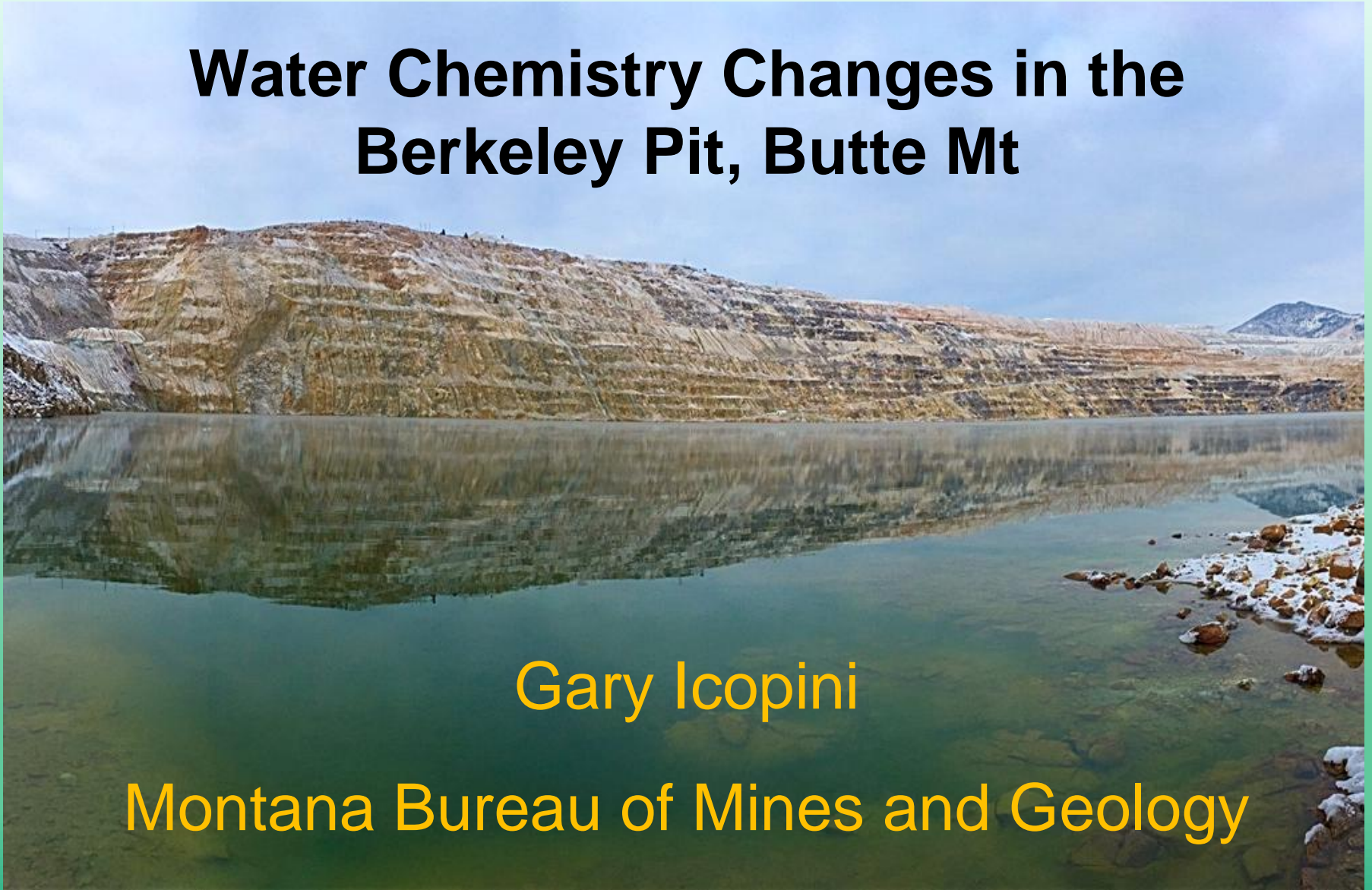


Water Chemistry Changes in the Berkeley Pit, Butte Mt

Gary Icopini

Montana Bureau of Mines and Geology



Acknowledgements

- Montana Resources and Atlantic Richfield
- DEQ and EPA
- MBMG – Ted Duaine, Nick Tucci, Steve McGrath, ...
- MT Tech – Chris Gammons, Bryce Hill, Drone Boat Crew

Monitoring the Berkeley Pit lake



- Monitored by MBMG
- Over 800 ft deep
- About 50 Billion Gallons
- No outlet (terminal lake)
- Poor water quality – 2012
 - 12 g/L TDS
 - pH 2.5 to 2.7
 - Fe: 200 to 1000 mg/L
 - Zn: 600 mg/L
 - Cu: 70 to 150 mg/L

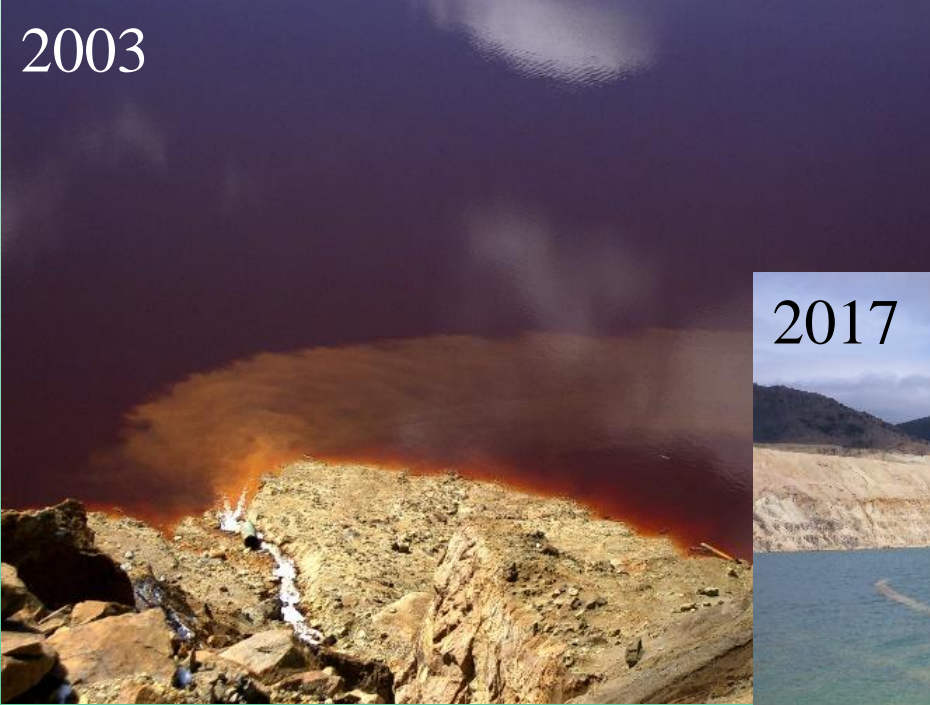




Berkeley Pit Slump – February 2013

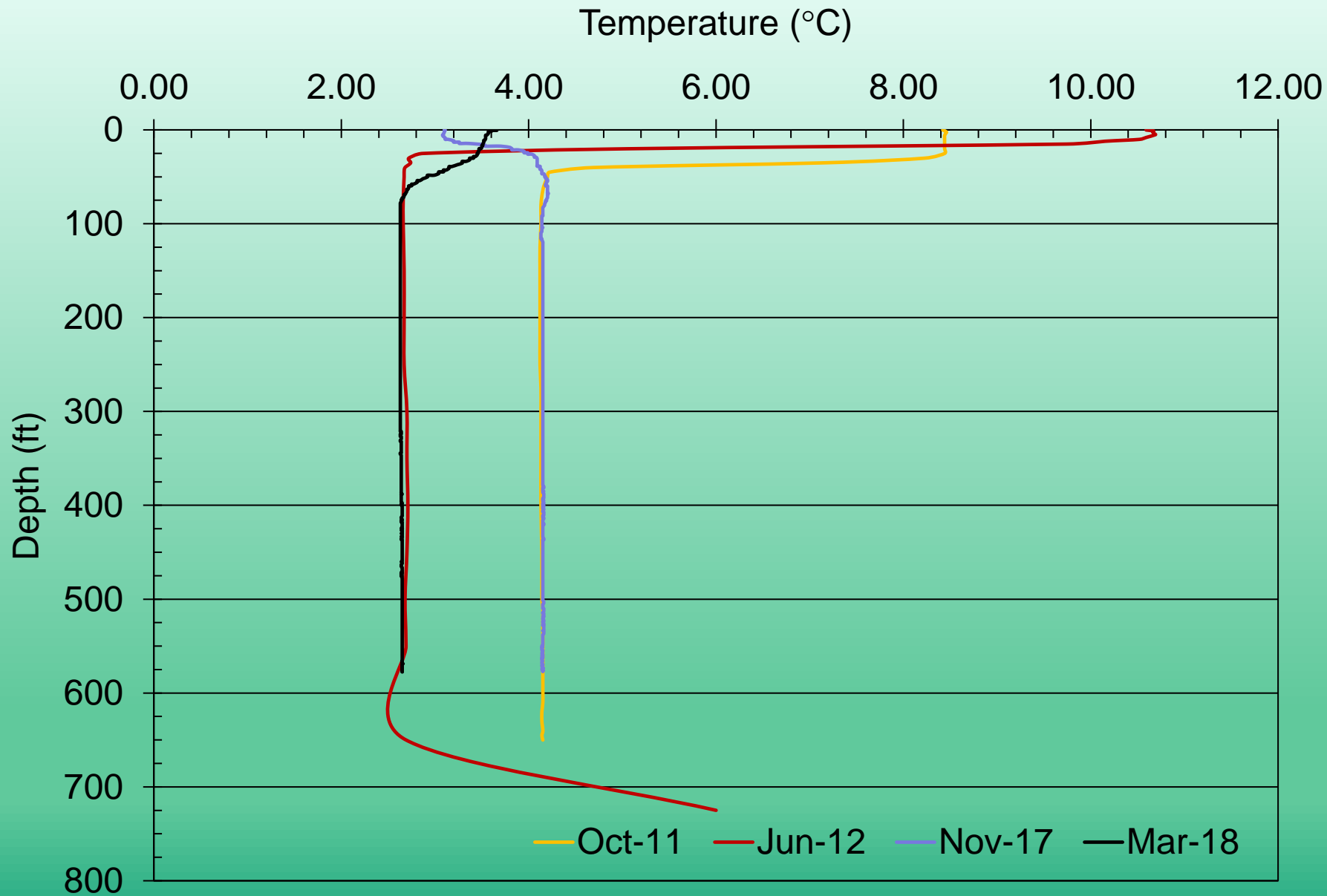
Changes from 2012 to 2017

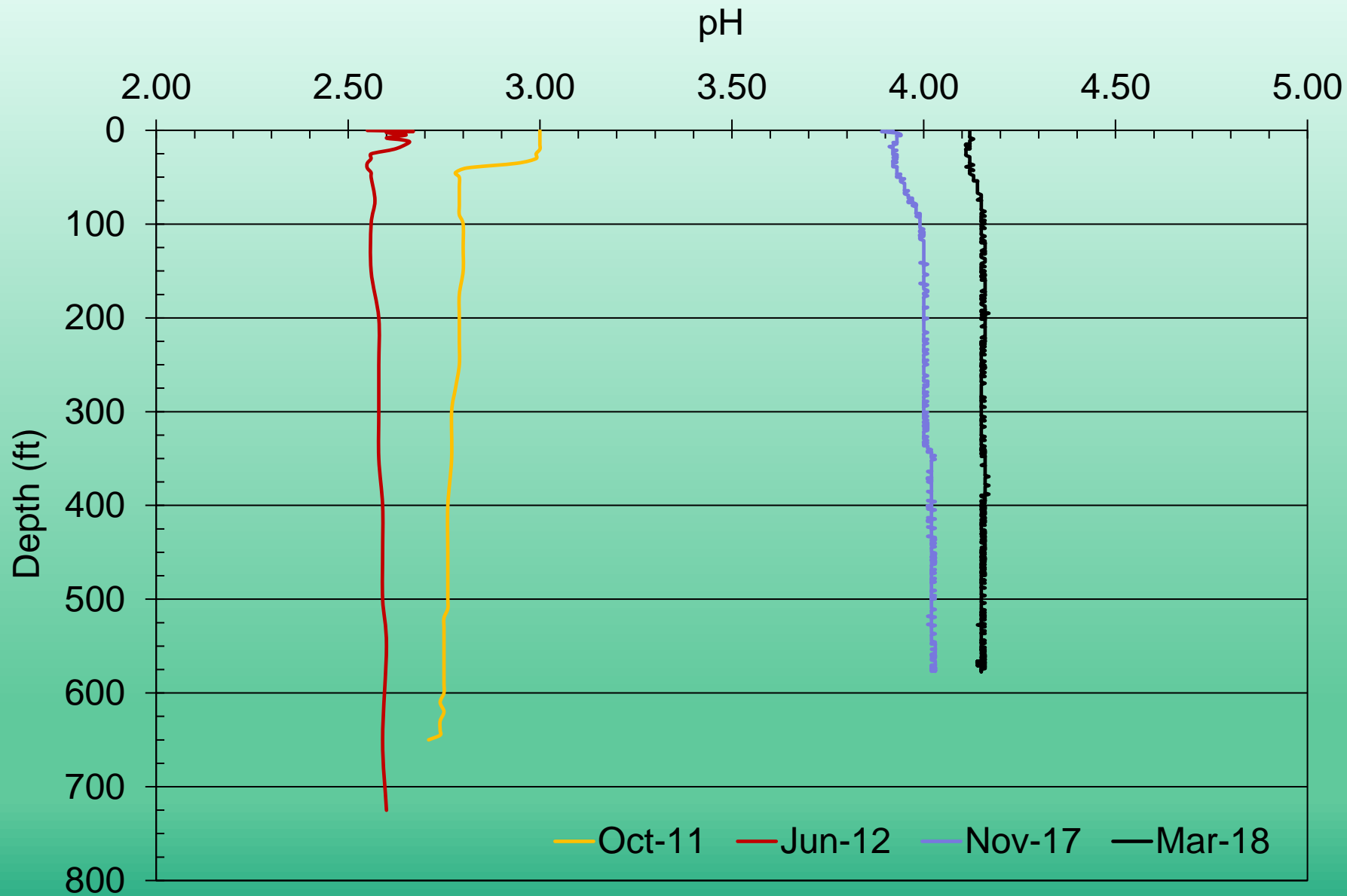
2003



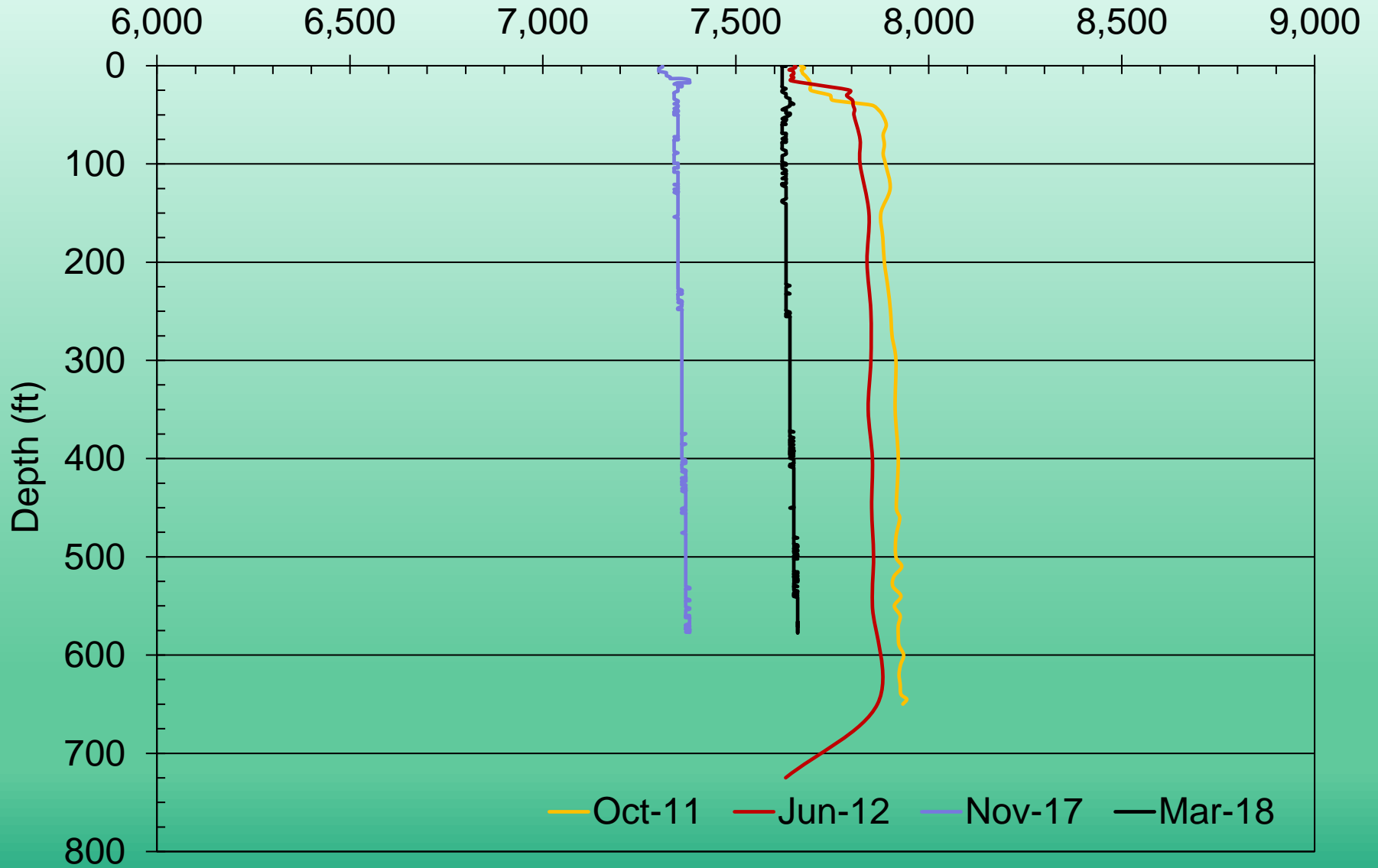
2017



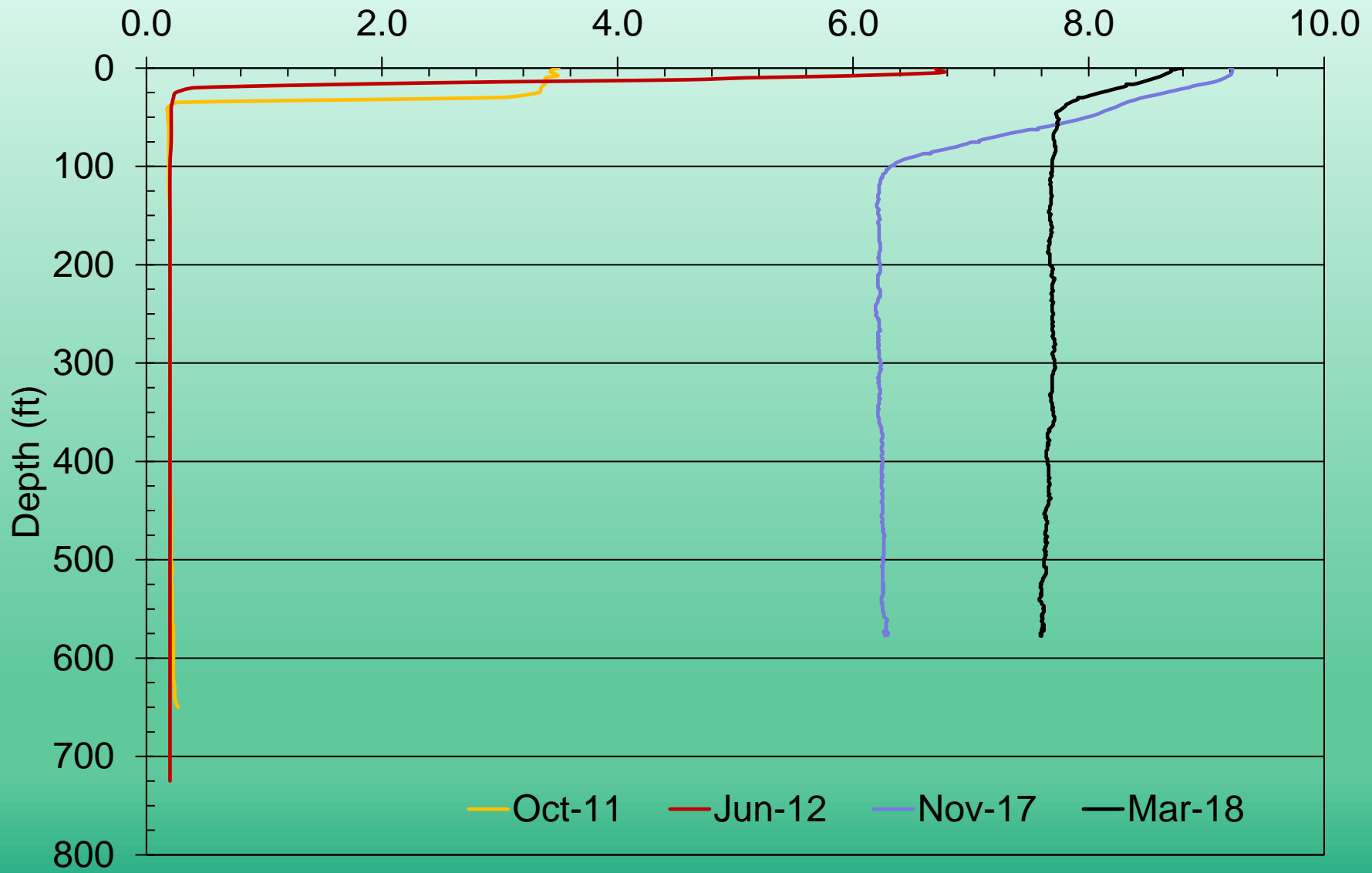




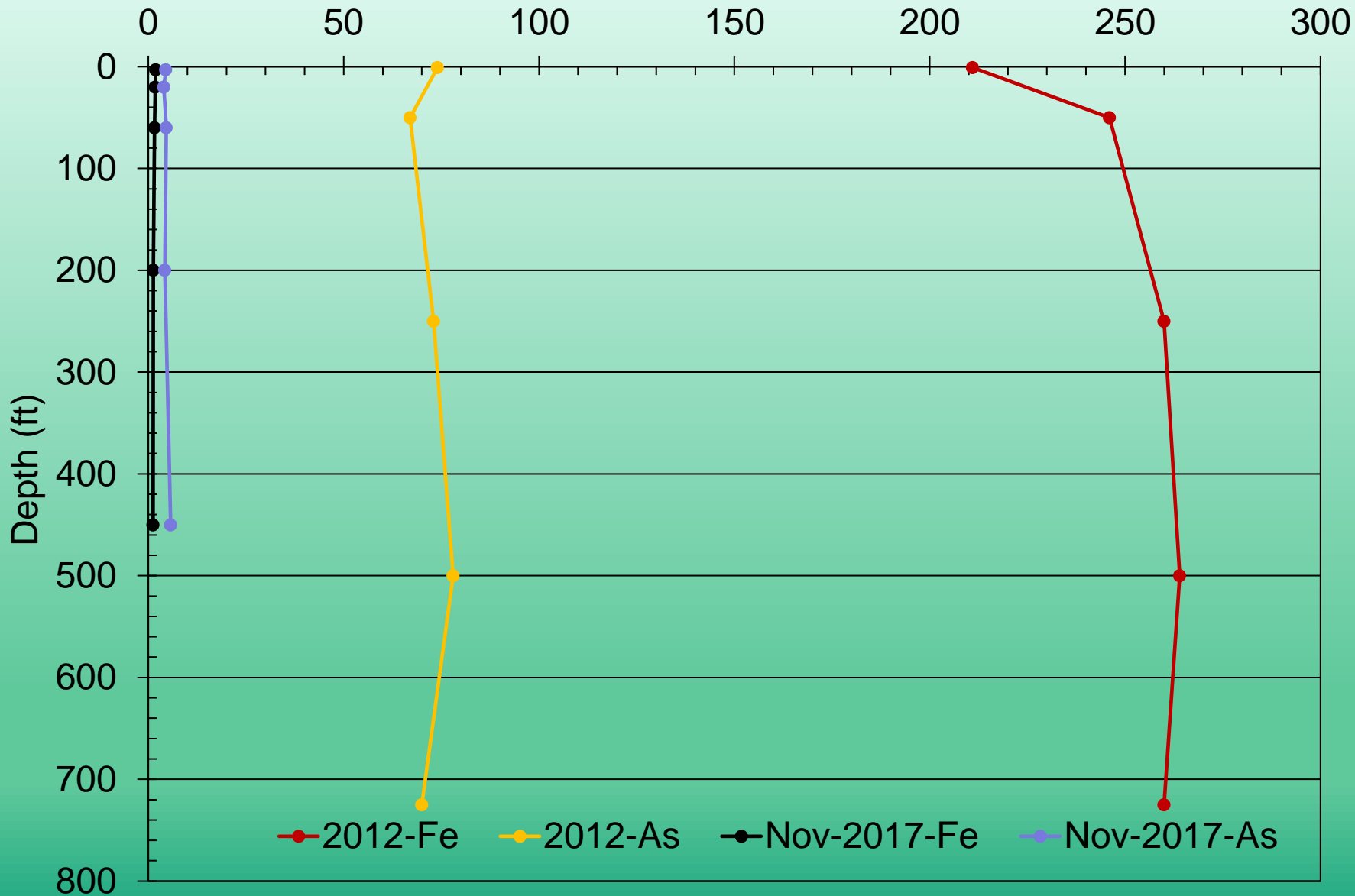
Specific Conductance ($\mu\text{mhos/cm}$)



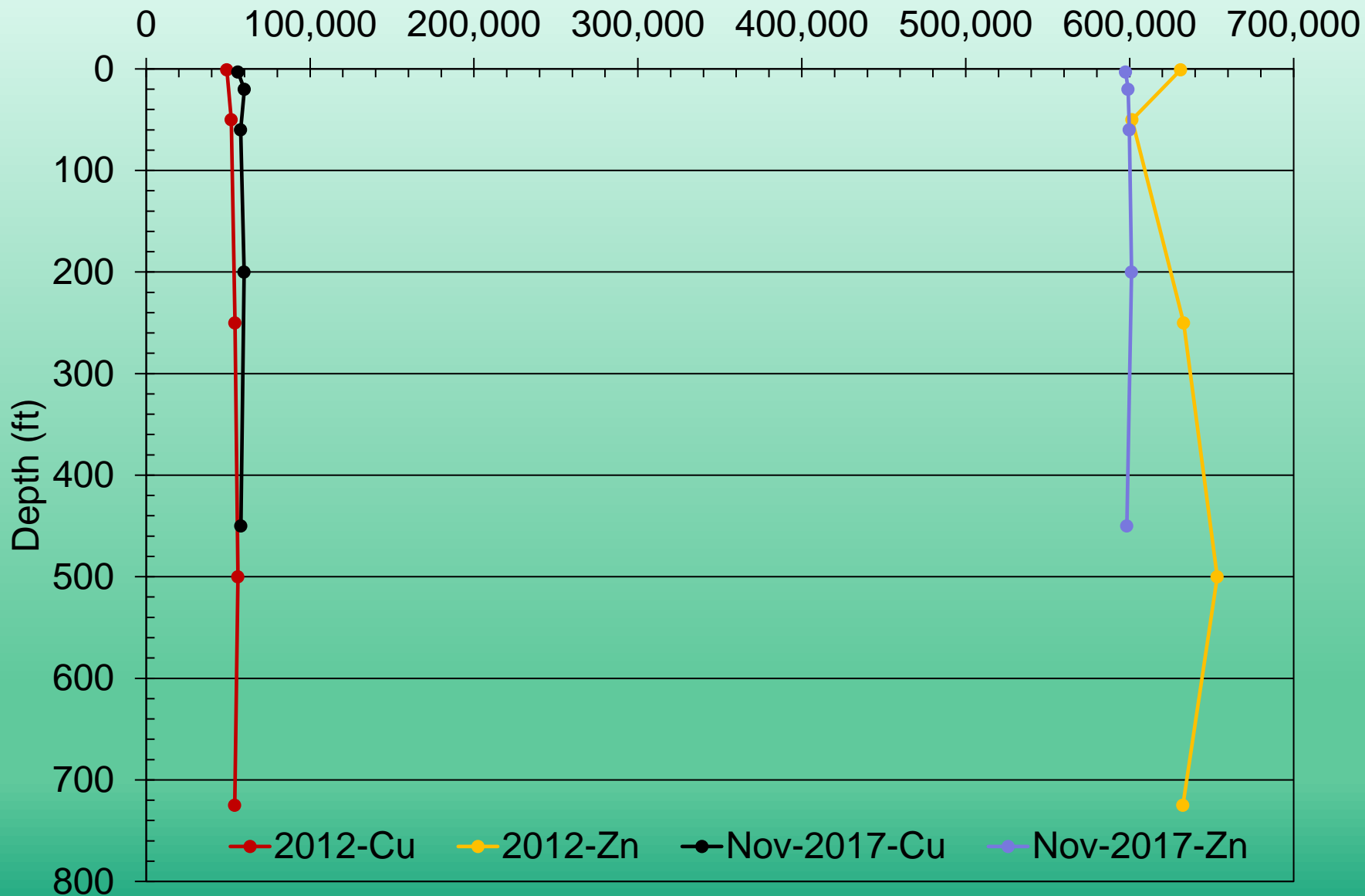
Dissolved Oxygen (mg/L)



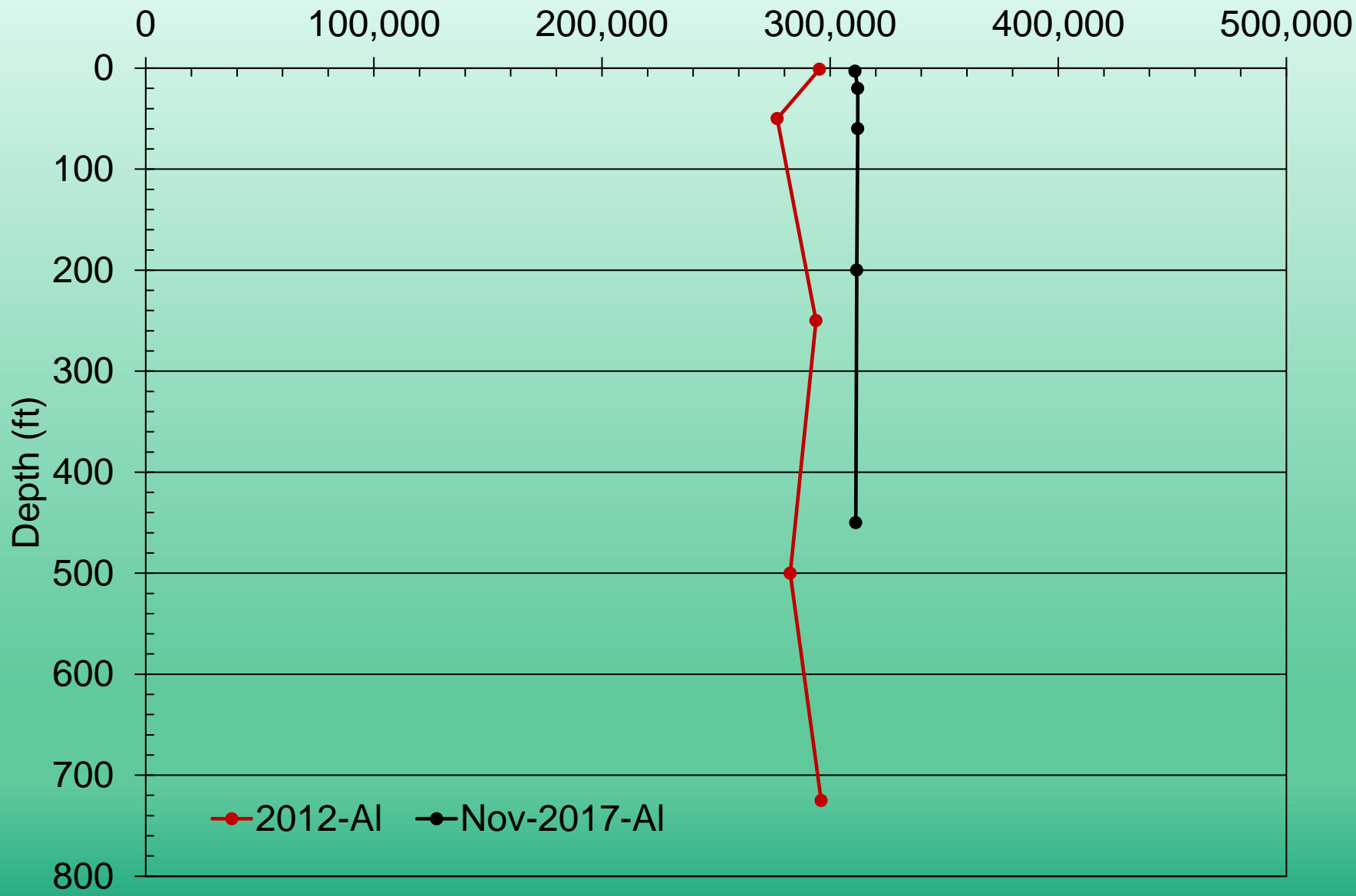
Concentration Fe (mg/L) and As ($\mu\text{g/L}$)



Cu and Zn Concentration ($\mu\text{g/L}$)



Al Concentration ($\mu\text{g/L}$)



Possible Causes

- Copper Recovery – Precipitation Plant
- $\text{Cu}^{2+} + \text{scrap Fe} \rightarrow \text{Fe}^{2+} + \text{Cu}$
- Fe oxidation and precipitation of schwertmannite causes a reduction of total acidity
- Tucci and Gammons, 2015
- Pit Cu recovery stopped February 2013 (resumed in 2019)

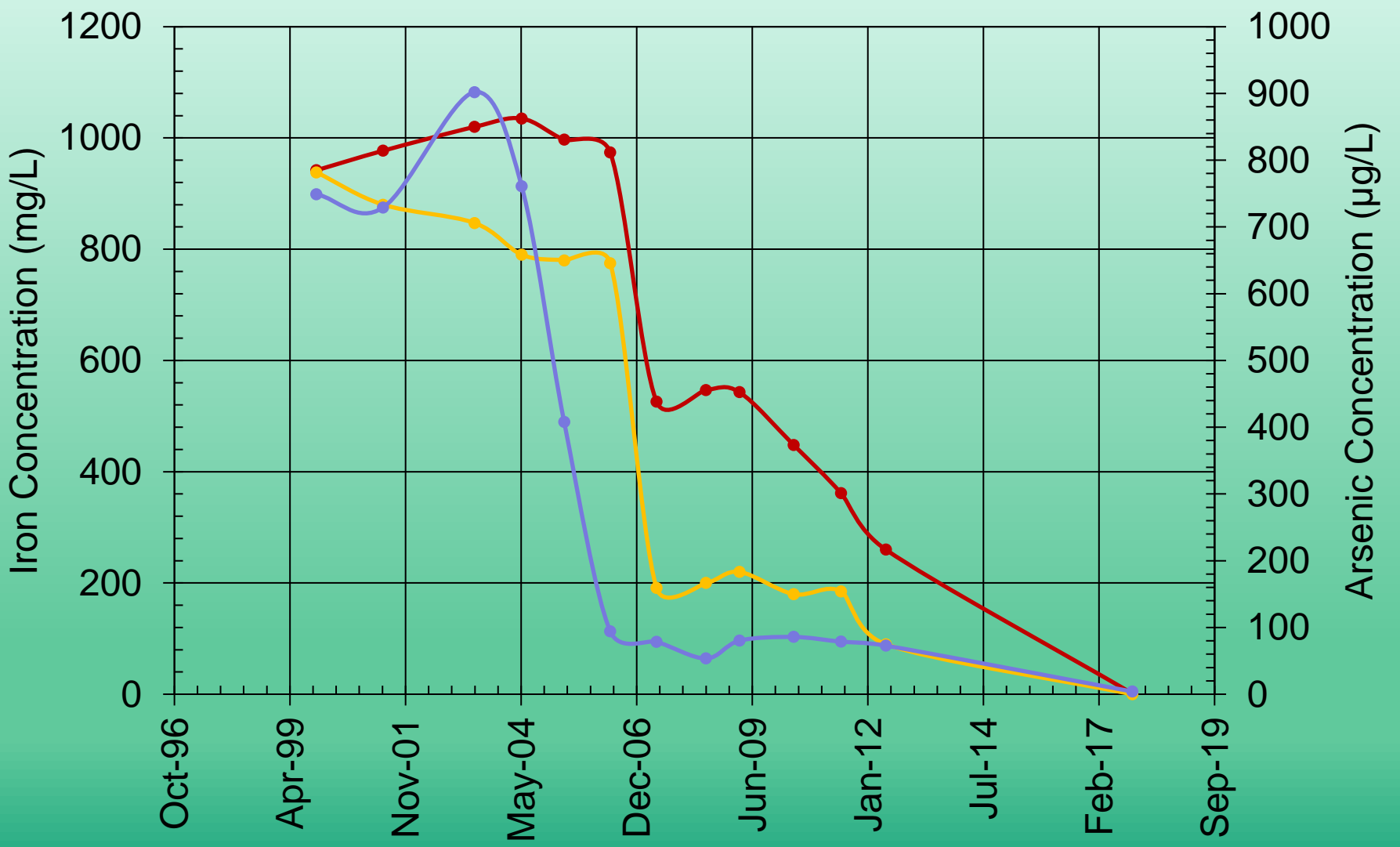


Possible Causes

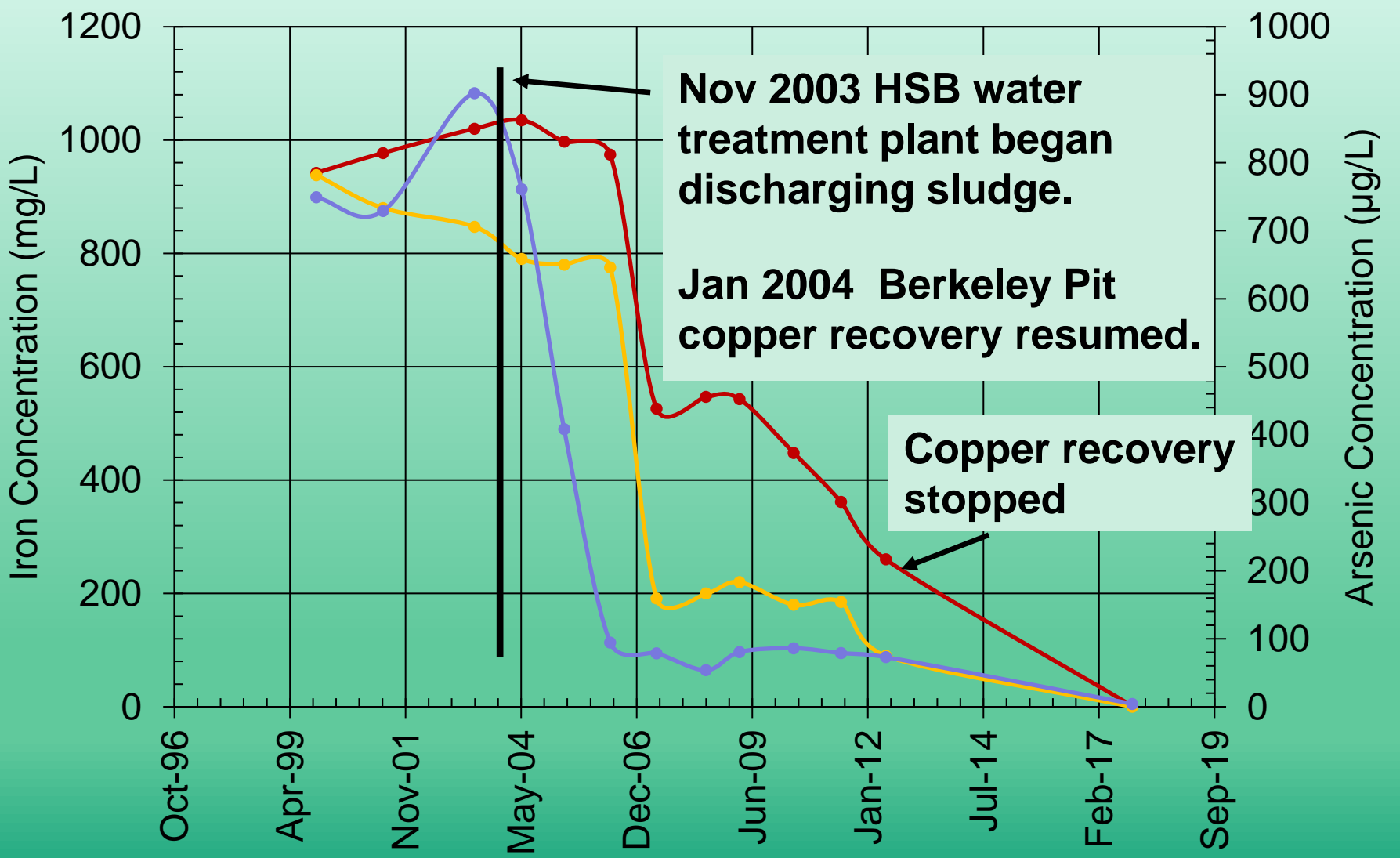
- Horseshoe Bend Treatment Plant Sludge
 - Lime treatment plant
 - Began November 2003
 - Discharges 0.26 MGD of alkaline sludge to the pit
 - Gammons and Icopini, 2019



—●— Total Iron —●— Fe 2+ —●— Arsenic



● Total Iron ● Fe 2+ ● Arsenic

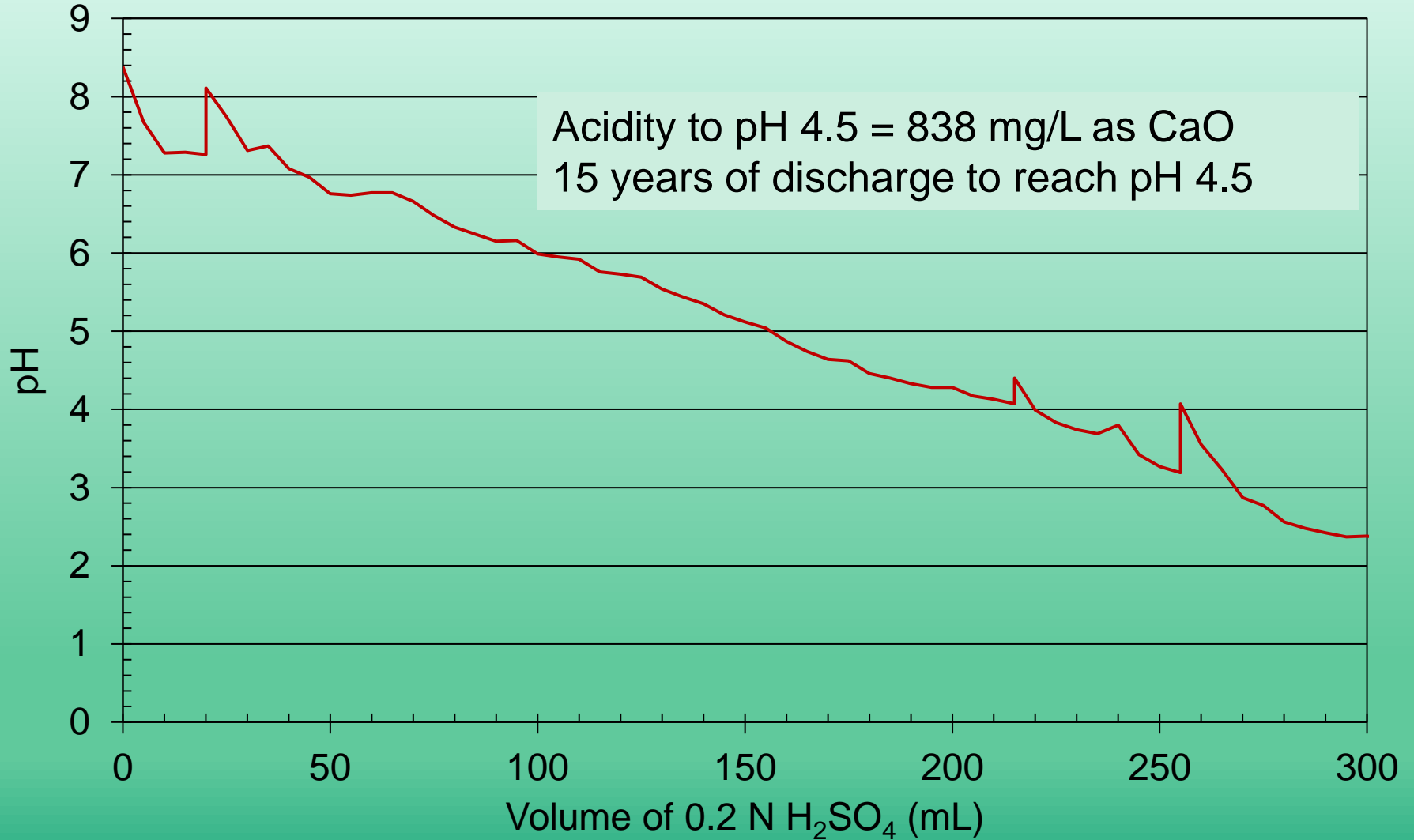


Nov 2003 HSB water treatment plant began discharging sludge.

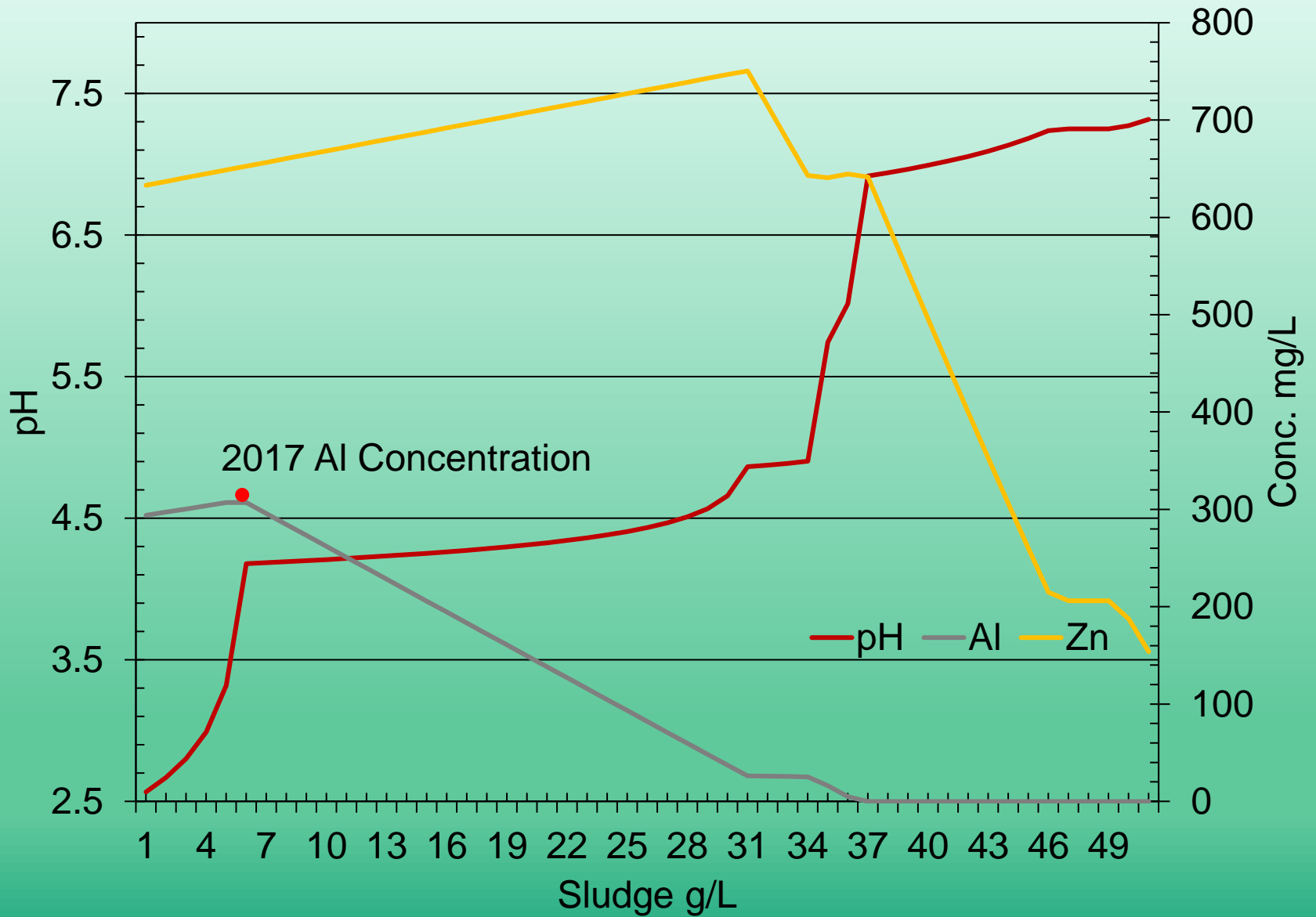
Jan 2004 Berkeley Pit copper recovery resumed.

Copper recovery stopped

Horseshoe Bend Sludge Titration



Theoretical Sludge Addition



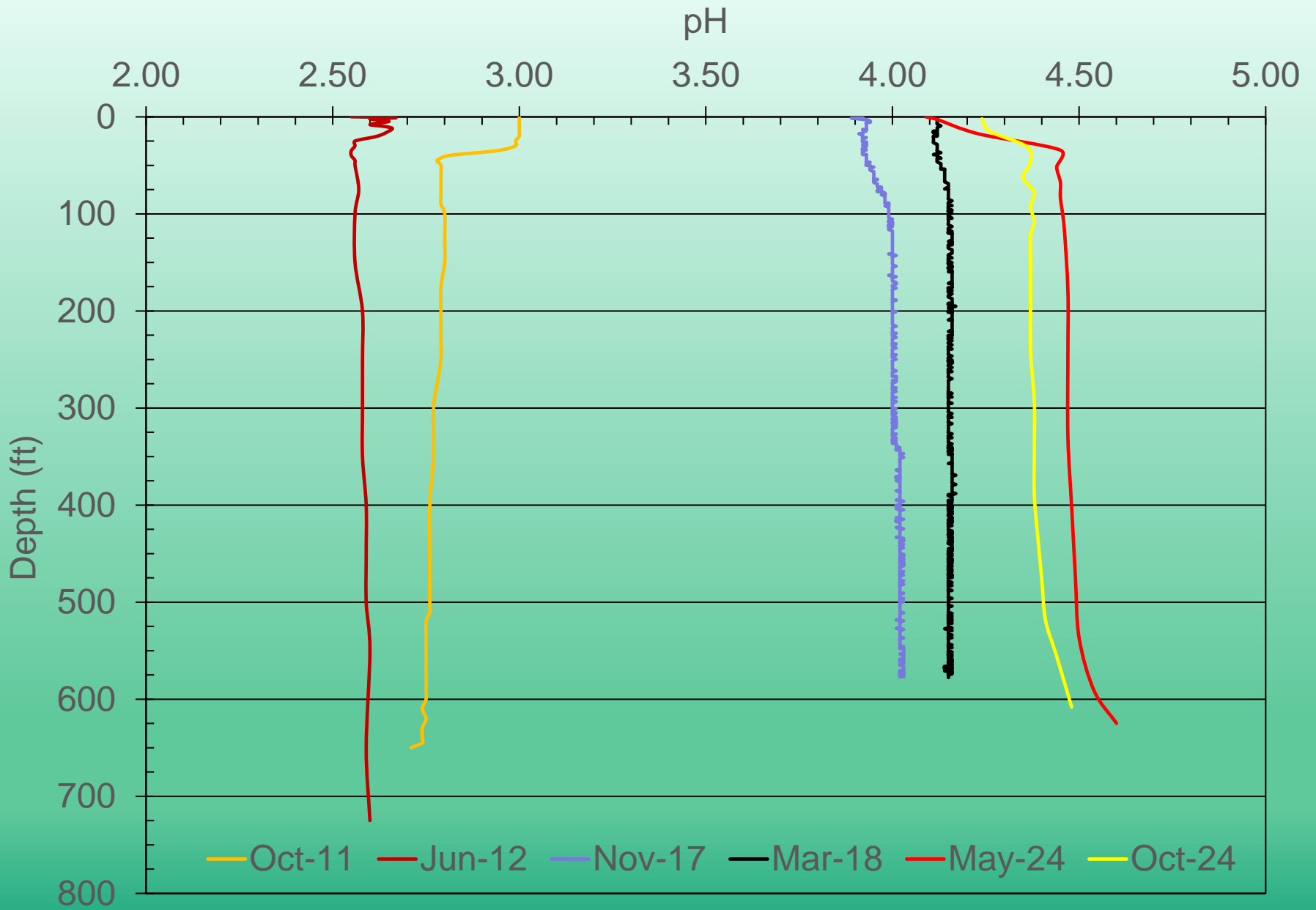
Conclusions

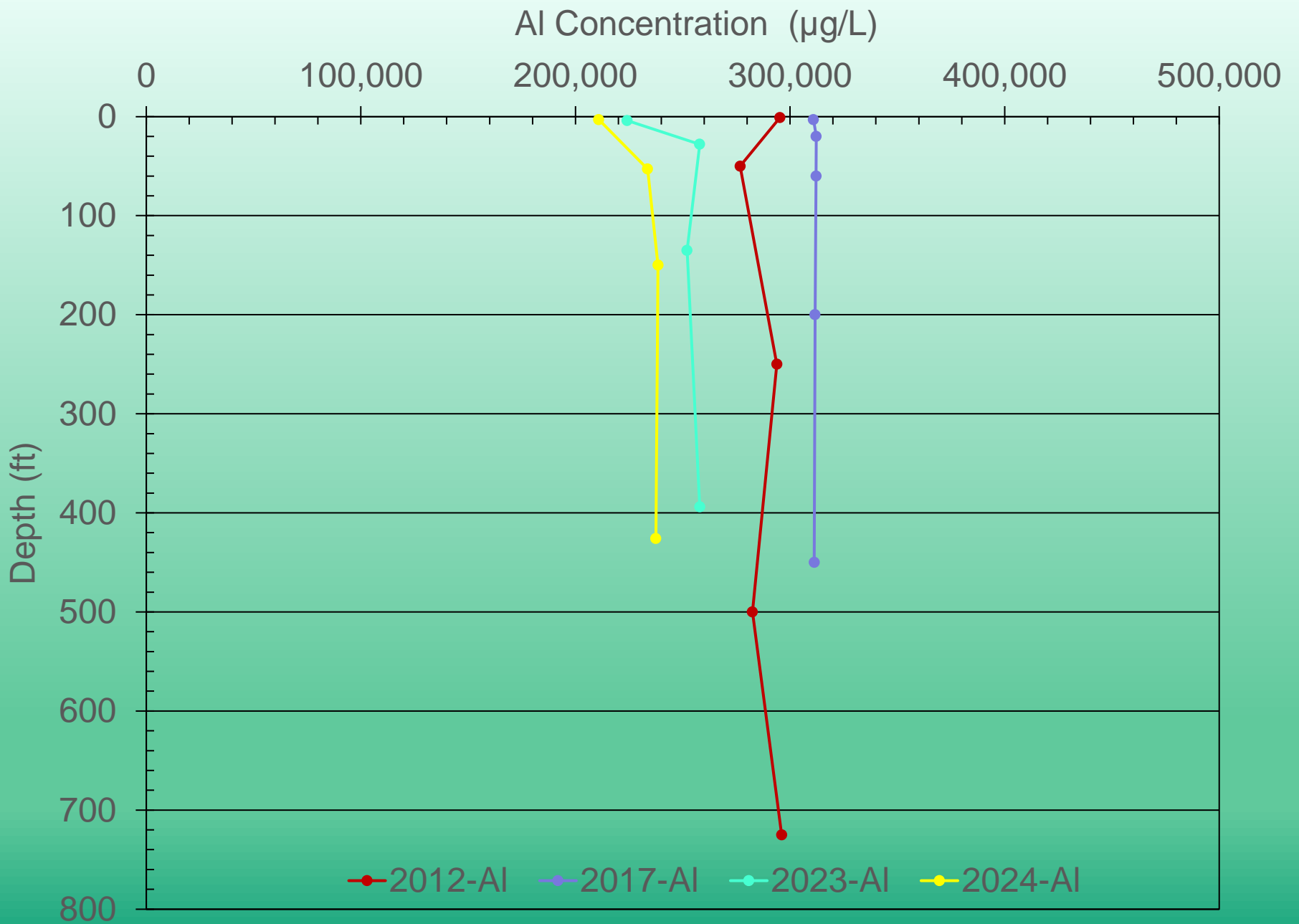
- Turnover appears to be occurring in the pit
 - No stratification except upper 100 ft
- Berkeley Pit water quality has improved since 2012
 - pH increased by 1.5 pH units
 - Fe concentrations decreased two orders of magnitude
 - As concentrations decreased an order of magnitude
 - Al concentrations slightly increased
 - Cu and Zn concentrations were similar to 2012 data
- Sludge discharge appears to be capable of explaining the changes in Berkeley Pit chemistry
 - Gammons and Icopini, 2019

Changes from 2017 to Present

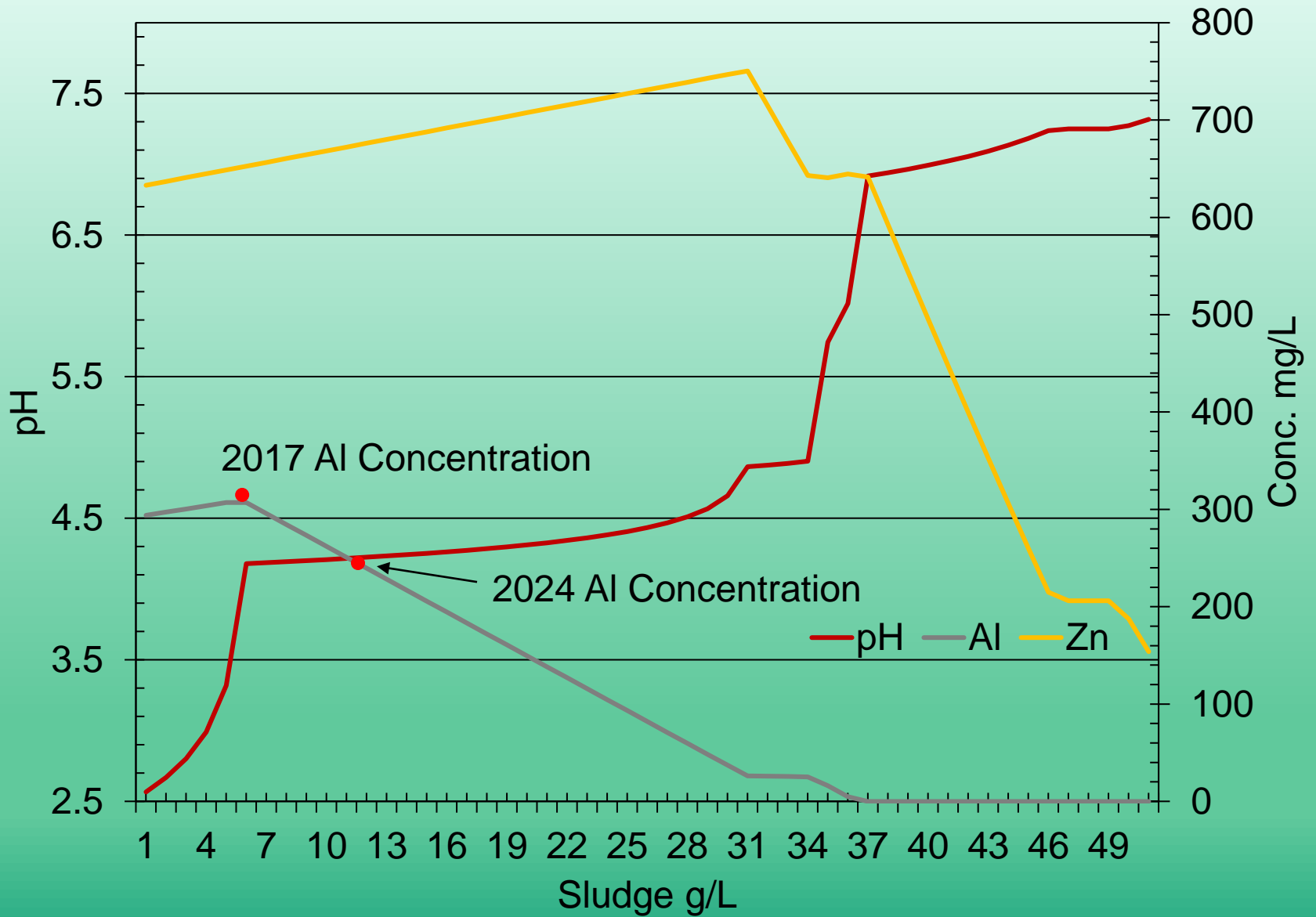
2017







Theoretical Sludge Addition



Conclusions II

- Turnover appears to be continuing to occur in the pit
 - No stratification except upper 100 ft
- Berkeley Pit water quality has changed since 2017
 - pH increased by 0.3 to 0.5 pH units
 - Dissolved oxygen has decreased
 - Al concentrations appear to be decreasing
- Sludge discharge appears to be continuing to cause changes in Berkeley Pit chemistry

Questions

