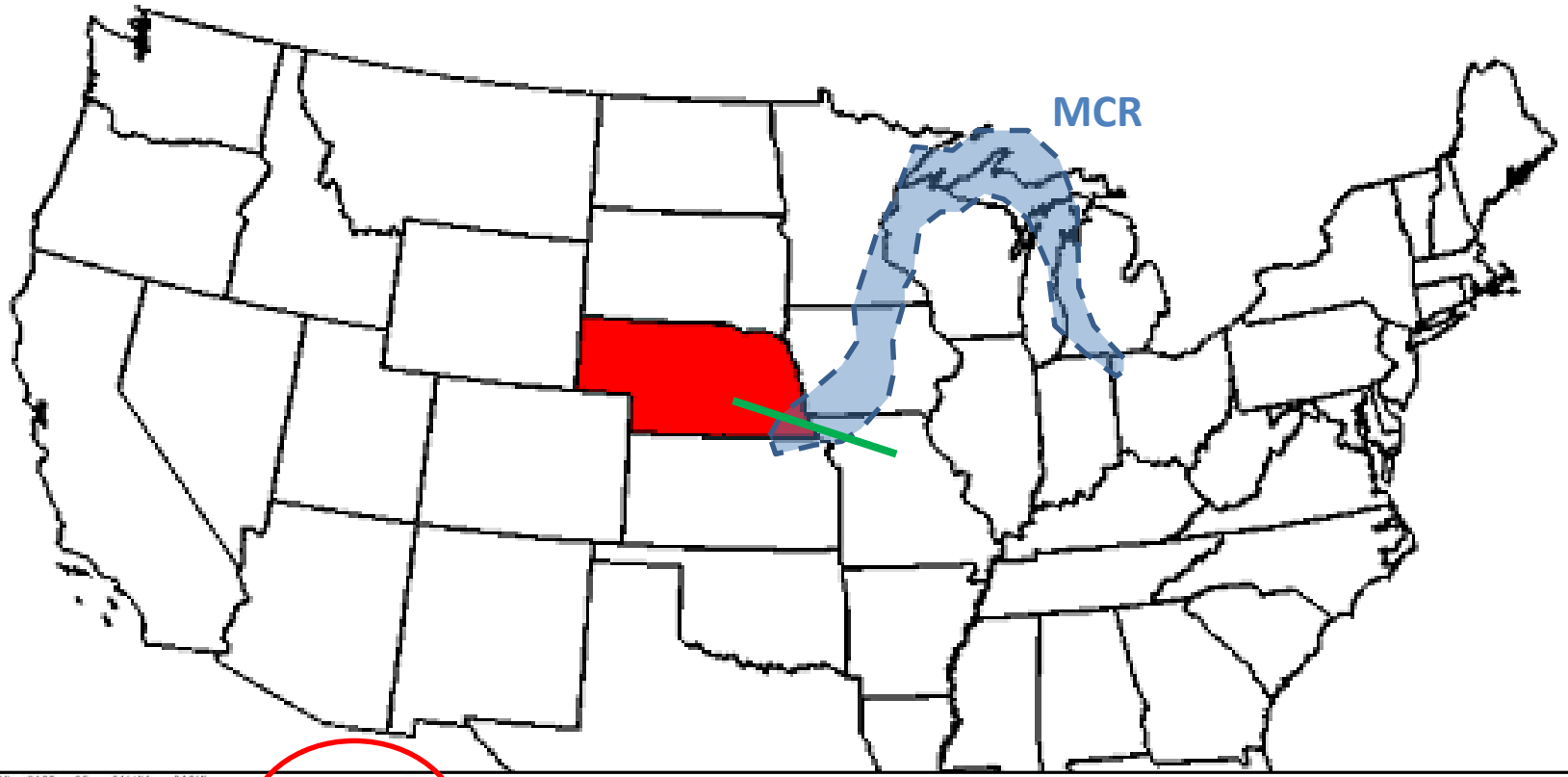
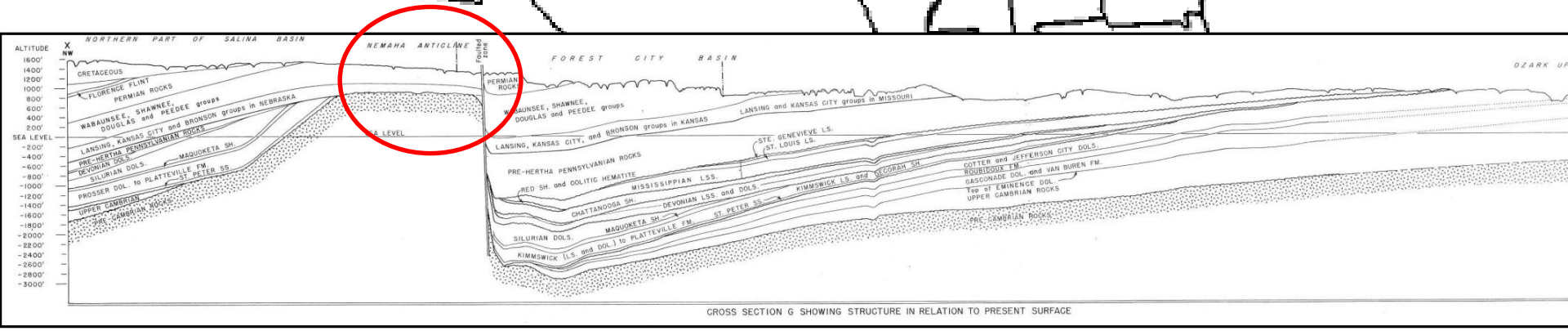
Just Add Water: The Importance of Groundwater in Your Mine Feasibility Study *(Paul Williams, Geoff Baldwin, Vladimir Ugorets)*

Goal: Advance Nb, Sc, Ti project to Feasibility Level in 10 mo.





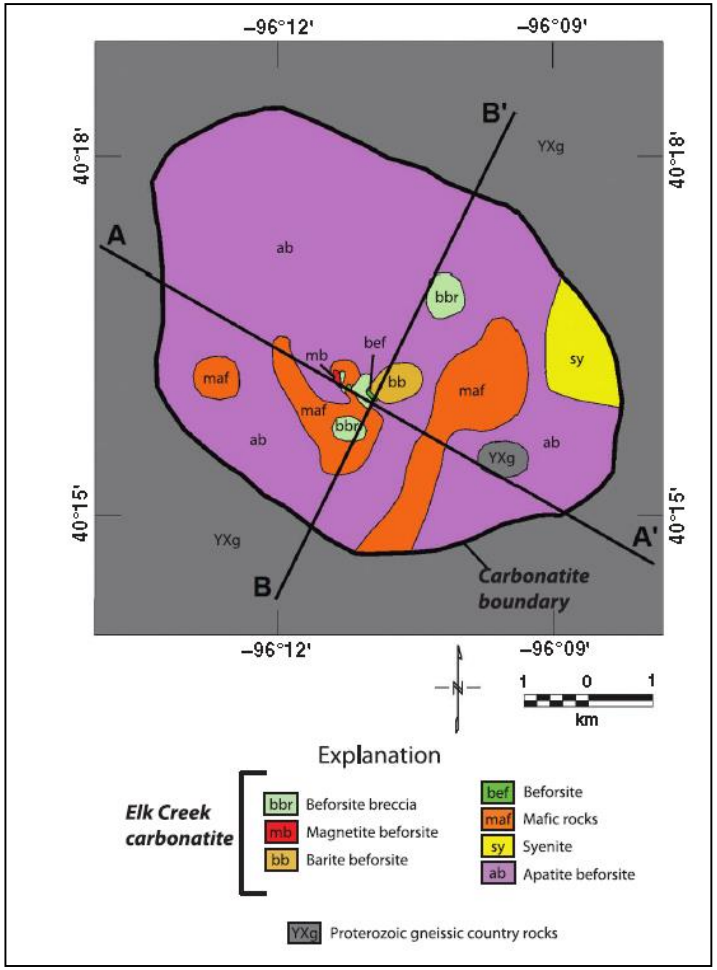
CROSS SECTION G SHOWING STRUCTURE IN RELATION TO PRESENT SURFACE

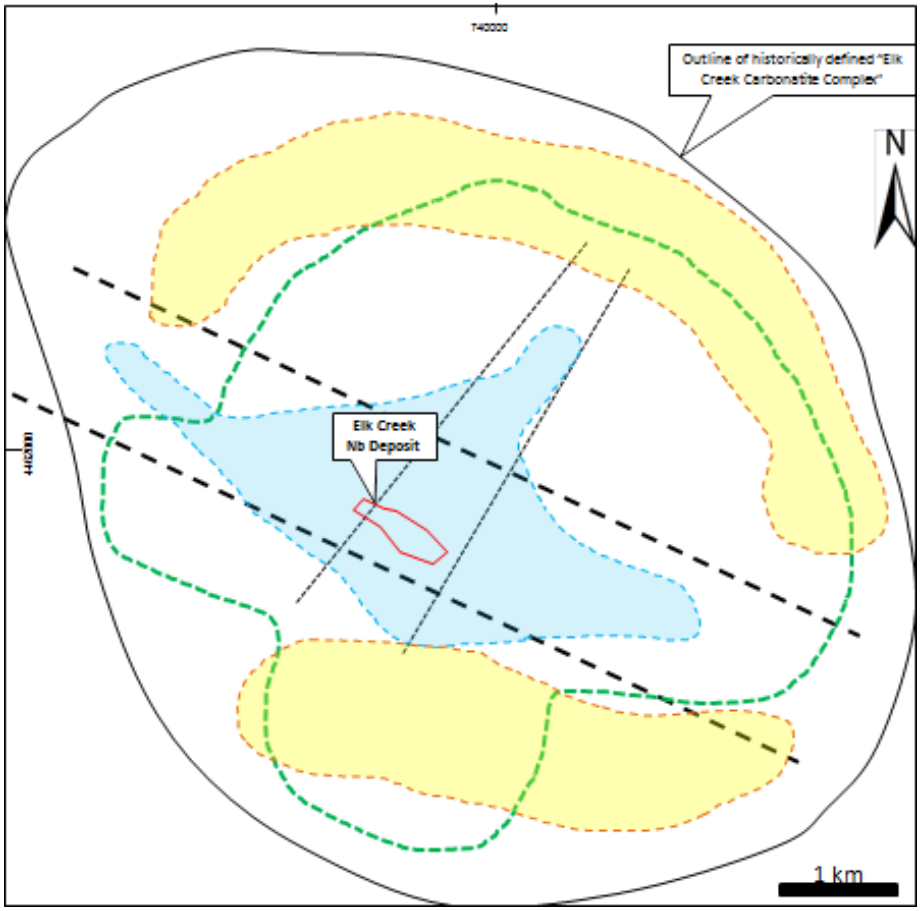
Till (0 to 30m)

Limestone & Shale (30 – 200m) – Pennsylvanian

Carbonatite (200 – 950m) - Cambrian

Geology beneath Mississippian Limestone:

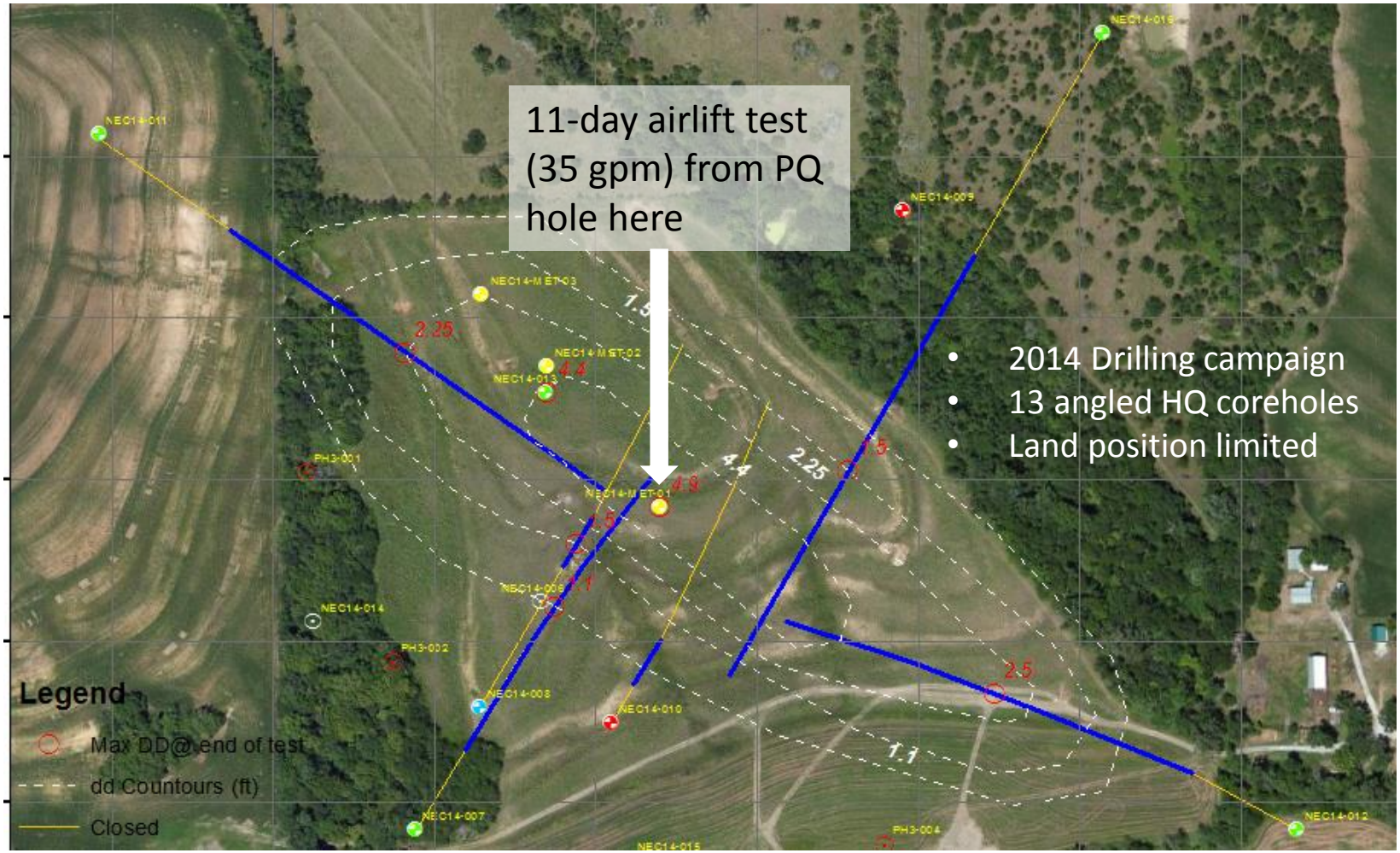


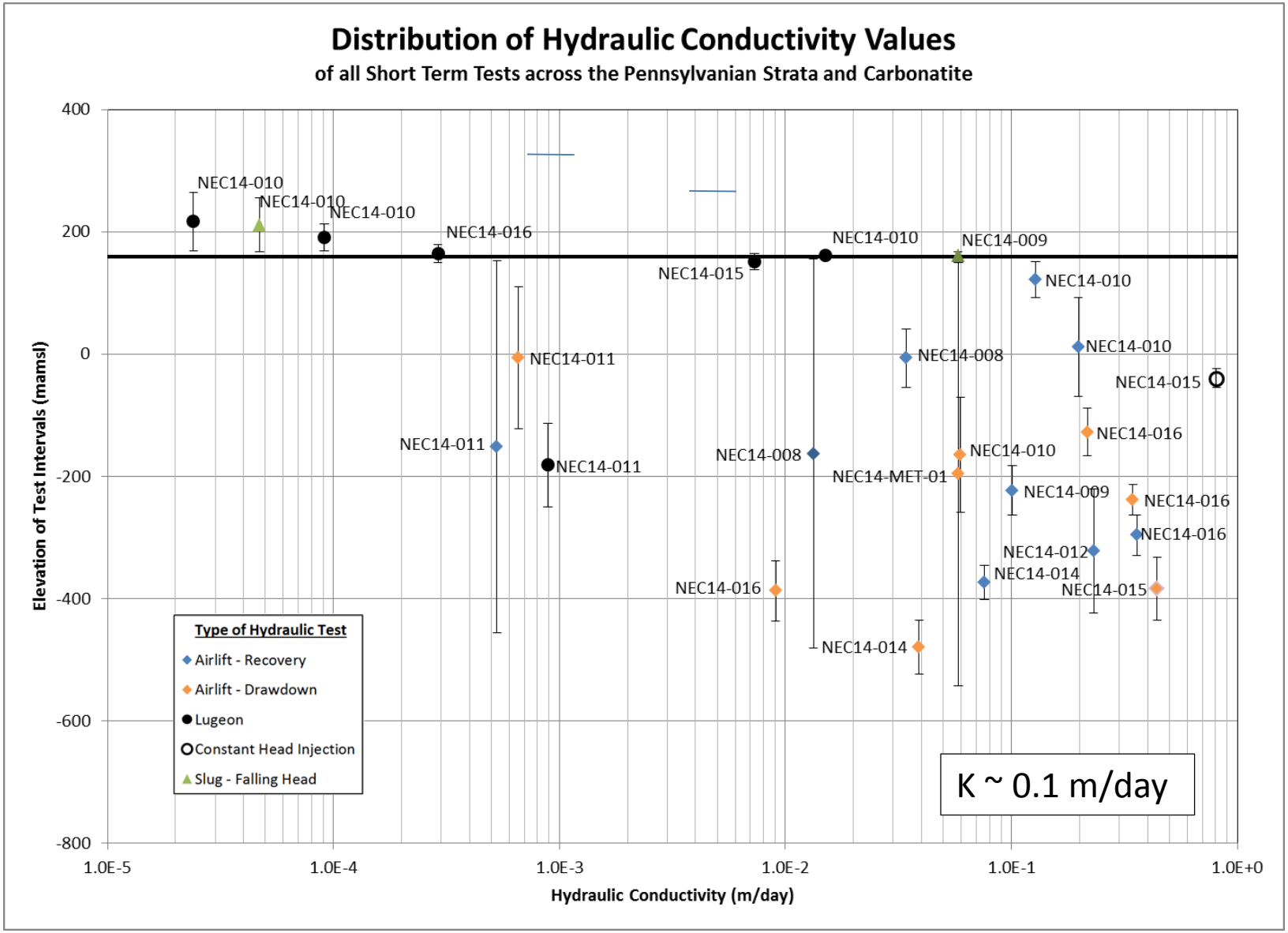


Geological map outline of the project area (provided by the client). Syenite (yellow); Beforsite (blue). Deposit outline in green. Dotted straight lines are magnetic lineaments. **From Elk Creek Structural Report**.

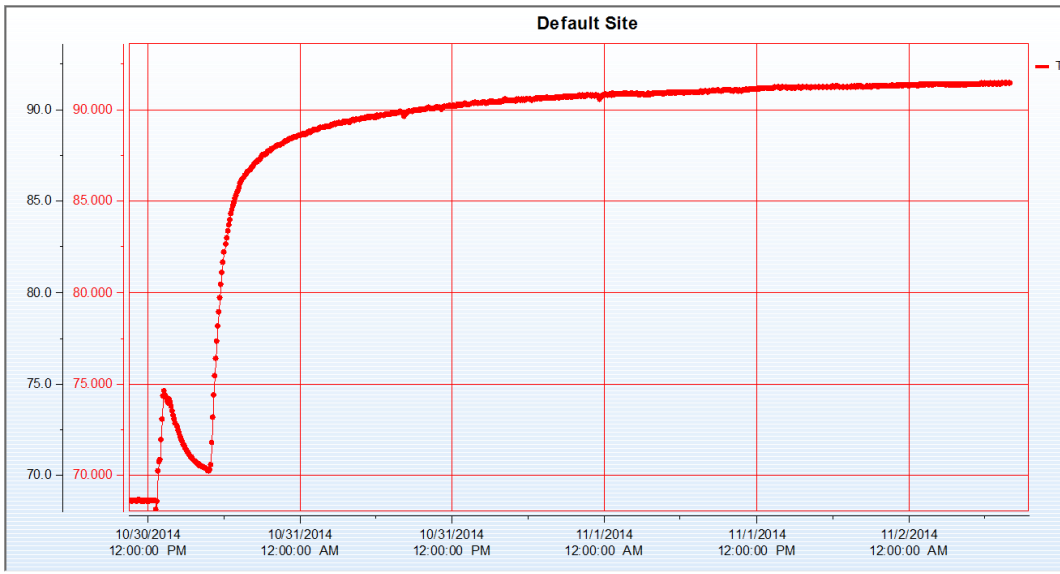
Drenth B., 2014. **Geophysical Expression of a buried niobium and rare earth element deposit: The Elk Creek carbonatite, Nebraska, USA**

2014 Field Program:




Distribution of Hydraulic Conductivity Values
of all Short Term Tests across the Pennsylvanian Strata and Carbonatite
Elevation of Test Intervals (mamsl)
400
200
0
-200
-400
-600
-800
1.0E-5
1.0E-4
1.0E-3
1.0E-2
1.0E-1
1.0E+0
Hydraulic Conductivity (m/day)
NEC14-010
NEC14-010
NEC14-010
NEC14-016
NEC14-011
NEC14-011
NEC14-011
NEC14-015
NEC14-010
NEC14-009
NEC14-010
NEC14-008
NEC14-010
NEC14-015
NEC14-016
NEC14-008
NEC14-010
NEC14-MET-01
NEC14-009
NEC14-016
NEC14-016
NEC14-012
NEC14-014
NEC14-016
NEC14-015
NEC14-014
Type of Hydraulic Test
Airlift - Recovery
Airlift - Drawdown
Lugeon
Constant Head Injection
Slug - Falling Head
K ~ 0.1 m/day

	Aqueous concentration (mg/l)				
drill hole	**Chloride**	**Iron (total)**	**Sodium (total)**	**Sulfate**	**Comment**
NEC14-006	755	15.6	597	320	full open borehole
NEC14-007	5200	10.65	3733	1670	full open borehole
NEC14-008	3520	0.46	2350	736	shallow completion
NEC14-014	10300	7.85	6158	1410	Packer-isolated - deep
NEC14-015	10500	4.34	5937	1400	Packer-isolated - deep
Met-01	10300	1.57	7357	1400	open borehole after 5 days of pumping.



Conclusions after ~5 months of Field Work :

- Water Levels are consistently low in carbonatite
  - ✓ In equilibrium with something distant.
  - ✓ Connection to larger system?
- Hydraulic Conductivity values are relatively high to total depth of the deposit (850m)
  - ✓ Lots of water
- Water is brackish
  - ✓ Water management problem

Can we proceed with the FS?

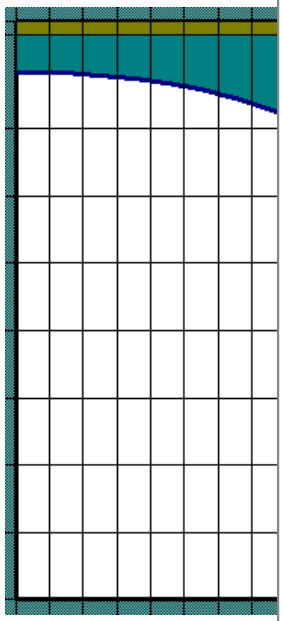
KEY FACTOR – WILL THE GRANITE ACTS AS A BOUNDARY?

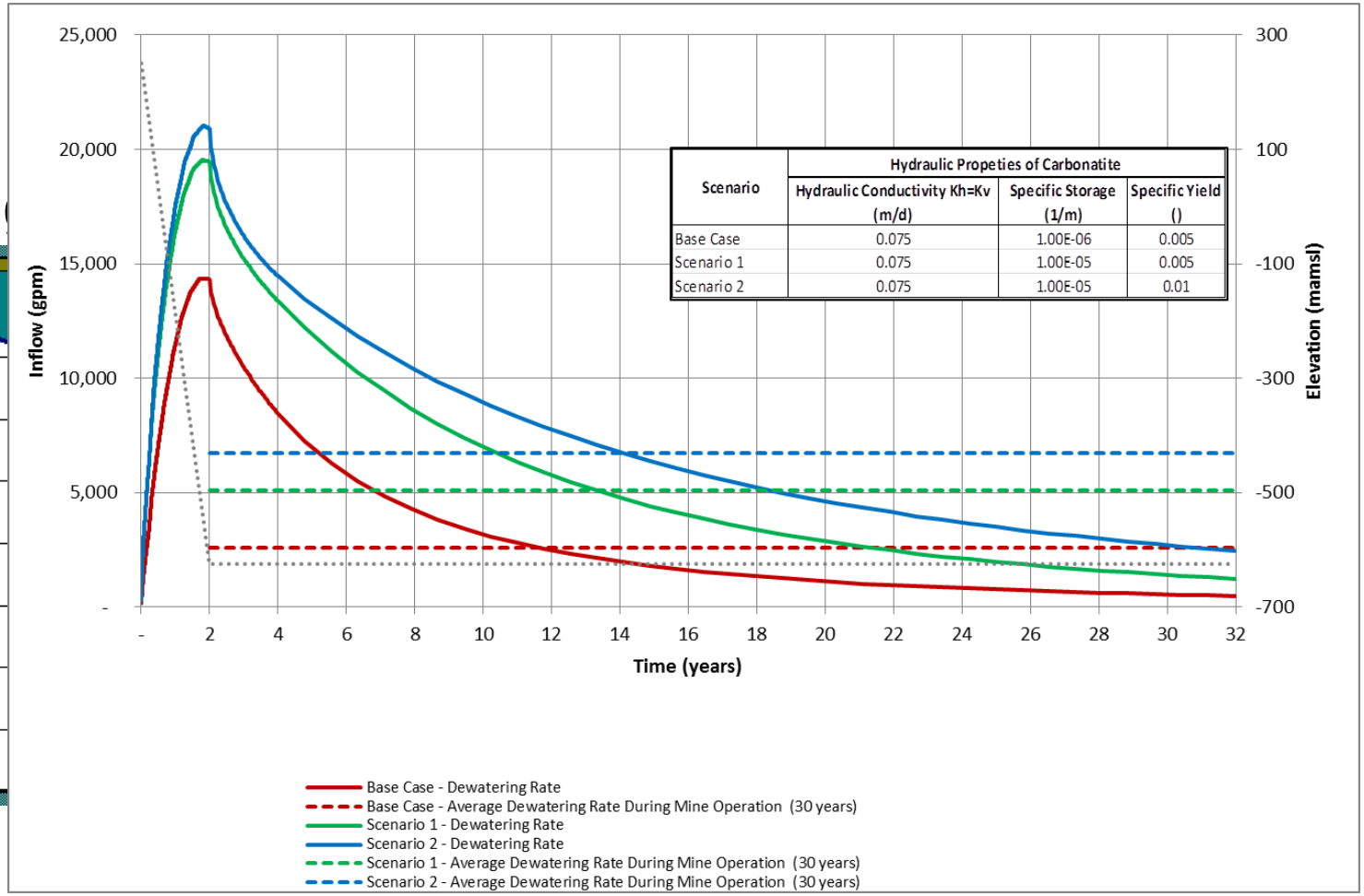
- Risk 1: Overestimate costs to actively dewater the mine
  - ✓ CAPEX for drilling, well network, piping
  - ✓ O&M for electricity

- Risk 2: Overestimate water management costs
  - ✓ Cl and Na content of water elevated
  - ✓ Discharge issues or Treatment costs?

Options:

- Modelin





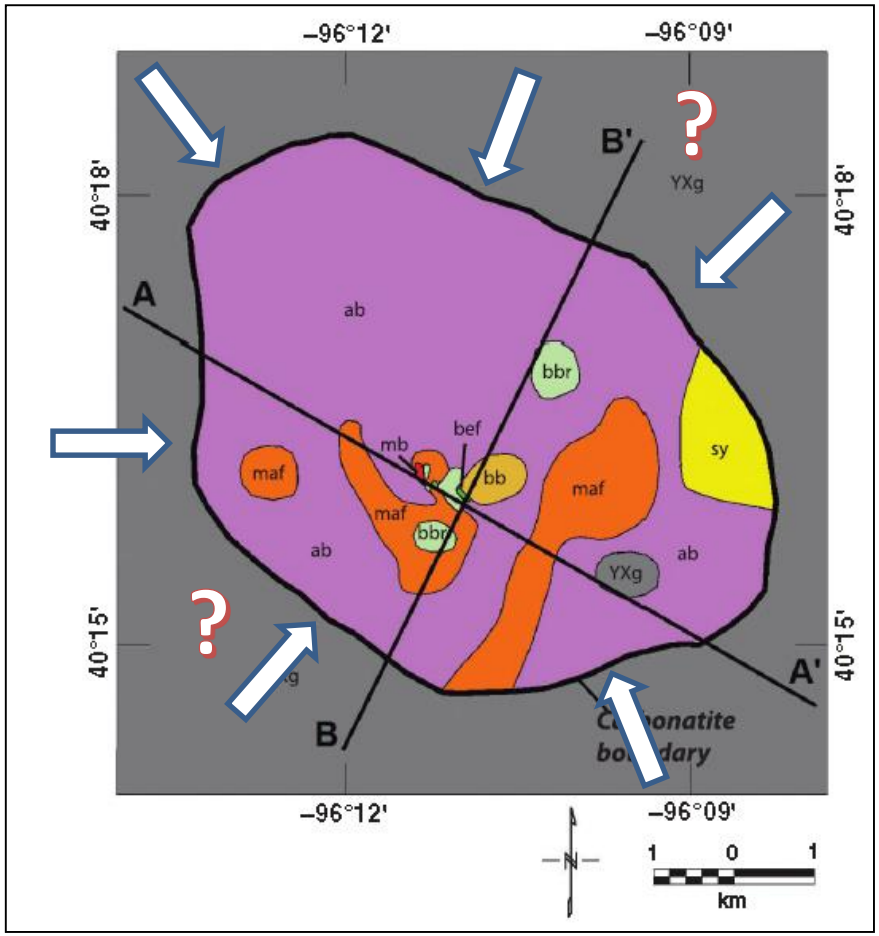
Scenario	Hydraulic Propeties of Carbonatite		
	Hydraulic Conductivity Kh=Kv (m/d)	Specific Storage (1/m)	Specific Yield ()
Base Case	0.075	1.00E-06	0.005
Scenario 1	0.075	1.00E-05	0.005
Scenario 2	0.075	1.00E-05	0.01

- Return to the field

Field Program II - Objectives:

- Improve understanding of the perimeter (granite) – this controls inflow to the mine from 5-30 years

- Decrease the significant uncertainty in active dewatering rates for life of mine (LOM)

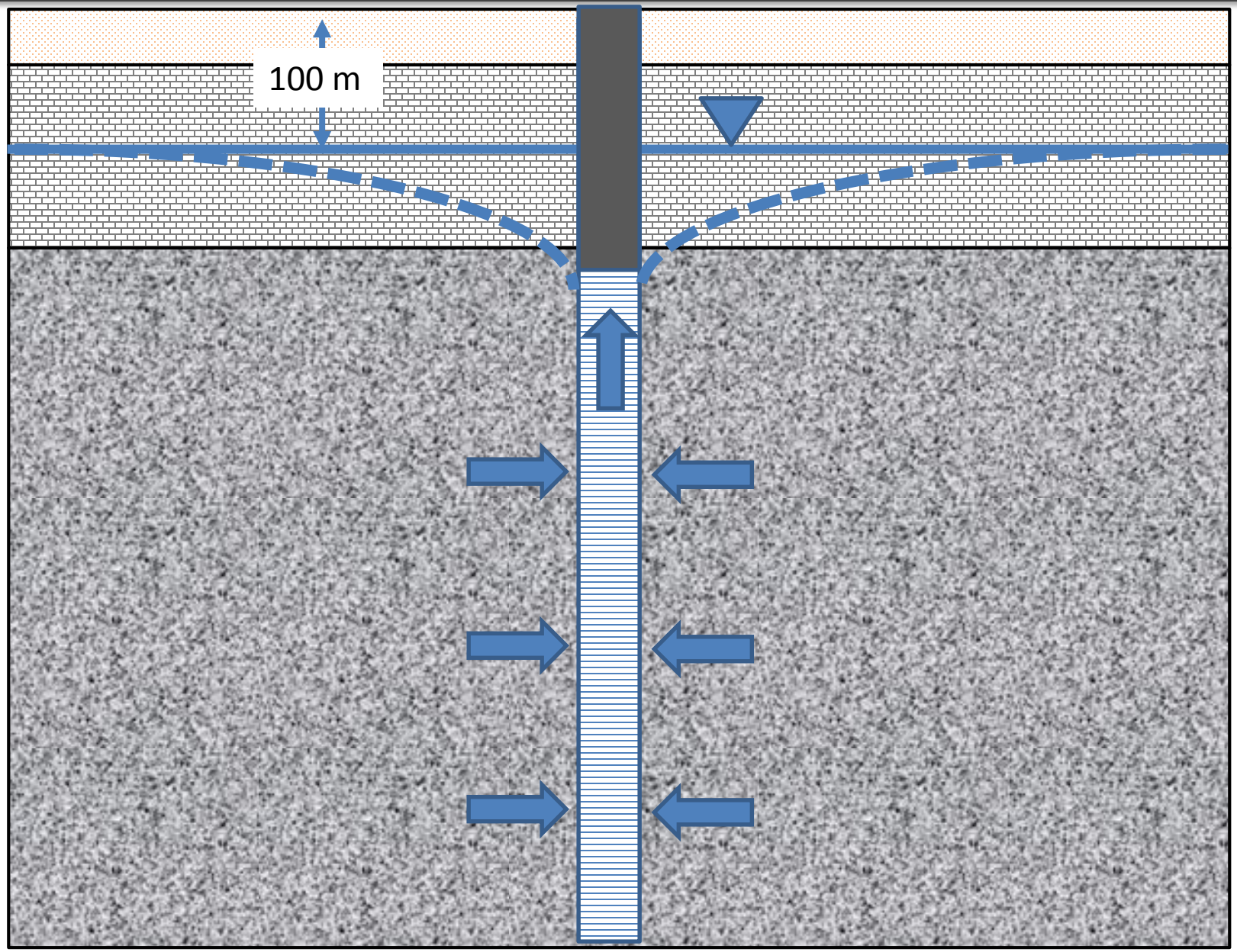


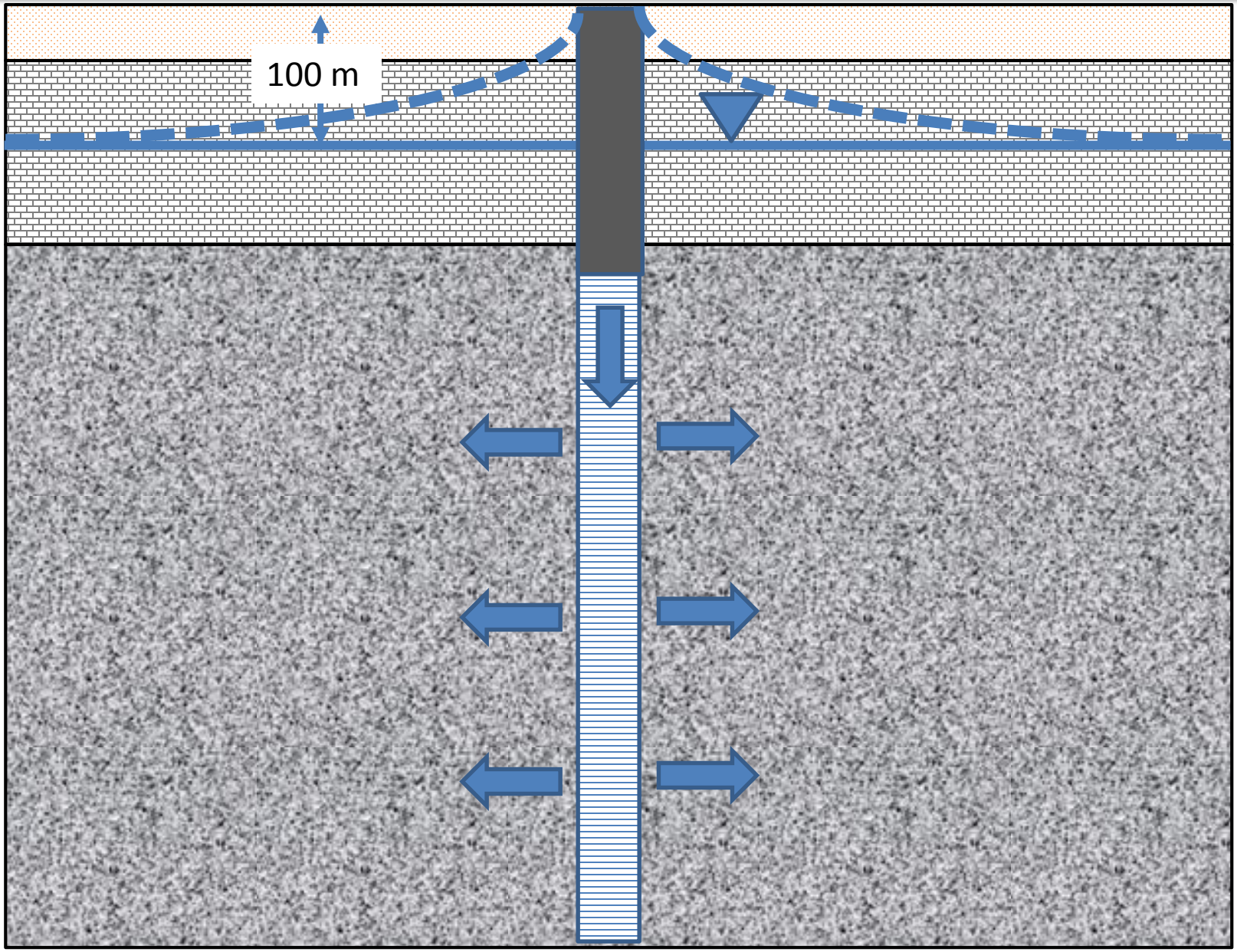
Impose a larger stress - Look for boundary effects

- Drill and install a test well. Conduct a long term test at a much higher rate (500 gpm) for 30 days.
- Conduct additional drilling lateral to the deposit – piezometers to monitor response from test
- Cost/Schedule?
  - ✓ 850-m deep 6-inch well
  - ✓ 2 deep, hybrid piezometer/VWP strings away from deposit
  - ✓ technical labor and oversight, including 30-day test
  - ✓ Schedule – 5 months

What to do with the water: (500 gpm, 30-day)?

- DISCHARGE (Elk Creek)
- TRUCK (lagoons)
- TREAT (discharge to Elk Creek - **NPDES**)
- STORE & RE-INJECT (construct lined ponds, **UIC**)

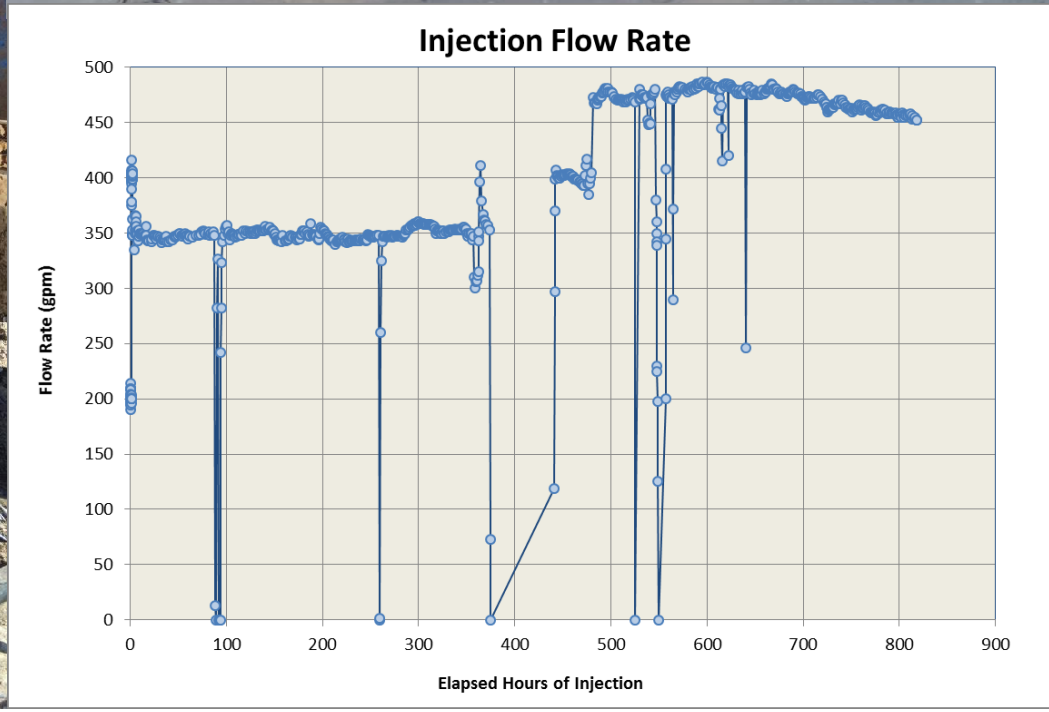

100 m


100 m

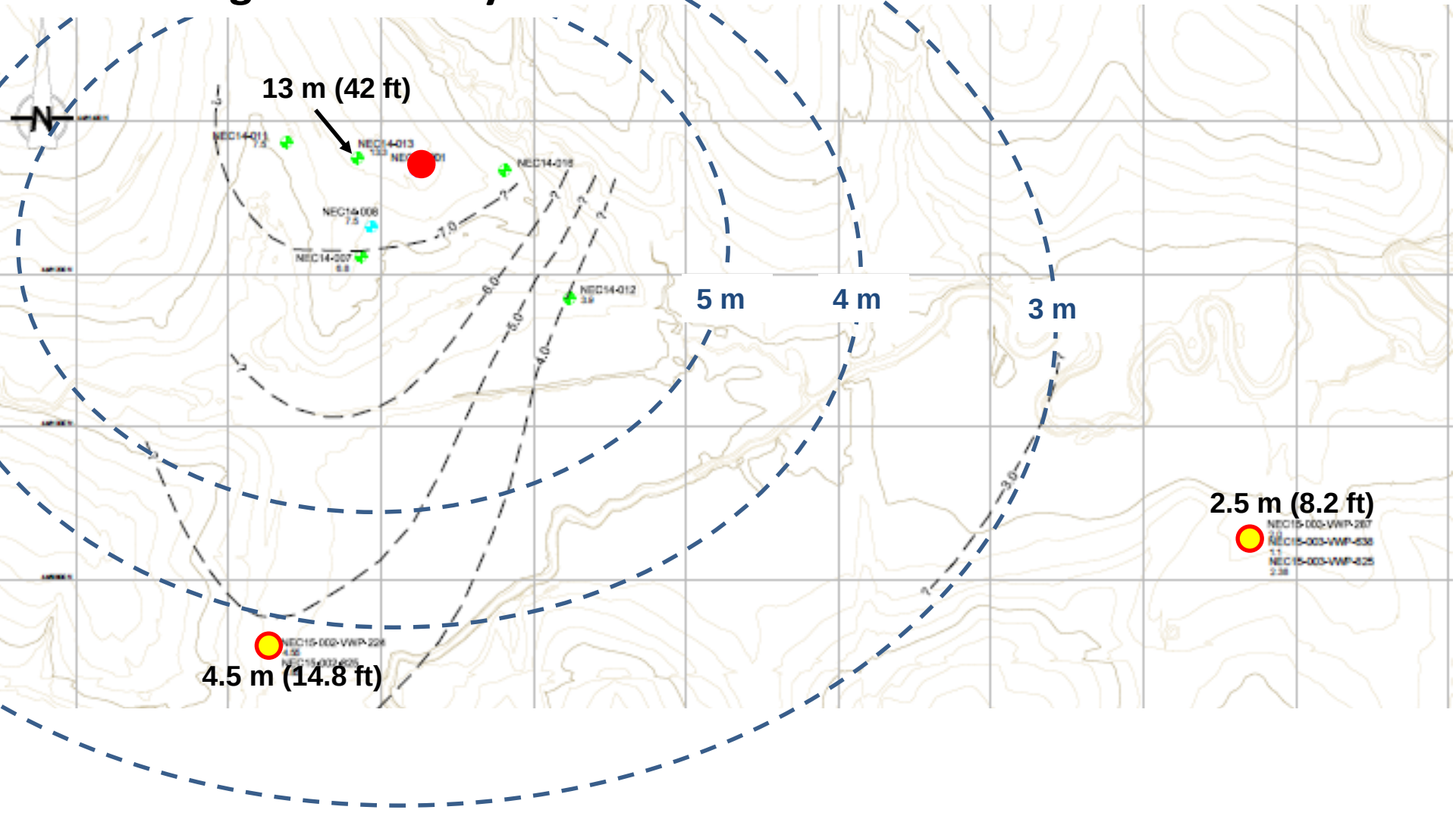

Senior Water Rights

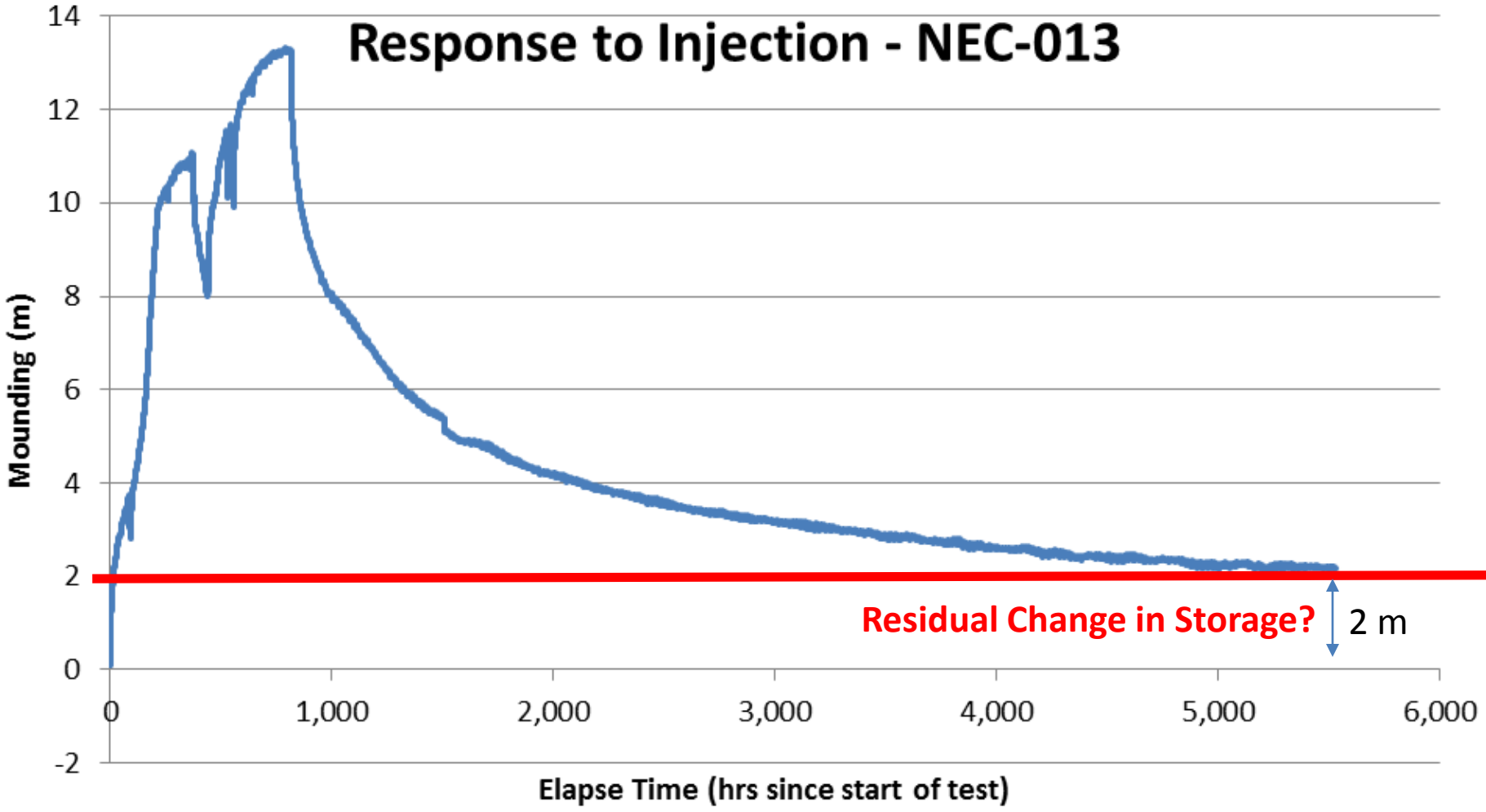

Engineered Reservoir – Todd Creek

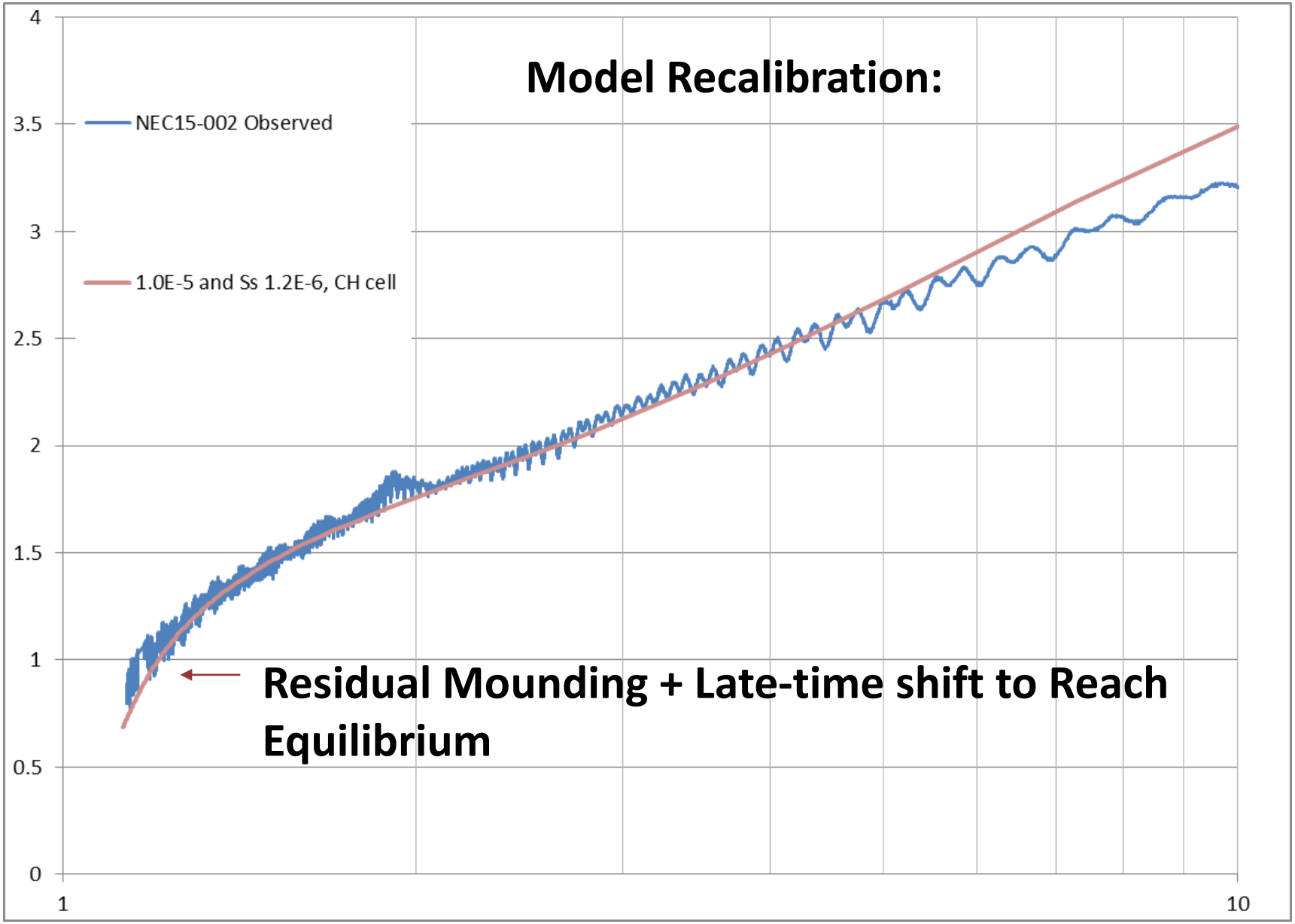

ECK-D
TCK-D
Creek Intake
1.2 km
0.65 km
NEC15-P1
NEC15-P2


Injection Flow Rate
Flow Rate (gpm)
500
450
400
350
300
250
200
150
100
50
0
0
100
200
300
400
500
600
700
800
900
Elapsed Hours of Injection

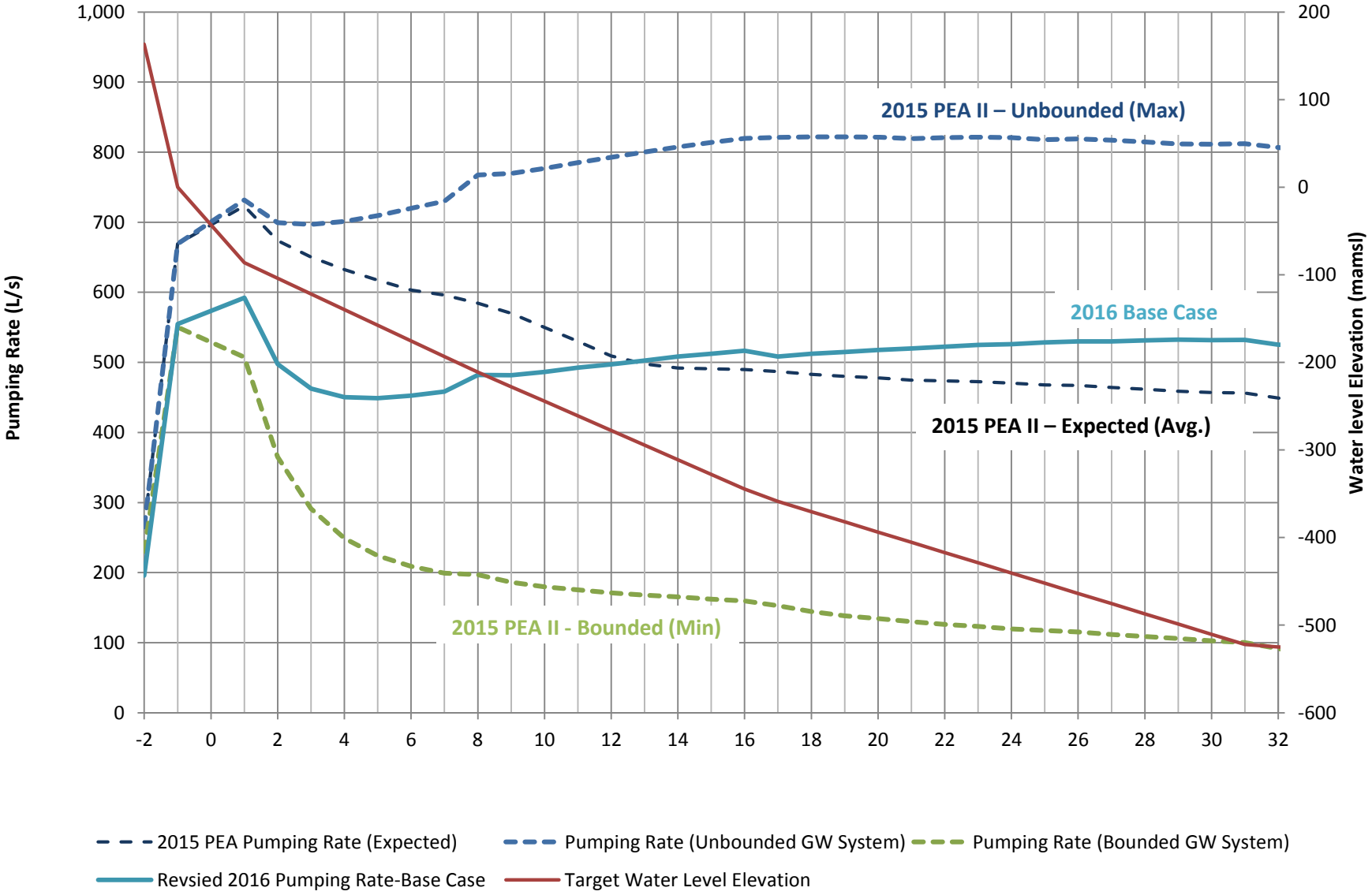
Mounding after 30 days:



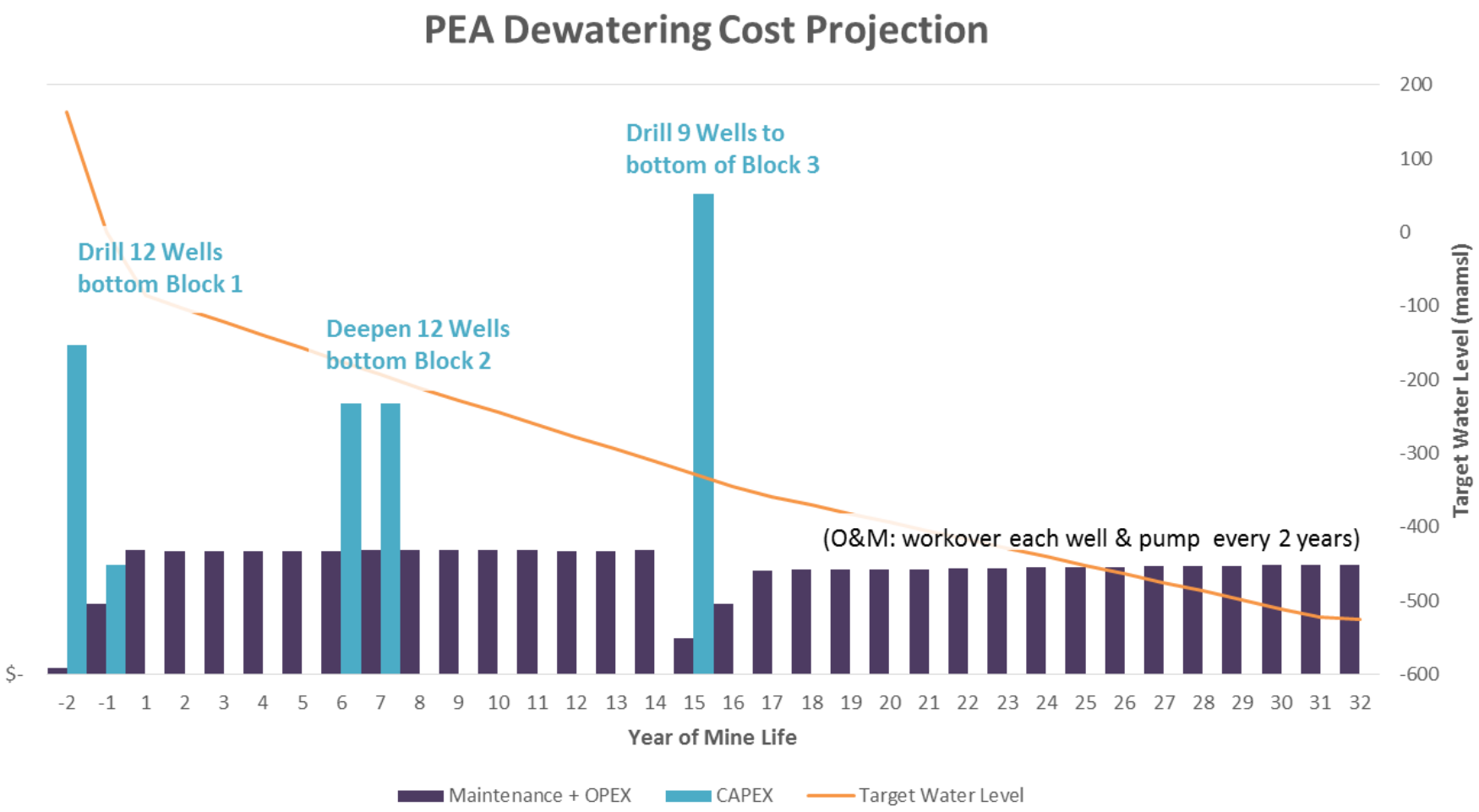

Response to Injection - NEC-013
Mounding (m)
14
12
10
8
6
4
2
0
-2
0
1,000
2,000
3,000
4,000
5,000
6,000
Elapse Time (hrs since start of test)
Residual Change in Storage?
2 m


Model Recalibration:
NEC15-002 Observed
1.0E-5 and Ss 1.2E-6, CH cell
Residual Mounding + Late-time shift to Reach Equilibrium
4
3.5
3
2.5
2
1.5
1
0.5
0
1
10

Predicted Pumping Rate and Water Level Elevation



Groundwater Model informs TEC



Take Aways:

1. Consider the Hydrogeology early in the program to allow for flexibility in mine planning and potentially more field work.

2. When hydrogeology is complex or rock is transmissive, we need time to figure out the hydrogeology

3. A good groundwater model is essential for evaluating alternatives