food supply]*
- Maintain healthy benthic community providing food for fish:
  - Representative freshwater benthic animals
  - *[Protect fish from indirect effects on their food supply]*
- Protect the health and ecological integrity of fish populations:
  - Early-life stage tests with eggs and fry
  - *[Protect fish from direct effects]*

TDS Test Species – Standardized Methods

- Phytoplankton – growth inhibition
  - Alga 72 h: *Pseudokirchneriella subcapitata*
  - Diatom 120 h: *Navicula pelliculosa*[a]
- Zooplankton – survival, growth
  - Water flea 21 d: *Daphnia magna*[a]
  - Water flea 7 d: *Ceriodaphnia dubia*
  - Rotifer 48 h: *Brachionus calyciflorus*[a]
- Chironomids – survival, growth
  - Midge 10 d: *Chironomus dilutus*[a]



[a]Genus found in lake

TDS Test Species (cont'd)

For fish, fertilization and egg-hardening stages generally the most sensitive to TDS

- Testing conducted with early life stages of two salmonids found in Snap Lake:
  - Lake Trout (*Salvelinus namaycush*)
  - Arctic Grayling (*Thymallus arcticus*)
- Exposures encompassed embryo-alevin-fry early life stages[a]
- Two exposures with each species:
  - One initiated prior to fertilization
  - One initiated subsequent to fertilization

[a]See also Poster: Effect of total dissolved solids on fertilization and development of two salmonids

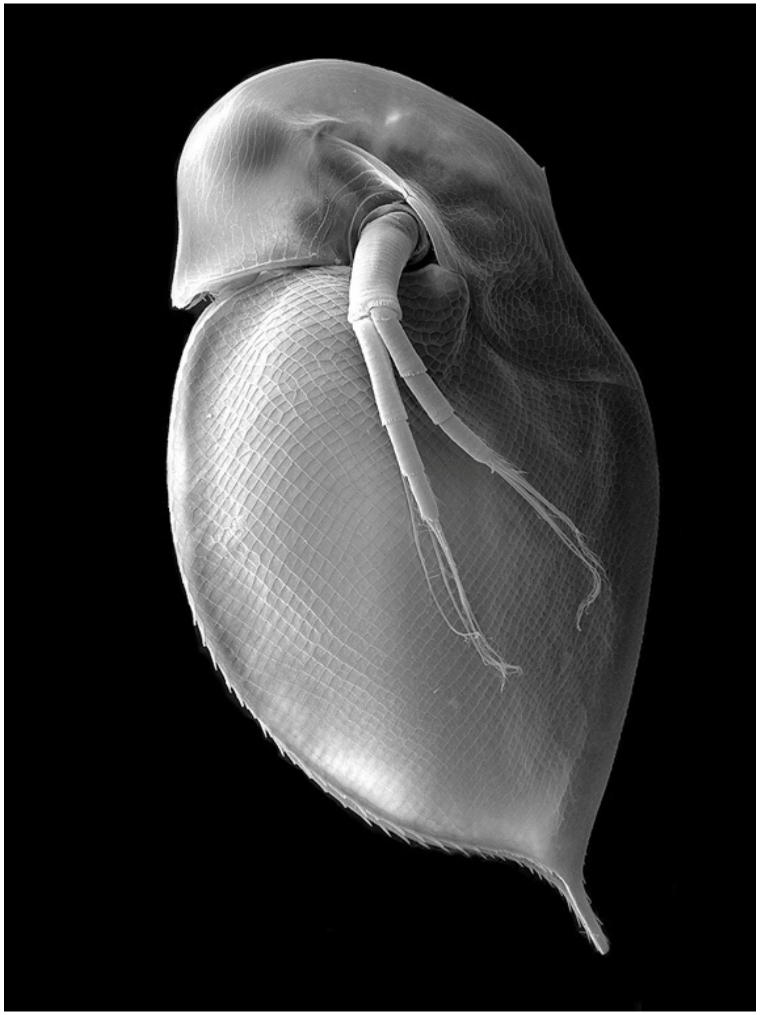
TDS: Grayling Development

TDS SSWQO Development: Data

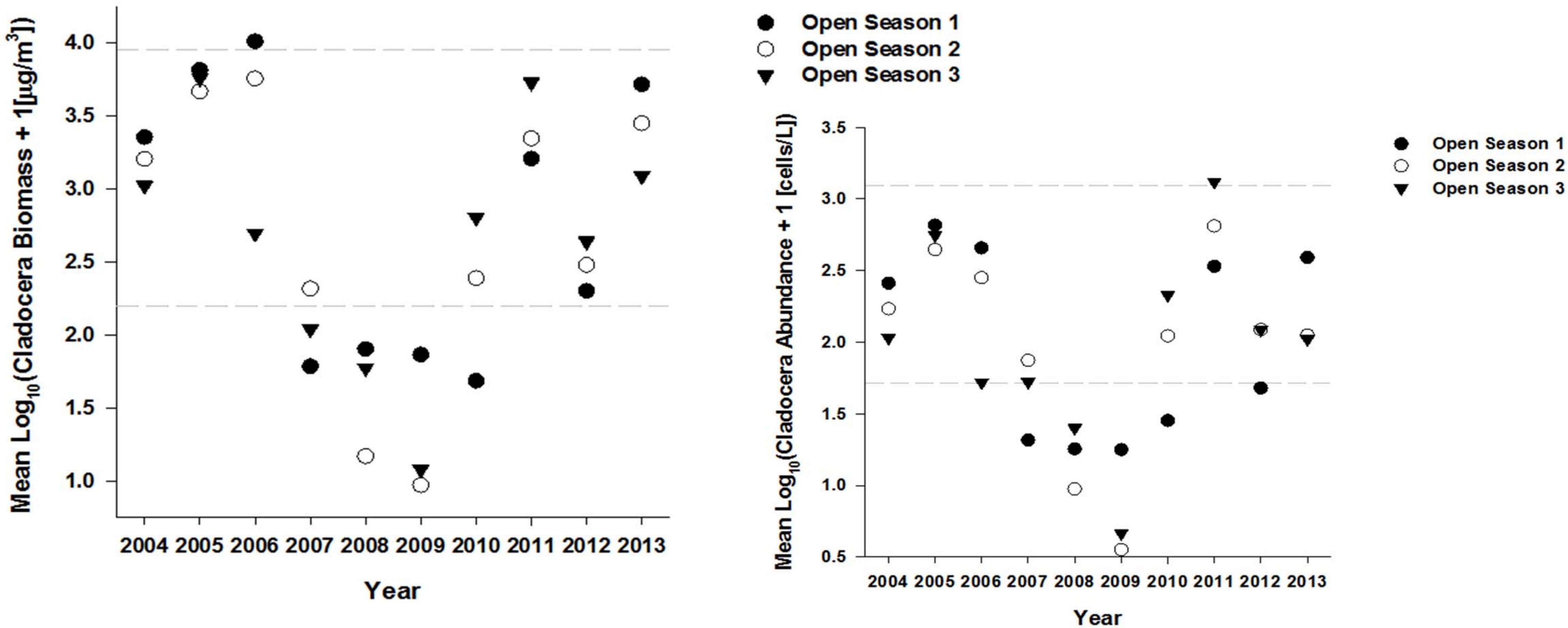
Test Species	Endpoint	[TDS]
Ceriodaphnia dubia (water flea)	IC10/IC20	560/778
Daphnia magna (water flea)	IC20	684
Chironomus dilutus (insect larvae)	IC10	>1,379
Pseudokirchneriella subcapitata (alga)	IC10	>1,474
Brachionus calyciflorus (rotifer)	IC20	>1,474
Navicula pelliculosa (diatom)	IC10	>1,487
Lake Trout	Dry fertilization LC20 fry survival IC20 fry weight and length (growth) Wet fertilization LC20 fry survival IC20 fry weight and length	991 >1,490 >1,484 >1,484
Arctic Grayling	Dry fertilization LC20 fry survival IC20 fry weight and length (growth) Wet fertilization LC20 fry survival IC20 fry weight and length	>1,419 >1,419 >1,414 >1,414

TDS SSWQO

- Species Sensitivity Distribution (SSD) approach not useful:
  - Almost all data points unbounded (i.e., > values)
  - Only three unbounded values
- *Ceriodaphnia* (not found in Snap Lake): IC10, 560 mg/L; IC20, 778 mg/L
- *Daphnia* (found in Snap Lake): IC20, 684 mg/L
- TDS SSWQO based on Daphnia IC20 x uncertainty factor
  - Daphnia make up about 2% of the zooplankton in Snap Lake
  - Copepods more tolerant of TDS (literature review)
  - Uncertainty factor of 1.0
  - TDS SSWQO: 684 mg/L (< *Ceriodaphnia* IC20) [same as TDS EQC due to mixing of treated minewater in Snap Lake]

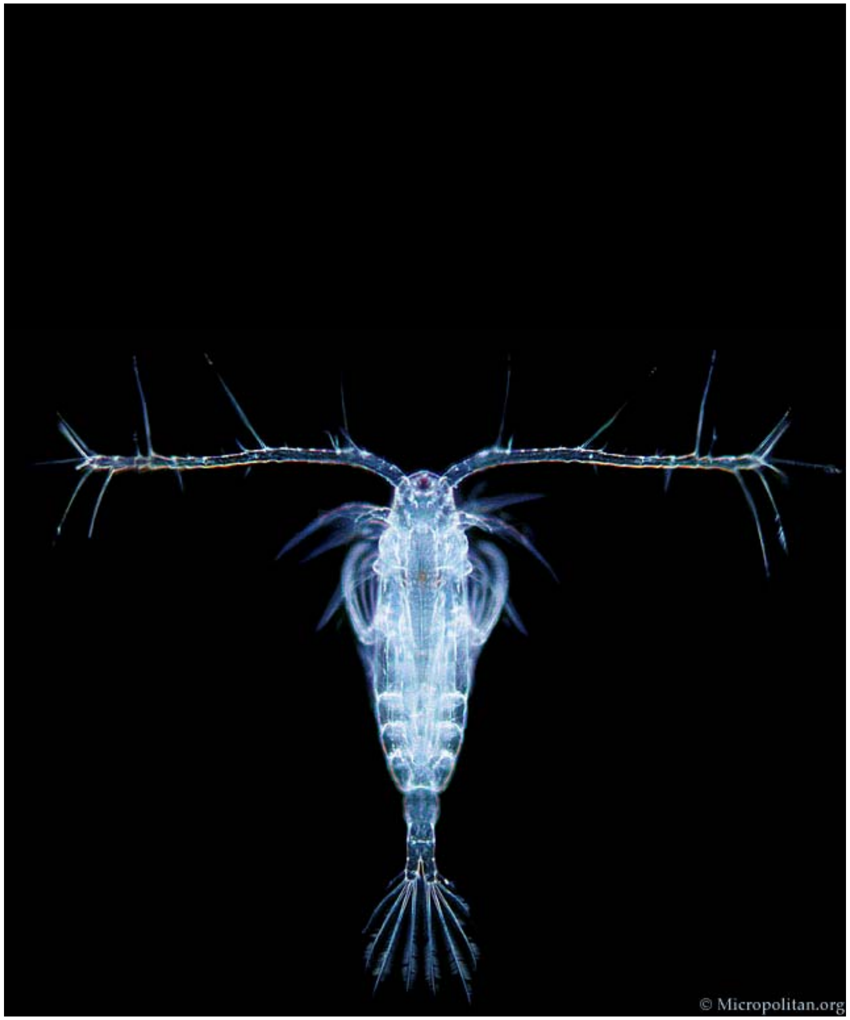


Cladoceran Biomass and Abundance



Zooplankton in Snap Lake

- From 2004 to 2013, relative zooplankton biomass in the main basin of Snap Lake has been consistently dominated by calanoid copepods, with cyclopoid copepods or rotifers as the sub-dominant group
- In 2004 (baseline), relative zooplankton biomass was 74% calanoid copepods, 18% cyclopoid copepods, 5% rotifers, and 3% cladocerans (Daphnids)
- Between 2005 and 2012, relative zooplankton biomass:
  - 43 to 72% calanoid copepods
  - 15 to 39% cyclopoid copepods
  - 4 to 29% rotifers
  - <1 to 7% cladocerans



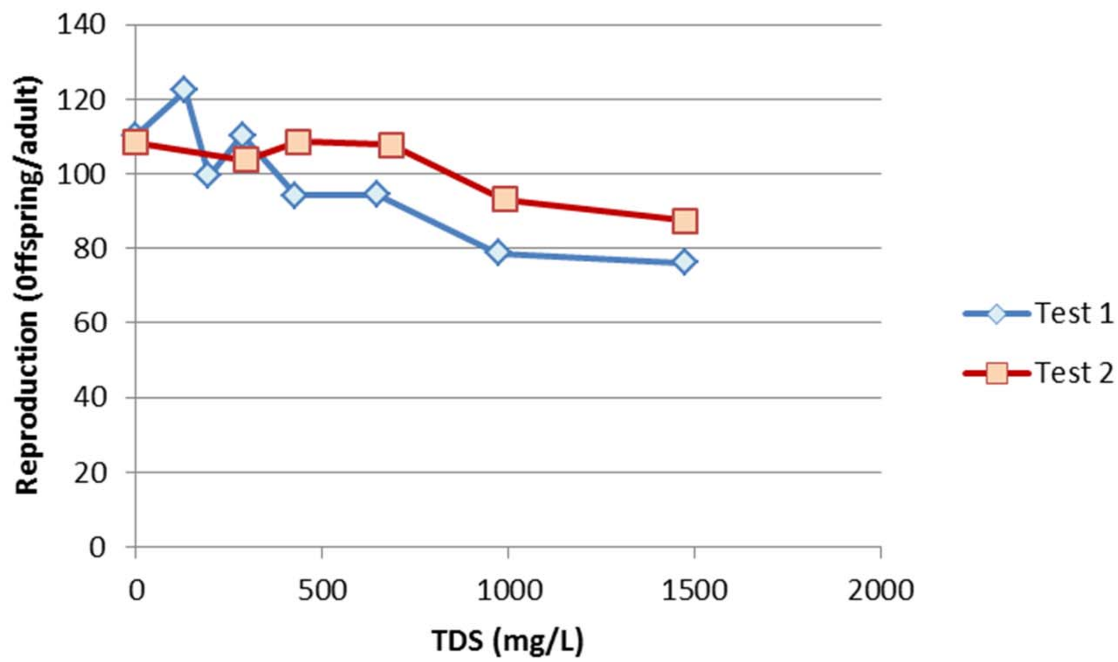
TDS SSWQO Information Session January 6, 2014

- TDS SSWQO presented to interested parties, including regulatory agencies and representatives of Aboriginal communities
- There was discussion following the presentation regarding the repeatability of the tests.
- As a result of the discussion regarding test repeatability, De Beers requested that Golder repeat the 21-day *D. magna* test that provides the basis for the proposed TDS SSWQO.

Daphnia Retest Results

- The *D. magna* retest (Test 2) produced a similar dose-response as the previous *D. magna* toxicity test (Test 1).
- However, the 20% inhibition concentration (IC20) for Test 2 was > 1477 mg/L compared to the first test (Test 1), where the IC20 was 684 mg/L.
- The flatness of the dose-response explains these differences, which are not unreasonably large

Geo-mean of the two studies = 1,005 mg/L



Canadian Council of Ministers of the Environment (2007)

- CCME (2007, Part II, Section 1-10 and 1-11): "*Multiple comparable records for the same endpoint are to be combined by the geometric mean of these records to represent the averaged species effects endpoint*."
- CCME (2007, Part II, Section 3.1-2): "*If there is more than one comparable record for a preferred endpoint, then the species effects endpoint is to be represented by the geometric mean of these records.*"
- Previous SSWQOs developed for the Ekati Diamond Mine followed the above approach, were approved by the WLWB and incorporated into the Ekati WL.
  - In cases where more than one acceptable value was available for an individual species endpoint, the values were combined using the geometric mean to produce a single value for each species.
  - This approach was specifically applied to daphnid toxicity data.
- Based on CCME (2007) and previous precedent in the NWT, the geometric mean of the two IC20 values (Tests 1 and 2) for *D. magna* of 1,005 mg/L could reasonably replace the originally proposed Snap Lake TDS SSWQO of 684 mg/L.

Alaska Water Quality Standards. 18 AAC 70

- TDS generally may not exceed 1,000 mg/L
- Site specific permit granted for the Kensington [gold] Mine of 1,000 mg/L based on scientific studies
- Site specific permit granted for the Red Dog Mine [lead, zinc] of 500 mg/L during fish spawning and up to 1,500 mg/L when fish are not spawning – provided calcium is present at levels greater than 50% by weight of the total cations
- Concentrations of TDS may not be present in water that cause an adverse effect to aquatic life

TDS SSWQO Development: Incorporating Daphnia Test 2

Test Species	Endpoint	[TDS]
Ceriodaphnia dubia (water flea)	IC10/IC20	560/778
Daphnia magna (water flea)	IC20	1,005
Chironomus dilutus (insect larvae)	IC10	>1,379
Pseudokirchneriella subcapitata (alga)	IC10	>1,474
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Developing Final Recommended TDS SSWQO

- Conduct at least one more Daphnia test (n=3)
- Conduct testing with copepods
  - Primary components of zooplankton
  - Testing attempted in 2012 but no set protocols for testing freshwater zooplankton
  - Literature indicates they should be relatively insensitive to TDS

- Based on the results of this additional testing provide final recommended TDS SSWQO
- A phased review of a higher TDS SSWQO and associated EQCs based on review of additional information may be appropriate

Comments/Questions?