PROPOSED MODIFICATION NWB IN-PIT TAILINGS DISPOSAL COMMENT RESPONSES

SNC·LAVALIN

Updated results (version 3) for contaminant transport model

September 25 th, 2018

Meeting Agenda

- Introduction
- Hydrogeological modelling Version 3 results
- Discussion
  - Thermal modelling and permafrost extent;
  - Model boundary conditions;
  - Contaminant migration from tailings to overlying Third Portage Lake;
  - Groundwater monitoring plan and groundwater monitoring wells

Introduction

- NIRB decision released on August 31st, 2018

  ''The NIRB has concluded that this proposed amendment to the Meadowbank Gold Mine may proceed to the licensing and permitting regulatory phase with no revisions to the existing Terms and Conditions of Project Certificate No. 004 required. ''

- NWB decision expected in December 2018.

NRCan Review Comment status

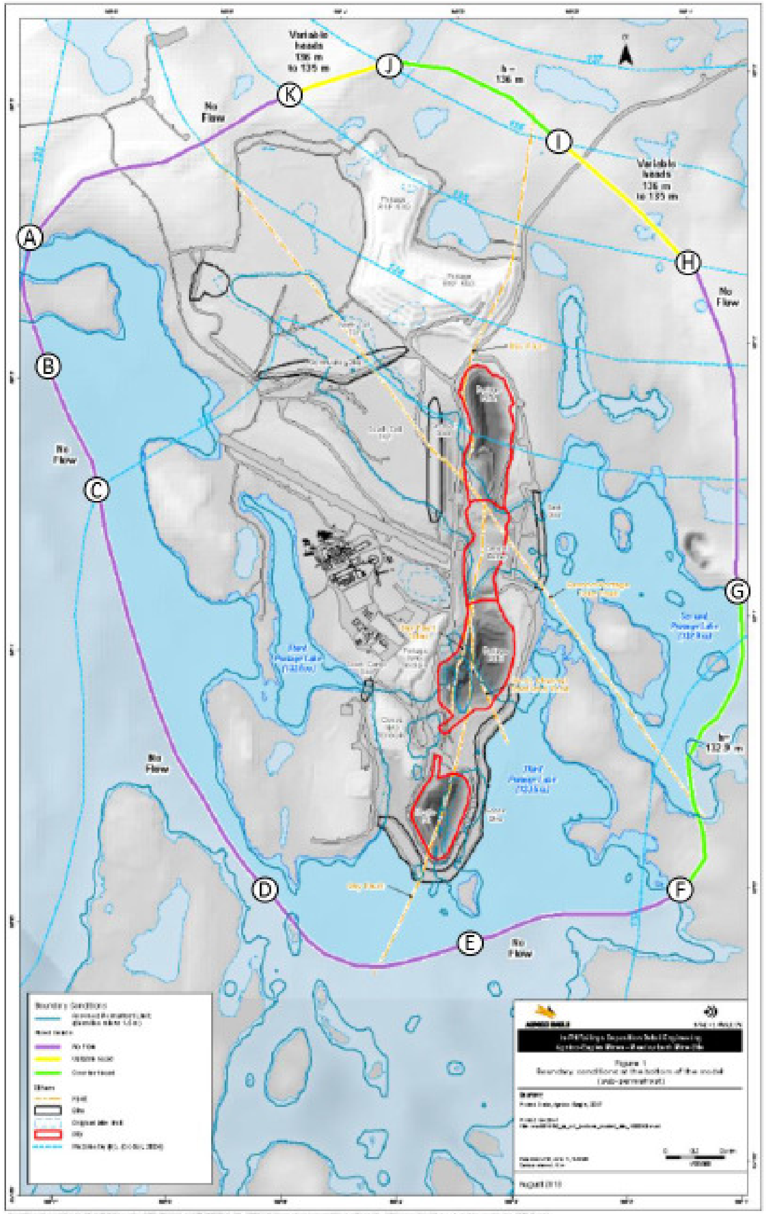
- Resolved #4, #5, #6, #10
- Thermal modelling and permafrost extent (#3, #7, #11);
- Model boundary conditions (#1, #2, #7, #11);
- Contaminant migration from tailings to overlying Third Portage Lake (#8);
- Groundwater monitoring plan and groundwater monitoring wells (#9, #12)

Review comment	Subjects	Status	Version
1	Model Extend	Update BC	3
2	BC Justification	Update BC	3
3	Permafrost Extent	Update thermal model	4
4	Goose WRSF Hydraulic Conductivity	Resolved	2
5	Water Level Control	Resolved	2
6	Tailings as a Contaminant Source	Resolved	2
7	In-Pit Periods + Scenarios	Update BC + Thermal Model	4
8	Contaminant Toward 3PL	Diffusion Model	3
9	Groundwater Monitoring	GW well table in report	
10	Central Dike Seepage	Resolved	2
11	Update Hydrogeological Modeling	Update BC + Thermal Model	4
12	Update Groundwater Monitoring Plan	Update GW modeling table	

Comparison of Version 3 BCs to NRCan Review Comments

Section	Version 3	NRCan
A-B	No Flow	136.6
B-C	No Flow	No Flow
C-D	No Flow	133.6-132.2
D-E	No Flow	No Flow
E-F	No Flow	132.9-132.7
F-G	132.9	132.7-132.9
G-H	No Flow	No Flow
H-I	135-136	135.6-136.6
I-J	136	136.6
J-K	136-135	135.6-136.6
K-A	No Flow	No flow

- Agreement regarding boundary conditions at the top of the model



1. Hydrogeological Model Version 3 Results

I. Model updates : Version 3
   - Boundary conditions
   - Goose Dump
   - Permafrost degradation (100 years scenario) (already in Version 2)
   - Contaminant source over all the tailings depth (already in Version 2)

II. Scenario 1 : Goose Pit filled with tailings for the entire duration of Portage Pit filling
   - Simulated head maps
   - Simulated transport of chloride from Goose pit (during 12 years)

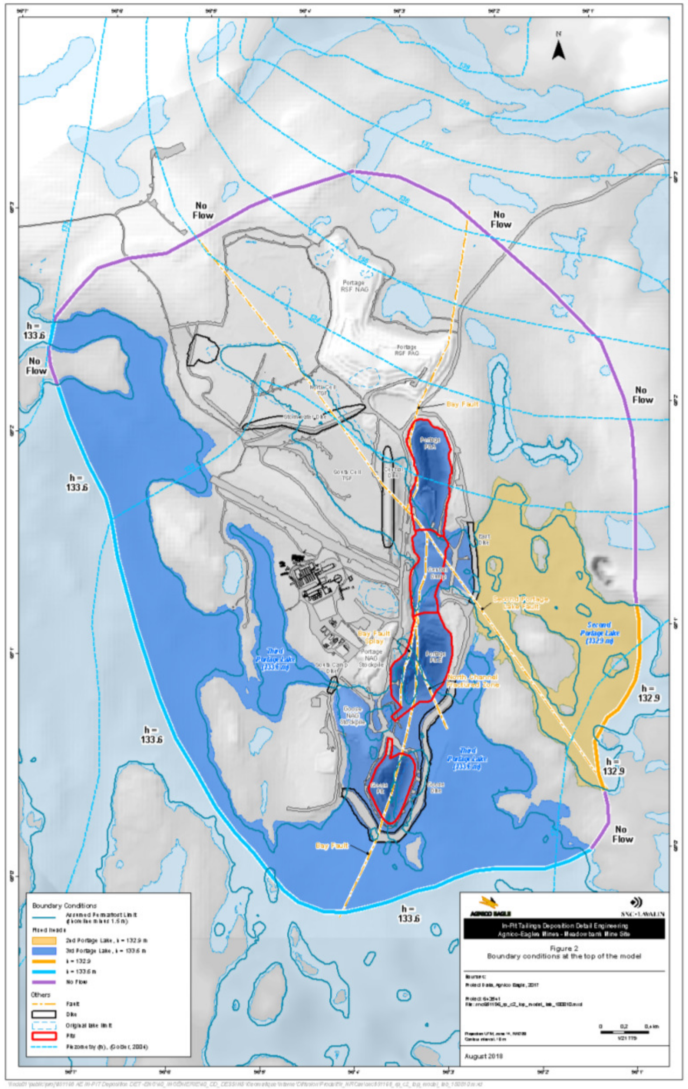
III. Scenario 2 : Post-closure, all pits filled with tailings and flooded
   - Simulated head maps (two cases comparison)
   - Simulated transport of chloride from pit A, pit E and Goose pit

I. Model updates : Flow boundary condition descriptions

Based on Golder 2004 and 2005 simulated water level and surveyed lake levels by AEM

Boundary conditions at the top of the model

Figure colors	Geographic position	Elevation (masl)	Layer	Boundary condition
Grey zone	Permafrost area	variable	1	no flow
Blue area	3PL area and limit	variable	1	h = 133.6 m
Yellow Area	2PL area and limit	variable	1	h = 132.9 m

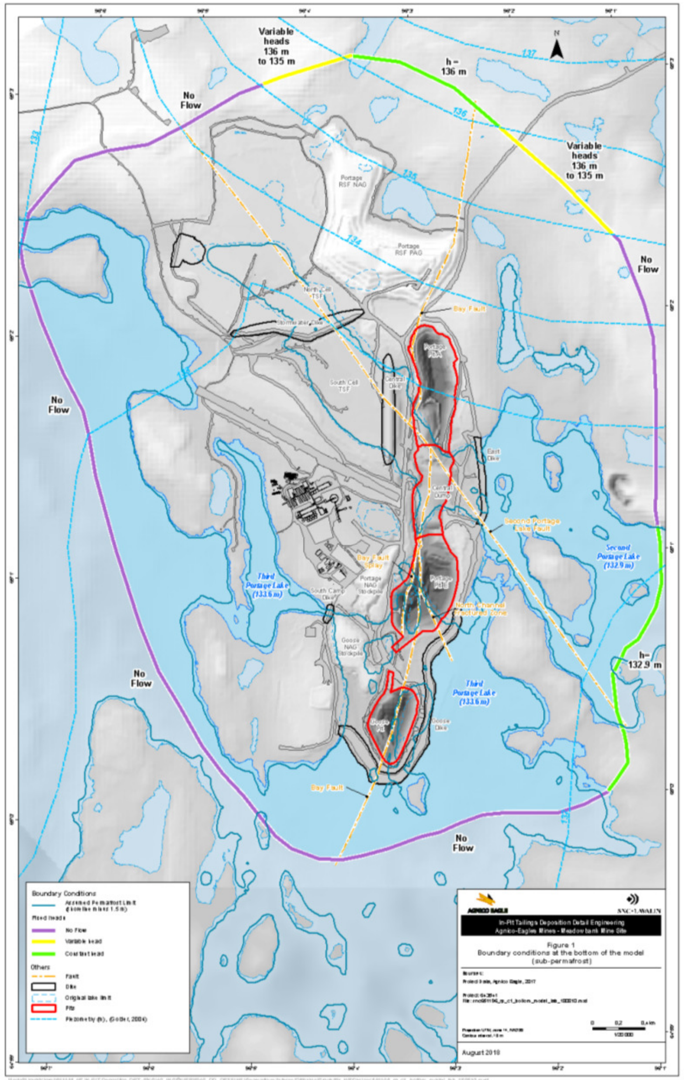


I. Model updates : Flow boundary condition descriptions

Based on Golder 2004 and 2005 simulated water level and surveyed lake levels by AEM

Permafrost and sub-permafrost boundary conditions

Figure Colors	Geographic position	Elevation (masl)	Layer	Boundary condition
Yellow	Nord	top to -250 m	1 to 39	no flow
Yellow	Nord	-250 to -800 m	40 to 50	135 < h < 136 m
Green	Nord	top to -250 m	1 to 39	no flow
Green	Nord	-250 to -800 m	40 to 50	h = 136 m
Yellow	Nord	top to -250 m	1 to 39	no flow
Yellow	Nord East	-250 to -800 m	40 to 50	135 < h < 136 m
Purple	East	top to -800 m	1 to 50	no flow
Green	South East	top to -800 m	2 to 39	no flow
Green	South East	top to -800 m	1 to 50	h = 132.9 m
Purple	South and west	top to -800 m	1 to 50	no flow



Scenario 1

Goose Pit filled with tailings for the entire duration of Portage Pit filling

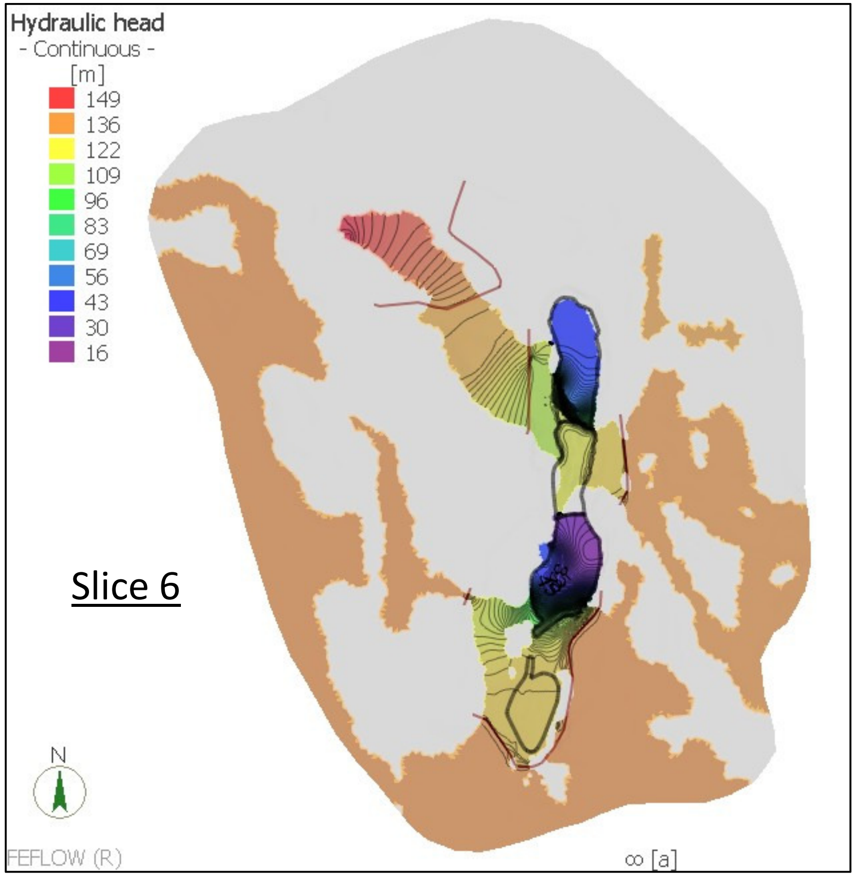
II. Scenario 1 : Model updates

Goose Pit filled with tailings for the entire duration of Portage Pit filling

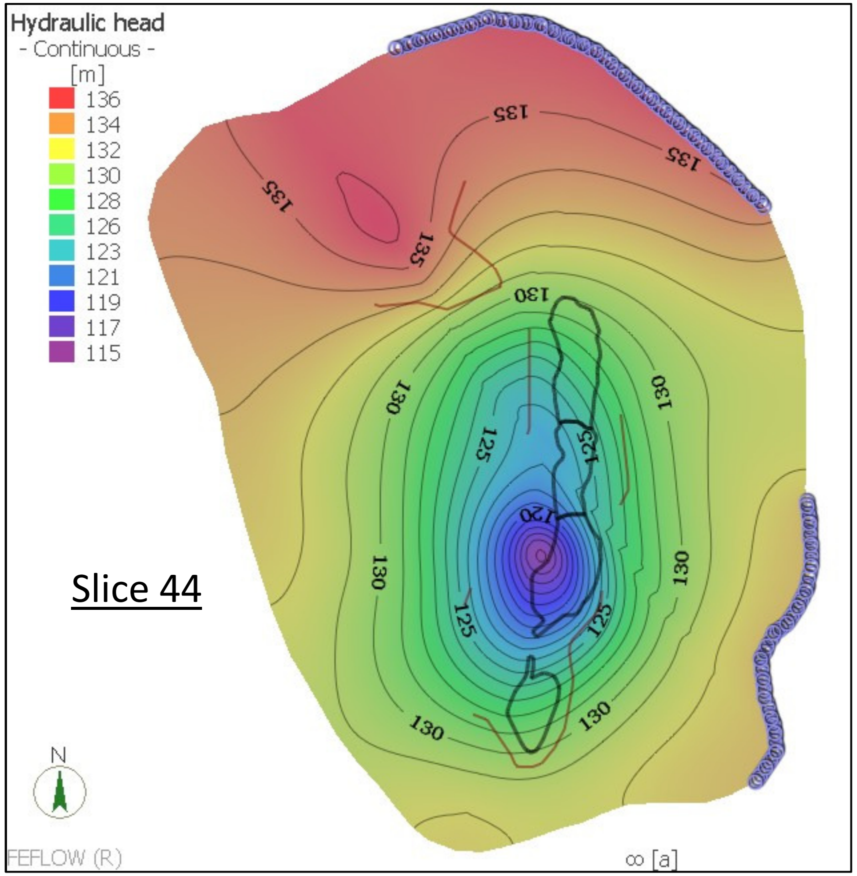
- Goose waste dump added ($1x10^{-3}$ m/s)
- Goose tailings elevation = 100 masl (based on detail engineering)
- Goose water elevation = 126 masl (based on detail engineering)
- Portage pits A and E are considered under dewatering condition during the entire Period 3. This way, we avoid variable BC and it represents a worst case, since the hydraulic gradient between Goose Pit and Pit E will be maximum
- North and South cells tailings are still unfrozen
- Central pond SD is still pumping
- No permafrost degradation
- Concentration in Goose Pit is 22 mg/L
- It would take 12 years to fill Portage pits

II. Scenario 1 : Hydraulic heads maps

Goose Pit filled with tailings and Portage pits are under dewatering conditions for 12 years



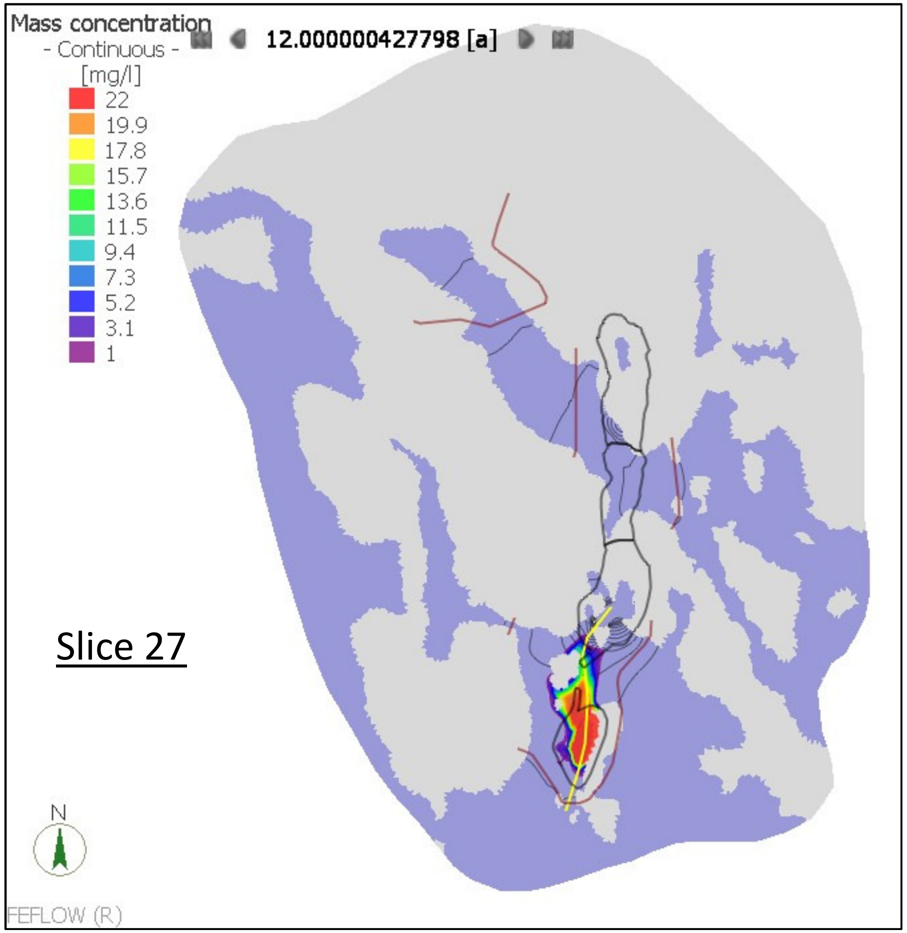
Permafrost conditions (~120 masl)

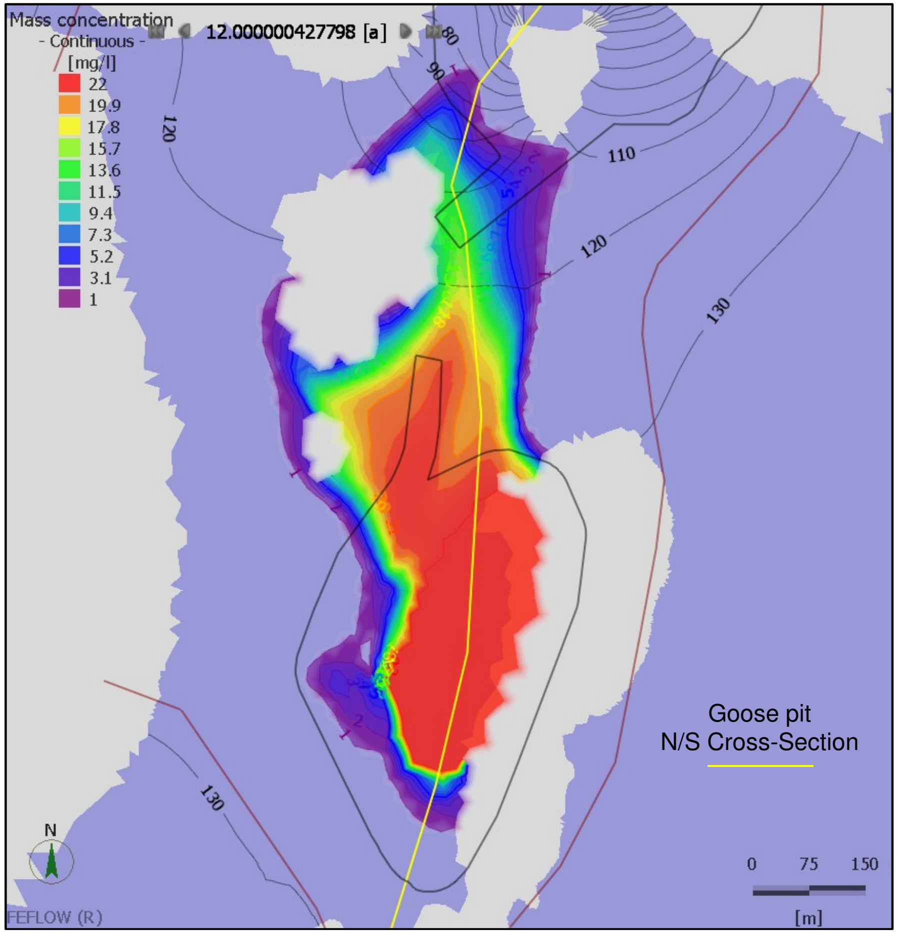


Sub-permafrost conditions (-500 masl)

II. Scenario 1 : Transport of chloride after 12 years

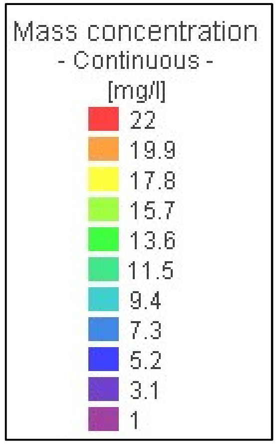
Goose Pit filled with tailings and Portage pits are under dewatering conditions for 12 years



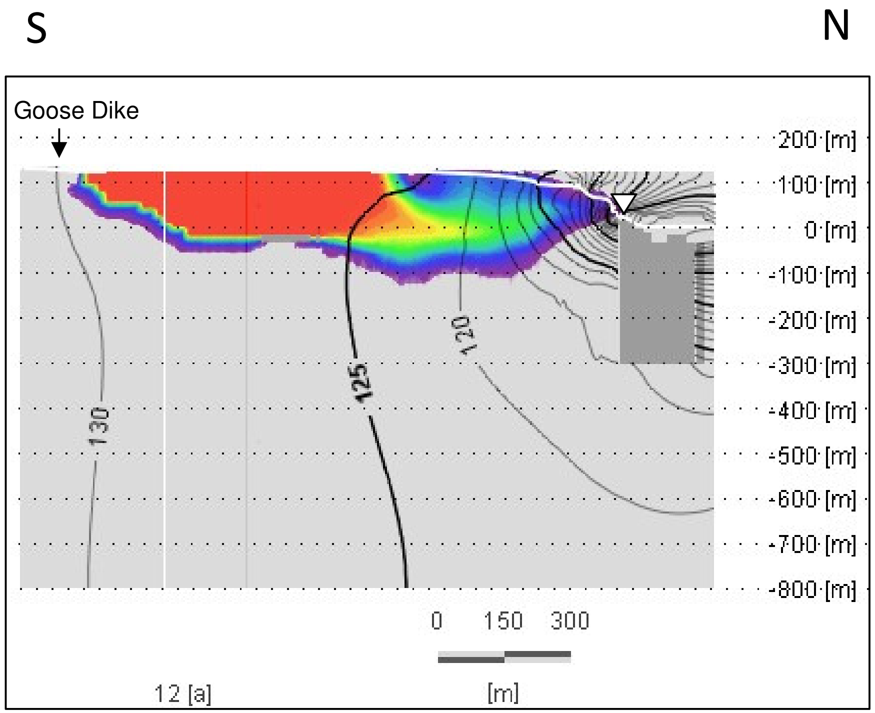


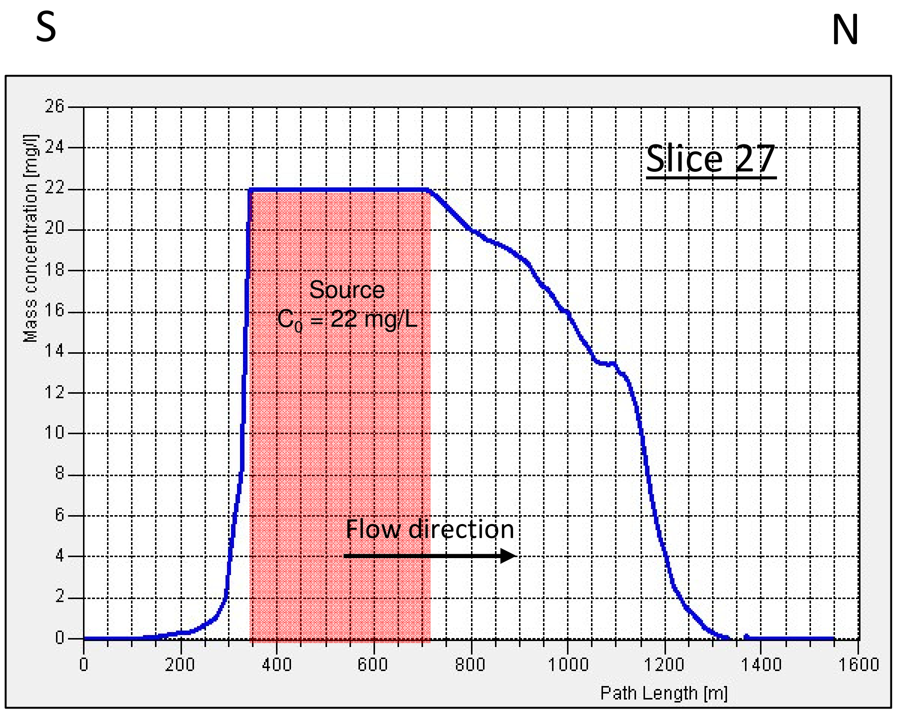
No discharge to 2PL, nor 3PL

II. Scenario 1 : Transport of chloride after 12 years



Goose Pit– N/S Cross Section
Goose Pit filled with tailings and Portage pits are under dewatering conditions for 12 years





Scenario 2

Post-closure, all pits filled with tailings and flooded

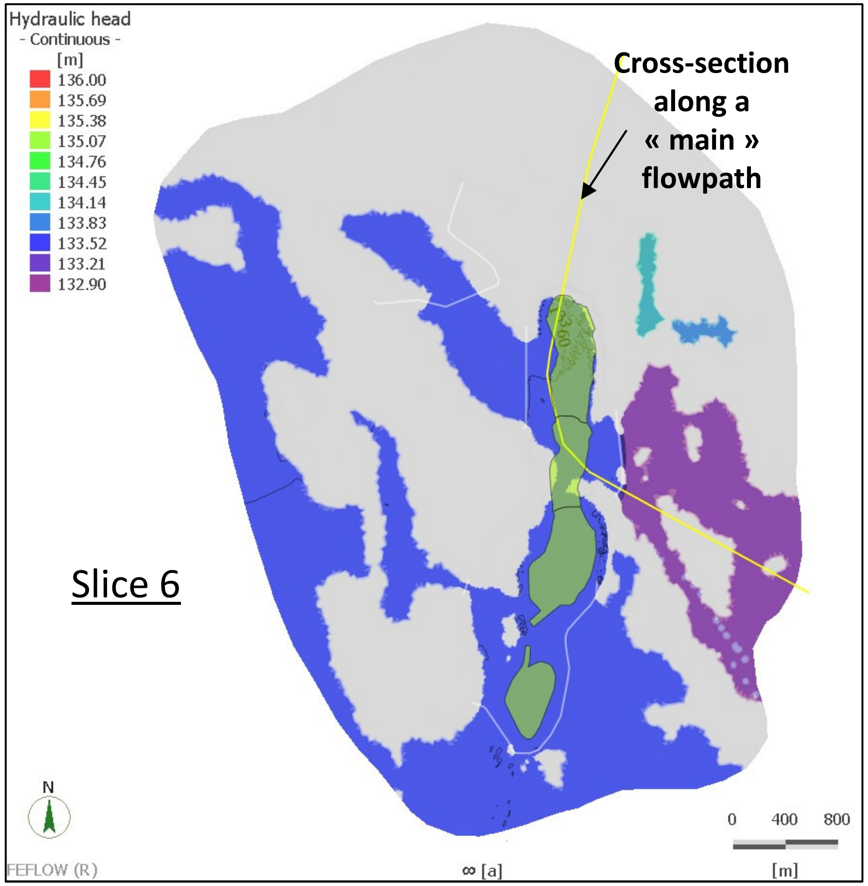
III. Scenario 2 : Model updates

Post-closure, all pits filled with tailings and flooded

- Goose waste dump added ($1x10^{-3}$ m/s)
- Tailings elevation = 125.6 masl (based on detail engineering, max capacity)
- Pits water elevation = 133.6 masl (3PL water level)
- North and South cells tailings are frozen
- No more pumping at Central Dike
- Permafrost degradation (thawing effects from the tailings as well as climate change were considered)
- Concentration in Goose Pit is 22 mg/L
- Concentration in Pit E is 141 mg/L
- Concentration in Pit A is 116 mg/L
- Dispersivity increased (x2) because of numerical errors. The front of the plume will reach receptor sooner.
- The initial concentrations for the Goose Pit are based on results from the Scenario 1 simulations with the contamination extending beyond Goose Pit
- Scenario 2 is run for 20,000 years to capture long term behavior of the plumes

III. Scenario 2 : Hydraulic heads maps

Post-closure, all pits filled with tailings and flooded



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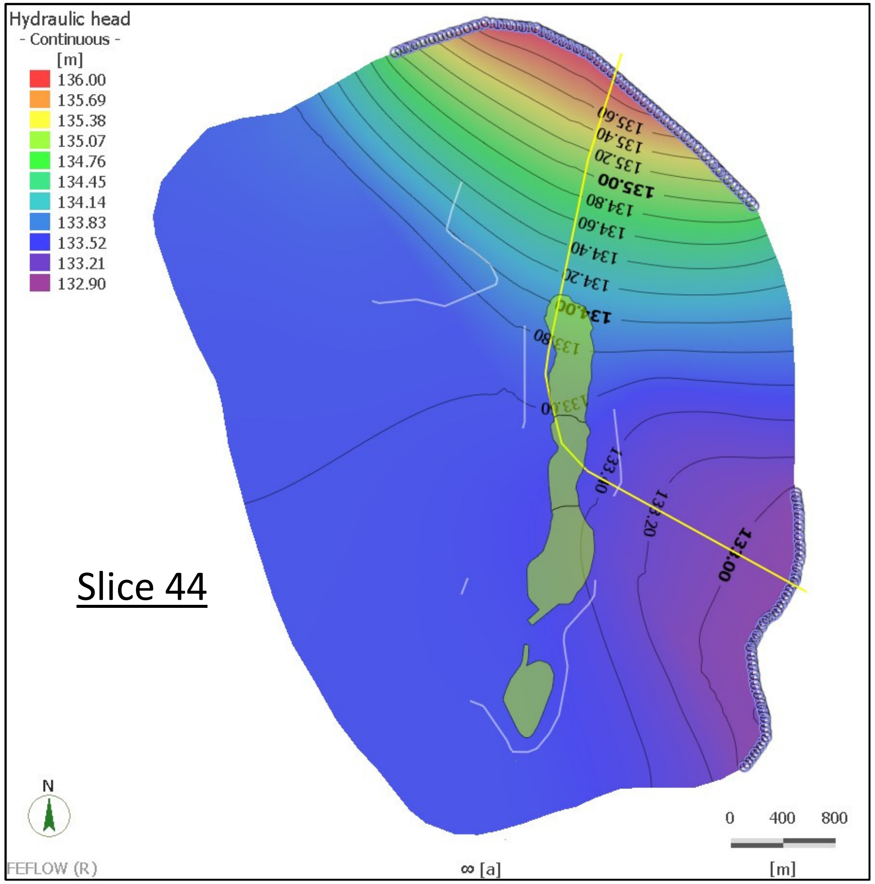
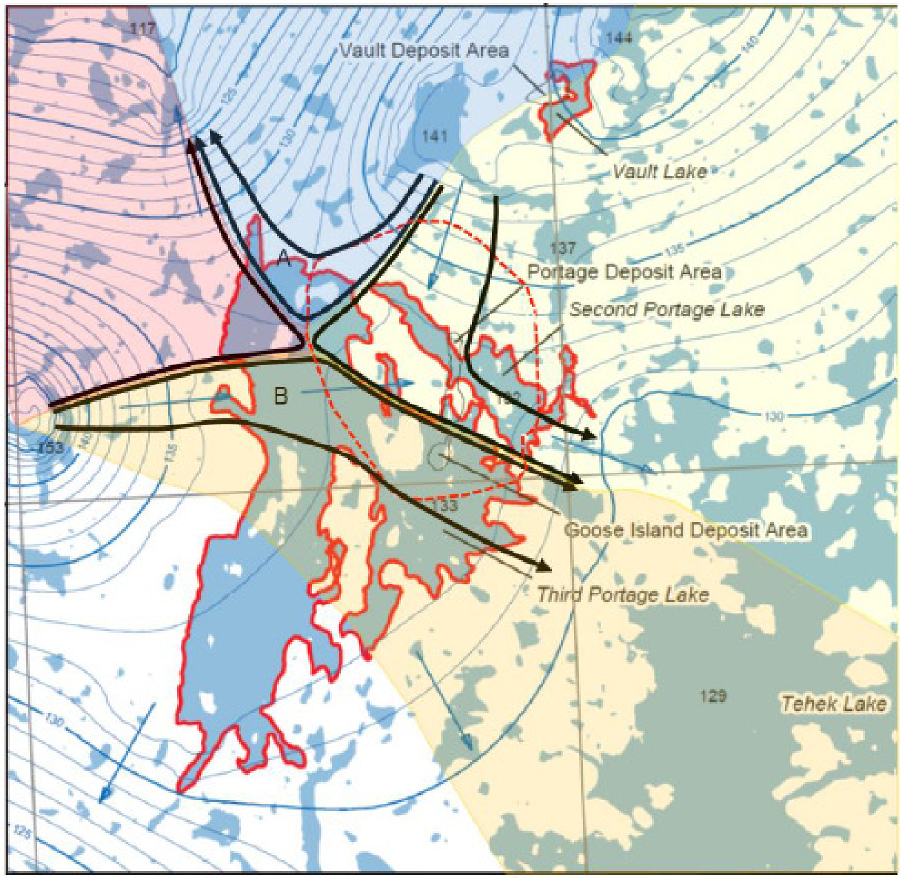
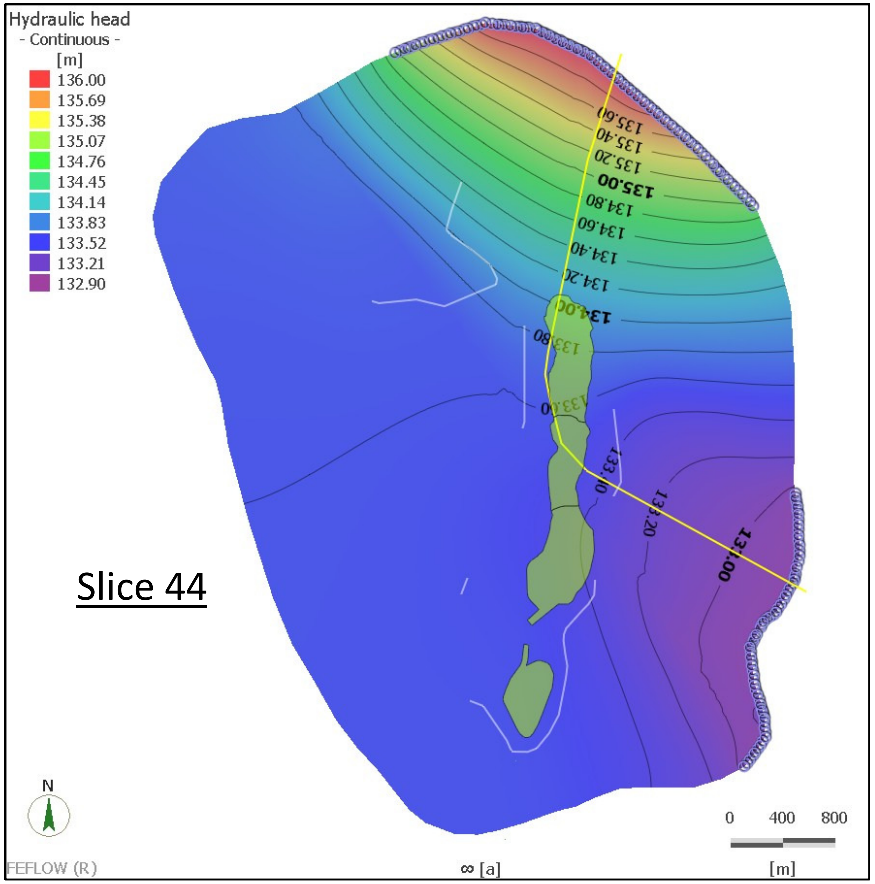


Sub-permafrost conditions (-500 masl)

III. Scenario 2 : Hydraulic heads maps

Comparison of Golder's regional model and SNCL (version3) sub-permafrost



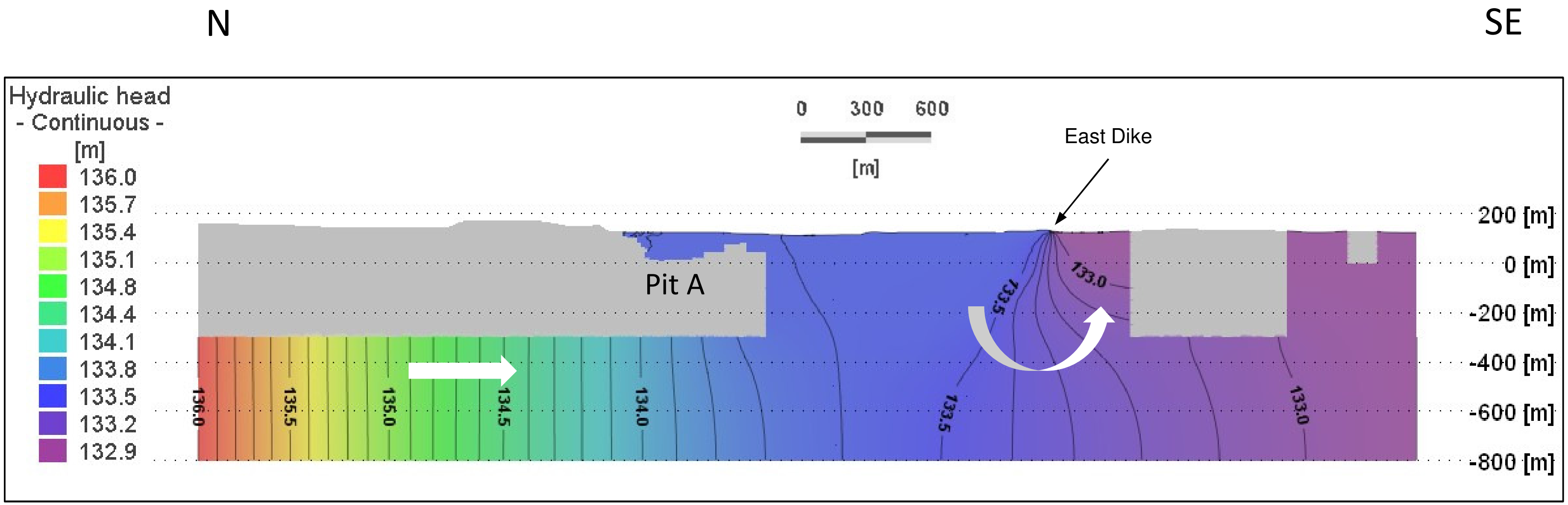


Sub-permafrost conditions (-500 masl)

III. Scenario 2 : Hydraulic heads maps

Post-closure, all pits filled with tailings and flooded

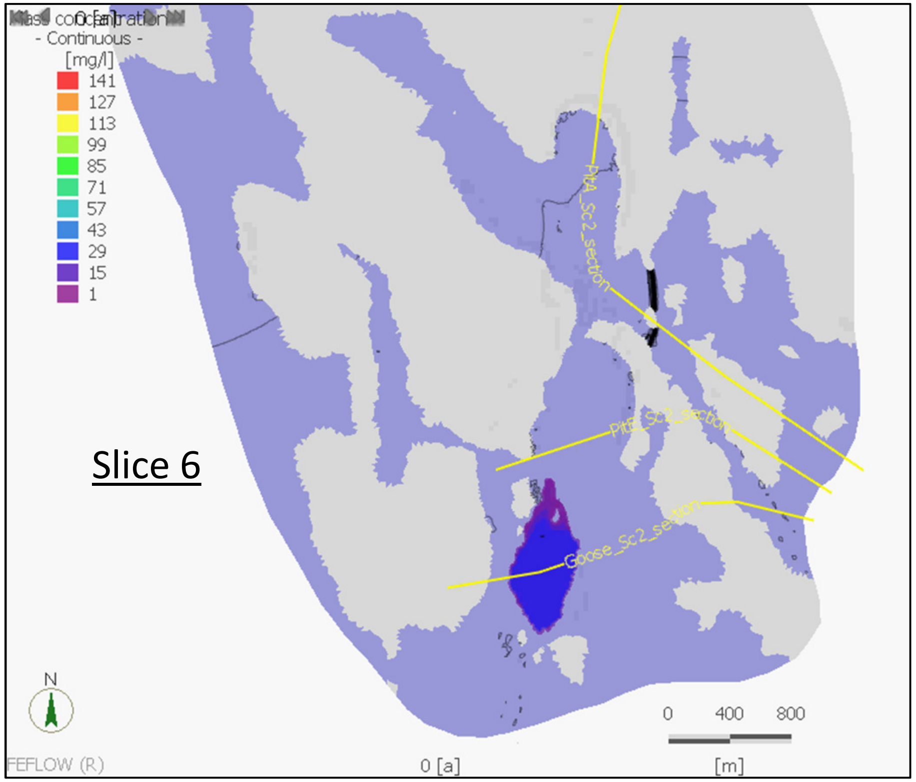
The model is driven by the flooded pit lake area (133.6m)

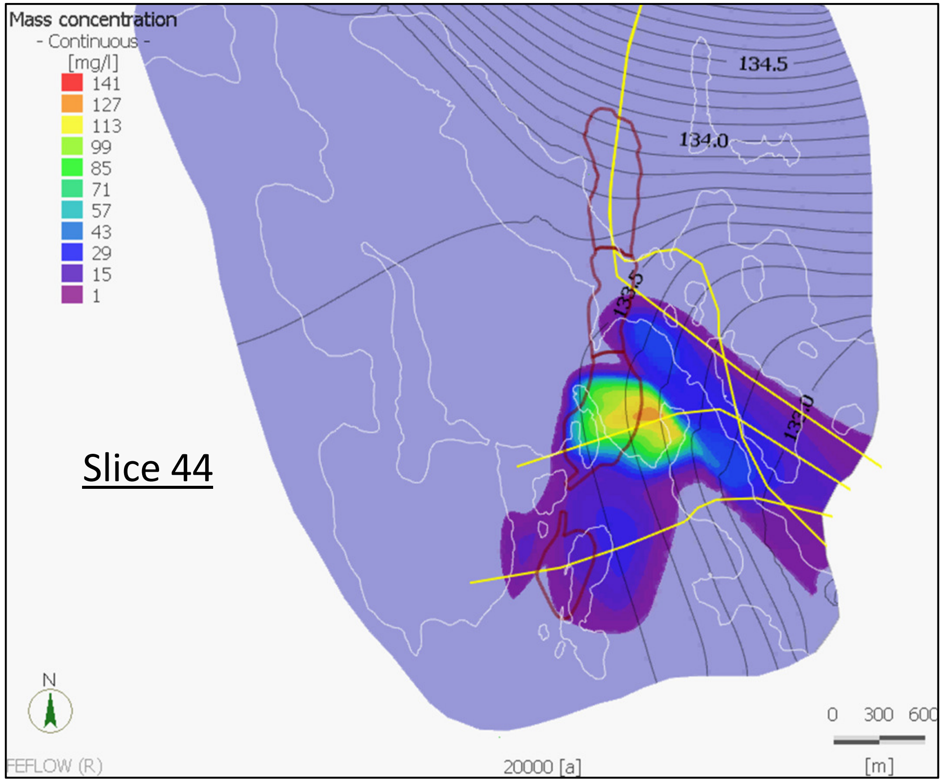


Cross section along the main flow path : from the northern limit (h = 136 masl) to 2nd Portage Lake (h = 132.9 m)

III. Scenario 2 : Transport of chloride – Map views

Post-closure, all pits filled with tailings and flooded (during 20 000 y)





Permafrost conditions (~120 masl)

Sub-permafrost conditions (-500 masl)

III. Scenario 2 : Transport of chloride – Map views

Post-closure, all pits filled with tailings and flooded (during 20 000 y)

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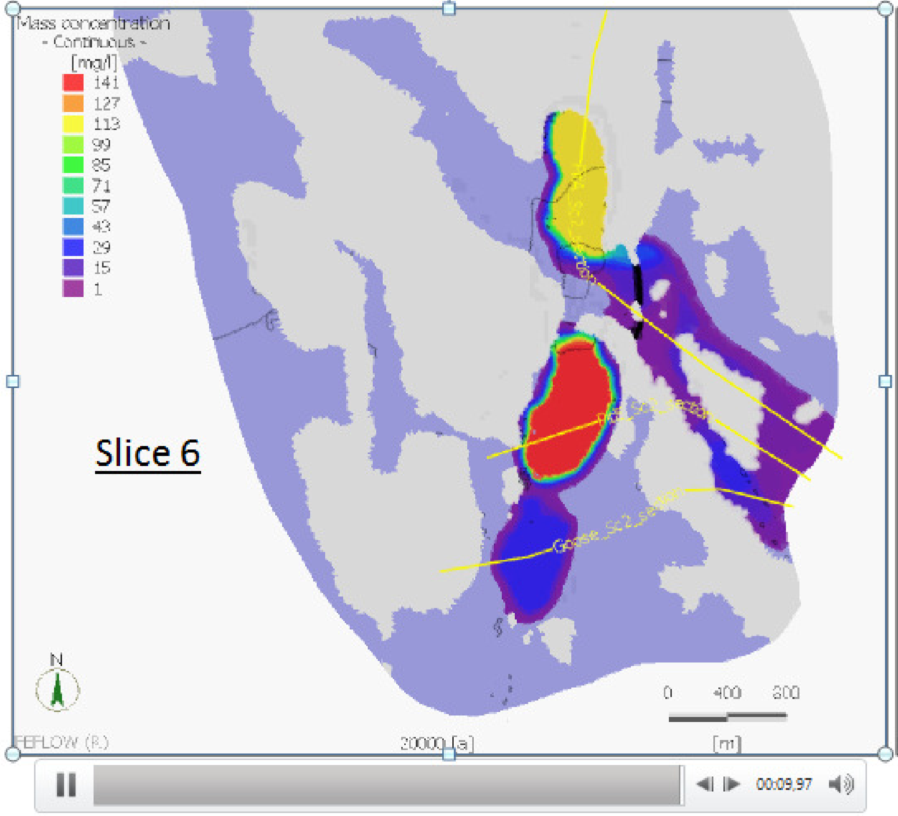

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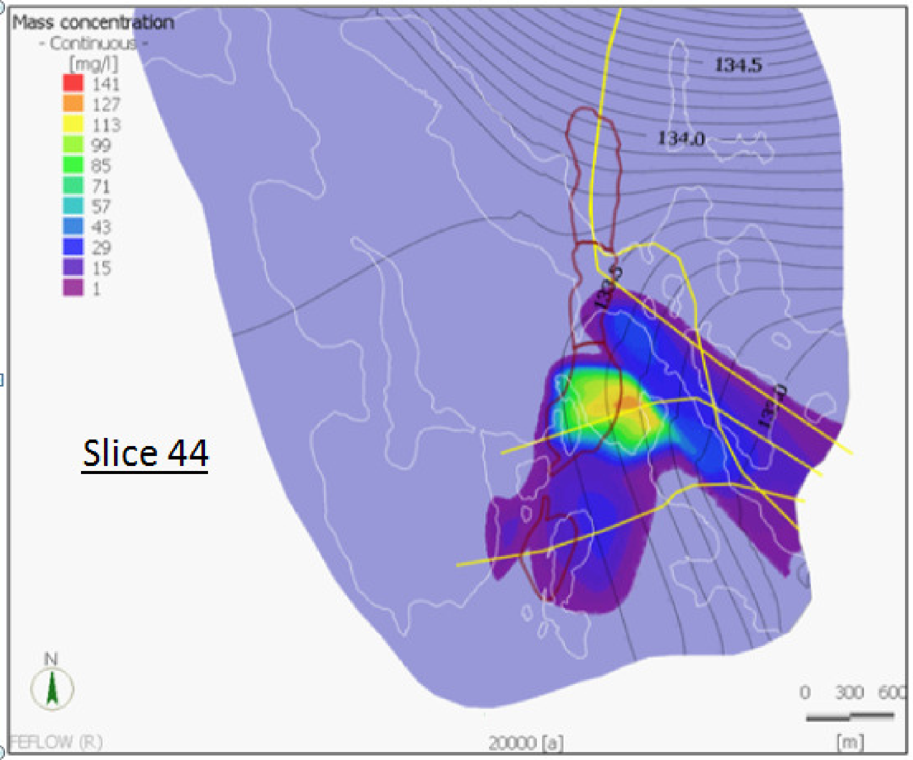
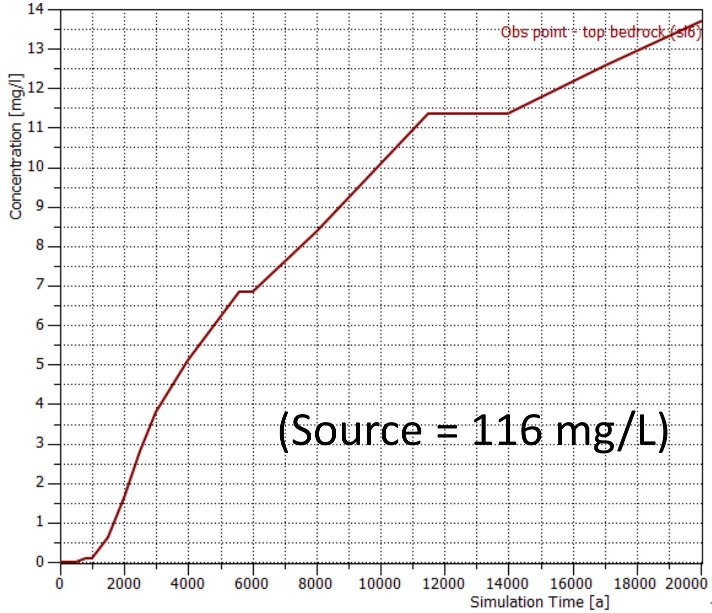
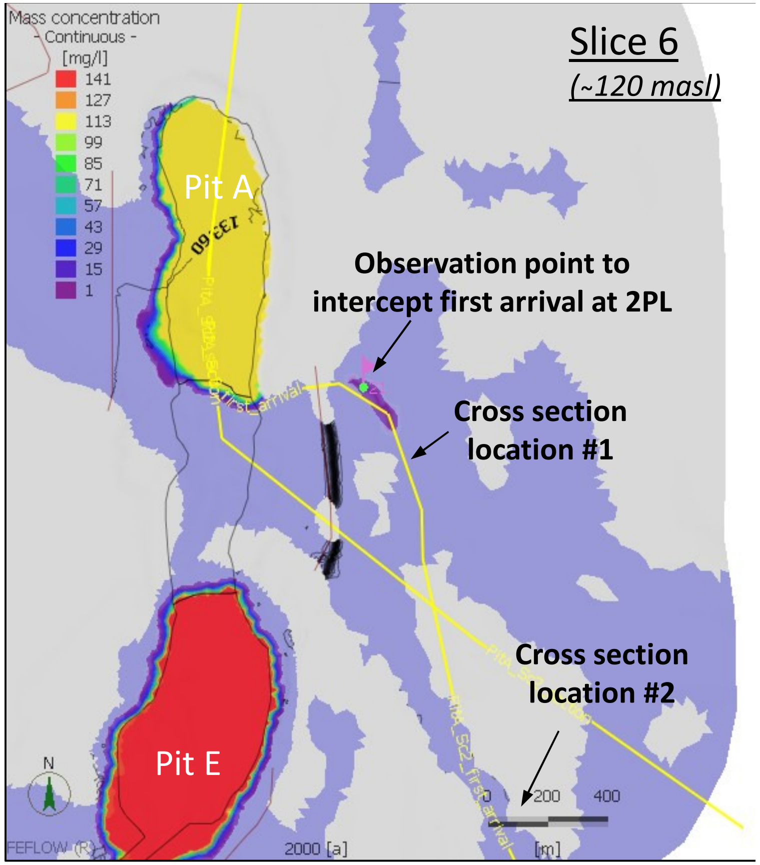


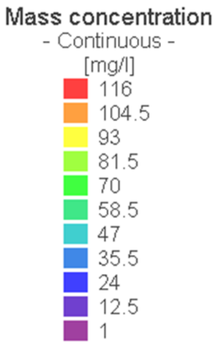
Sub-permafrost conditions (-500 masl)

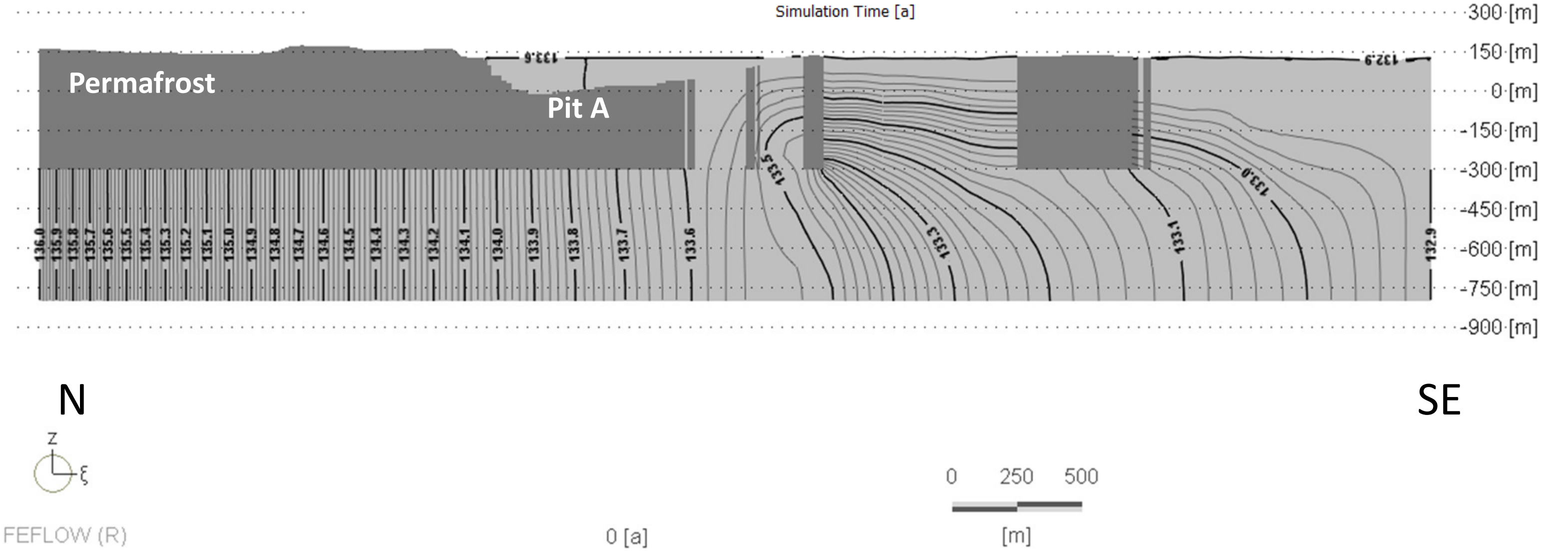
III. Scenario 2 : Transport of chloride

Pit A cross-section #1 : *along the first arrival of the plume at 2PL (slice 6 = top of the roc)*









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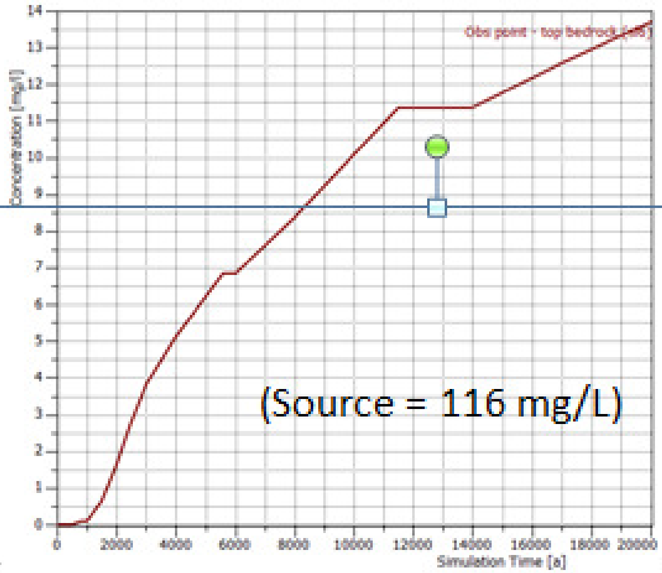
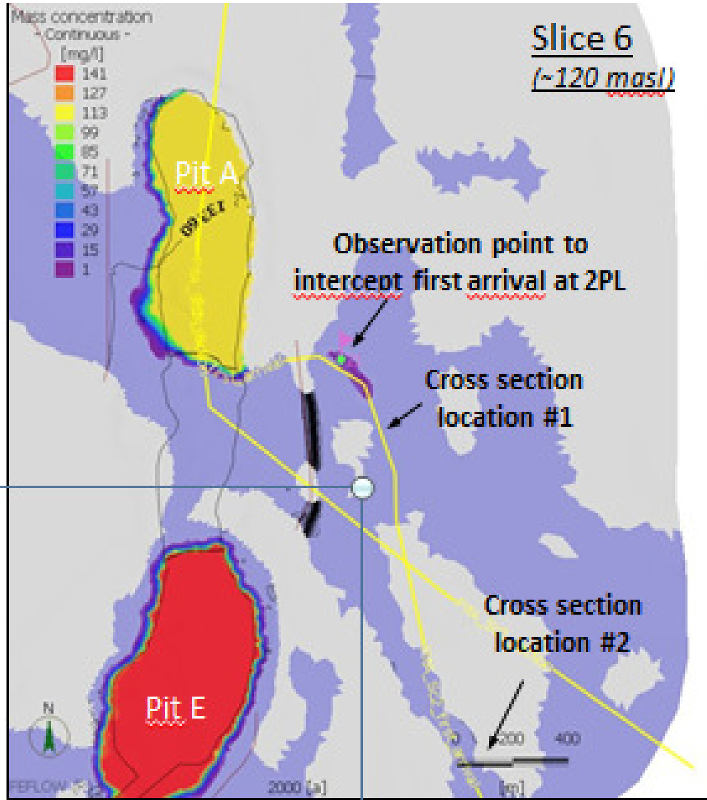
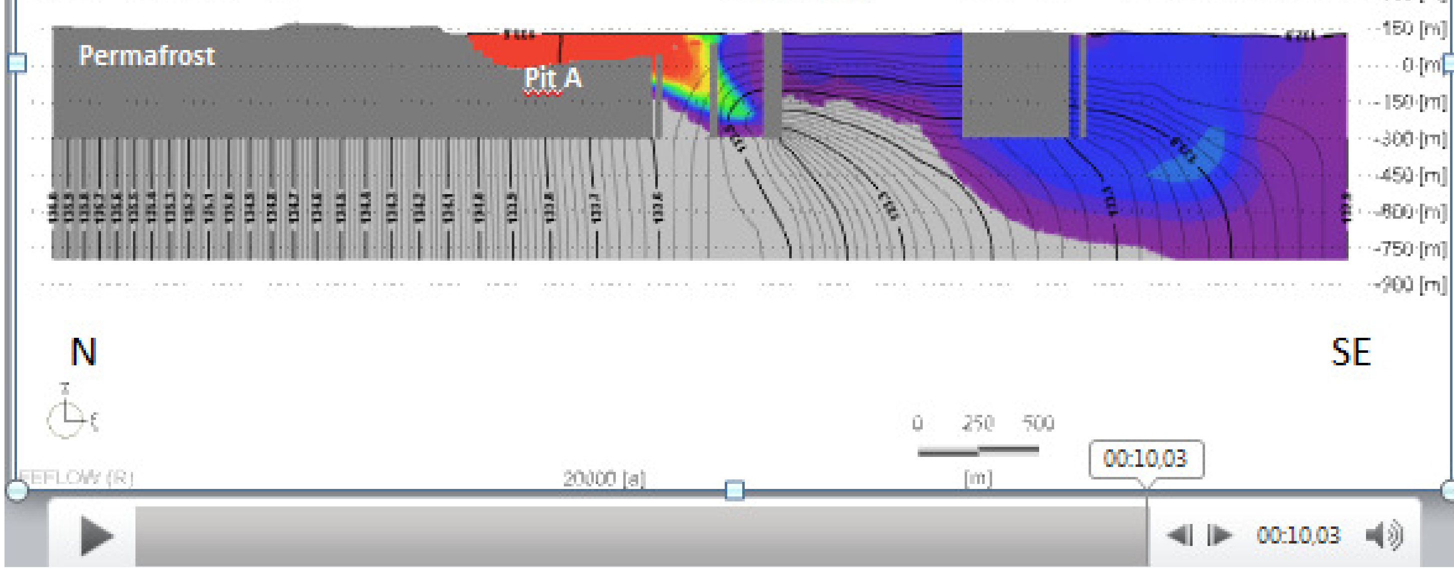
Pit A cross-section #1 : along the first arrival of the plume at 2PL (slice 6 = top of the roc)







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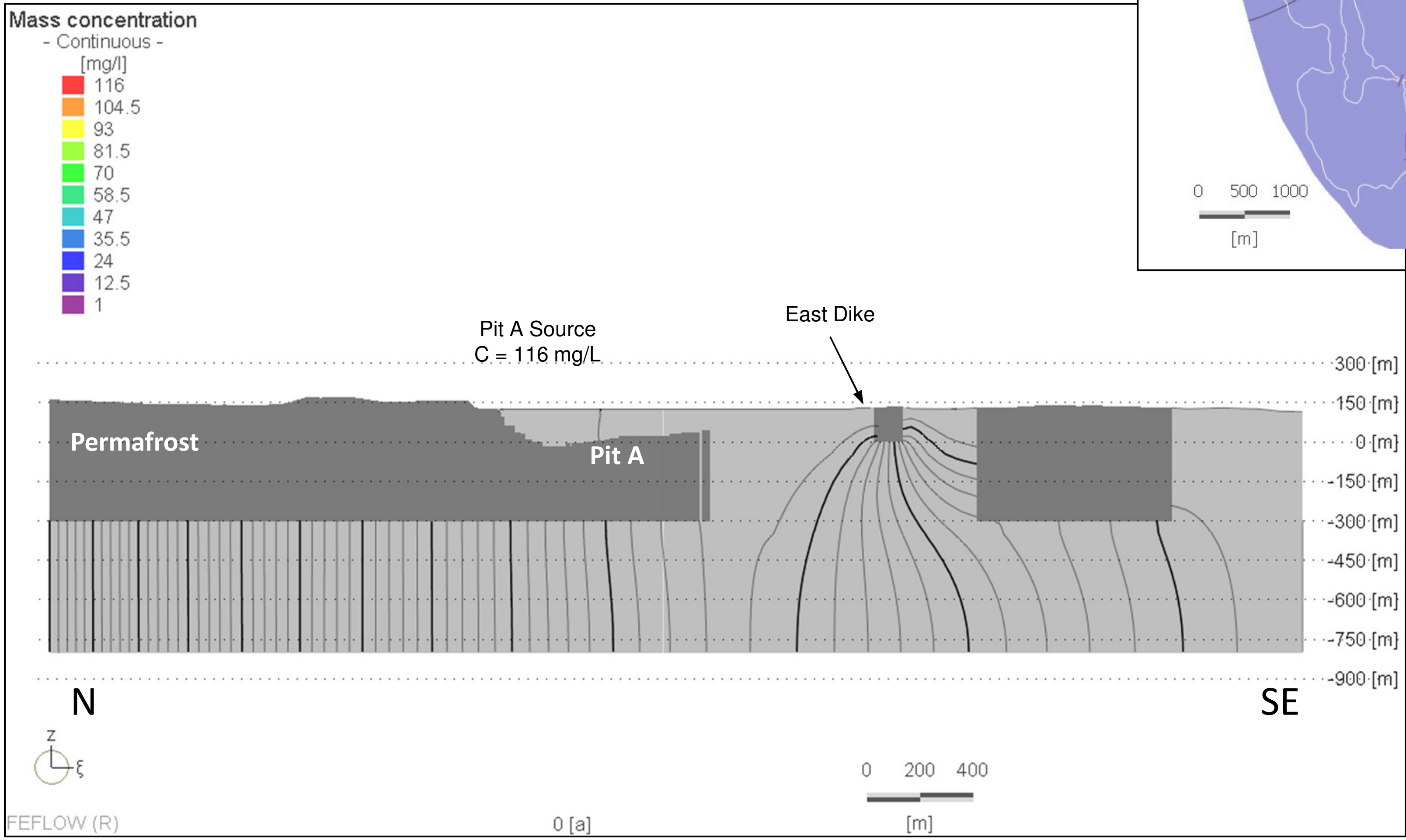
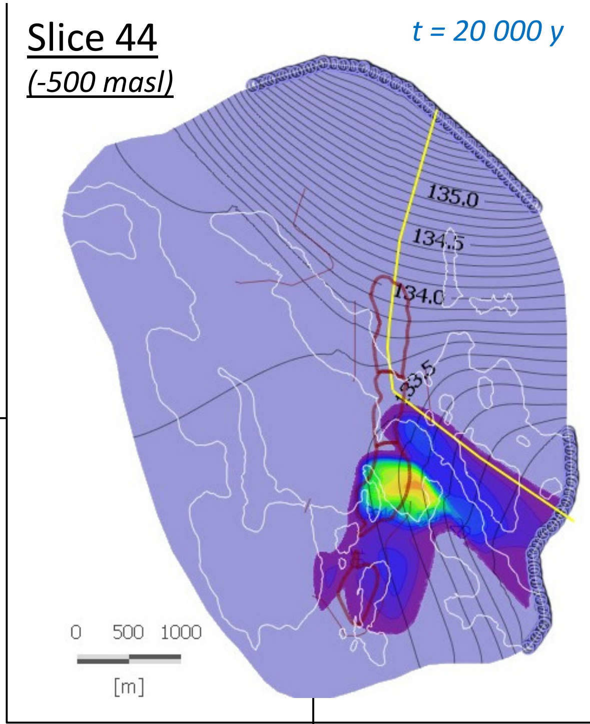
III. Scenario 2 : Transport of chloride

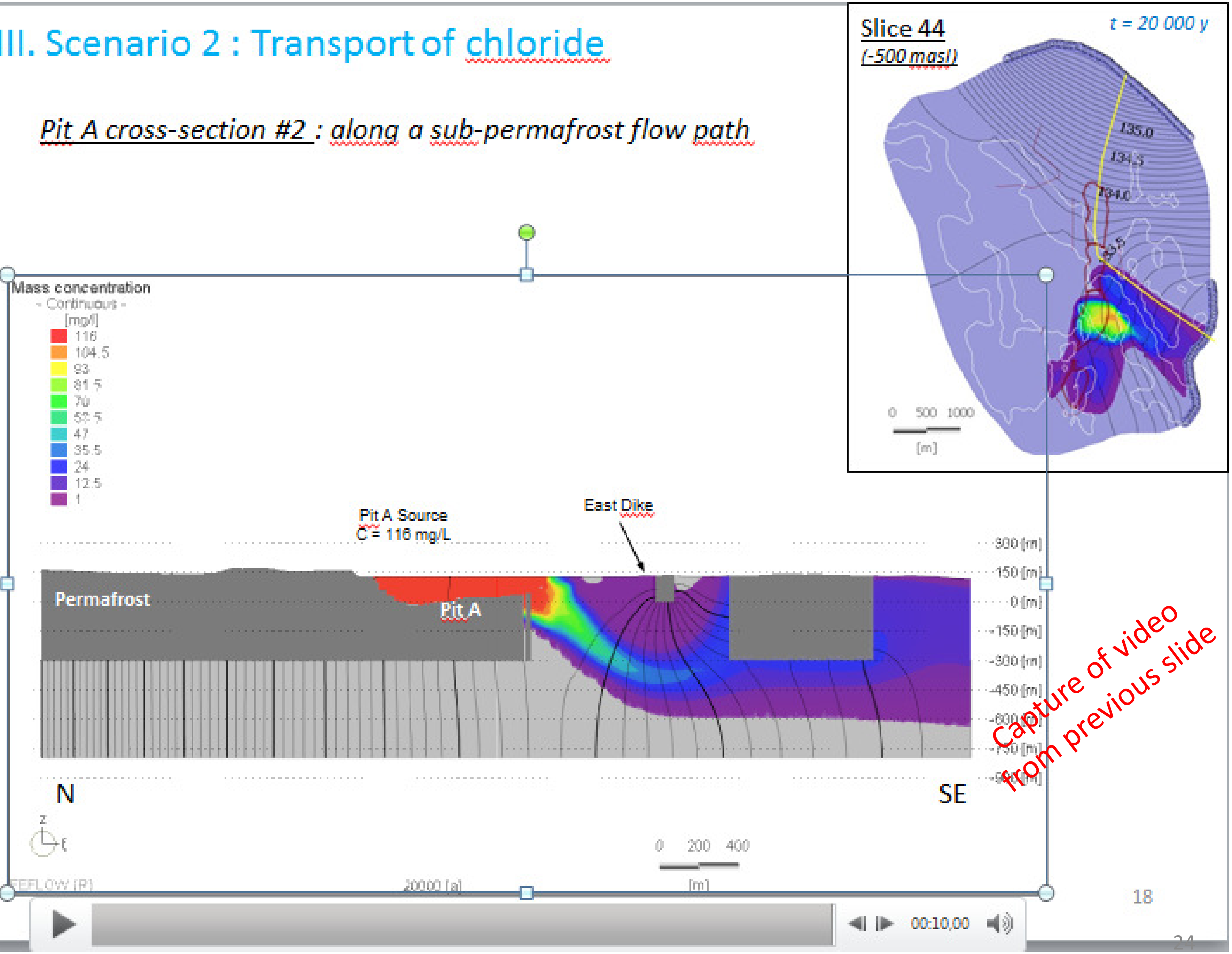
<u>Pit A cross-section #2</u> : along a sub-permafrost flow path





III. Scenario 2 : Transport of chloride

Pit A cross-section #2 : along a sub-permafrost flow path



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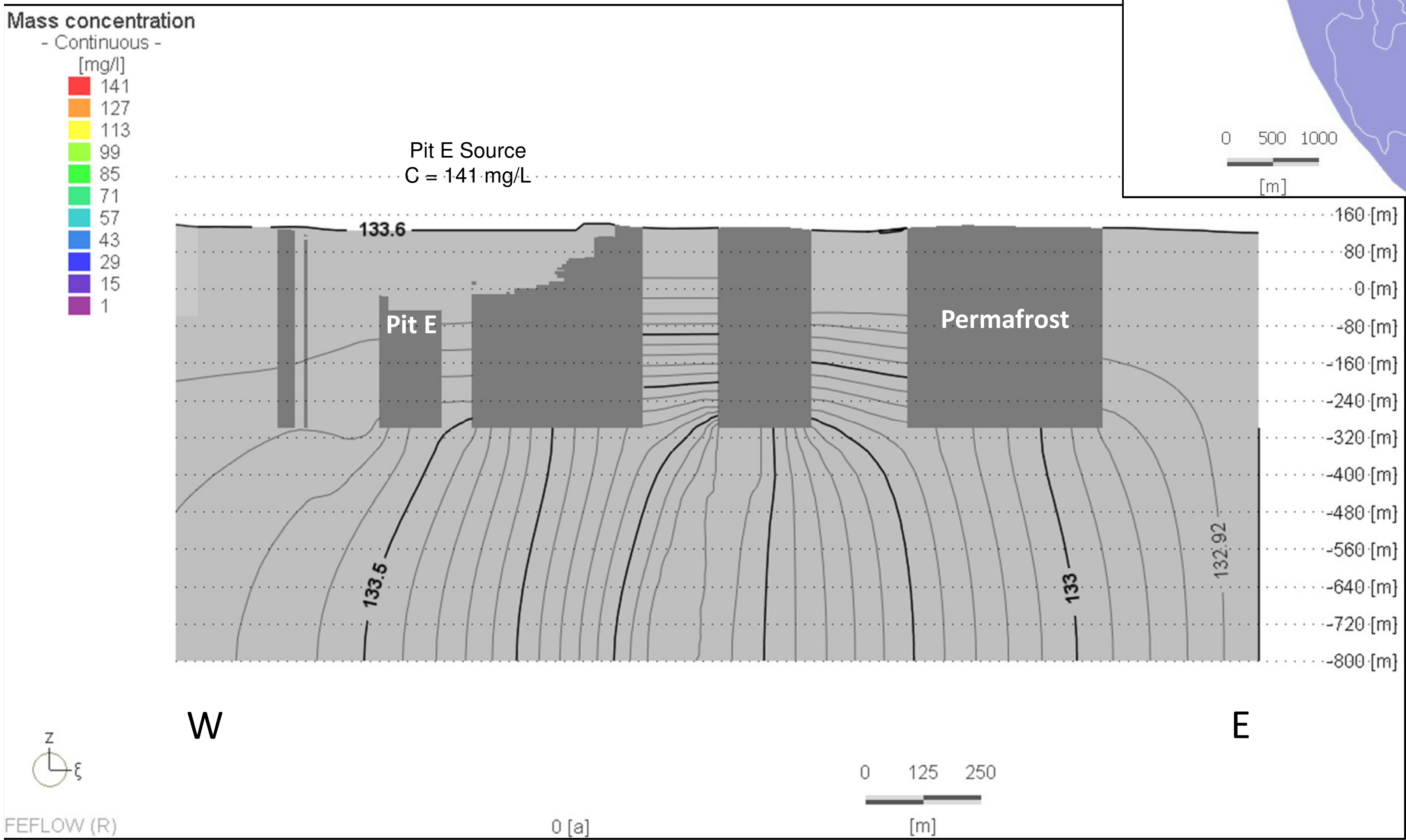
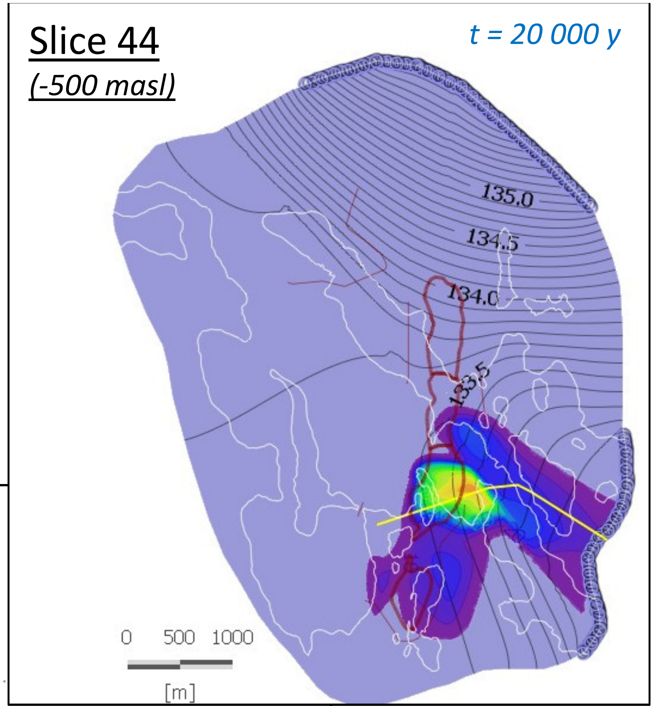
III. Scenario 2 : Transport of chloride

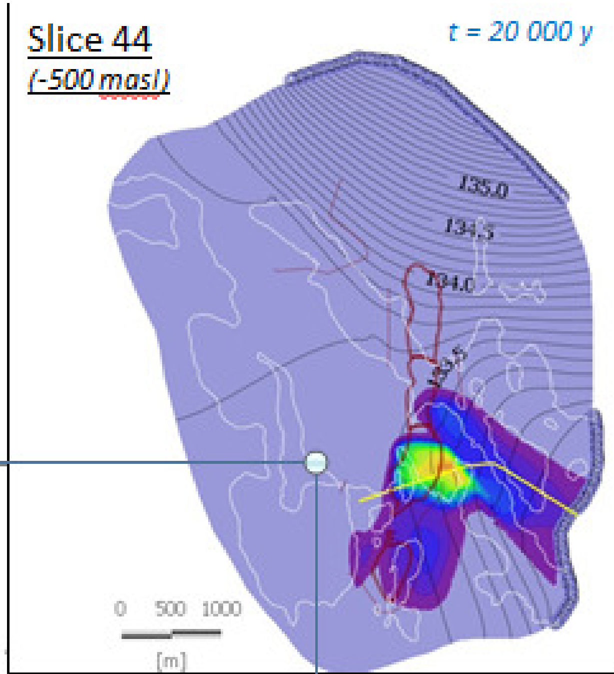
Pit E cross-section

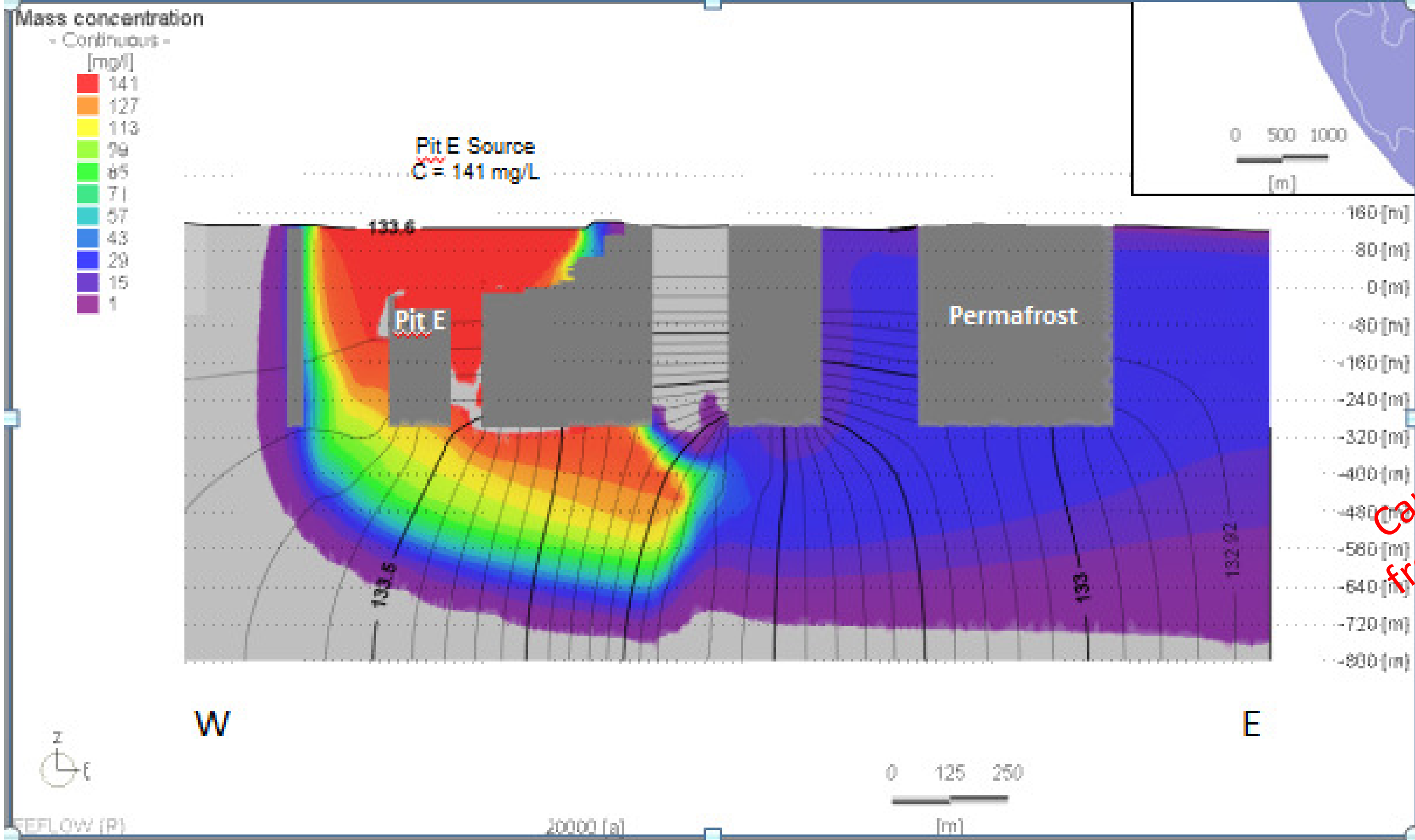




III. Scenario 2 : Transport of chloride

Pit E cross-section





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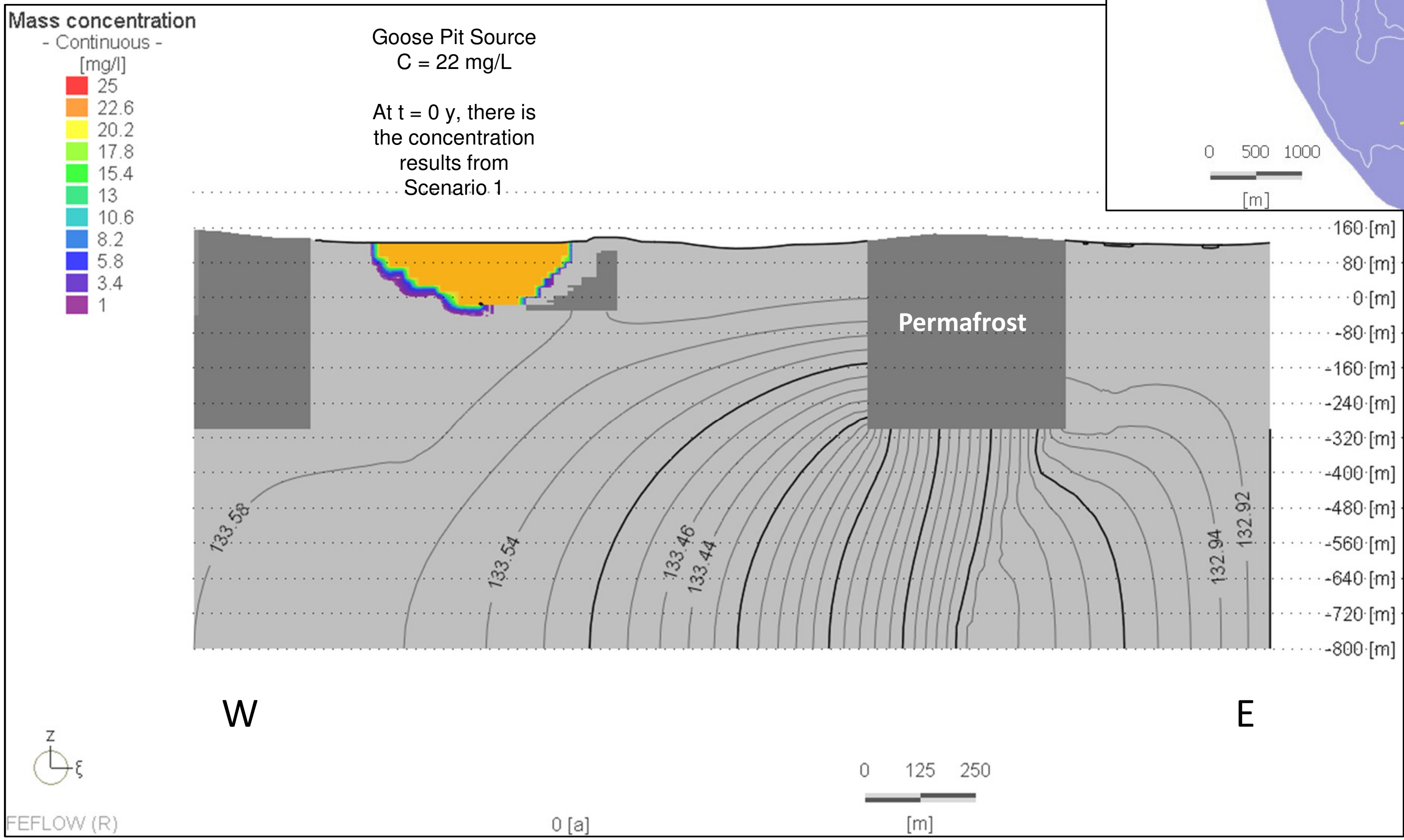
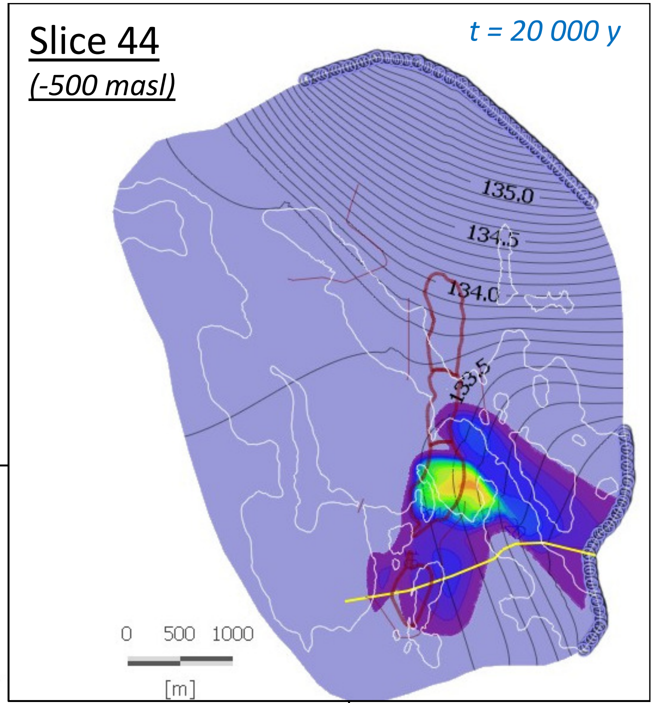
III. Scenario 2 : Transport of chloride

Goose Pit cross-section





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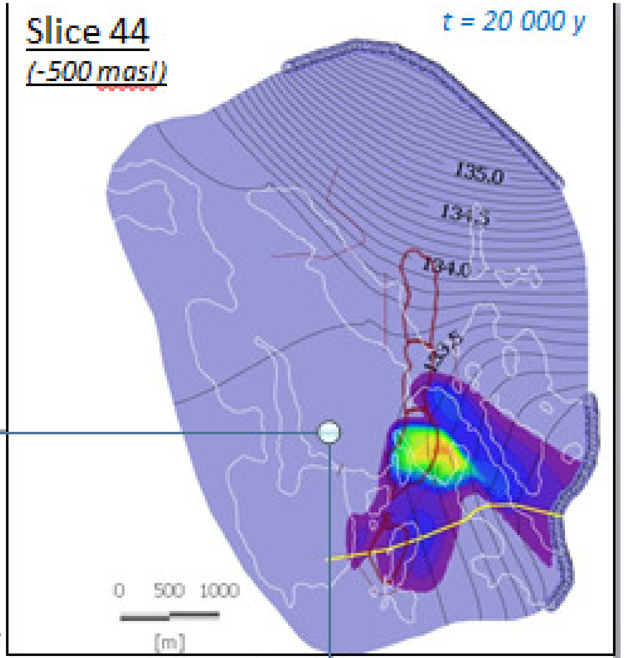

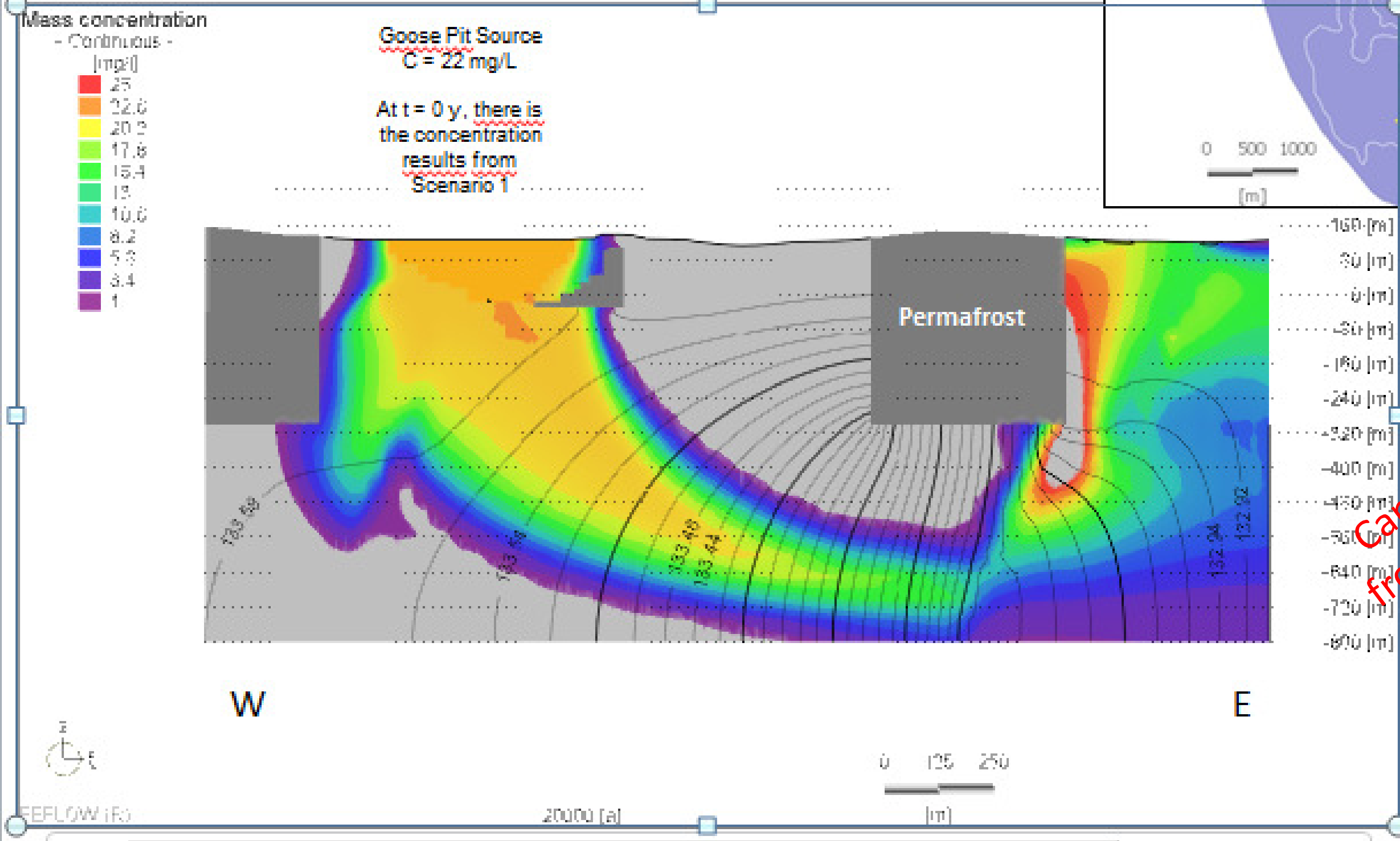

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Discussion – Review Comment Status

- Resolved #4, #5, #6, #10
- Thermal modelling and permafrost extent (#3, #7, #11);
- Model boundary conditions (#1, #2, #7, #11);
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Discussion – Thermal modelling and permafrost extent;

NRCan recommends that the proponent conduct thermal modelling along three cross-sections key to the potential migration of groundwater contaminants:

i. a NW-SE cross-section through the SE corner of Portage pit A (where permafrost is preventing groundwater flow),

ii. an approximate N-S cross-section through the northern portion of Portage Pit E (where the distance between the pre-mining extents of Second and Third Portage Lakes is smallest), and

iii. a N-S section through all three pits and extending north of Portage Pit A (similar to cross-section 2 of Fig. 6.2 in Cumberland Resources, 2005b).

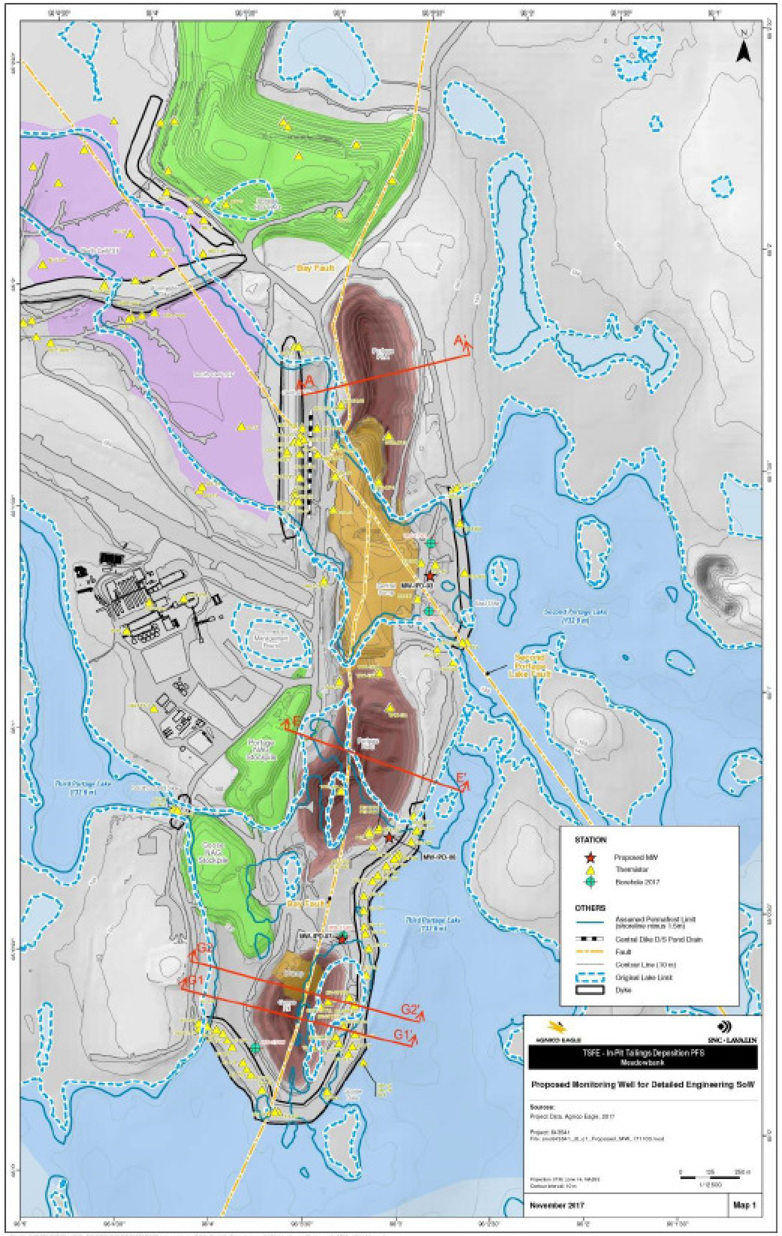
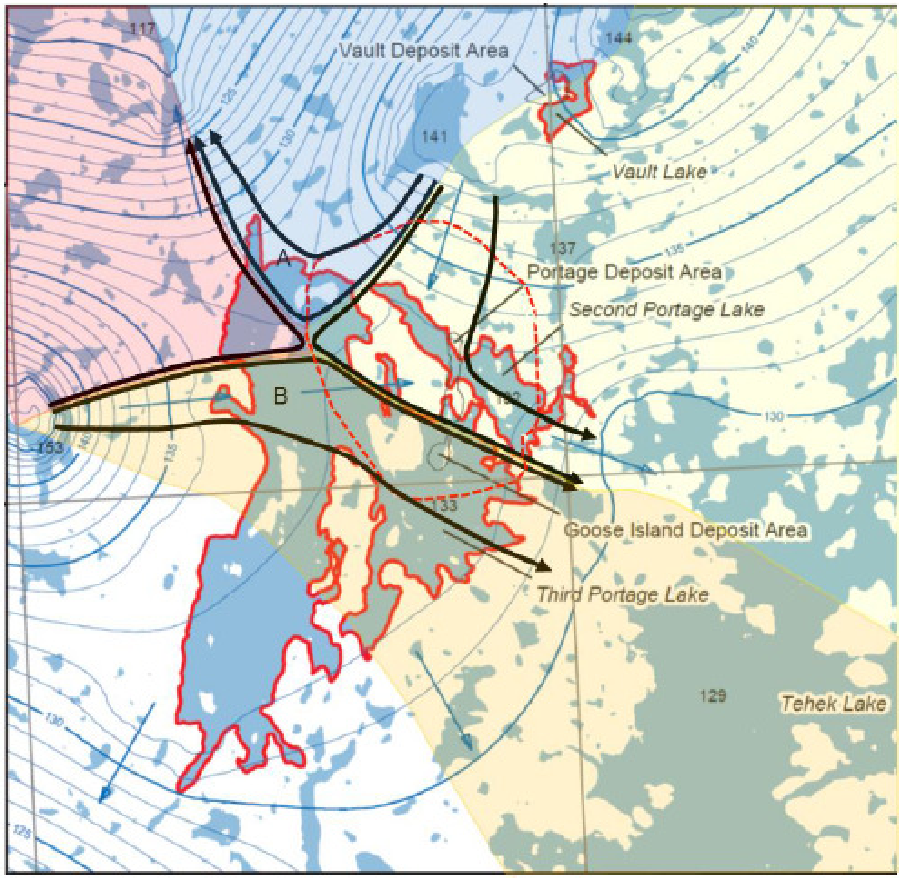
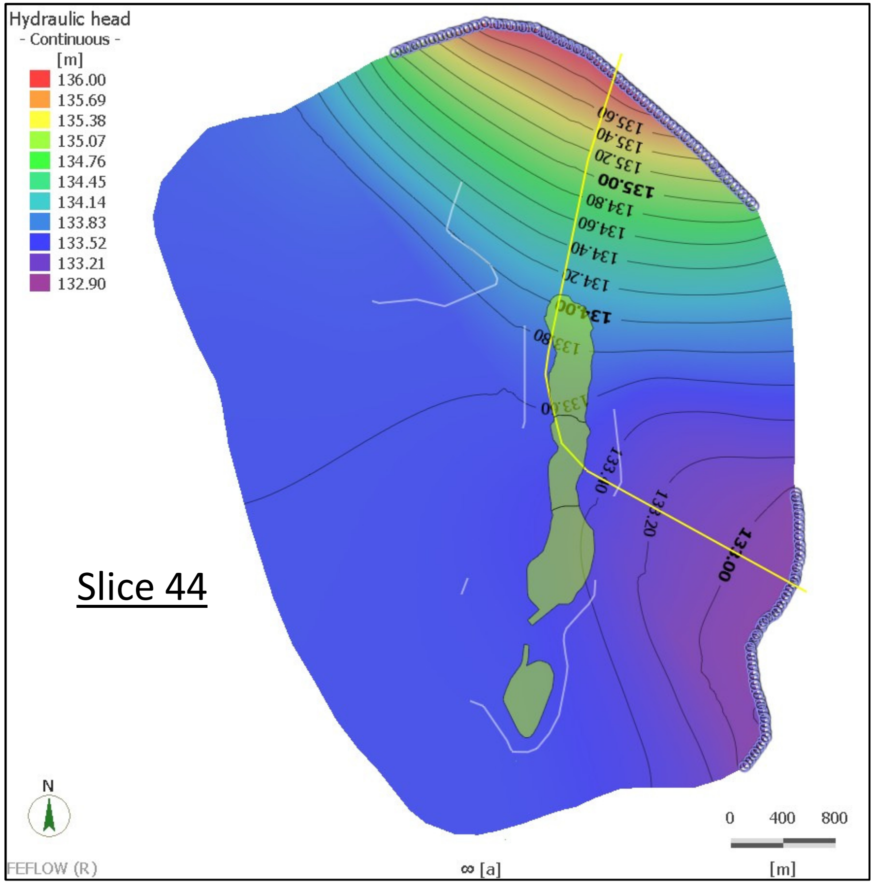


Figure 4-1 : Site Plan showing thermistor location and sections analyzed

Discussion – Model boundary conditions



Groundwater flowpaths in sub-permafrost groundwater based on Golder (2004) modelling results.



SNC sub-permafrost conditions (-500 masl)

Discussion – Boundary conditions at the bottom of the model

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A-B	No Flow	136.6
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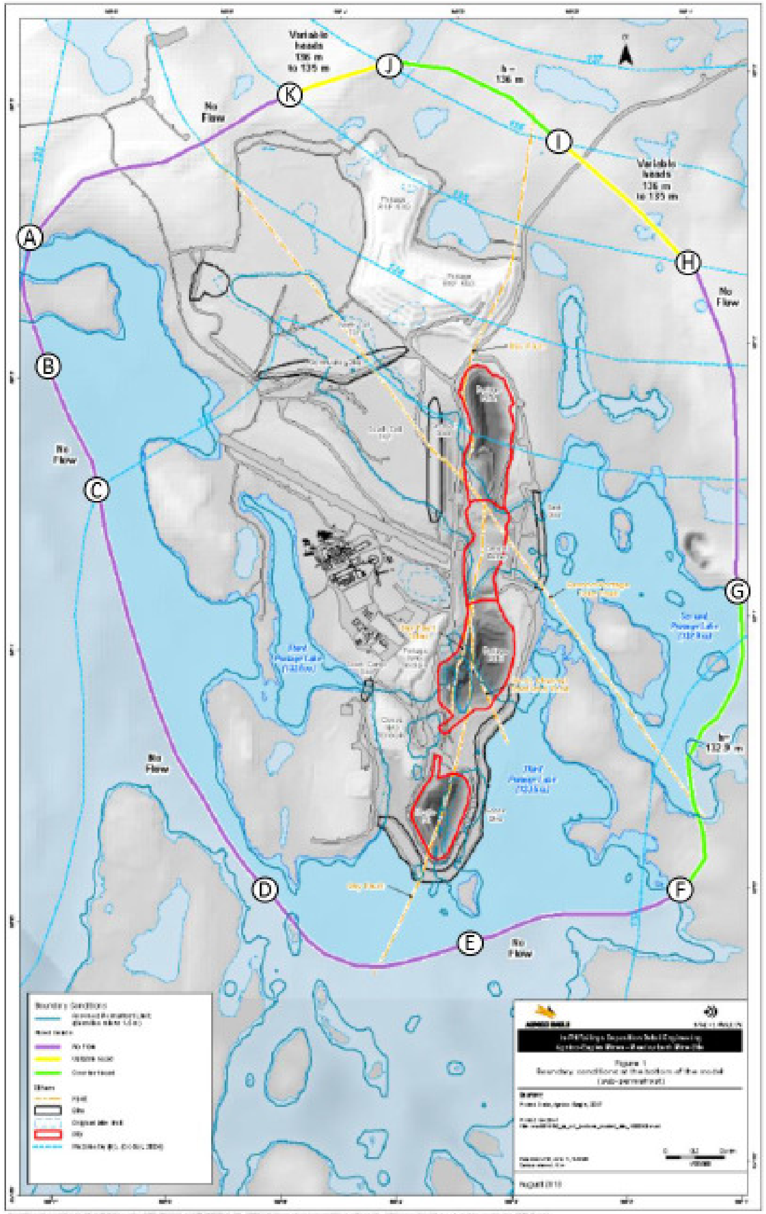
C-D	No Flow	133.6-132.2
D-E	No Flow	No Flow
E-F	No Flow	132.9-132.7
F-G	132.9	132.7-132.9
G-H	No Flow	No Flow
H-I	135-136	135.6-136.6
I-J	136	136.6
J-K	136-135	135.6-136.6
K-A	No Flow	No flow



C-D: no flow to be aligned with regional model flow.
E-F: no flow to keep same model logic under 3PL
F-G: suggest to used 2PL elevation.
F-G - H-I + I-J + J-K: driven by Turn Lake elevation no field measurement supporting this change

Discussion – Contamination migration from tailings to overlying Third Portage Lake

Diffusion rate calculation from the tailings to the water cover (pit lake)

Based on the Fick Law in a simple aqueous nonporous system, the contaminant mass flux J can be expressed as :

$$\boldsymbol{J = -D_d \,.\, (\Delta C . \Delta x)} \quad [\mathrm{mg / cm^2.s}]$$

D_d : coefficient of diffusion [cm^2/s]
ΔC: gradient operator [mg/L]
Δx: distance considered, 1 meter [m]

D =	1E-05	cm^2/s	
Δc =	141	mg Cl / L solution	
Δx	100	cm	
J =	-1.41E-08	$mg/s/cm^2$	
	-1E-03	$mg/day/cm^2$	
	-1E-07	$mg/day/m^2$	

Discussion – Groundwater monitoring plan and groundwater monitoring wells

Recommandation 9

''NRCan recommends that the proponent provide a table of all anticipated groundwater monitoring wells to be used following the flooding of the pits. The table should indicate the locations and depths monitored, when a conservative tracer (e.g., chloride) of groundwater contamination is expected to intercept each well, when the concentration will peak, and the maximum modelled concentration at each well location.''

GW monitoring well ID	Location	Depth	Interception Date	Max Concentration

Discussion – Groundwater monitoring plan and groundwater monitoring wells

Review Comment #12

"NRCan recommends that the NWB establish a timetable for an update of the groundwater monitoring plan and the required content of the plan."

GW monitoring plan update:

- After completion of the Hydrogeological Model Version 4
- As per water licence requirement
- One year prior to closure as per final closure plan.