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Snap Lake Diamond Project Technical Sessions

Water Quality and Quantity

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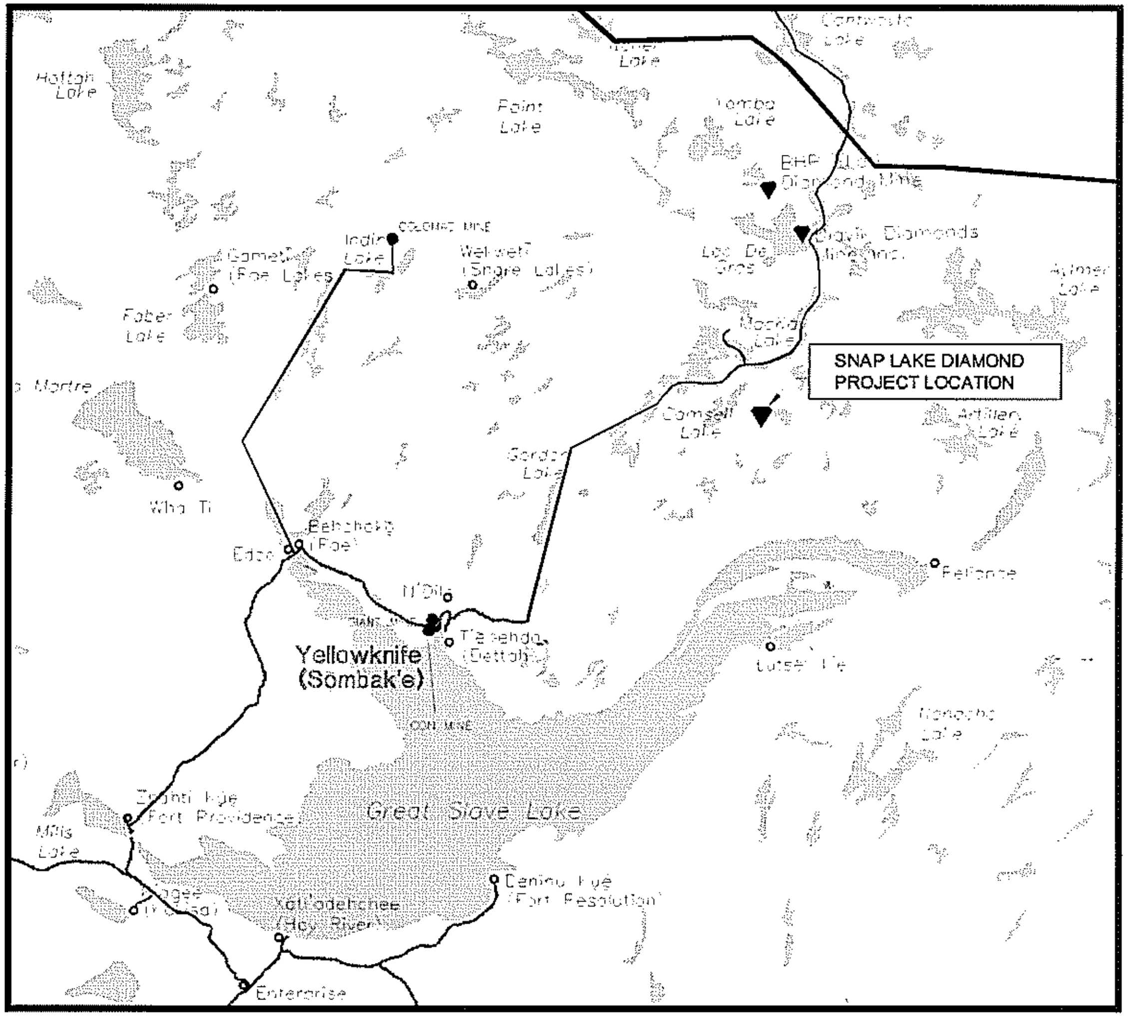
Project Location



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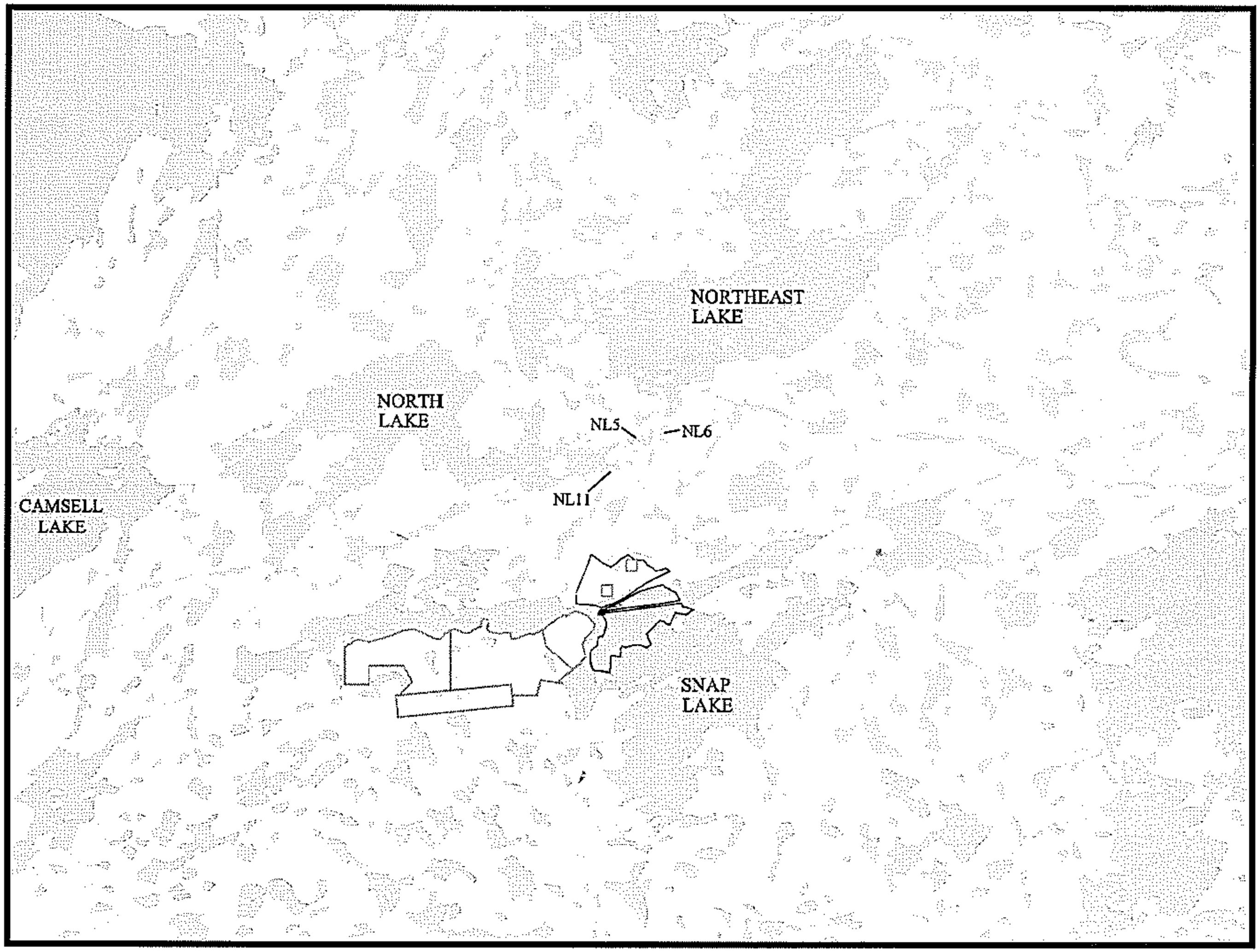
Location of North Lake, Northeast Lake and Snap Lake



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Water Quality and Quantity Session

November 26, 2002:

Morning:

- Description of Site Water Flows
- Groundwater

Afternoon:

- Water Management System Overview
- Sewage and Water Treatment

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Water Quality and Quantity Session

November 27, 2002

- Snap Lake Water Quality Predictions
- Snap Lake Sediment Impacts
- North Lakes Groundwater and Surface Water Quality and Quantity

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Water Quantity and Quality North Lakes

- Groundwater Flow Directions and Quantities
- Changes in Groundwater Quality between Snap Lake and Northeast Lake
- North Lakes Water Quality

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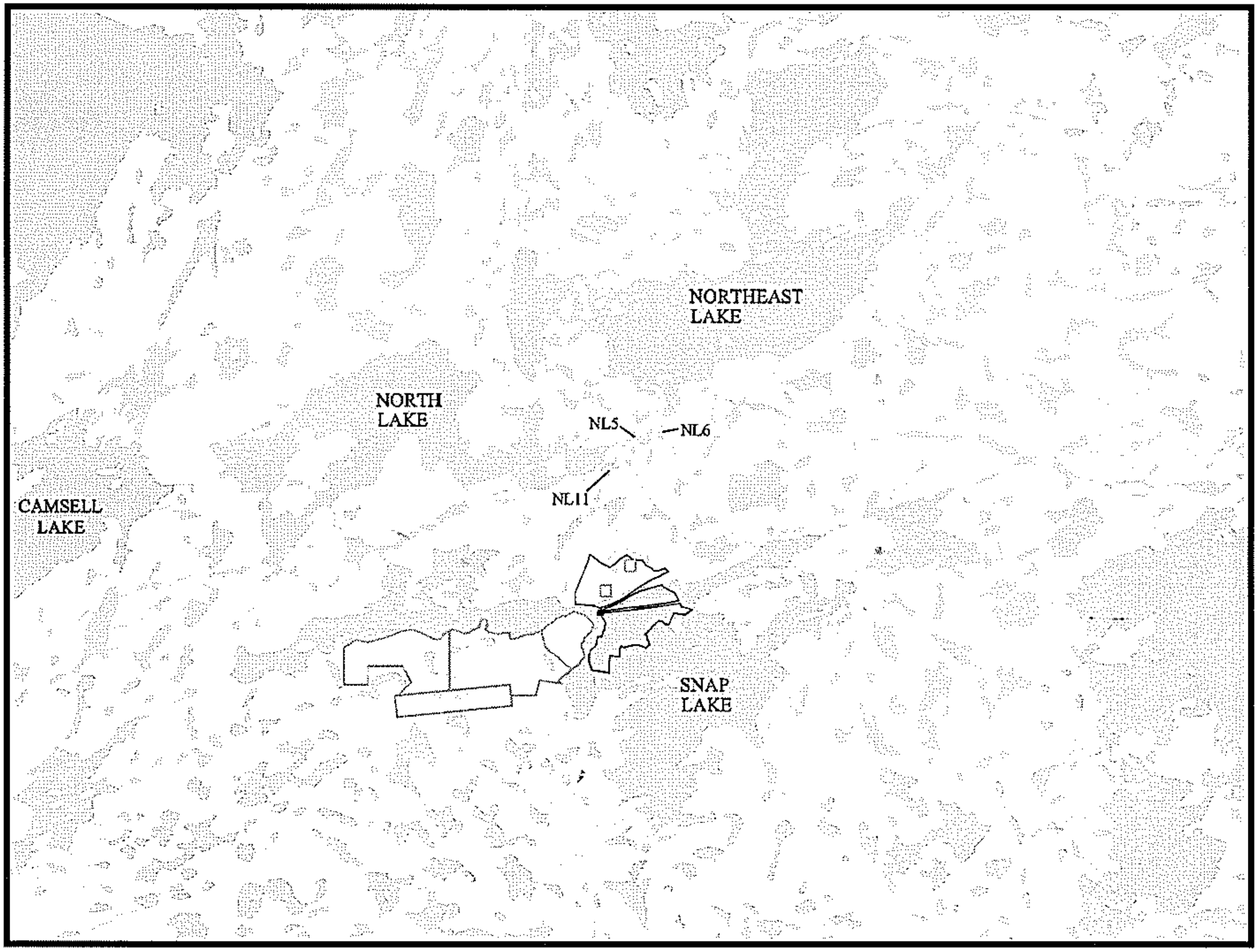
Location of North Lake, Northeast Lake and Snap Lake



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Topic Has Been Addressed

- Environmental Assessment Report
- North Lakes Report
- North Lakes Technical Information Session
- Responses to Information Requests

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Water Quality Near the Discharge in Snap Lake

Purpose

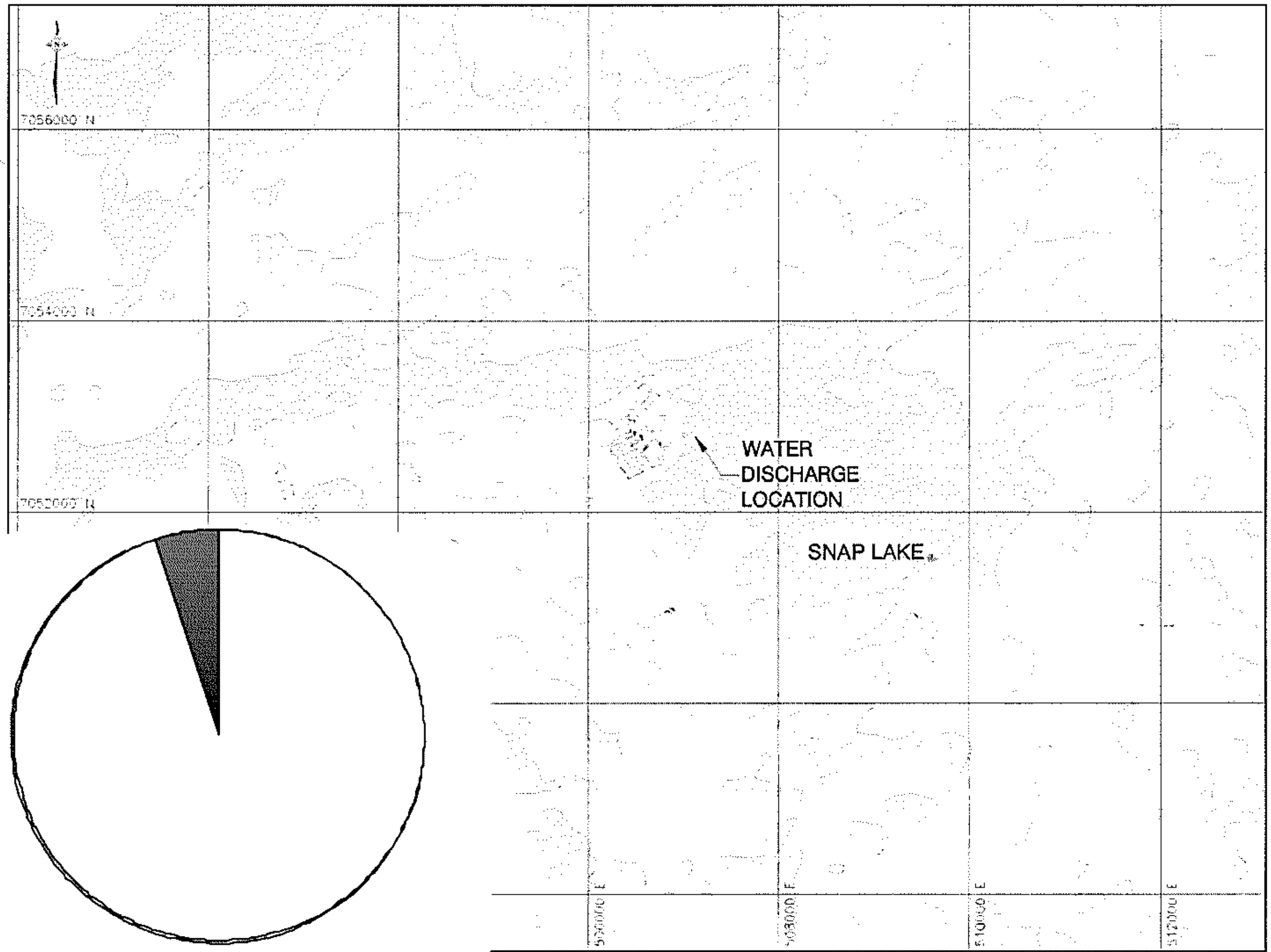
To provide more information on the assessment of water quality near the discharge in Snap Lake:

- To determine the area within which substance concentrations may be above guidelines
- To describe the effects related to that area

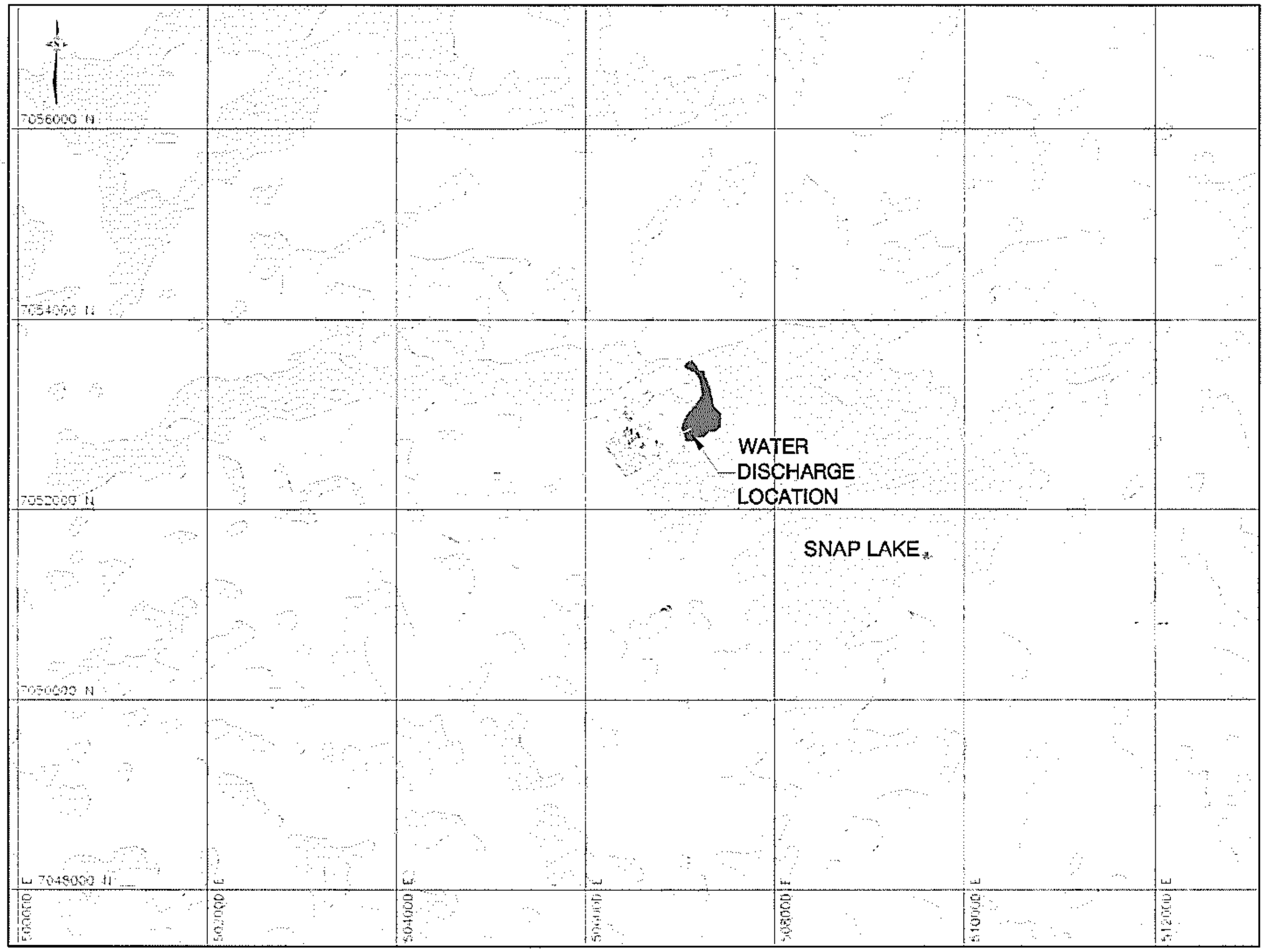
Topic Has Been Addressed:

- Environmental Assessment Report
  - Section 9.4
  - Appendix IX-7
- Responses to Information Requests
  - IR 1.56
  - IR 3.4.7
  - IR 4.1.7

Water Discharge Location in Snap Lake



Water Quality Near the Discharge in Snap Lake



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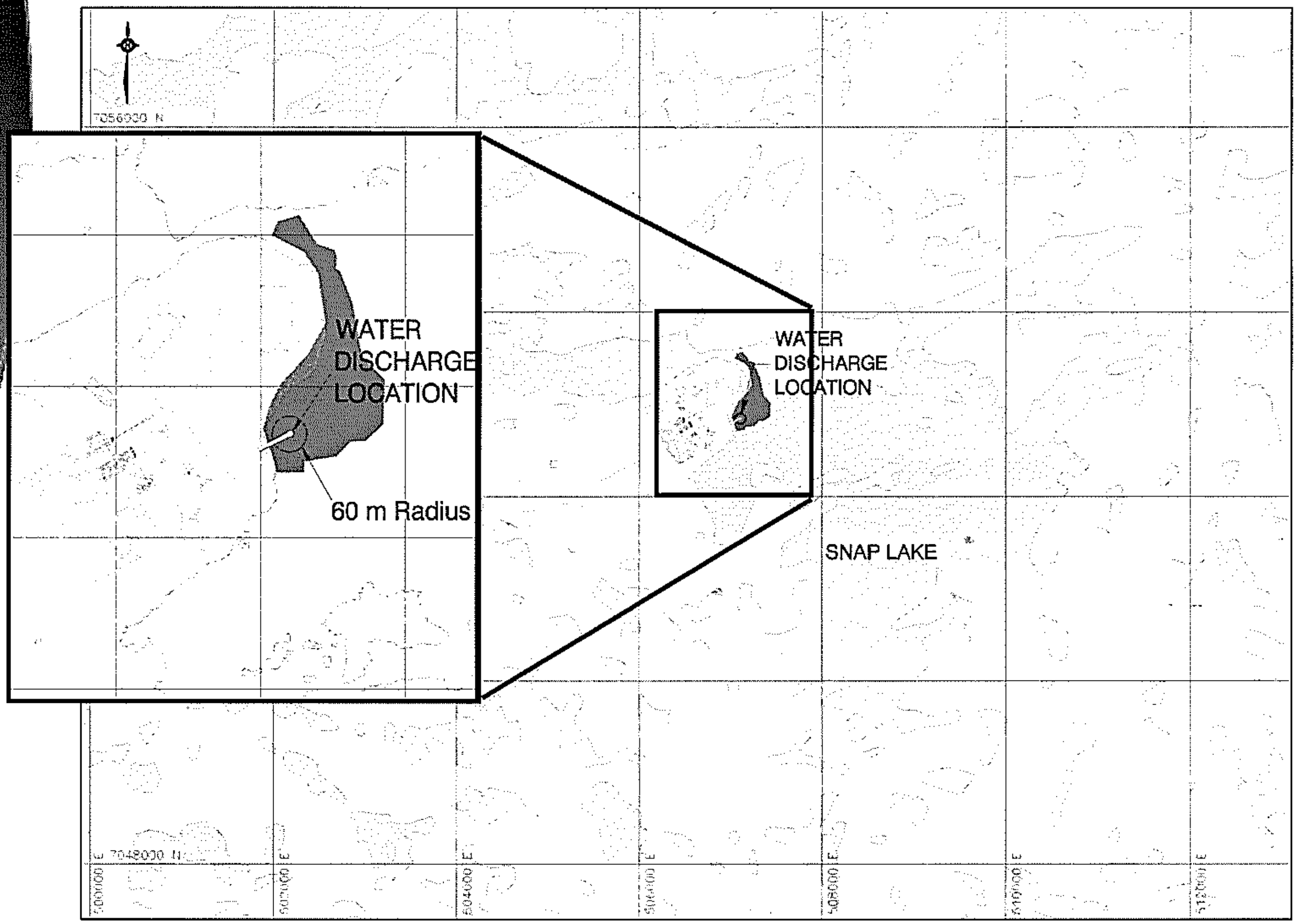
Water Quality Near the Discharge in Snap Lake



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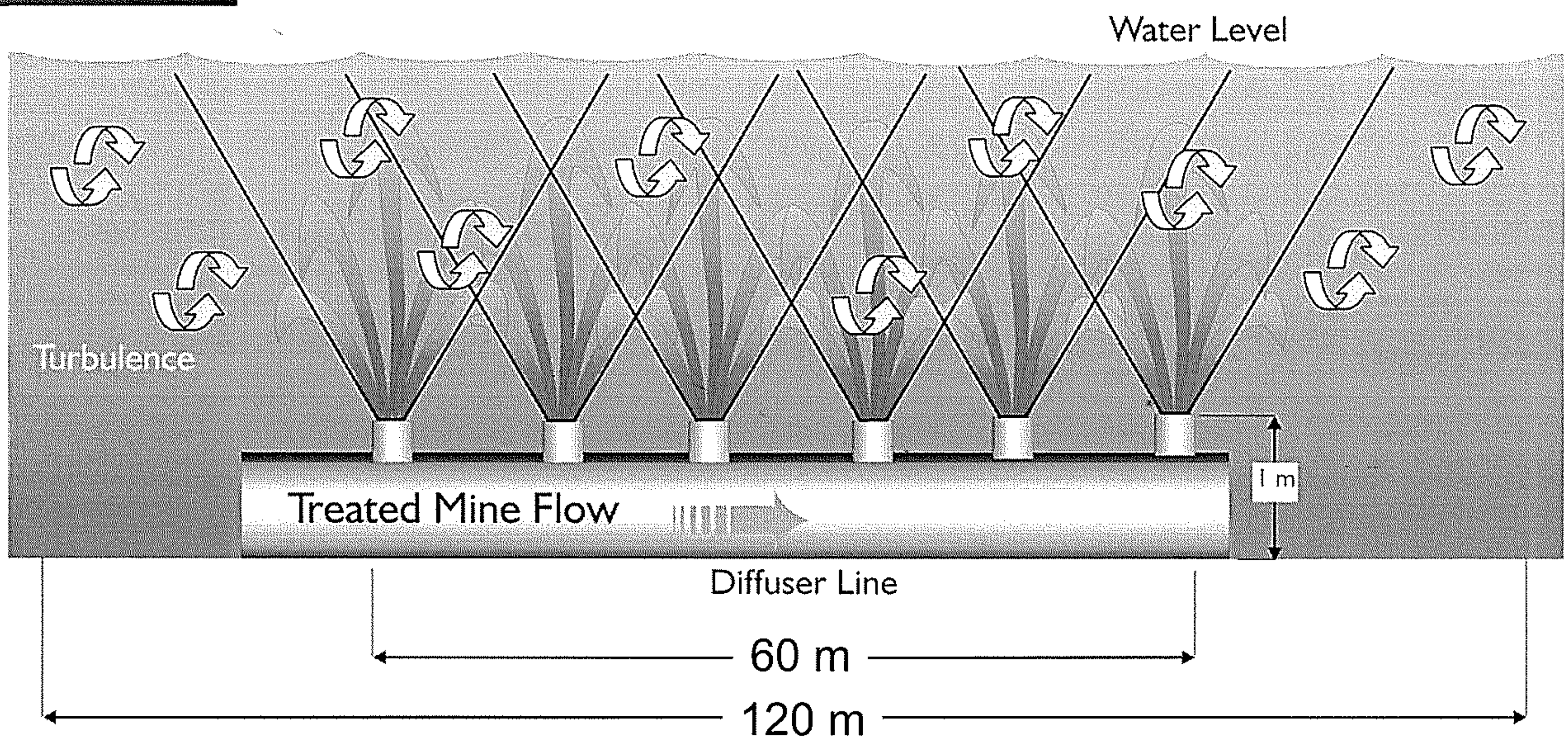
Diffuser for Mine Water Discharge



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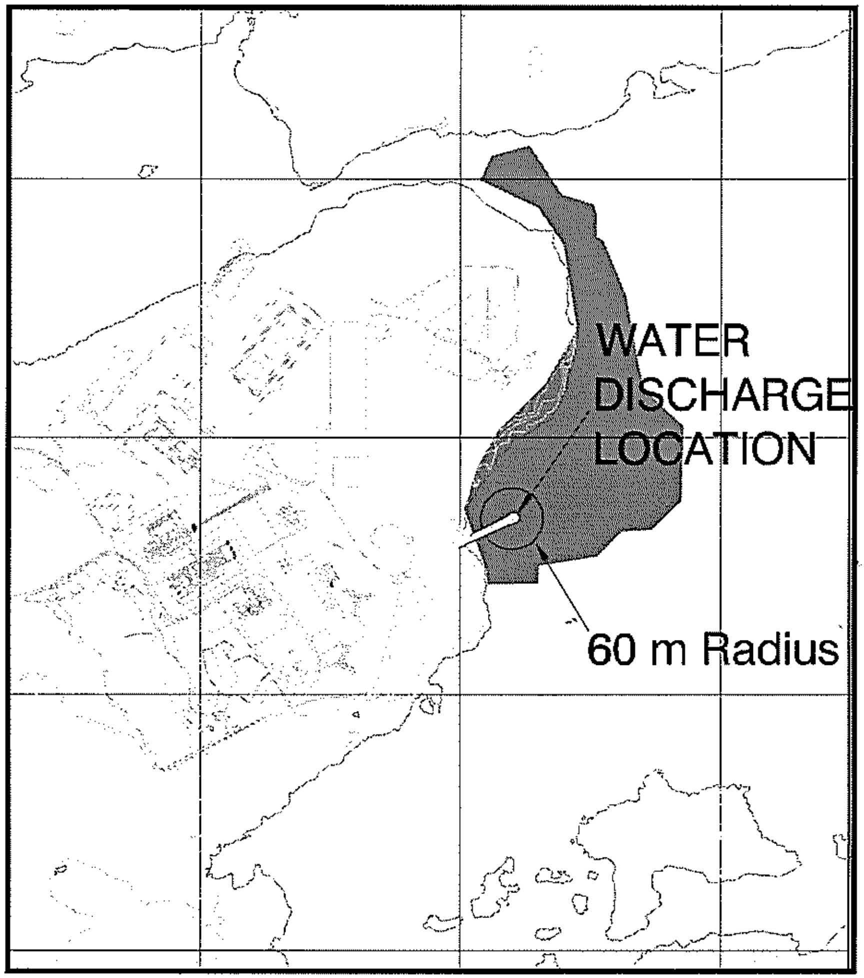
Water Quality Near the Discharge in Snap Lake



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Maximum Areas Above Water Quality Benchmarks in Snap Lake

Water Quality Benchmark	Cadmium	Copper	Hexavalent Chromium	Chronic Whole Effluent Toxicity
$>HC_5$	<1%	0	<1%	-
$>HC_{10}$	0	0	<1%	-
$>HC_{20}$	0	0	0	-
Threshold	-	-	-	1.1%

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Conclusions

- Water quality assessment used a protective threshold for negligible effects to aquatic populations and communities in Snap Lake

Concentrations > benchmarks in <1% of Snap Lake

- This threshold:
  - Provides overall protection for aquatic populations and communities in Snap Lake
  - Limits potential effects to sensitive aquatic organisms to <1% of Snap Lake

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Water Quality Benchmarks and Impact Assessment Criteria

Purpose:

- To provide information on the methodology used to develop the water quality benchmarks and impact assessment criteria
- To clarify the hazard concentrations used as cut-offs for identifying minor, moderate and major effects (i.e., HC_5, HC_{10}, HC_{20})

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Topic Has Been Addressed:

- Environmental Assessment Report
  - Section 9.4.2
  - Section 9.4.2.1.1
  - Appendix IX.8
- Responses to Information Requests
  - IR 3.4.5
  - IR 3.4.7

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Development of Water Quality Benchmarks Specific to Snap Lake

- Impact Assessment Process:
  - Step 1: Maximum discharge concentrations were compared to available water quality guidelines
  - Step 2: Parameters exceeding generic guidelines in the discharge were carried forward and modelled in Snap Lake
  - Step 3: More detailed assessment was completed on parameters that exceeded generic guidelines within Snap Lake
- Site-specific benchmarks were developed as part of Step 3 for application to Snap Lake

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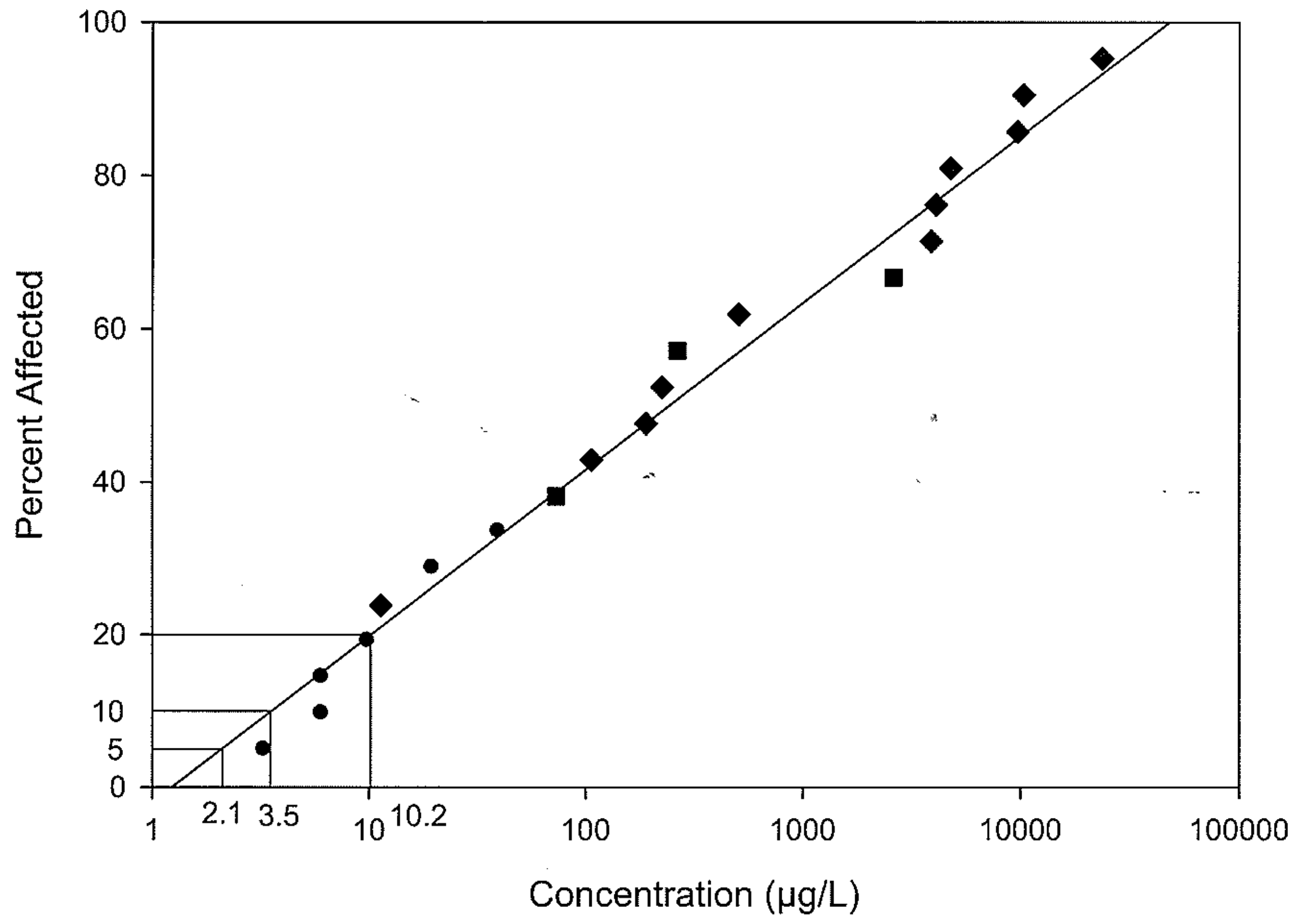
Example: Water Quality Benchmark Development

Hexavalent Chromium Species Sensitivity Distribution Based on Measured or Predicted Chronic Concentrations (●= cladocerans, ■= fish and ♦= other invertebrates)



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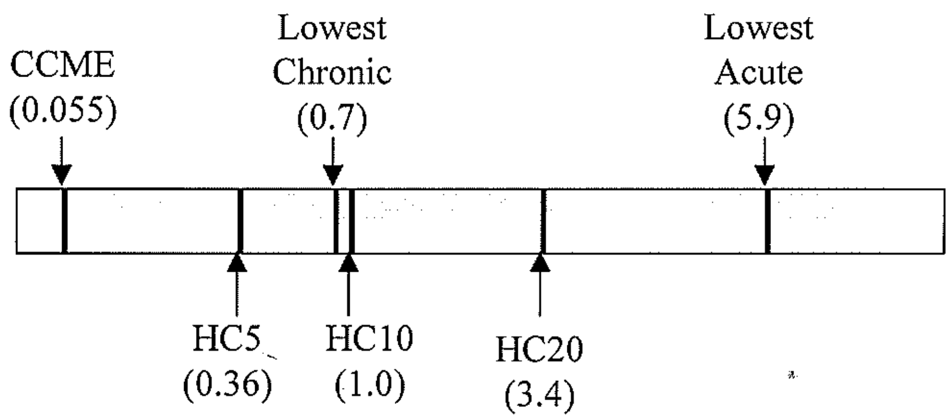
Site-Specific Benchmarks Relative to Measured Effect Levels – Cadmium



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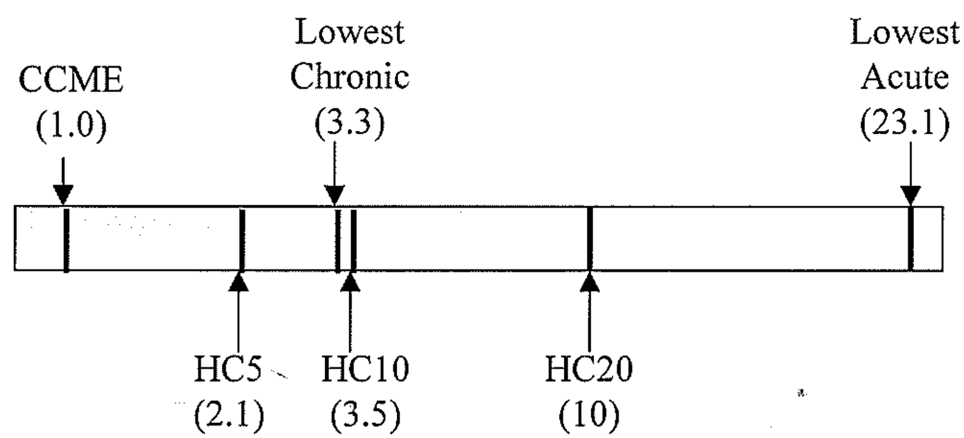
Site-Specific Benchmarks Relative to Measured Effect Levels – Chromium VI



Summary of Site-specific Water Quality Benchmarks

Parameter	Units	General Water Quality Guideline	Site-Specific Water Quality Benchmarks		
			HC_5	HC_{10}	HC_{20}
Cadmium	µg/L	**0.055**	**0.36**	**1.0**	**3.4**
Copper	µg/L	**4**	**7.9**	**12.6**	**21.3**
Trivalent chromium	µg/L	**8.9**	**46.0**	**72.2**	**118.2**
Hexavalent chromium	µg/L	**1**	**2.1**	**3.5**	**10**

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Impact Magnitudes Developed from Water Quality Benchmarks

- Impact assessment takes into consideration both concentration and the area affected

Concentration	Percent of Waterbody Affected			
	0 – 1%	1 – 10%	10 – 20%	20-100%
$<HC_5$	negligible	negligible	negligible	negligible
HC_5 - HC_{10}	negligible	low	low	low
HC_{10} - HC_{20}	negligible	low	moderate	moderate
$>HC_{20}$	negligible	low	moderate	high
> General Guideline	negligible	low	moderate	high

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Confidence in Approach

- Benchmark approach used by other jurisdictions
- Benchmark approach uses all data and also provides a level of conservatism for the development of the HC_5 benchmark value
- HC_{10} and HC_{20} are consistent with risk-based thresholds used by other agencies and expert working groups

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Conclusions

- Impact assessments are based on the maximum concentrations predicted to occur in Snap Lake
- At no point within Snap Lake are concentrations predicted to exceed the HC_{20}
- Concentrations above the HC_{10} or HC_5 are predicted to occur within less than 1% of the lake

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Secondary Effects of Eutrophication

Purpose:

To provide more information on secondary effects of increased algal concentrations on water quality in Snap Lake

- Potential secondary effects:
  - Increased algal decomposition could result in decreased levels of dissolved oxygen particularly in winter
  - Decrease in oxygen concentrations could result in changes in nutrient and metal mobility in sediments

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Topic Has Been Addressed:

- Environmental Assessment Report
  - Section 9.4
  - Appendix IX-7
- Responses to Information Requests
  - IR 2.1.6
  - IR 3.4.6

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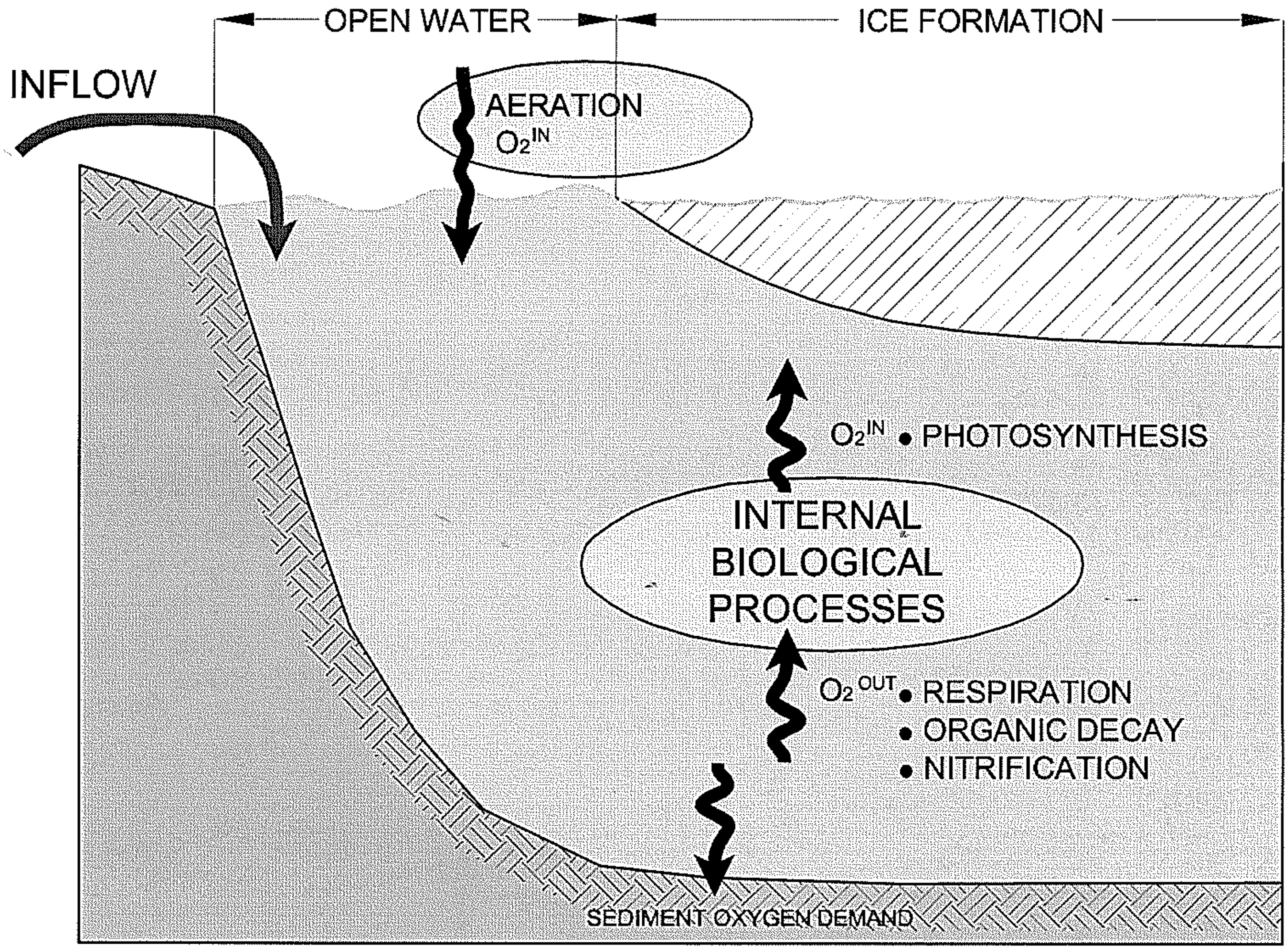
Dissolved Oxygen Cycle



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Secondary Effects on Dissolved Oxygen - EA Approach

- Effects of increased algal concentrations on dissolved oxygen levels were assessed:
  - Nutrient model was used to predict changes in summer dissolved oxygen concentrations
  - Winter oxygen modelling assumed that all algae would decay over winter and consume oxygen
  - Modelling also accounted for nitrification of ammonia

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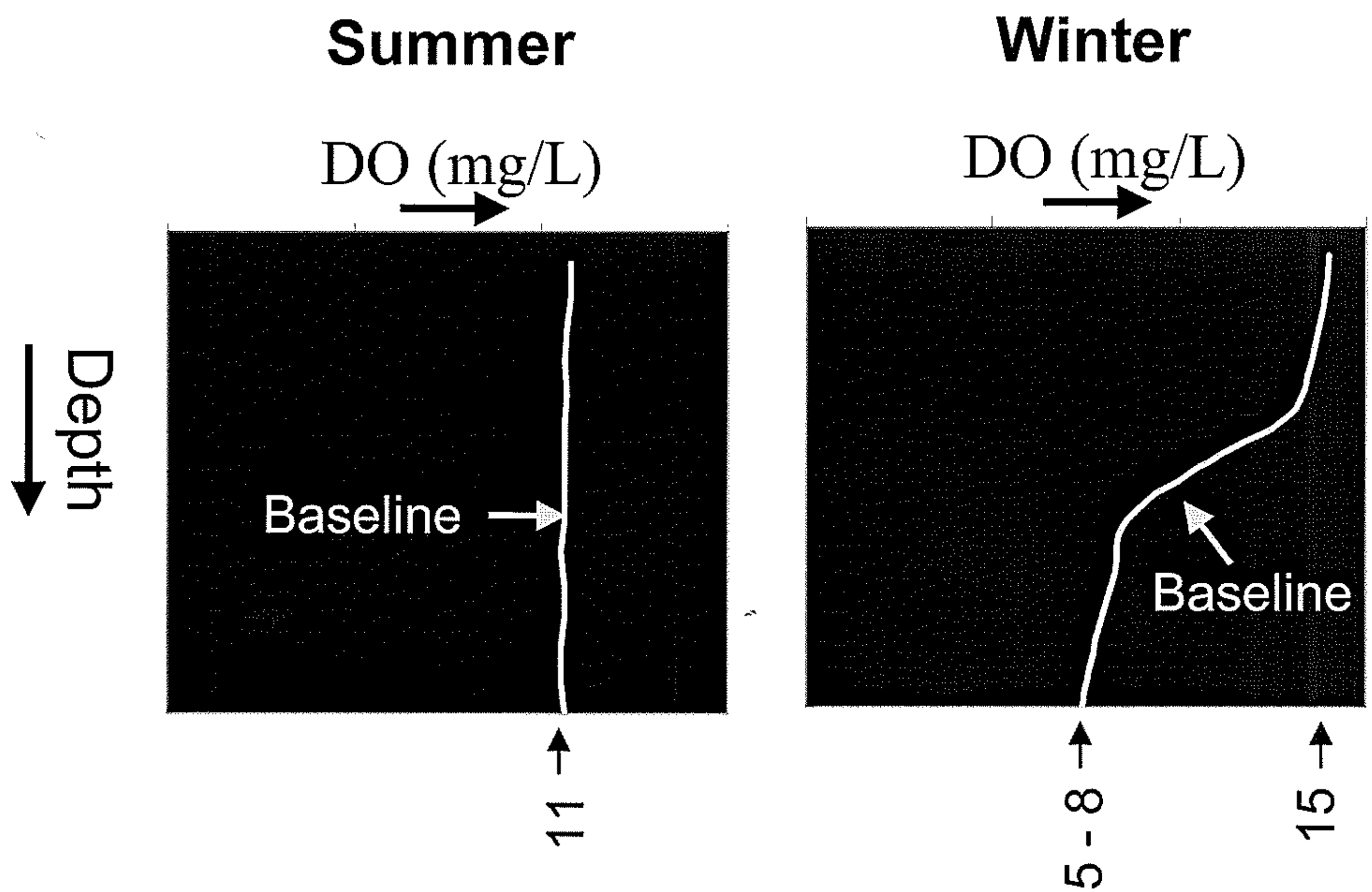
Dissolved Oxygen (DO) Profiles: Baseline



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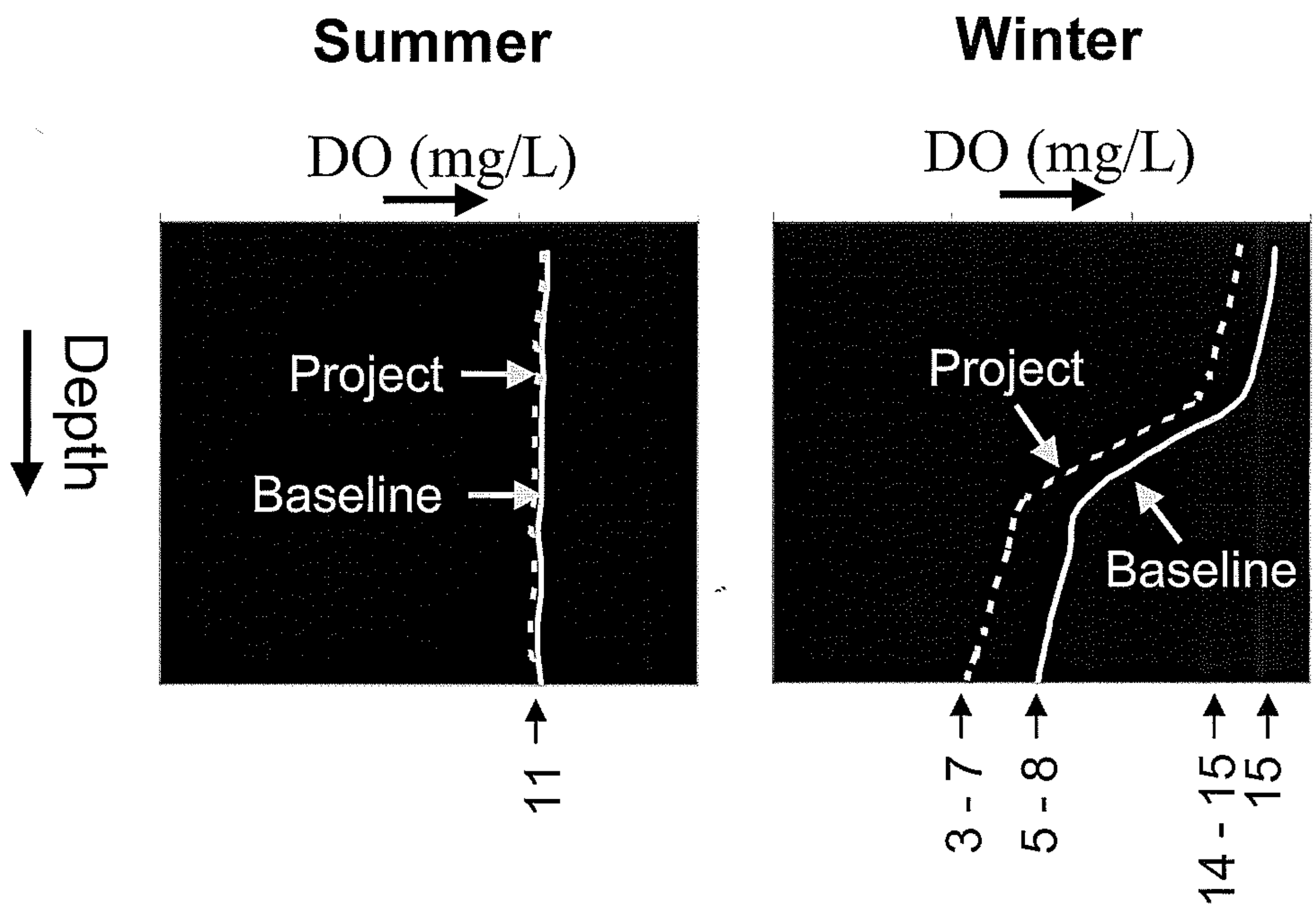
Dissolved Oxygen (DO) Profiles: Project



Conclusions

- Changes in dissolved oxygen concentration will be:
  - Not measurable in summer
  - A maximum decrease of 1 to 2 mg/L in winter
- Dissolved oxygen levels will remain above levels that could affect mobility of nutrients and metals in Snap Lake

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Effect on Snap Lake Sediment Quality

Purpose:

To provide more information on potential effects to sediment quality in Snap Lake

- Potential Pathways to Sediments:
  - Settling of fine solids in treated discharge
  - Adsorption of metals to suspended solids or directly to bed sediments

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Topic Has Been Addressed:

- Environmental Assessment Report
  - Sections 9.4 and 9.5
- Responses to Information Requests
  - IR 1.62
  - IR 3.4.8

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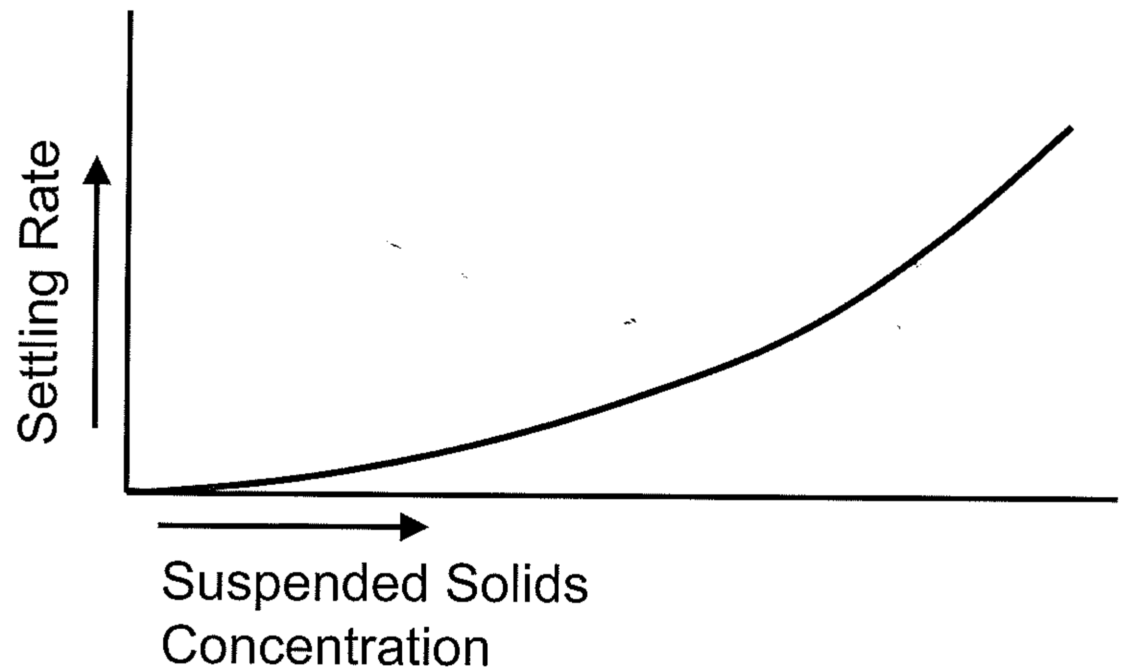
Settling of Suspended Solids

- Water treatment plant will achieve a very high level of solids removal (< 5 mg/L)
- Remaining fine suspended solids are not expected to settle in Snap Lake



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Sediment Reactivity

- Metals in mine water come from groundwater and rock material, which have low reactivity
  - Low levels of dissolved metals tend to remain dissolved
  - Particulate metals tend to remain as particulates, either incorporated into the mineral framework or adsorbed to solids
- Mining and process plant do not add metals to water discharge
- Water treatment process will preferentially remove reactive forms of metals

Conclusions

- Effects on sediment quality are expected to be negligible for two reasons:
  - High level of suspended solids removal in water treatment plant (< 5 mg/L in discharge)
  - Low sediment "reactivity"

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Eutrophication Modelling In Snap Lake

Purpose:

To provide more information on:

- The nutrient model
- Phosphorus in groundwater, which makes up most of the treated water discharge
- Response of algae in Snap Lake to nutrient inputs from the treated water discharge

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Topic Has Been Addressed:

- Environmental Assessment Report
  - Section 9.4
  - Appendix IX.7
- Responses to Information Requests
  - IR 1.53
  - IR 3.3.5
  - IR 3.4.6
  - IR 3.8.9
  - IR 4.1.8

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Snap Lake Nutrient Model

- Because the Project doesn't yet exist, changes that could occur in Snap Lake must be predicted
- A two-dimensional hydrodynamic and water quality model called RMA was selected
- Why RMA?
  - Uses established equations for nutrient and phytoplankton dynamics
  - Simulates lake circulation and mixing
  - Predicts changes in water quality over time
  - Model credibility - widely used, proven

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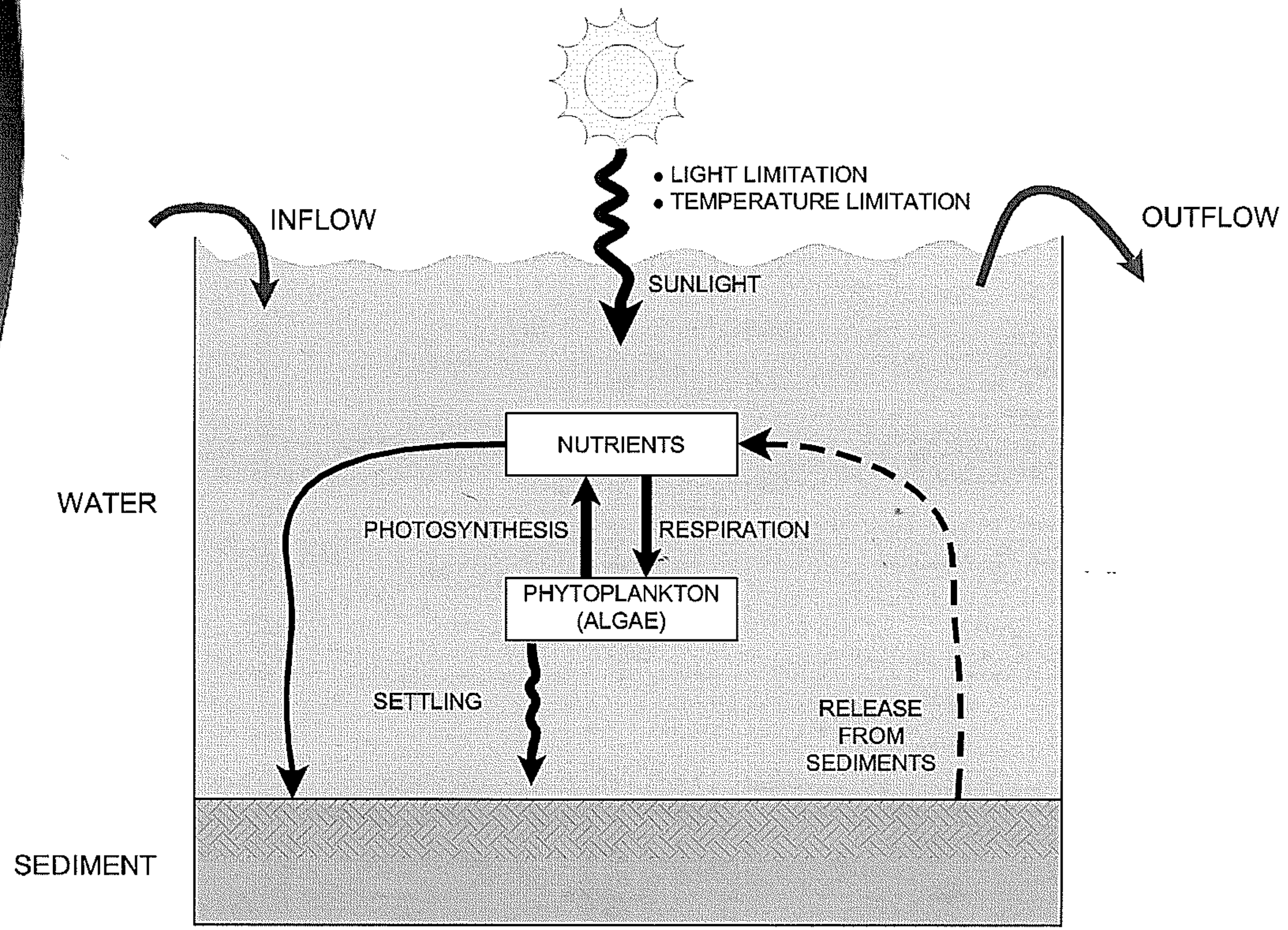
Simplified Nutrient and Algae Processes



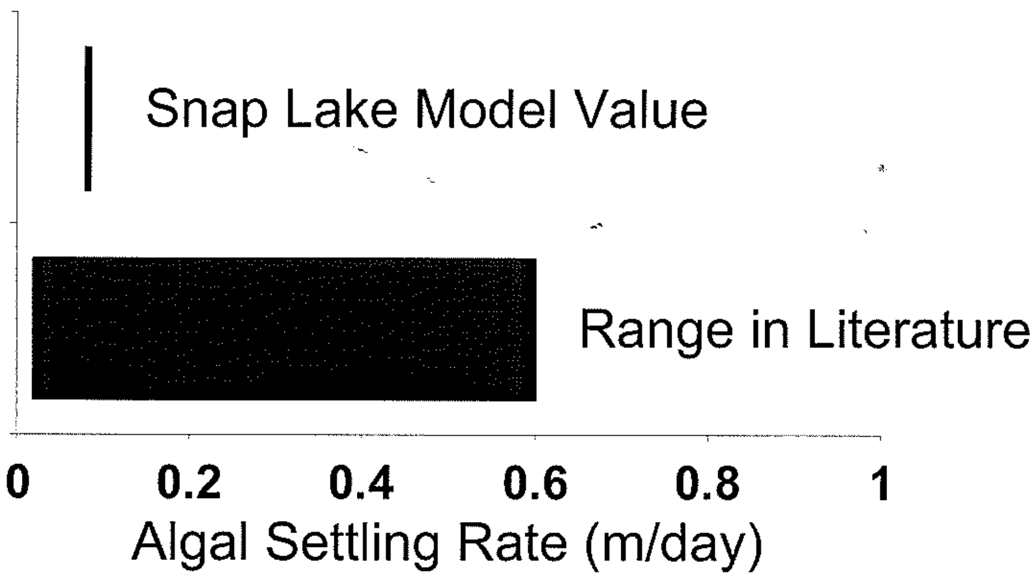
Snap Lake Nutrient Model

- How was RMA used?
  - Model was calibrated to baseline conditions
  - Model parameters varied within accepted ranges and ranges appropriate for northern lakes
  - Model included the sources of nutrients that could affect eutrophication in Snap Lake

Parameter	Units	Measured	Calibration
Algal Concentration	mg/L	0.057	0.052
Total Phosphorus	ug/L	9	9
Orthophosphate	ug/L	2	2
Total Nitrogen	mg/L	0.331	0.336
Ammonia	mg/L	0.018	0.018
Nitrate	mg/L	0.020	0.023

Snap Lake Nutrient Model

- How was RMA used?
  - Model was calibrated to baseline conditions
  - Model parameters varied within accepted ranges and ranges appropriate for northern lakes
  - Model included the sources of nutrients that could affect algal concentrations in Snap Lake



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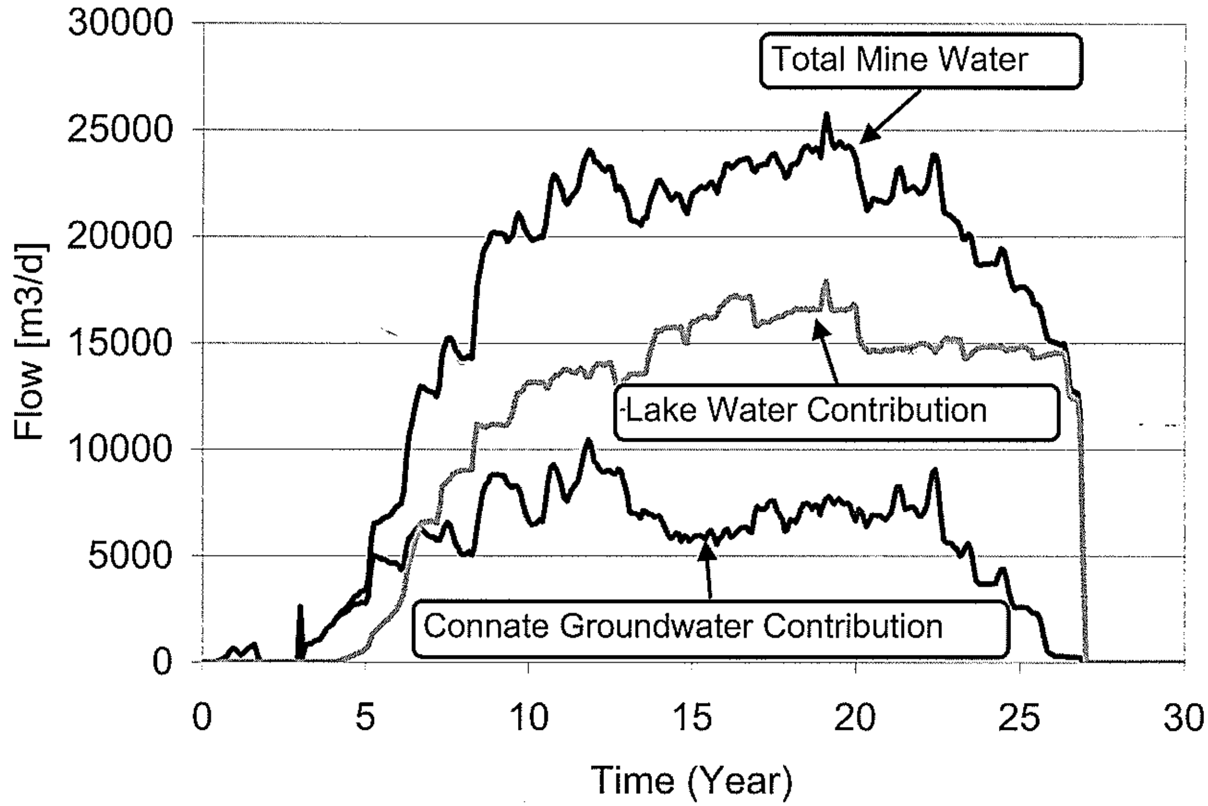
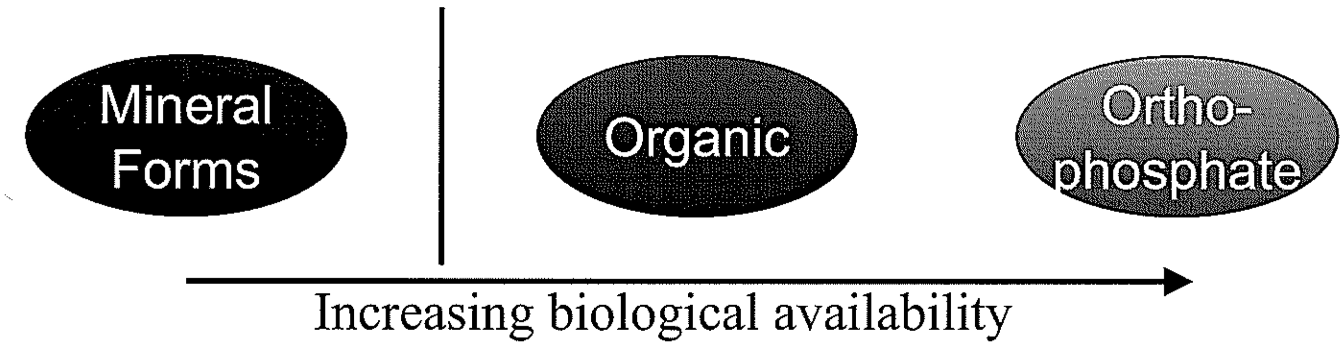
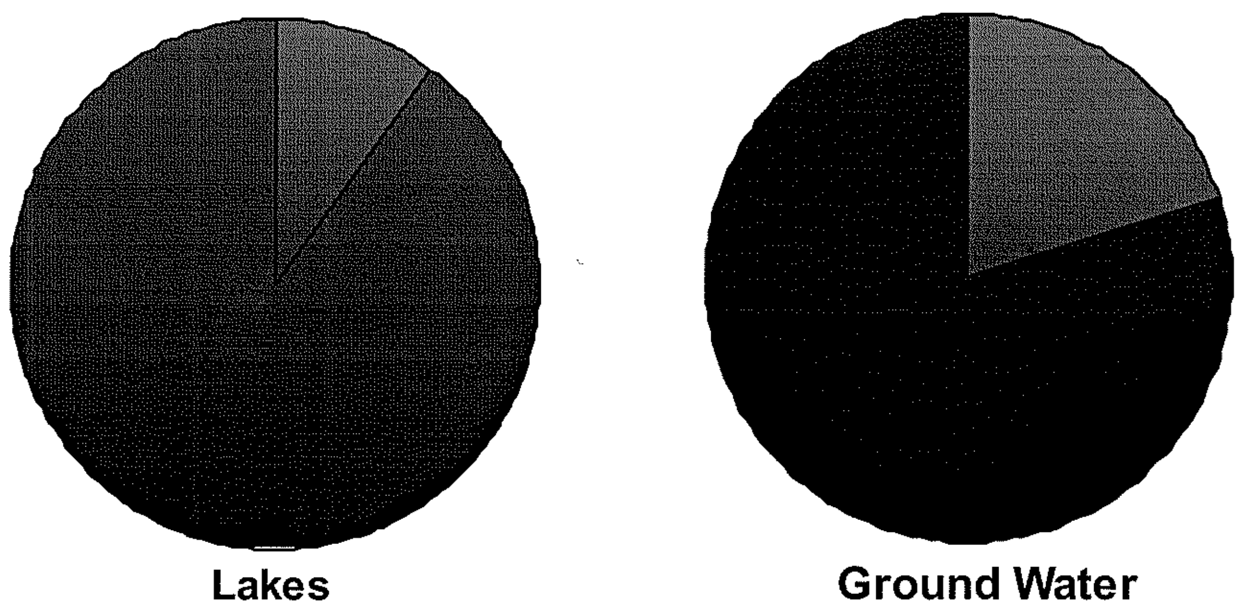
Phosphorus Sources in Mine Inflow

- Initial source of mine inflow is connate groundwater
- Proportion of inflow from Snap Lake increases over time



Forms of Phosphorus in Lakes and Groundwater/Minewater





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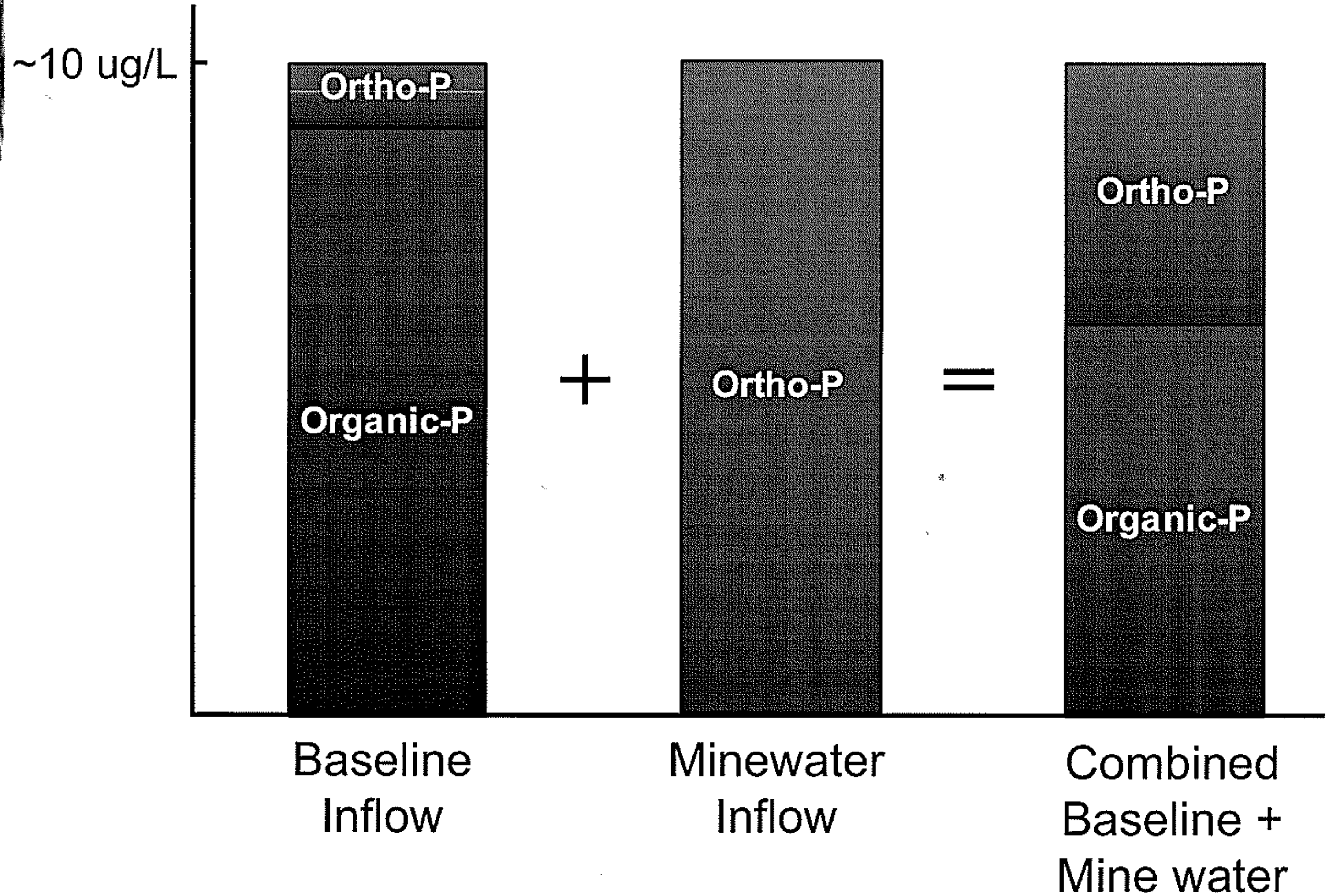
Changes in Phosphorus in Inflows to Snap Lake



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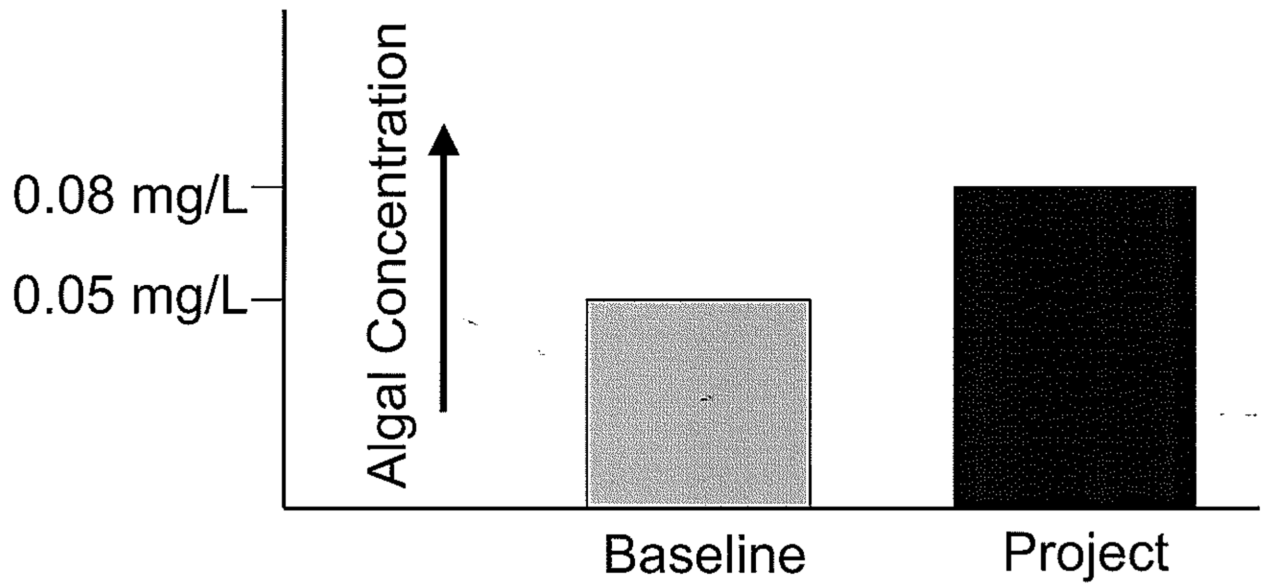
Maximum Predicted Increases in Algal Concentrations in Snap Lake



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Phosphorus Removal During Water Treatment Pilot Testing

Why EA results are conservative:

Parameter	Units	Untreated	Treated
Total Phosphorus	ug/L	111	9
Dissolved Phosphorus	ug/L	15	8
Orthophosphorus	ug/L	20	5

- EA OrthoP in Water Discharge = 8 – 23 ug/L
- EA OrthoP > Total P in treated water from pilot testing

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Decrease in Phosphorus Concentrations in Snap Lake

- No increase total bioavailable phosphorus in releases
- Considerable increase in proportion of orthophosphate
- Increase in Algae without increase in TP
- Results in an increase P loss to sediment through settling
- P loss = [Algae] x Fraction P x Algal Settling Rate

Baseline Modelling Results

Parameter	Units	Calibration	No Algal Settling
Total Phosphorus	ug/L	9	11
Algae	mg/L	0.05	0.08

Conclusions

- The nutrient model was appropriate for predicting effects of nutrient inputs in Snap Lake
- Concentrations of total bioavailable phosphorus in Snap Lake are not expected to increase above baseline concentrations
- The greater proportion of orthophosphate in the minewater discharge could increase algal concentrations in Snap Lake by up to 40%
- Water treatment is expected to result in lower increases in algal concentrations in Snap Lake

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END

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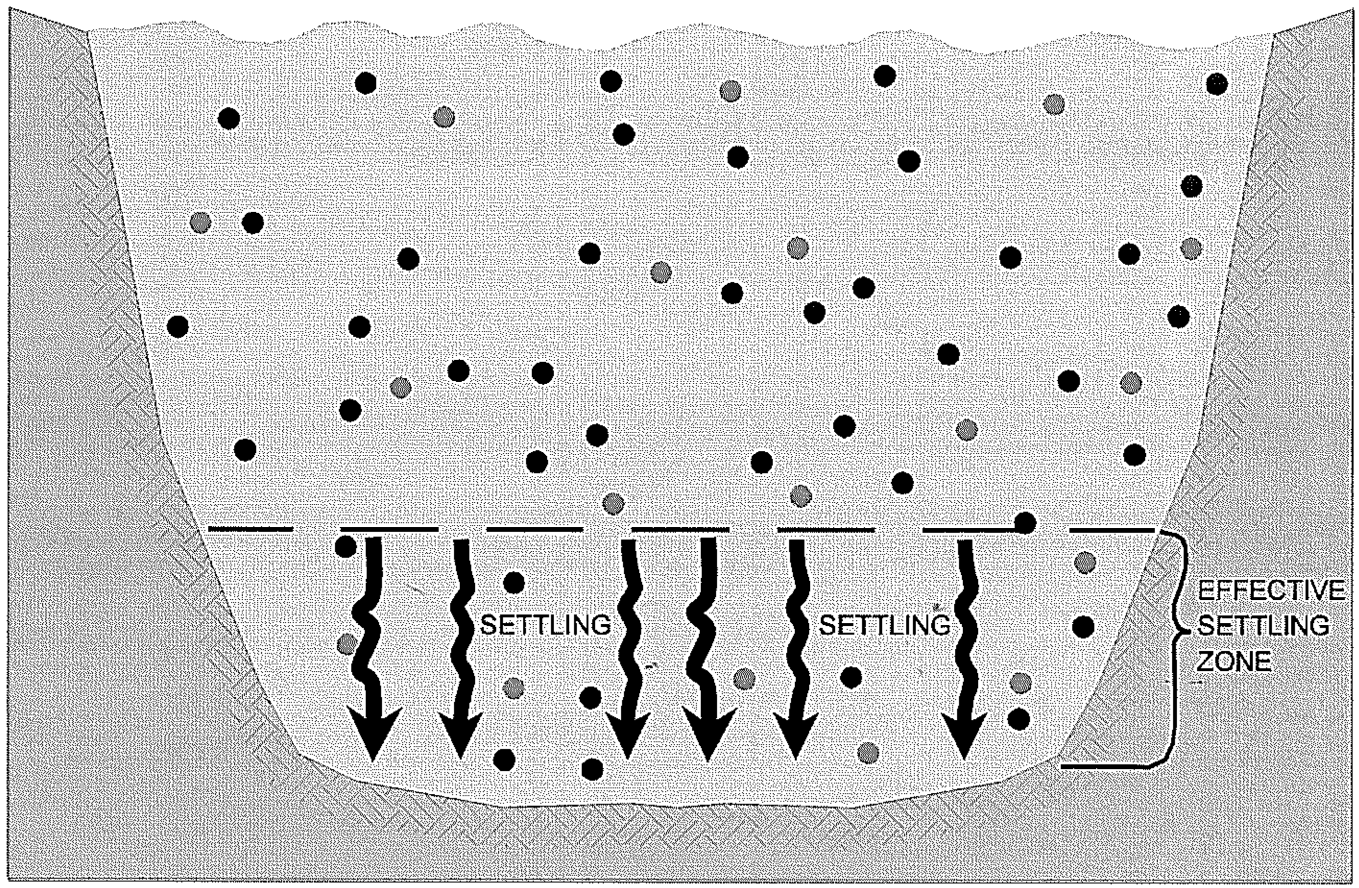
Algal and Particulate Organic Phosphorus Settling and Nutrient Removal



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Water Quality Near the Discharge in Snap Lake

Background

- Water from the project is treated prior to release to Snap Lake
- With treatment, concentrations of some substances > water quality guidelines
- Concentrations < guidelines are achieved close to the point of discharge in Snap Lake
- In the EAR, the overall effect was determined to be negligible to low

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Groundwater Flow Directions and Quantities

- Purpose: to provide information on groundwater flow directions and quantities to the North Lakes during all phases of the project

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Topic Has Been Addressed:

- Environmental Assessment Report
  - Section 9.2.2
- North Lakes Report
- Responses to Information Requests
  - IR 2.1.5
  - IR 4.1.5

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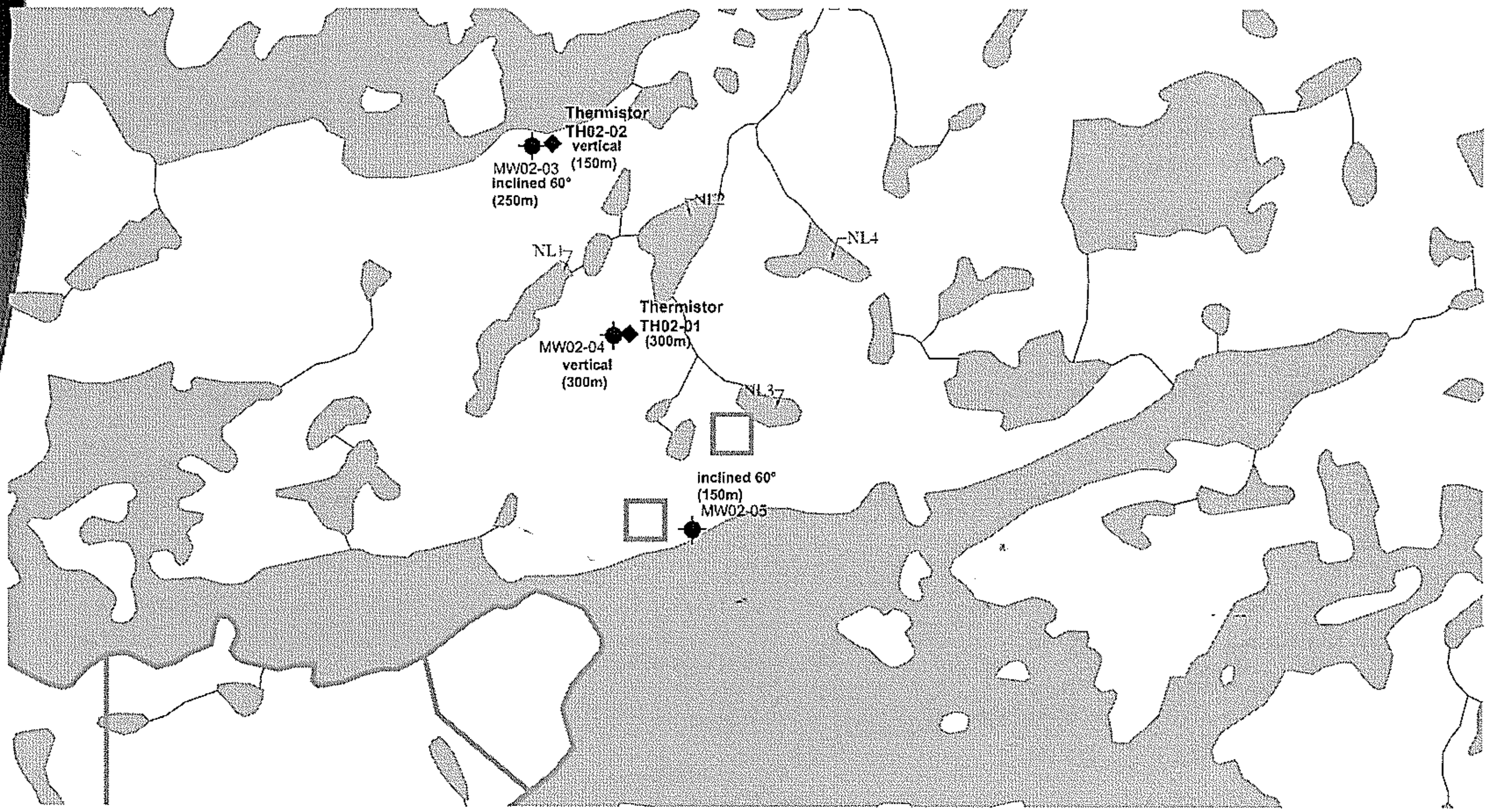
Location of Thermistors and Wells



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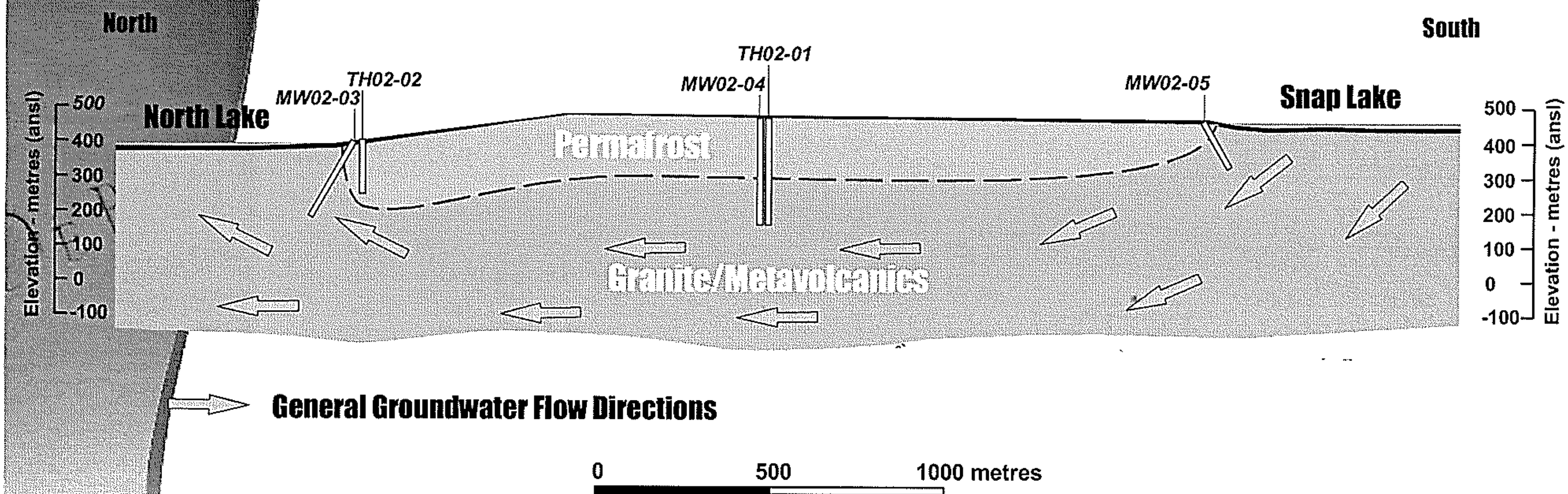
Groundwater Flow

Schematic diagram showing cross-section



Note: No vertical exaggeration
Scale 1:1

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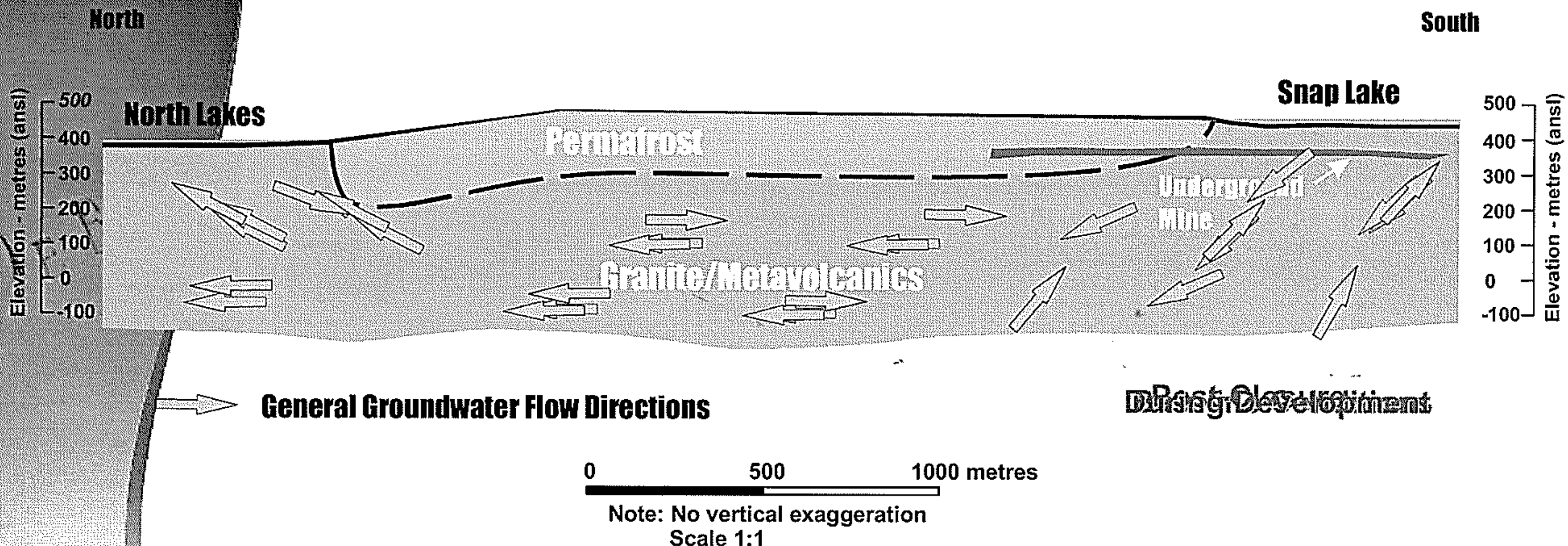
Groundwater Flow

Schematic diagram showing cross-section



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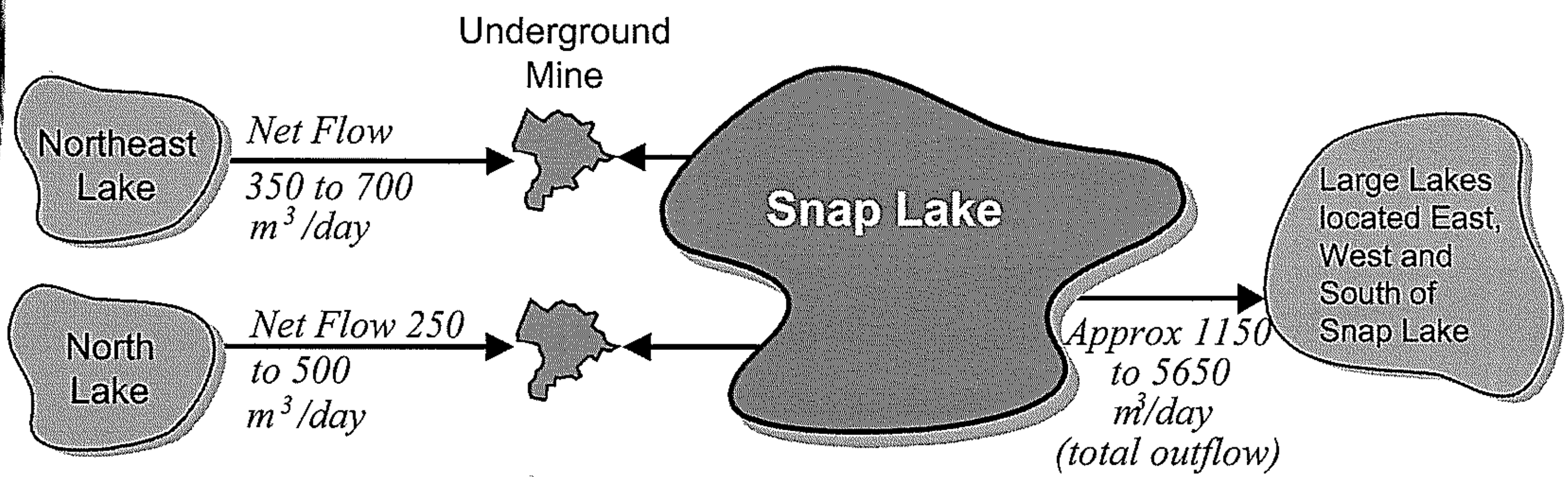
Conclusions - Groundwater Flow During Mining



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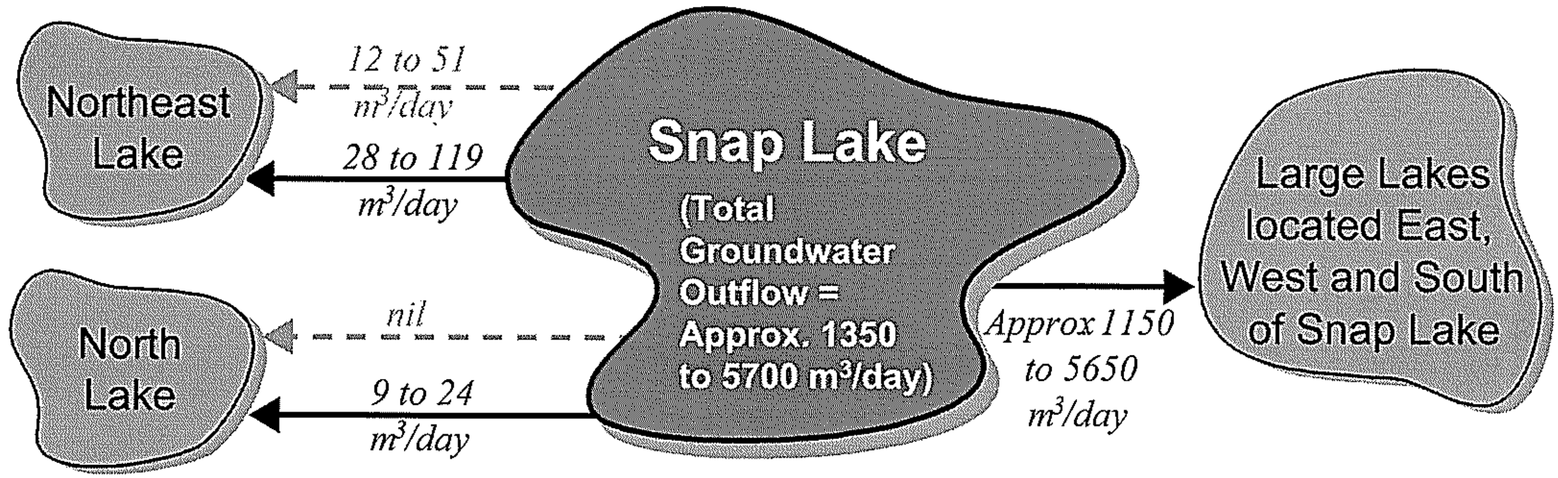
Conclusions - Groundwater Flow Post-Closure



Legend:

---- groundwater that passes through the mine

— groundwater that does NOT pass through the mine

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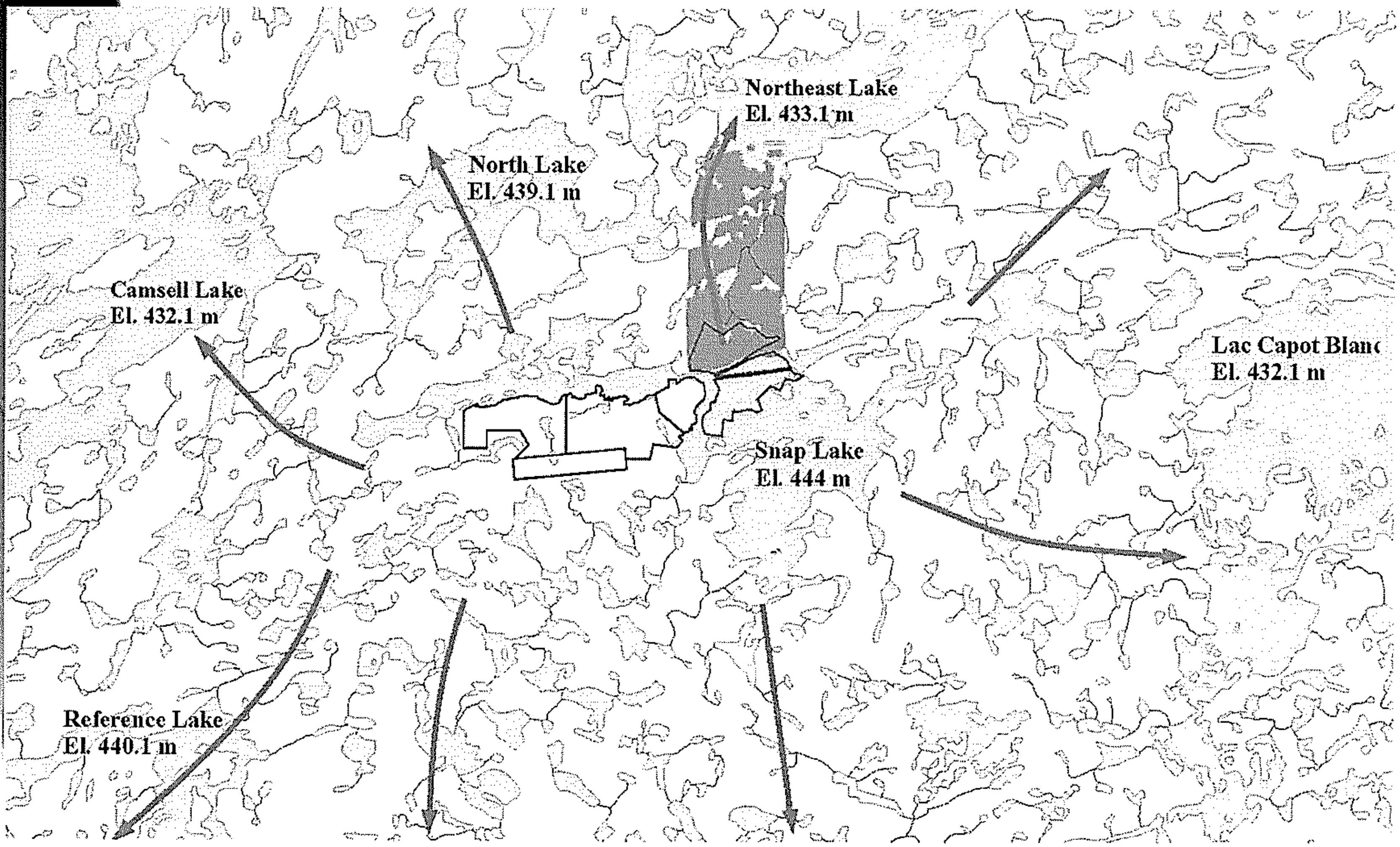
Groundwater That Has Passed Through Mine Workings



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Changes in Groundwater Quality between Snap Lake and Northeast Lake

- Purpose: to provide background and rationale for the expected changes in groundwater quality between Snap Lake and Northeast Lake

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Topic Has Been Addressed:

- North Lakes Report
- North Lakes Workshop
- Relevant External References
  - Palmer and Puls (1994)
  - Drever (1988)
  - Appelo and Postma (1993)
  - Brookins (1988)
  - Freeze and Cherry (1979)

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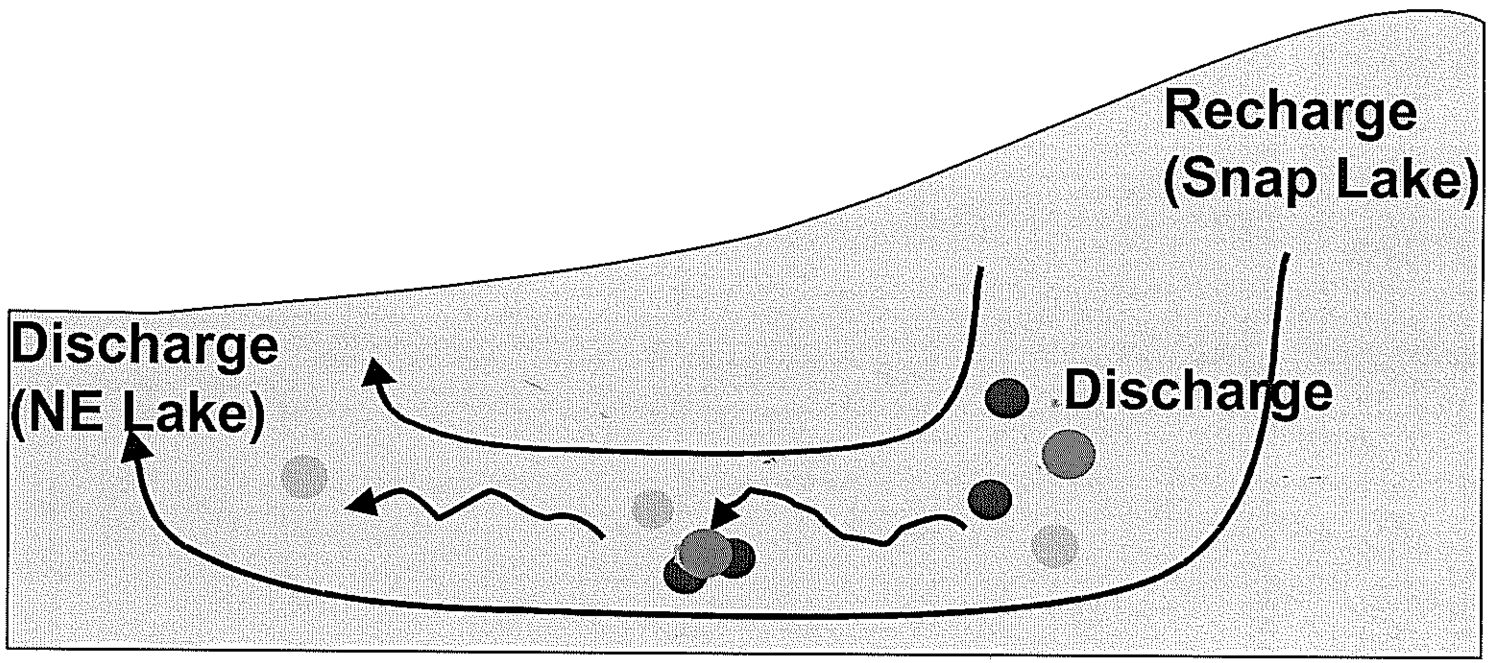
Changes Along the Flow Path



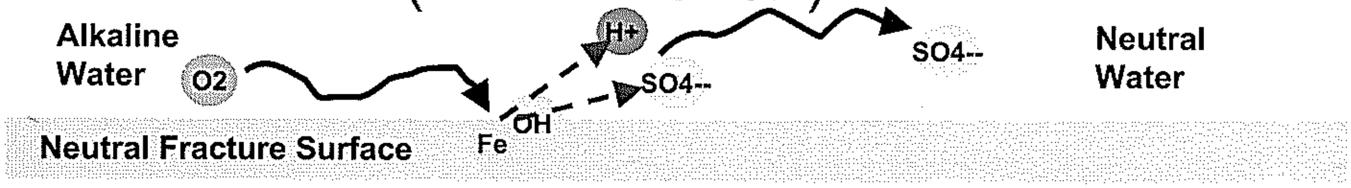
Changes in Groundwater Chemistry

Expected Chemical Changes

- Decrease in pH value
  - Alkaline cemented paste backfill
  - Equilibration with bedrock
- Decrease in concentrations of Al, Cr, Cu
- No change expected for Mo

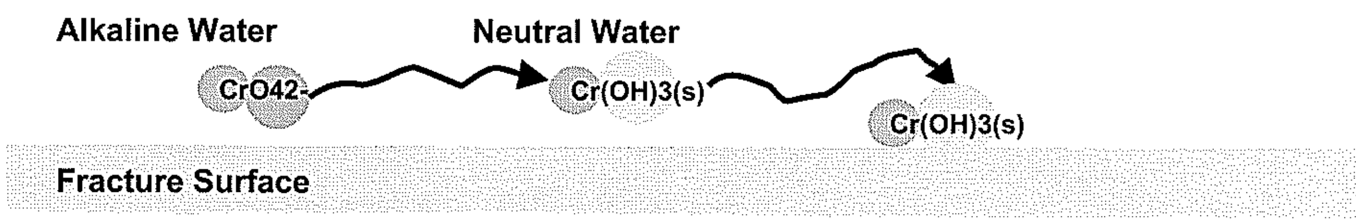
Chemical Mechanisms

Reactions (neutralization)



Adsorption (sticks to surface)

Precipitation (scaling)



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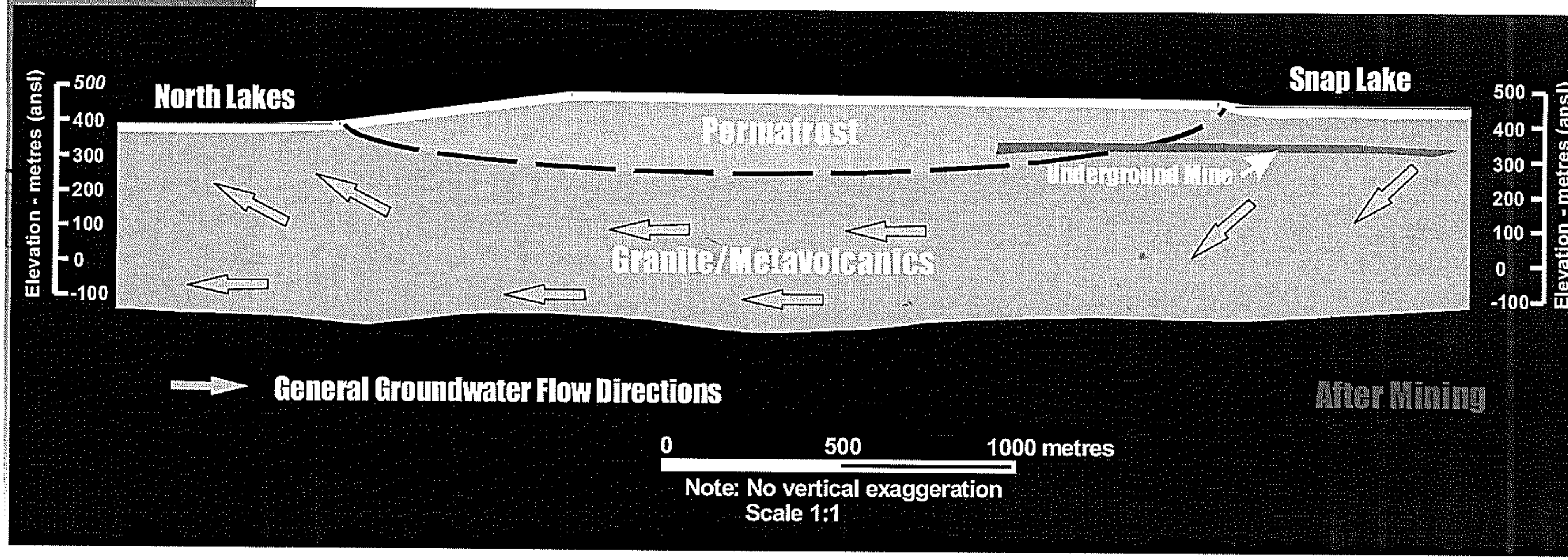
Setting

- Time (> 150 years)
- Isolated system
- Equilibrium / Interaction with Bedrock



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Conclusion

- Given the timeframe for flow and the geological system between Snap Lake and Northeast Lake, the expected changes to groundwater chemistry are considered appropriate

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North Lakes Water Quality

Purpose:

To provide more information on how the Project could affect water quality in the north lakes after mine closure

- Changes controlled by:
  - Amount of groundwater flow to north lakes
  - Maximum concentrations in groundwater
  - Changes along groundwater flow pathway and in sediment porewater
  - Dispersion in sediment porewater

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Topic Has Been Addressed:

- Environmental Assessment Report
  - Section 9.4
  - Appendix IX-7
- North Lakes Report
- Responses to Information Requests
  - IR 3.9.8
  - IR 4.1.9

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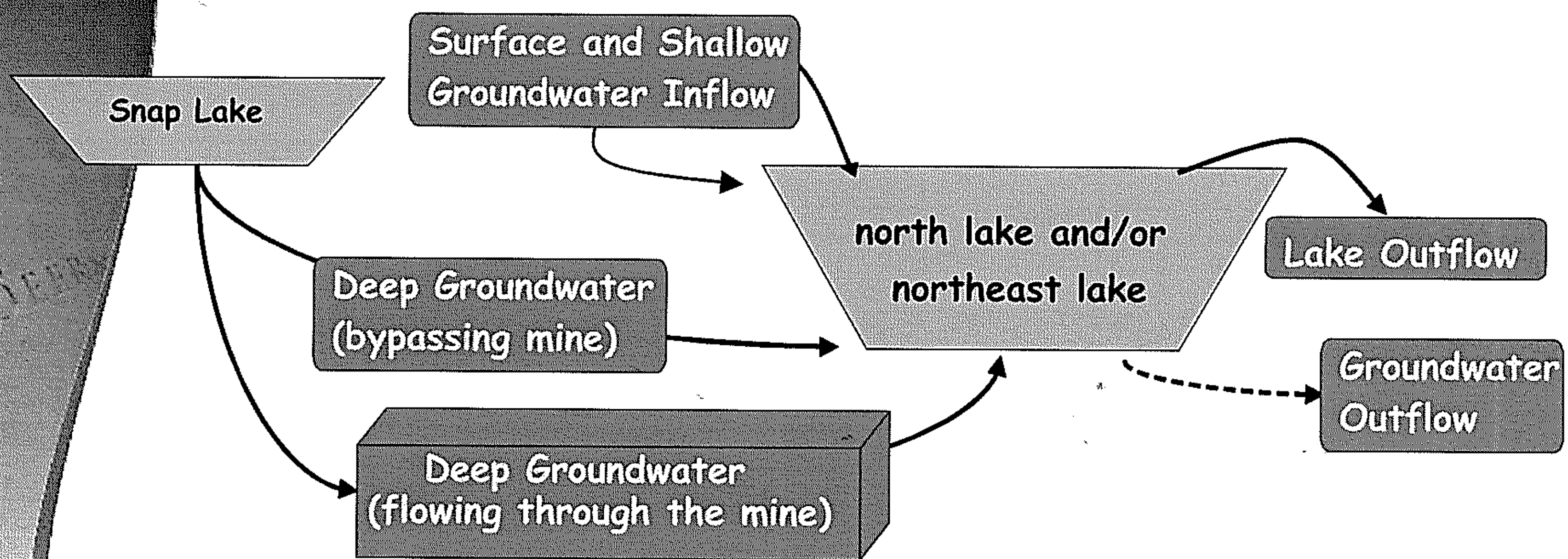
North Lakes Water Quality

Flow Pathways



northeast lake only

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Groundwater Flow to North Lakes

- Groundwater modelling showed that after mine closure:
  - No water passing through the mine workings will reach the north lake
  - 30% of groundwater inflows to the northeast lake will pass through the mine workings
- Water quality results were used to determine the total amount of groundwater flow to northeast lake

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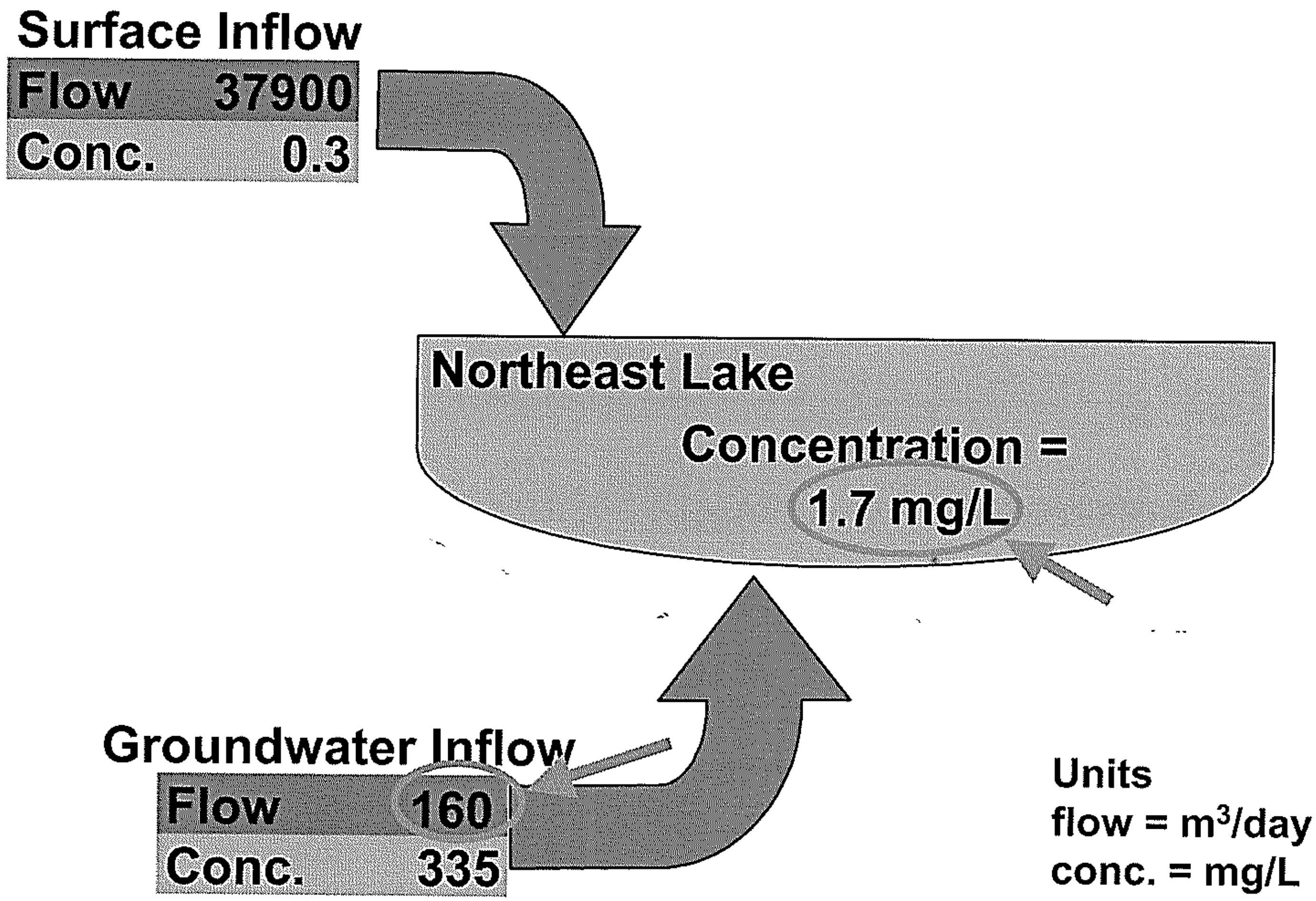
Updated Chloride Mass Balance: Northeast Lake - Baseline



Units
flow = m^3/day
conc. = mg/L

Groundwater Flow to North Lakes

- Groundwater flow to northeast lake
  - Mass balance results showed that total groundwater inflows to the northeast lake are between 40 and 160 m^3/day
  - 30% of these total flows or 12 to 51 m^3/day of this inflow would pass through mine workings
- Groundwater flow to north lake
  - No water passing through the mine workings will reach the north lake

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Changes in Groundwater Chemistry

- As presented earlier:
  - Ongoing kinetic test work has indicated that metal concentrations in groundwater within the paste backfill will be lower than predicted in the EA
  - Concentrations of metals and pH levels in groundwater will decrease between the mine workings and the northeast lake

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Changes in Porewater Chemistry

- Within lake bottom sediments:
  - Denitrification will decrease nitrate concentrations within lake bottom sediments
  - Chemical reactions and precipitation may result in additional decreases in metal concentrations

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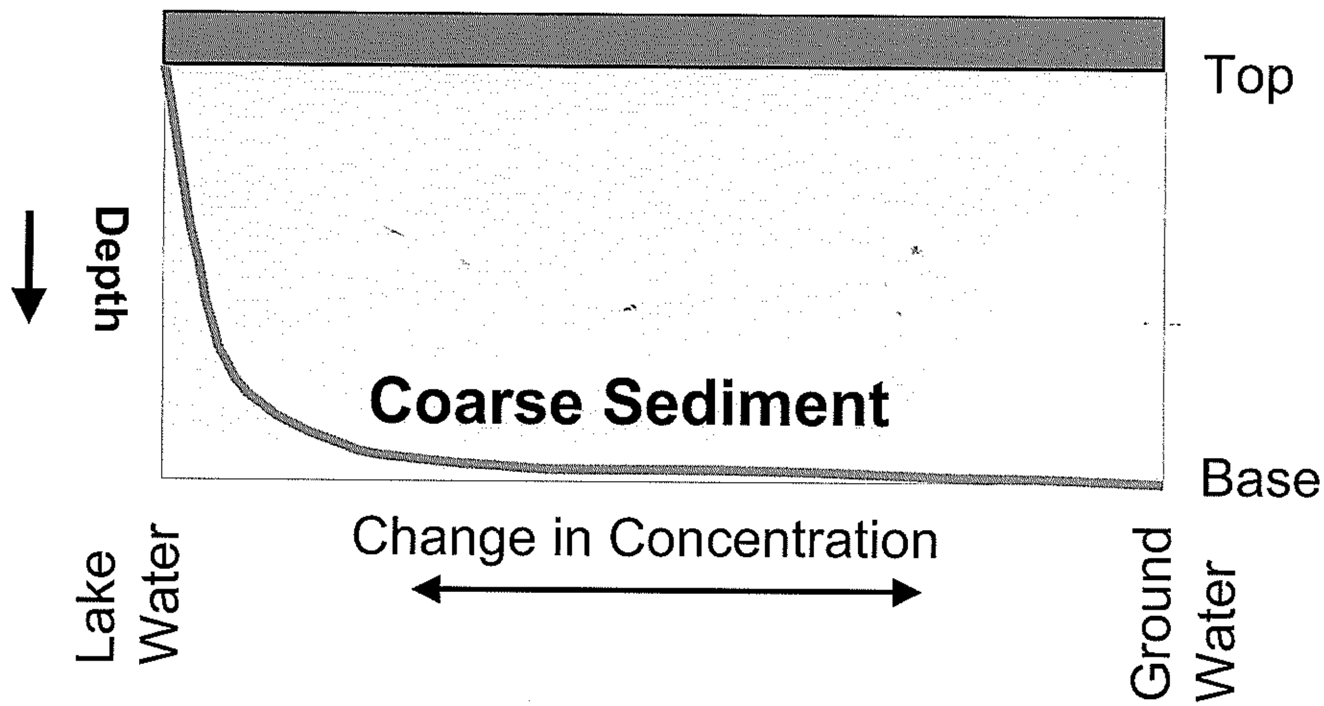
Dispersion in Coarse Sediment and Water Column

- Groundwater inflow to the northeast lake will mix rapidly within the water column and concentration gradients will not develop
- Porewater chemistry of coarse sediments will be similar to the overlying water column



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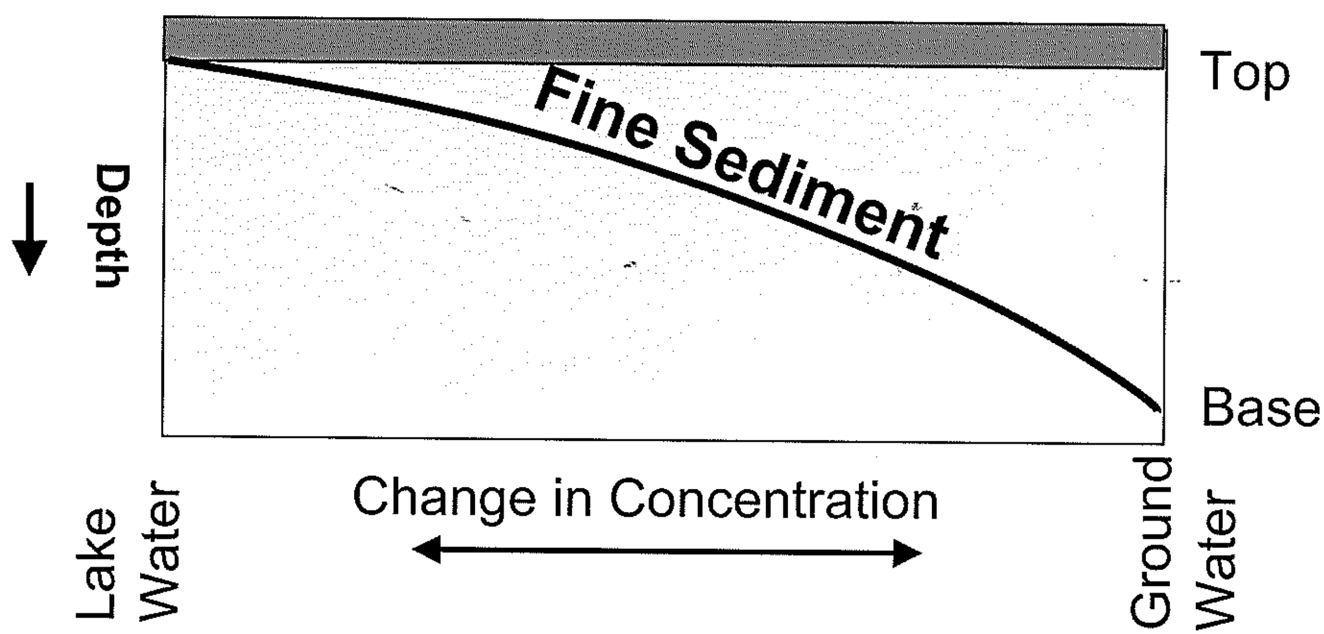
Dispersion in Fine Sediment

- Mixing in porewater controlled by molecular diffusion
- Concentrations equal to water column at top of sediment and to groundwater at base



Conclusions

- North Lake - Water Column and Sediment
  - No effect on water quality or sediment quality in north lake

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Conclusions

- Northeast Lake - Water Column
  - Water quality guidelines will be met for all parameters throughout the water column
  - Assessment was completed without including expected decreases in groundwater chemistry

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Conclusions

- Northeast Lake - Lake Bottom Sediment
  - Assessment area in the northeast lake consists of about 85% coarse sediment and 15% fine sediment
  - Water quality guidelines will be met at the sediment-water interface for all parameters in areas of coarse and fine sediments
  - Water quality guidelines will be met within porewater of areas with coarse substrate
  - Porewater concentrations within areas of fine sediment could not be quantified, but are expected to be substantially lower than predicted in the EA