Modeling of Mines Selbaie Pit Lake

Calibration and Long-term Forecasting

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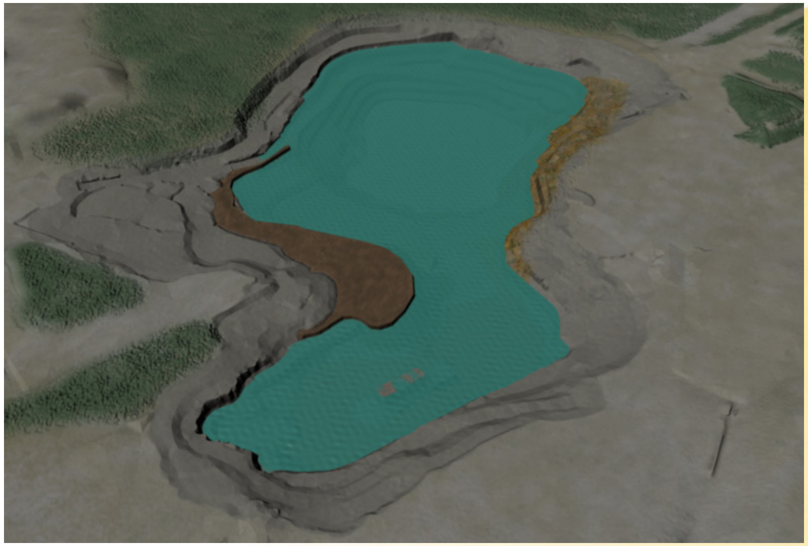
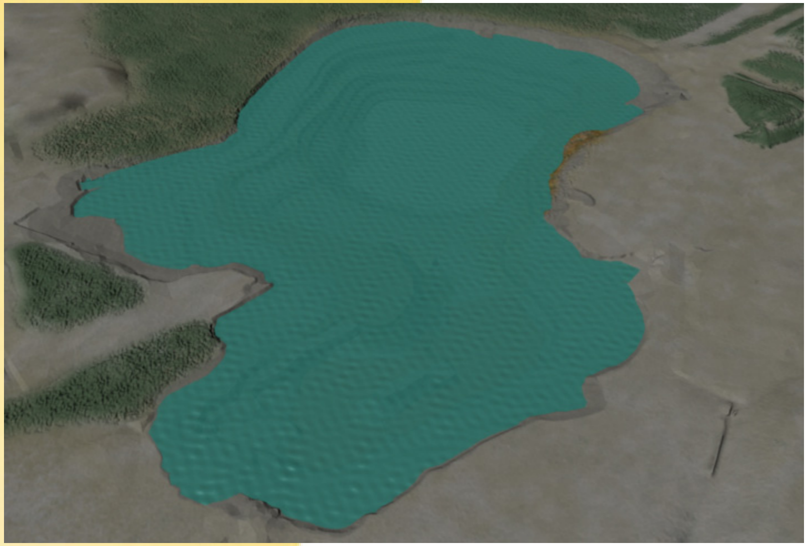
• **Characteristics of Existing Pit Lake**
  - **Circulation and importance of WTP discharge**

• **Model Calibration and Verification Using Data from 2004 and 2005 Period**





• **Results of Long-term modeling**

• **Sensitivity Results**

• **Prevention/Mitigation Recommendation**

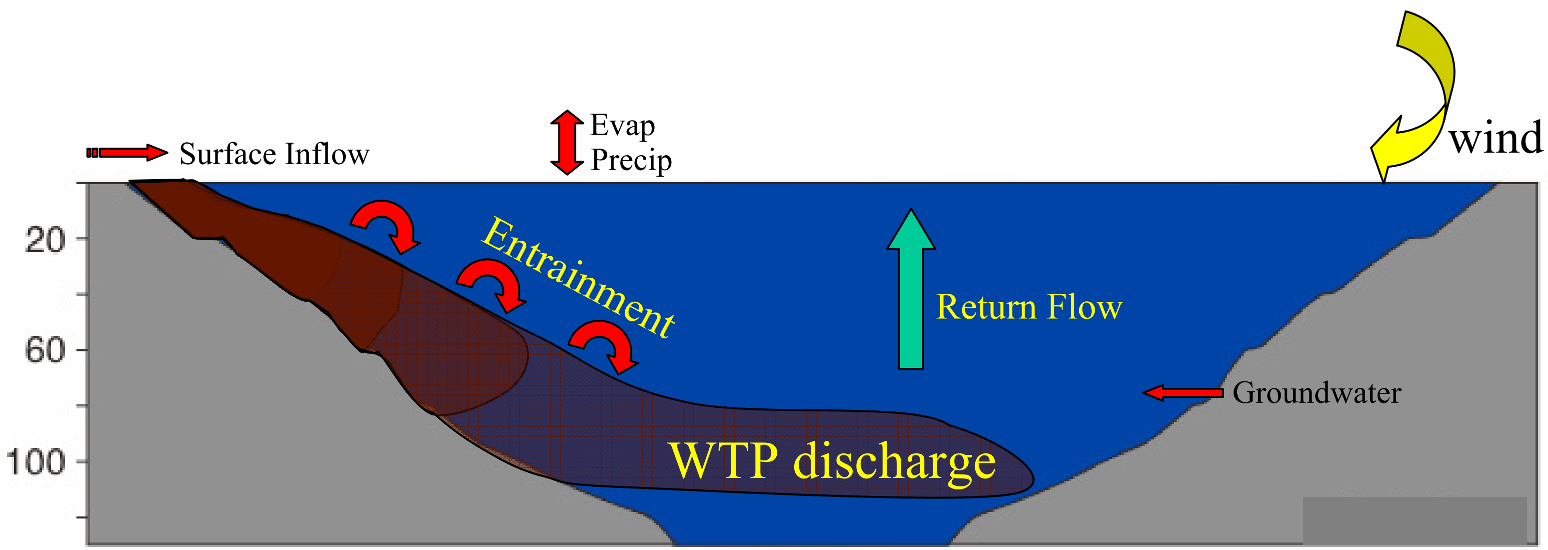
Selbaie Pit Lake Water and Zinc Balance Model Calibration

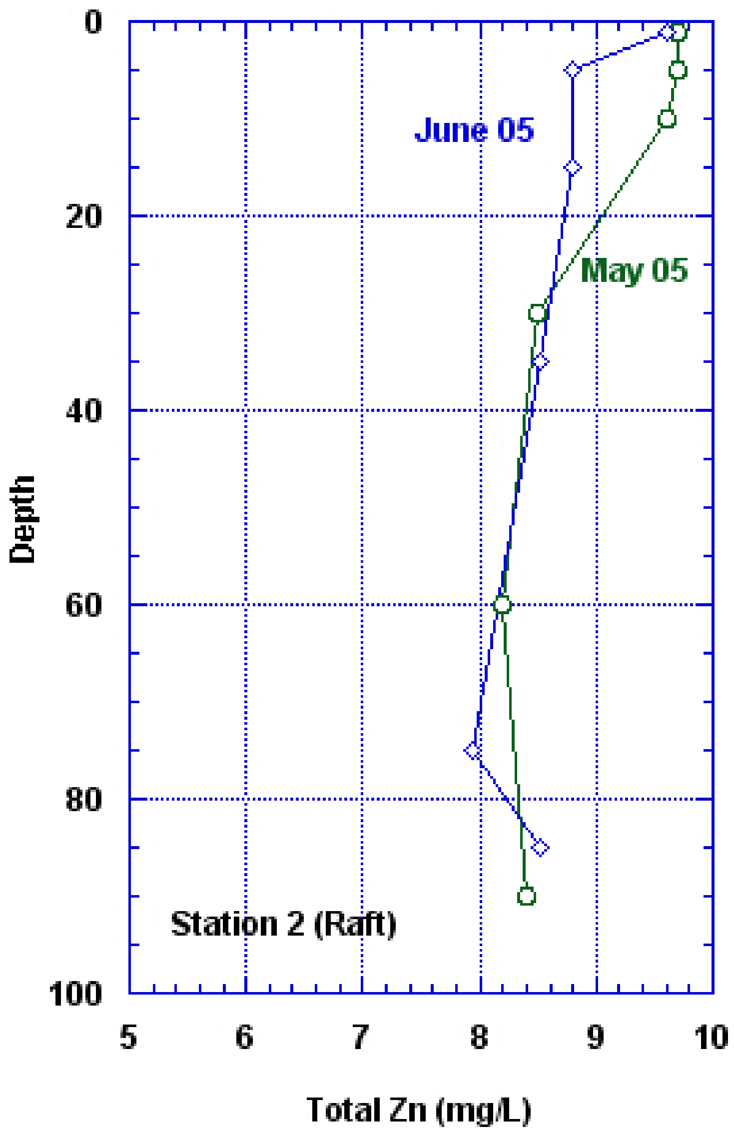
- Circulation in Selbaie pit lake
- Water balance derivation
- Zinc mass loading
- DYRESM model for Selbaie

Circulation in Selbaie pit lake

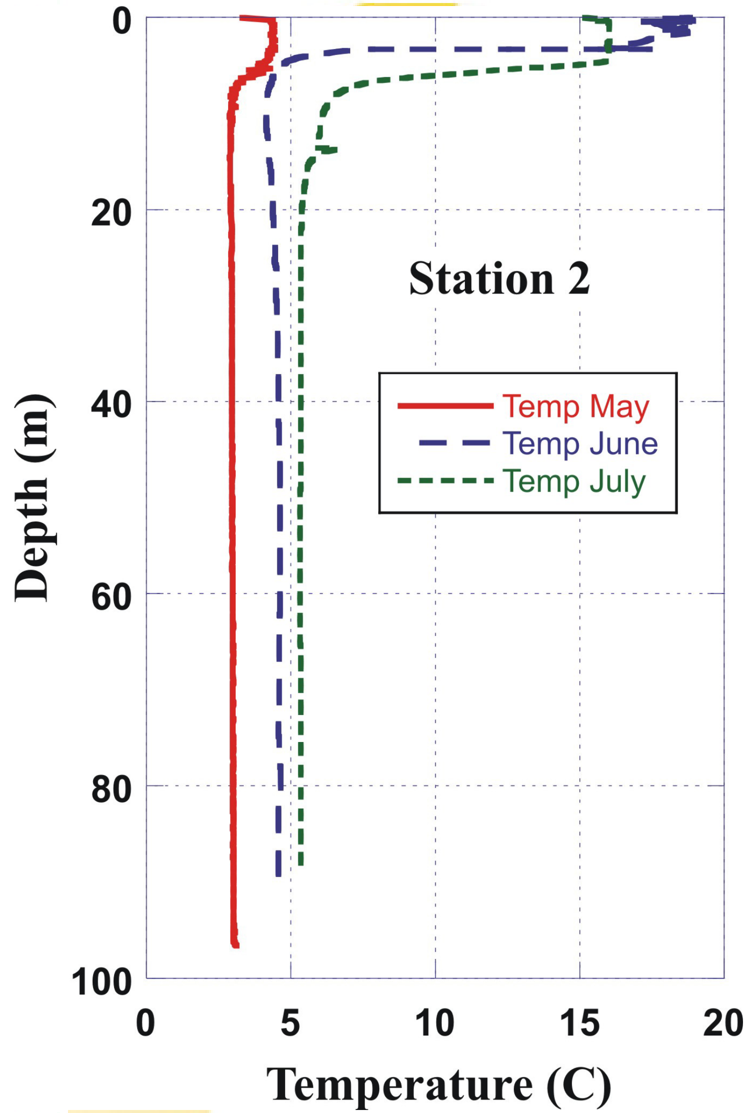
Impact of WTP discharge on the distribution of water properties

Examples
- Equity Silver Mine, Houston, BC
- Wabush Lake, Labrador City, Nfld





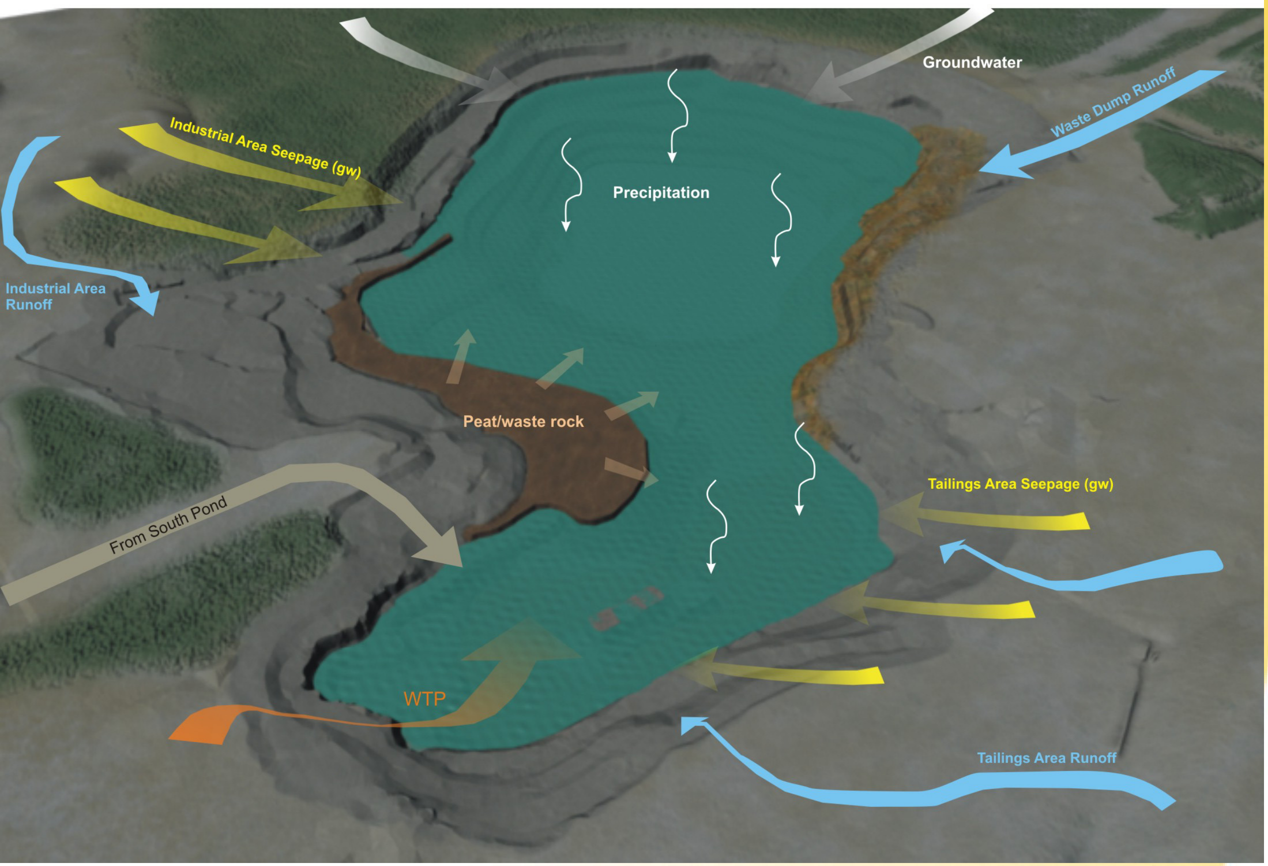
June 05
May 05
Station 2 (Raft)
Depth
Total Zn (mg/L)
0
20
40
60
80
100
5
6
7
8
9
10



Station 2
Temp May
Temp June
Temp July
Depth (m)
Temperature (C)
0
20
40
60
80
100
0
5
10
15
20

Water Balance Derivation 2004 to 2005

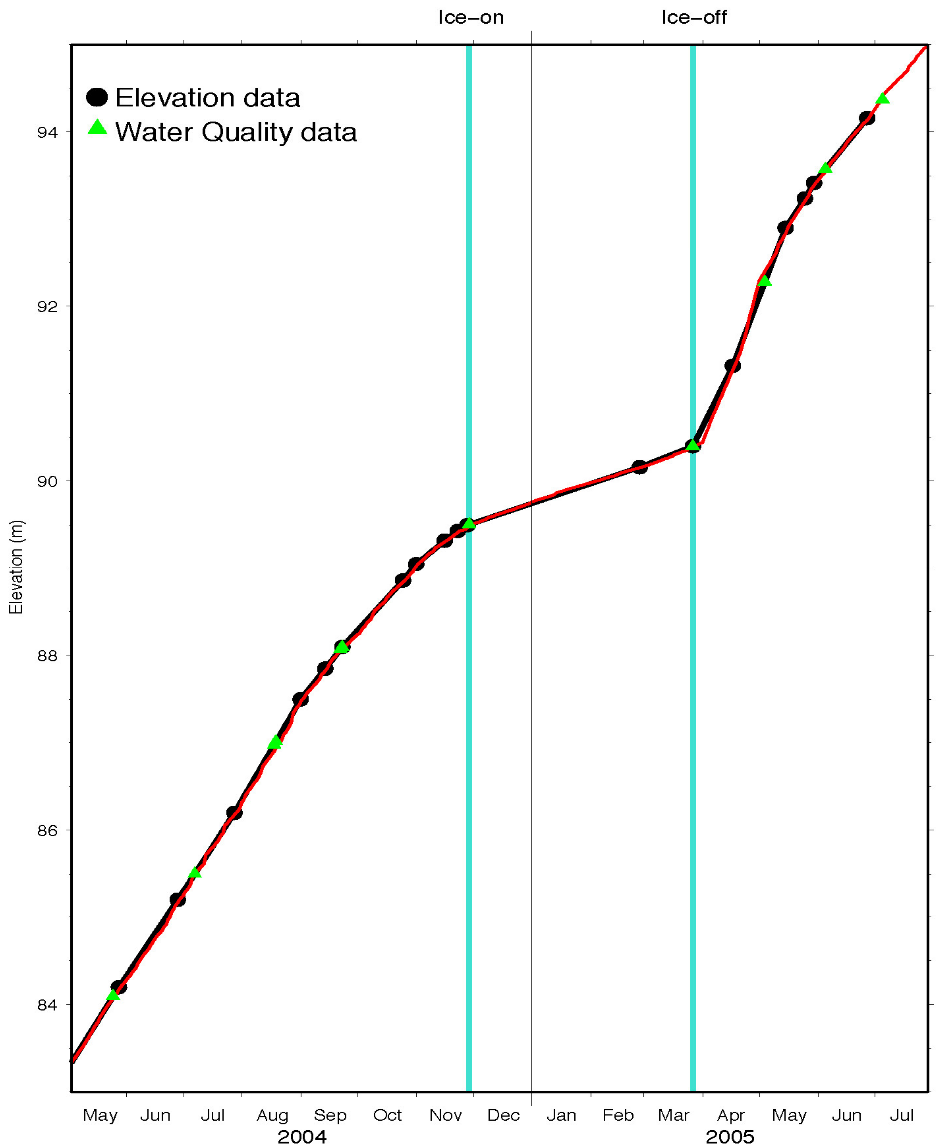
Objective: Calculate values for each Component subject to constraints



Components

- Direct Precipitation
  - Rain
  - Snow
- Evaporation
- Surface inflows
  - Tailings Area
  - Waste Dump
  - Industrial Area
  - South Pond
  - WTP
- Groundwater inflows
  - Tailings Area
  - Waste Dump
  - Other
- Peat/waste rock (Zn)

Water balance - Fill curve
May 3, 2004 - July 29,2005



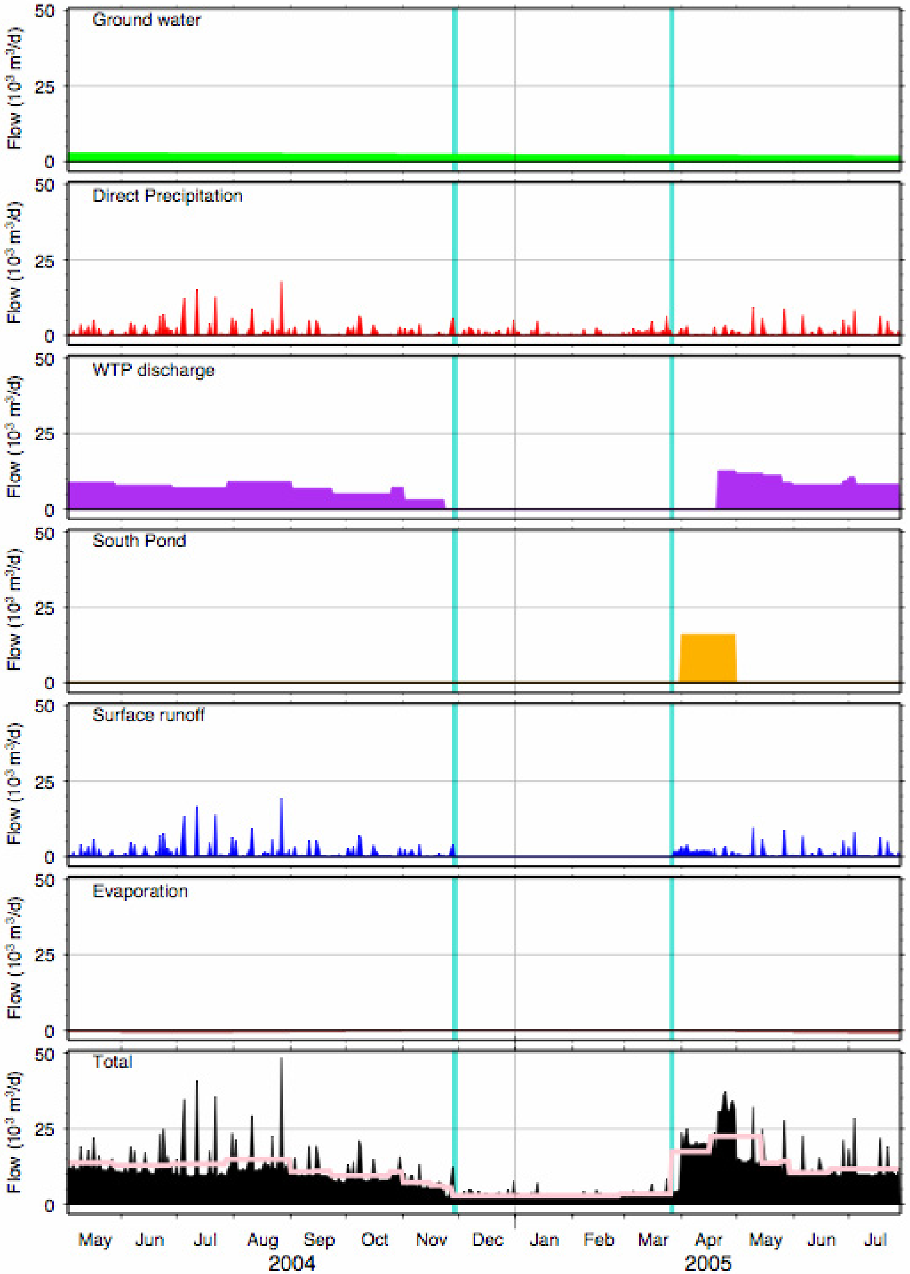
- Fill curve constrains the total net inflow between data points
- Ice-on Ice-off period corresponds to reduced inflow - groundwater only

Groundwater inflow can be deduced from volume change under ice less precipitation (P=203 mm over 119 days):

$$Q_g = \frac{\Delta V_L - V_P}{\Delta t}$$

$$= 2300 \text{ m}^3/\text{day}$$

$$(V_P \approx 711 \text{ m}^3 / \text{day})$$



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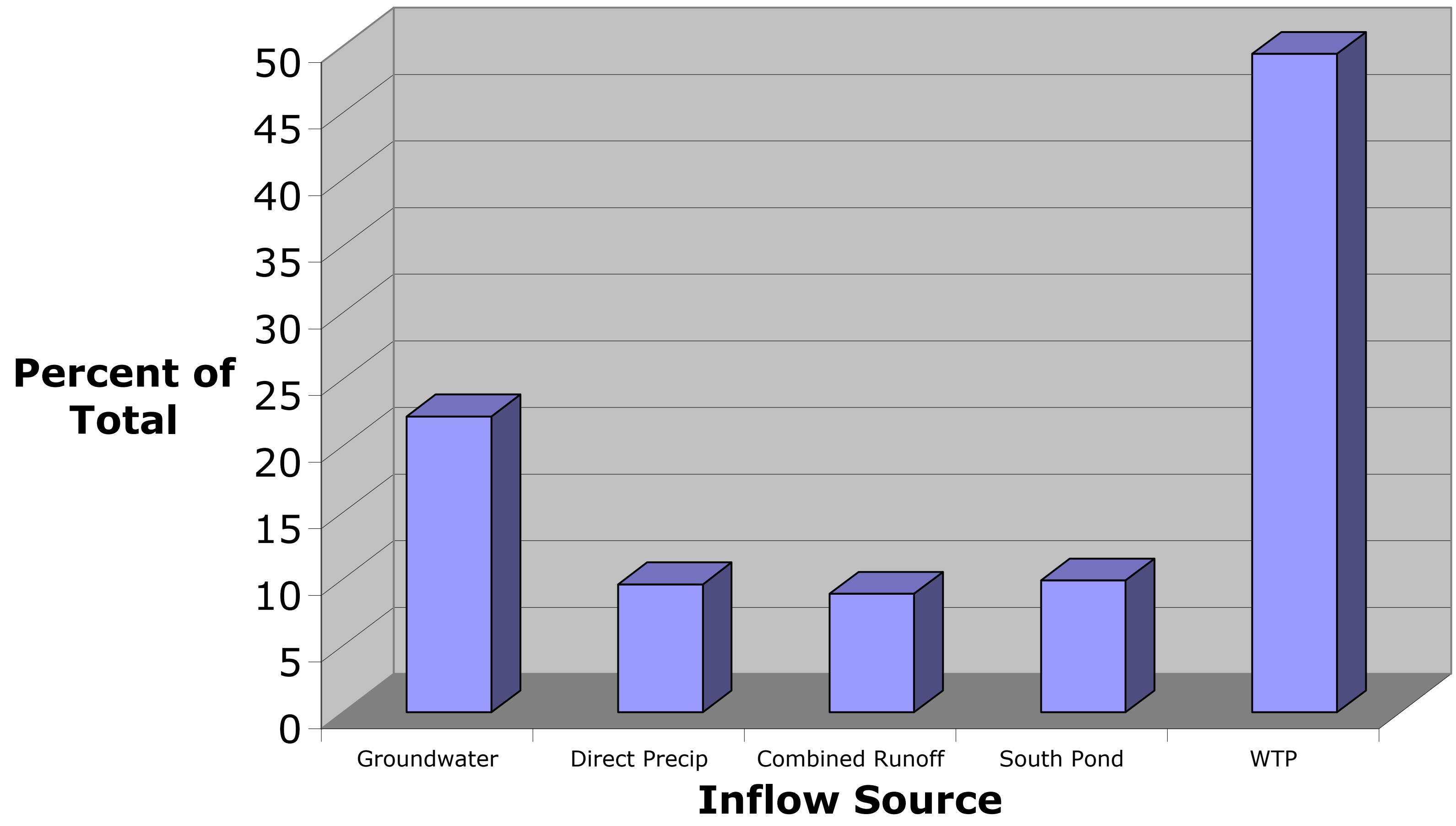
Flow constraints

- Fill curve
  - Sets absolute limit on mean inflows.
- WTP
  - Max. design capacity of 800 m^3/hr
  - Total from Apr - Jul 2005 known from lime consumption
  - Known shutdown periods



Percent of Total
50
45
40
35
30
25
20
15
10
5
0
Groundwater
Direct Precip
Combined Runoff
South Pond
WTP
Inflow Source

Zn mass loading - Total

	2004					2005			
	May 25	July 7	Aug 18	Sep 22	Nov 29	Mar 27	May 4	June 5	July 5
Day	22	65	107	142	210	328	366	398	428
Bottom (m)	84.1	85.5	87.0	88.1	89.5	90.4	92.3	93.6	94.4
Total Zn (T)	31.37	96.80	106.05	144.71	164.25	164.26	181.10	187.32	198.74
Zn load (kg/d)		**1521**	**220**	**1104**	**287**	**0**	**443**	**194**	**381**

Depth (m)	**[Zn] (mg/L)**								
0	2.37	2.62	2.90	5.12	7.70	7.57	9.75	9.55	7.03
1								9.55	7.03
5	1.88	4.17	2.90	5.12			9.55	8.58	8.58
10		4.39	6.80	8.34	8.13	7.99	8.80		
15								8.42	8.59
20	1.48	7.71	6.00	7.38					
30							8.15		
35								8.60	9.23
50	1.73	4.74	5.59	7.84					
61							7.70		
70									9.30
75	2.09	3.76	5.80	7.56				8.31	
Bottom	2.09	3.76	5.80	7.56	8.13	7.99	8.90	8.50	9.73

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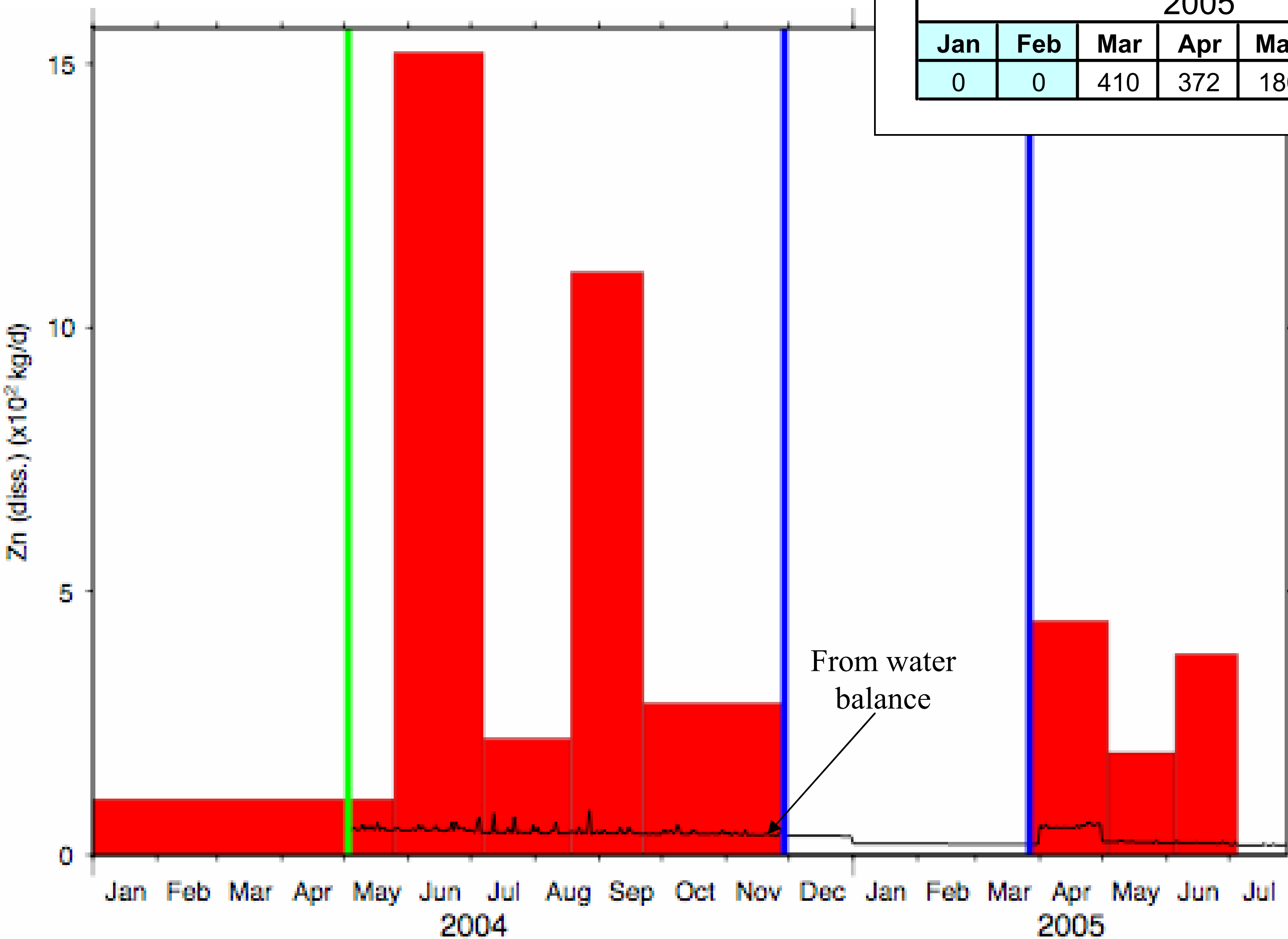
[Zn] data used to calculate the total Zn inventory in the lake

Mean peat/waste rock loading (kg/day)

2004							
May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
370	1472	425	575	818	245	239	0

2005						
Jan	Feb	Mar	Apr	May	Jun	Jul
0	0	410	372	180	200	33



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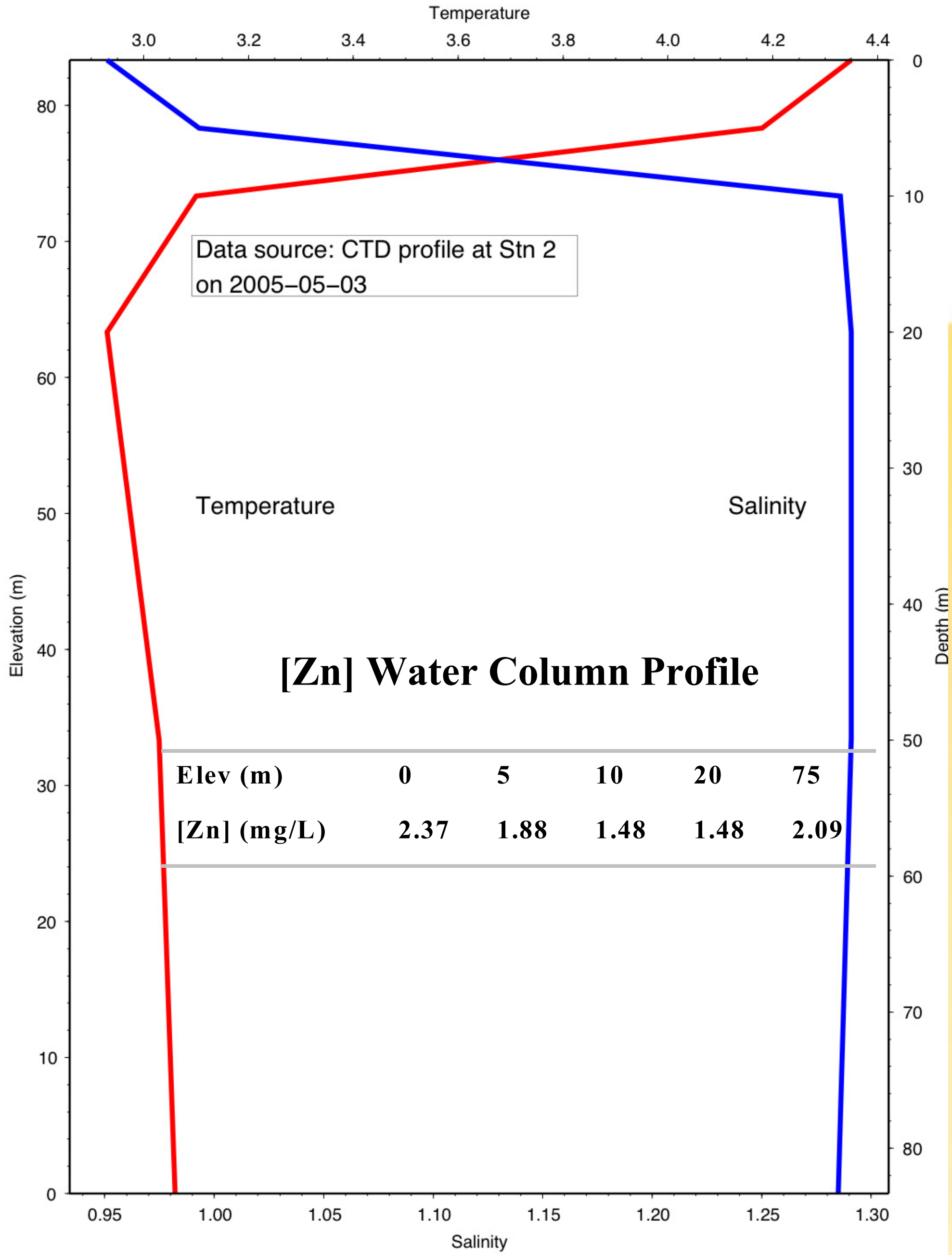
DYRESM model for Selbaie

- One-dimensional, horizontally integrated
- Pit morphology
- Heat budget
- Wind mixing
- Surface and groundwater inflows and outflows, precipitation & evaporation
- Negatively buoyant plume and entrainment
- Conservative tracer (e.g., [Zn]) (No diss. Fe; fully oxygenated)

DYRESM Initial Conditions

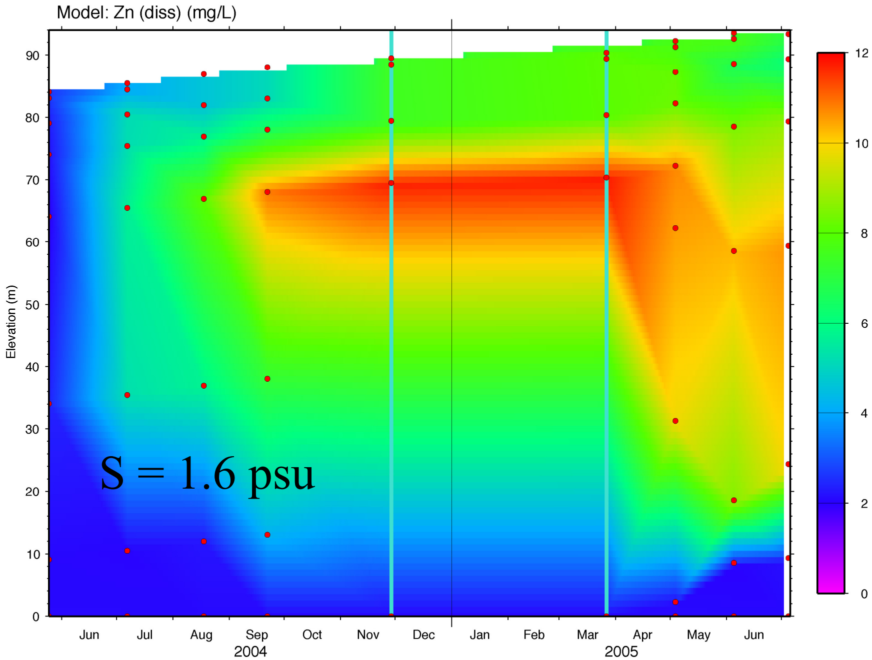
May, 2004

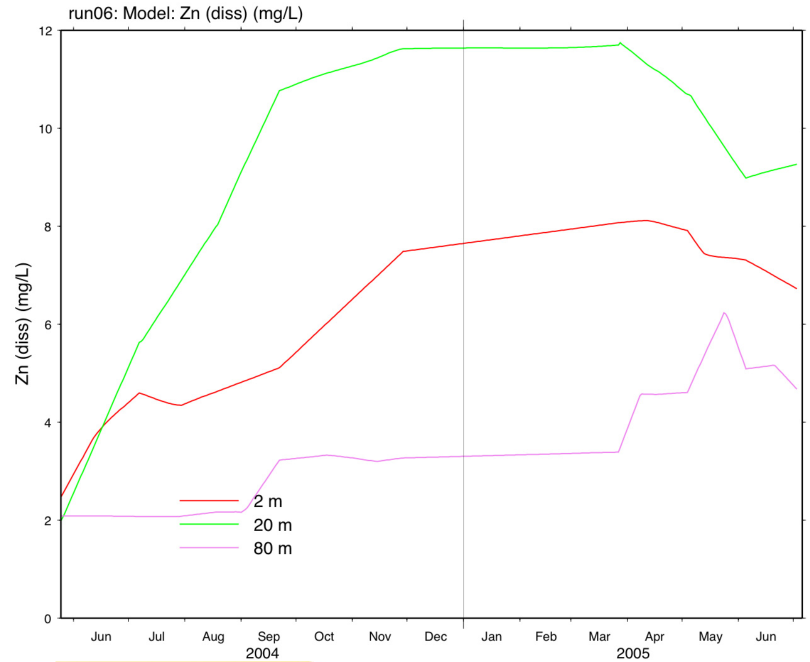


[Zn] Water Column Profile

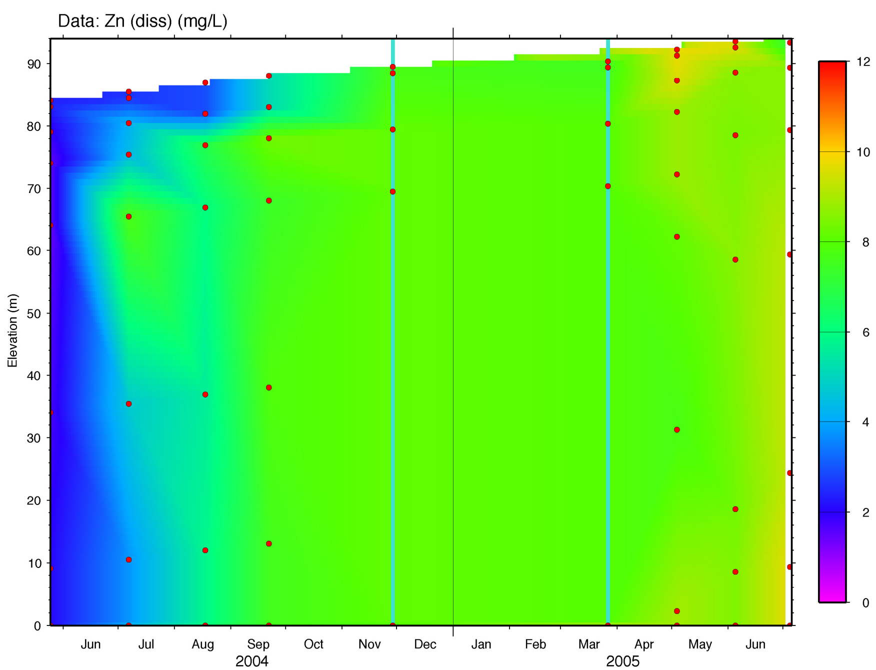
Elev (m)	**0**	**5**	**10**	**20**	**75**
[Zn] (mg/L)	**2.37**	**1.88**	**1.48**	**1.48**	**2.09**

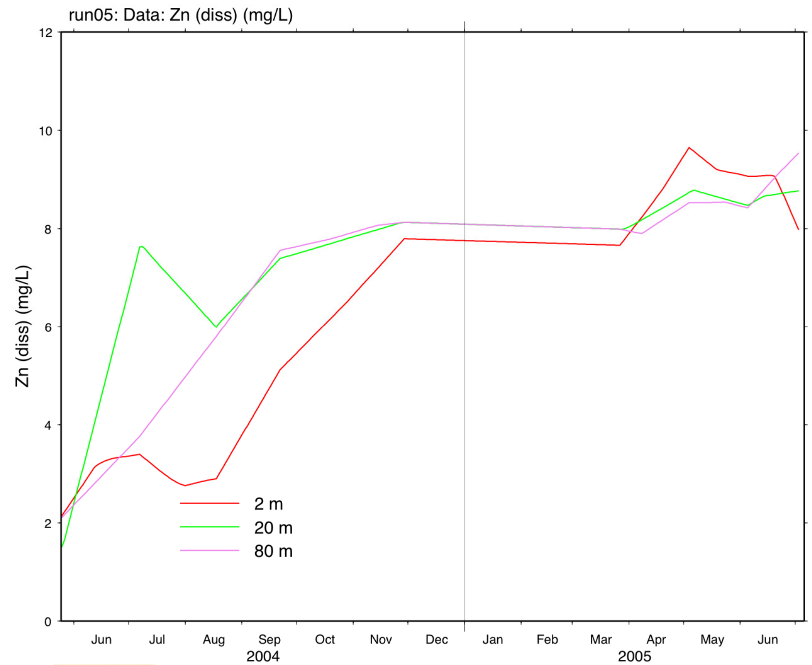
Modeled [Zn] Distribution



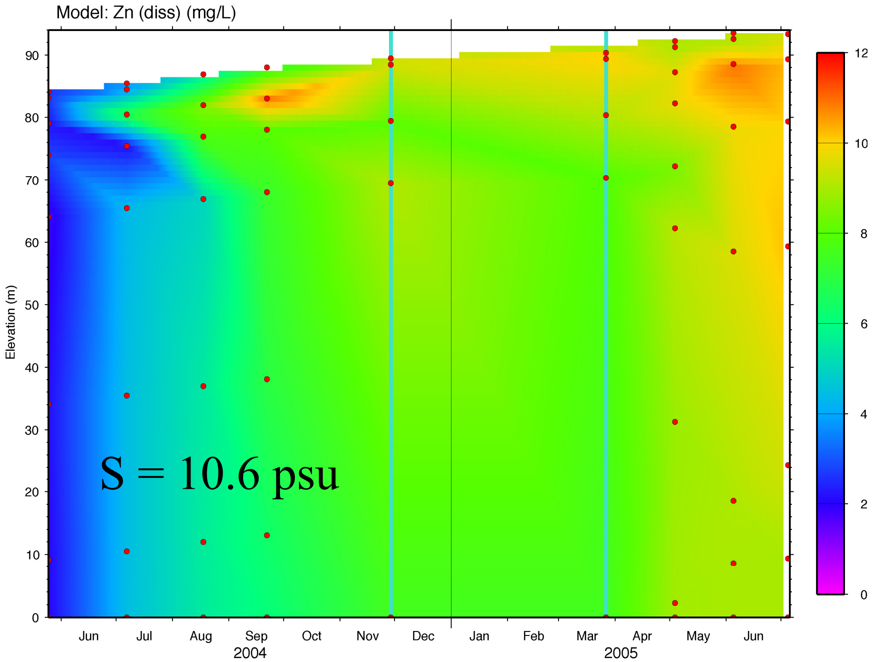


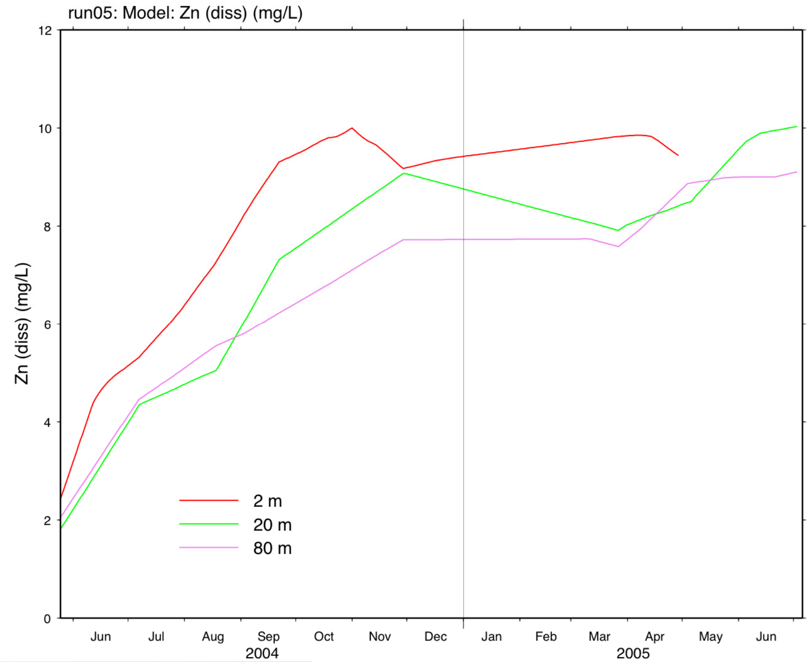
Actual [Zn] Distribution



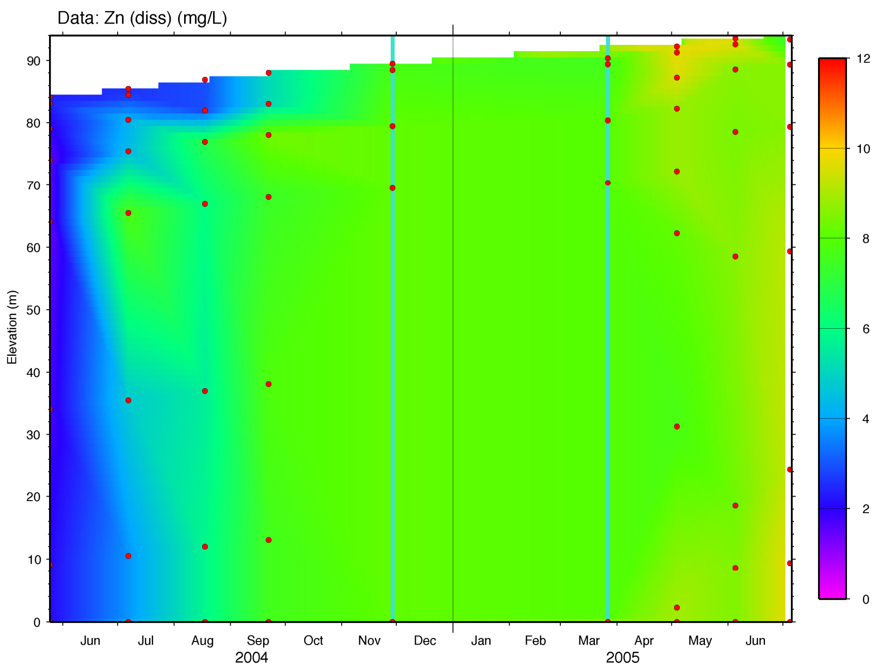


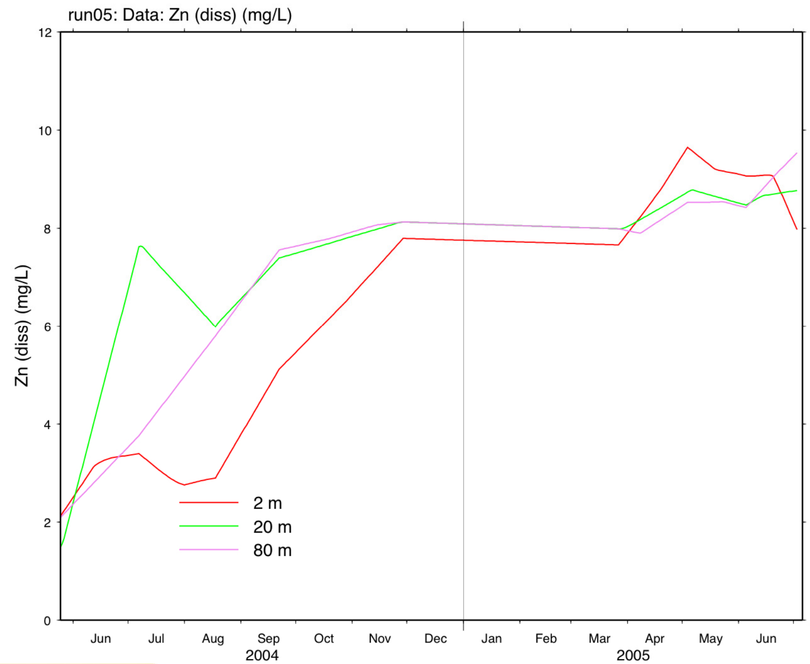
Modeled [Zn] Distribution





Actual [Zn] Distribution





Summary of Calibration

- **Circulation and vertical distribution of water properties are dominated by WTP discharge.**

- **A consistent water balance has been derived from surface elevation measurements.**

- **Zn loading during May, 2004 - July, 2005 period was dominated by the peat / waste dump source.**

- **DYRESM model output over the analysis period confirms the critical role of the WTP discharge and is consistent with measurements of [Zn].**

Long-term Modeling of Selbaie Pit Water Quality

Overview

Utilize calibrated pit lake model as a predictive tool

- Long-term (25 yrs) modeling of pit lake to predict Zn evolution and distribution and determine if surface overflow is discharge compliant

- Assumed Zn to behave conservatively (i.e., no allowance for geochemical/biological removal)

- Sensitivity Analysis of Key parameters

Prescribed Conditions

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- **Assumes filled pit lake that has been treated to achieve 0.25 mg/L [Zn] throughout water column**
- **Expected Case Hydrological Conditions**
  - **Surface runoff from Industrial Area and tailings area are clean and diverted away from pit lake to environment**
- **Zn flux from submerged peat/oxidized waste as per Ecometrix "expected condition"**
- **Seasonal Water treatment plant discharge with Zn concentration of 0.06 mg/L**

Expected Condition Zn Flux

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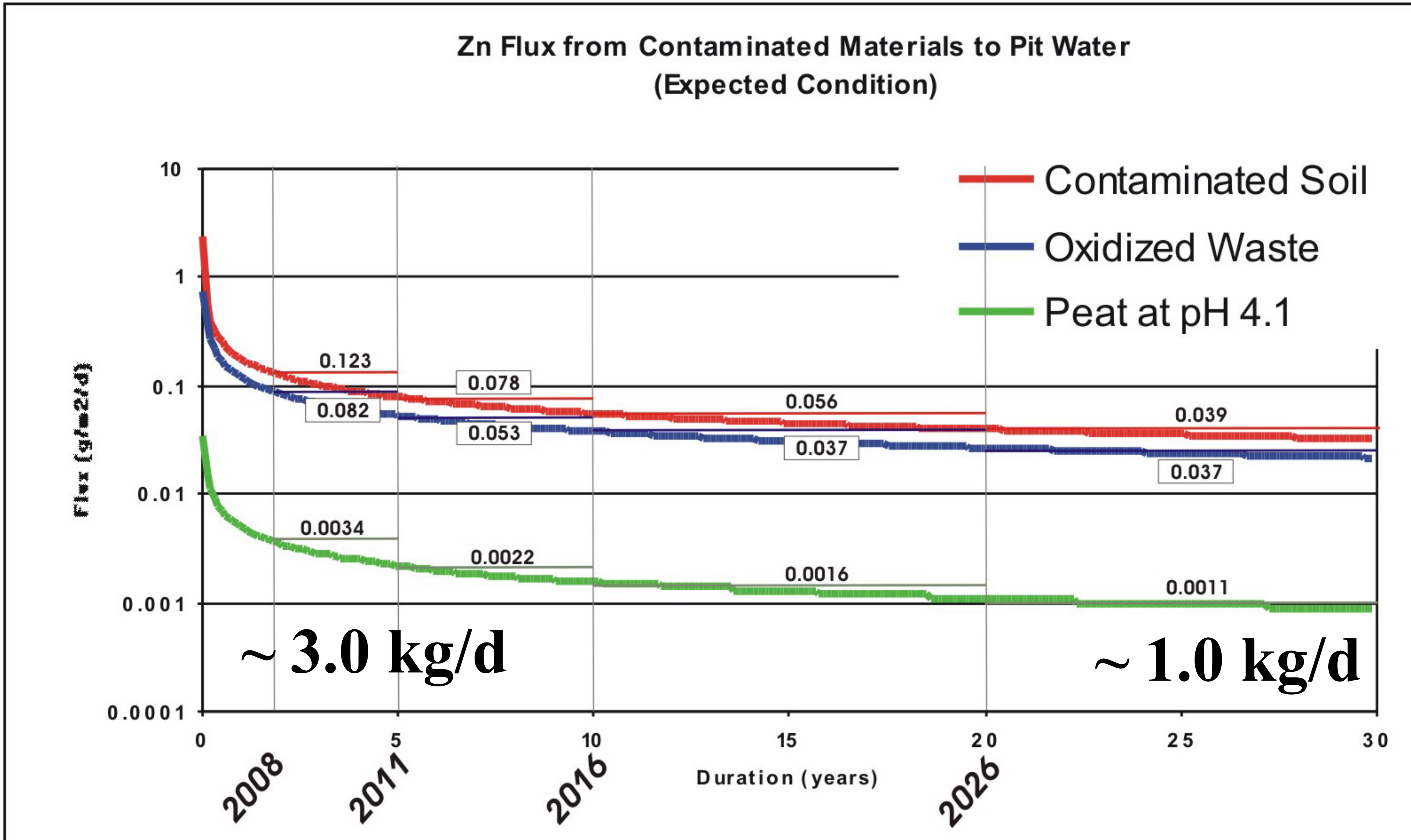
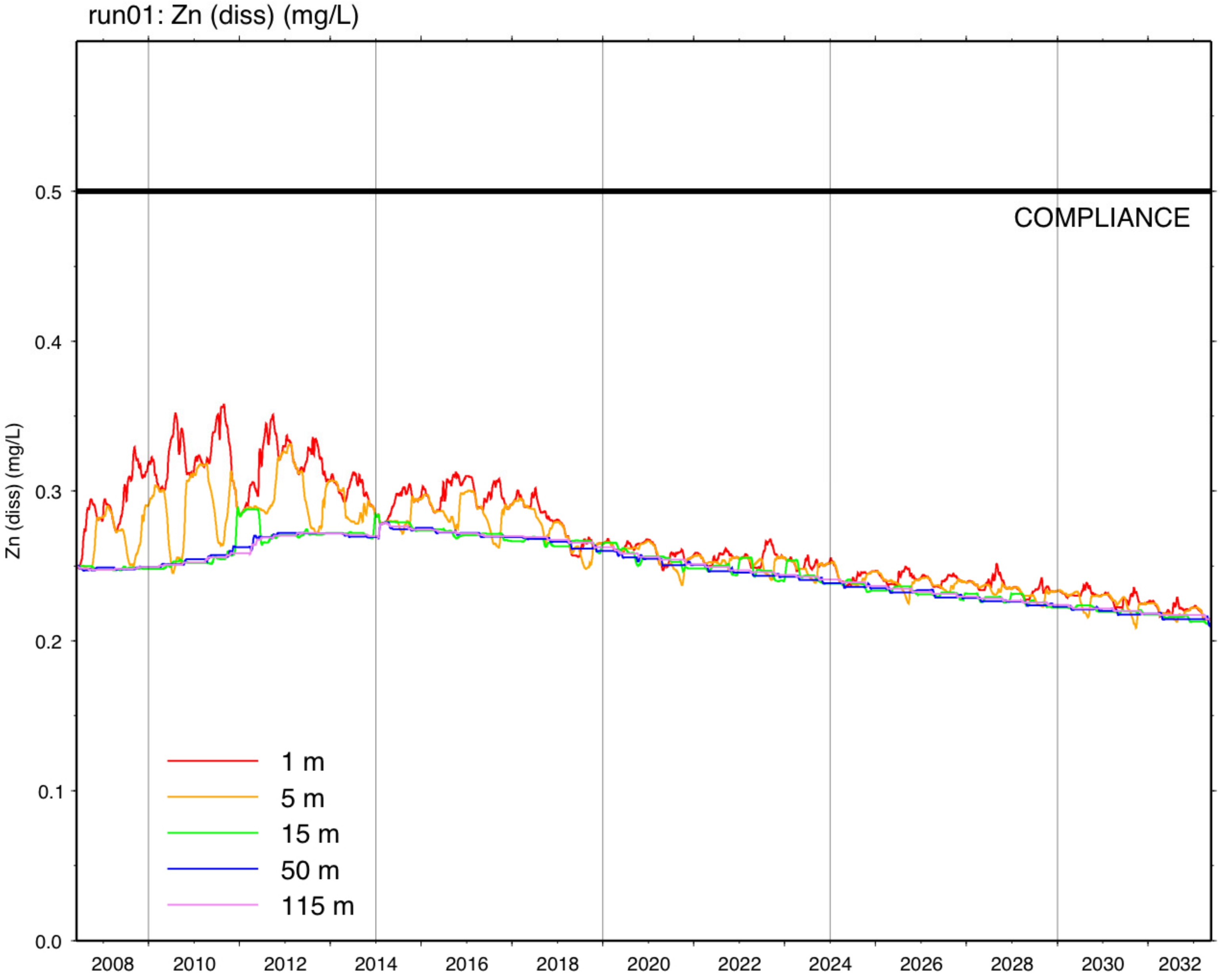
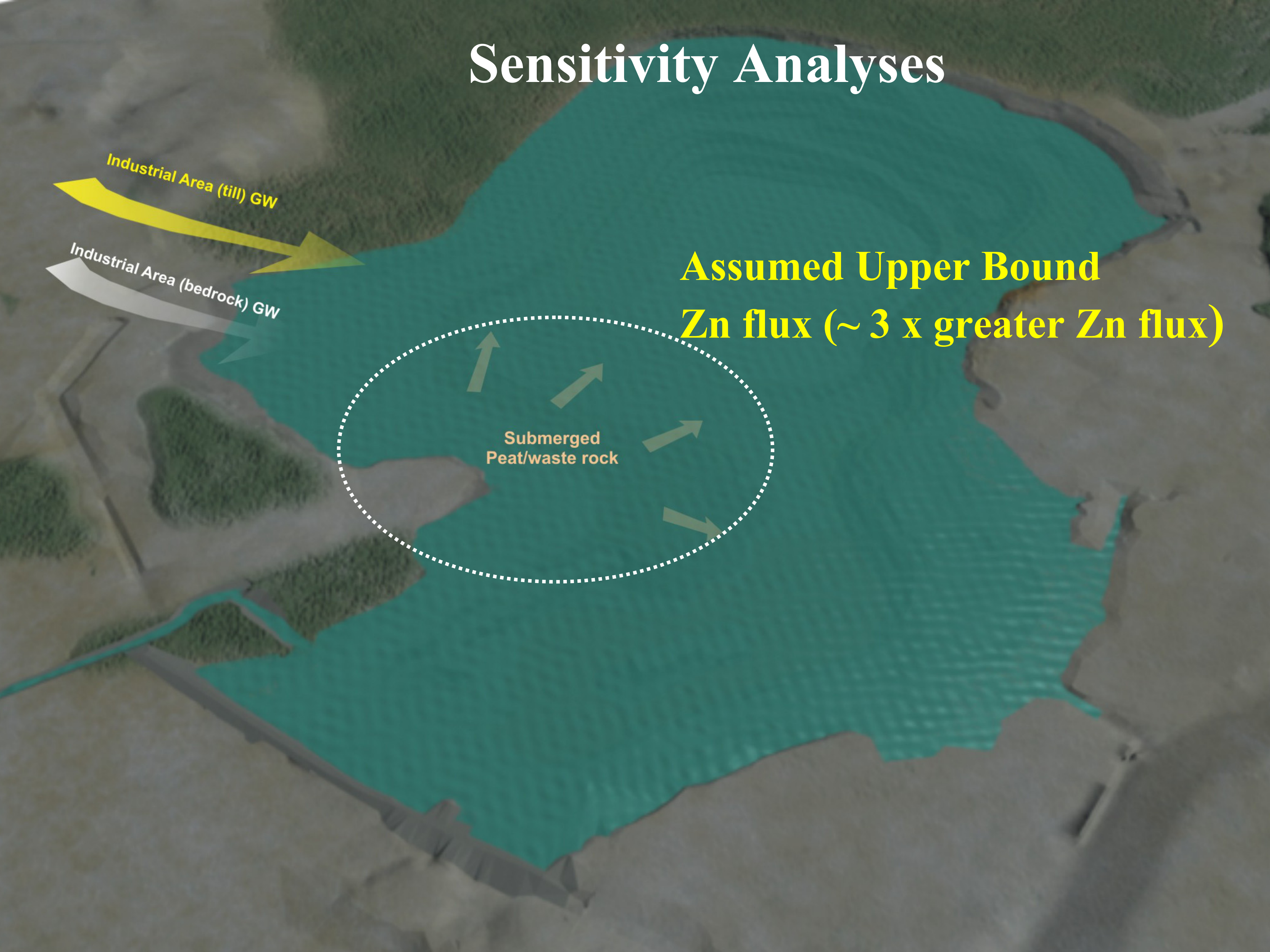


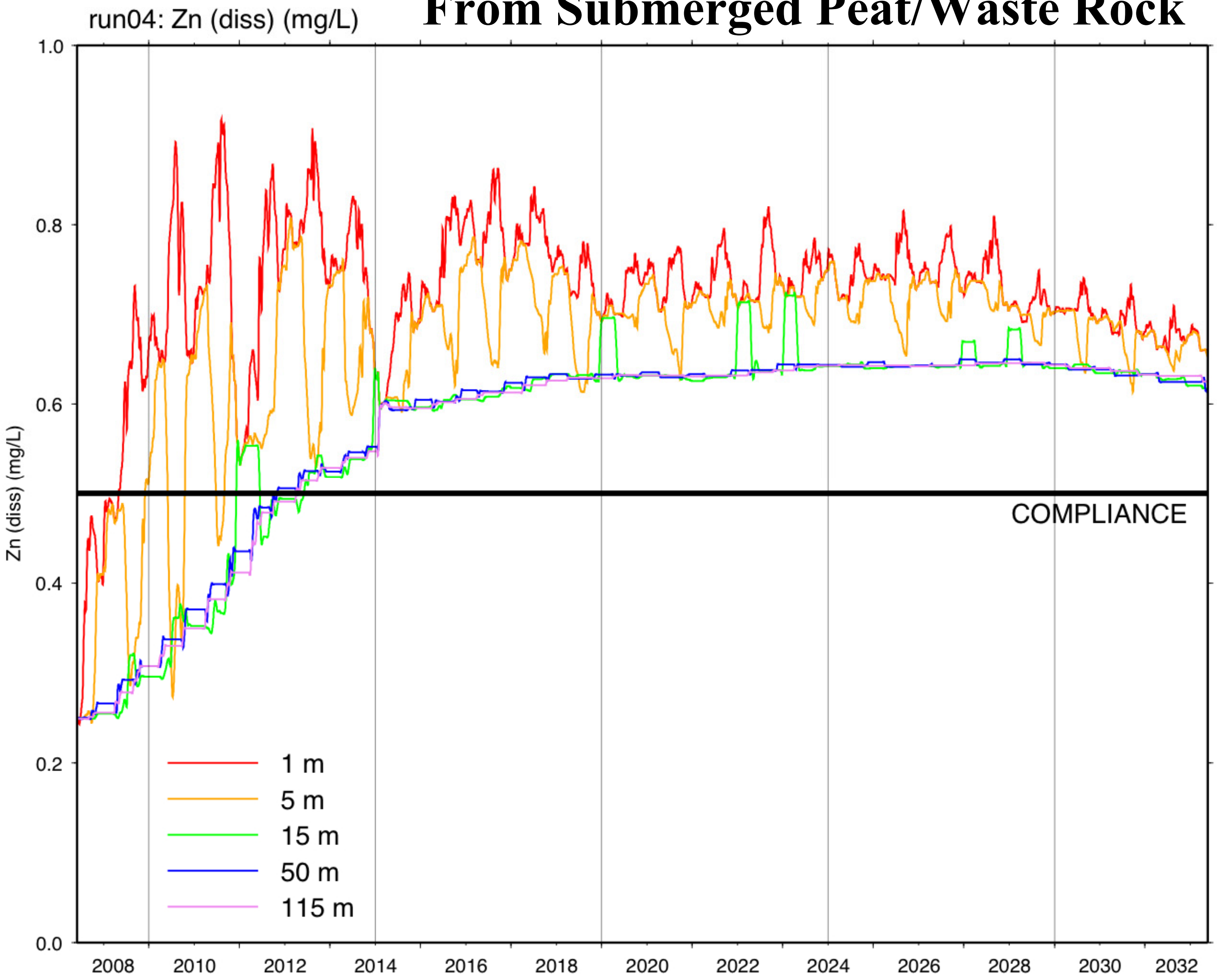
Expected-Base Case – Zn



Sensitivity Analyses



Sensitivity– Higher Zn Flux From Submerged Peat/Waste Rock



Summary of Key Findings

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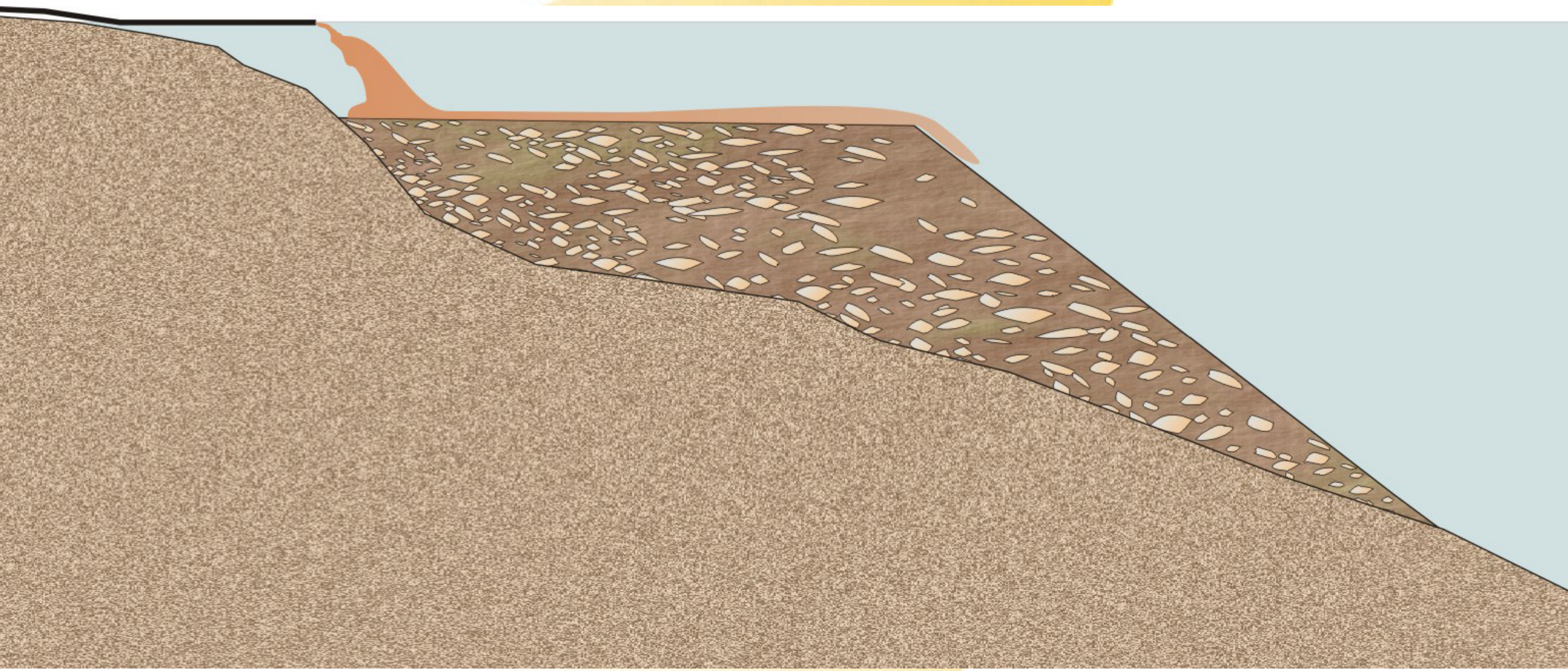
- **Expected Hydrological and expected Zn flux from submerged peat/waste rock results in ~ 0.1 mg/L <u>incremental</u> increase in [Zn] in pit lake**

- **Compliance is maintained provided initial lake [Zn] assumptions are valid (*i.e.* ≤ 0.25 mg/L)**

- **Higher-than-expected Zn fluxes from submerged material could result in non-compliant water quality**
  - **focus management on reducing potential flux from submerged waste**

Prevention-Mitigation

- **Place a diffusion barrier over the submerged peat/oxidized waste rock**
- **Use WTP sludge as diffusion barrier material**



Prevention-Mitigation

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- **Discharge from a floating and movable pipeline**
- **WTP sludges are alkaline, fine-grained and have the best chance of covering the irregular surface of the submerged waste**