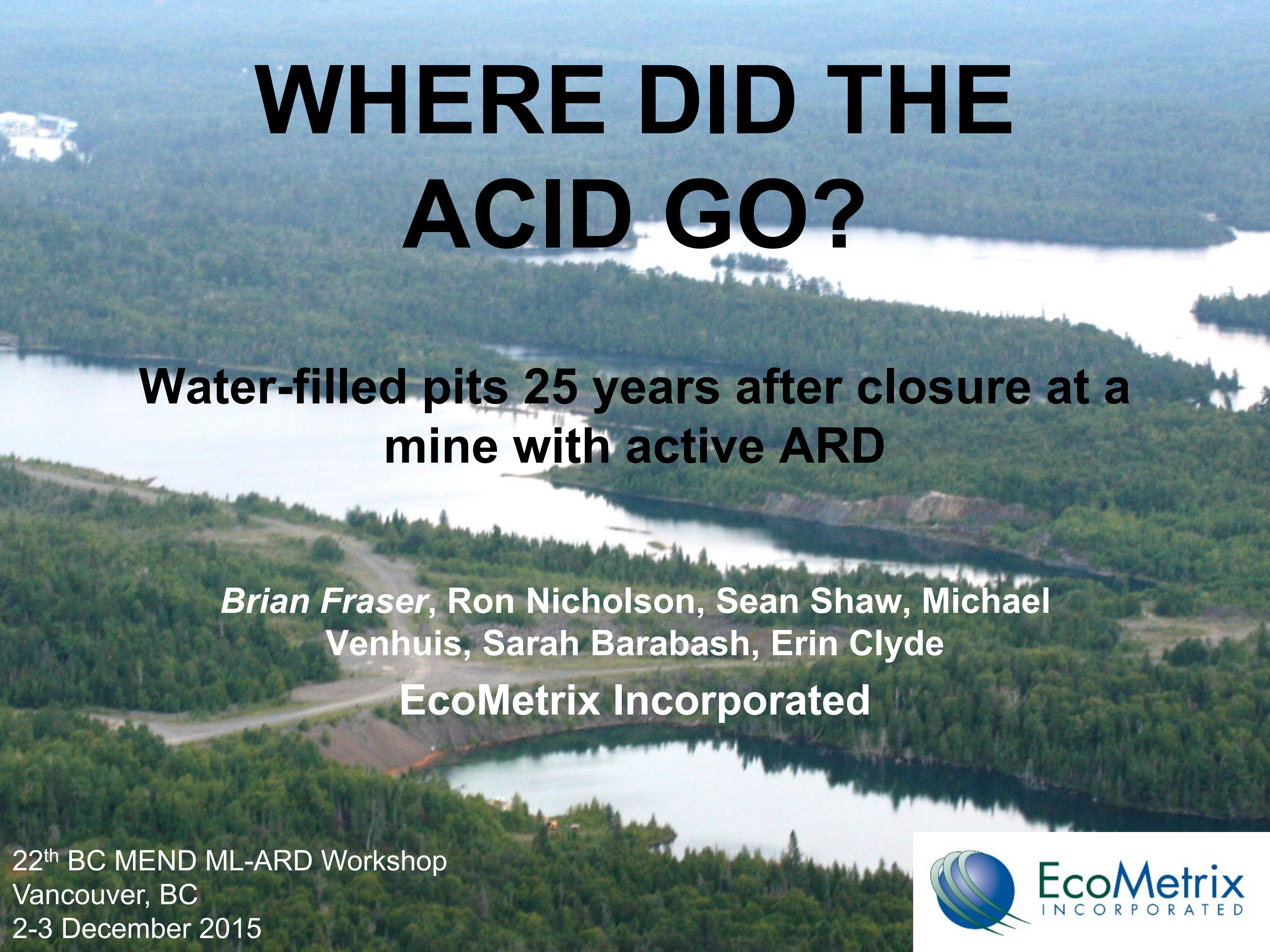

WHERE DID THE ACID GO?

Water-filled pits 25 years after closure at a mine with active ARD

Brian Fraser, Ron Nicholson, Sean Shaw, Michael Venhuis, Sarah Barabash, Erin Clyde

EcoMetrix Incorporated

22th BC MEND ML-ARD Workshop
Vancouver, BC
2-3 December 2015

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Outline

- Site description and history
- Historical and current sources of acid and metal leaching to the open pits
- Water quality in pit waters
  - stratification
  - temporal trends
  - future prognosis
- Effects on the downstream receiving environment

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Site Description and History

- Iron mine at Temagami (ON)
- Iron pellets used at Dofasco's Hamilton steel-making operations
- Five open pits
- Closed in 1990
- Open pits filled with water prior to 1995

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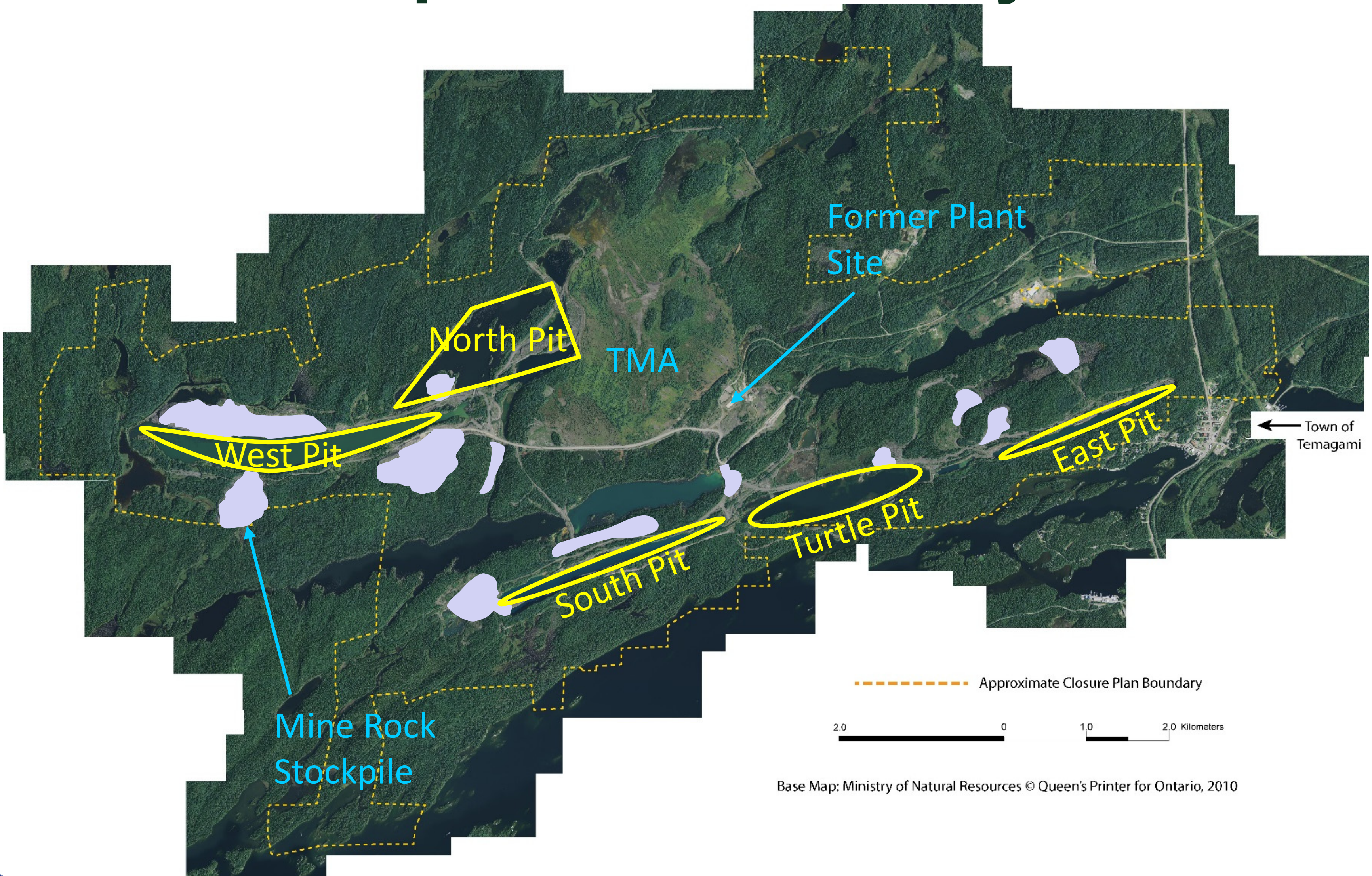
Site Description and History



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Sources of Acid and Metal Leaching to the Open Pits

- Historical sources
  - Sulphide bearing rock in pit walls and rubble in pits
  - Mine rock stored on surface largely Non-PAG, with isolated pockets (relatively low volume) of PAG material

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Sources of Acid and Metal Leaching to the Open Pits

- Current sources
  - Limited to isolated pockets (relatively low volume) of PAG material
  - Inputs from primary sulphide bearing source materials mitigated
    - Pit walls – sulphide zones blasted and relocated to pit floor
    - Rubble – became inactive from ARD perspective when open pits flooded

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Sources of Acid and Metal Leaching to the Open Pits

Summary

- Source acid and metals largely related to operational phase of mining
- ARD/ML engine turned off when pits filled
- Current source inputs are minor and of relatively good quality
- Legacy water quality issues isolated at the bottom of the flooded pits

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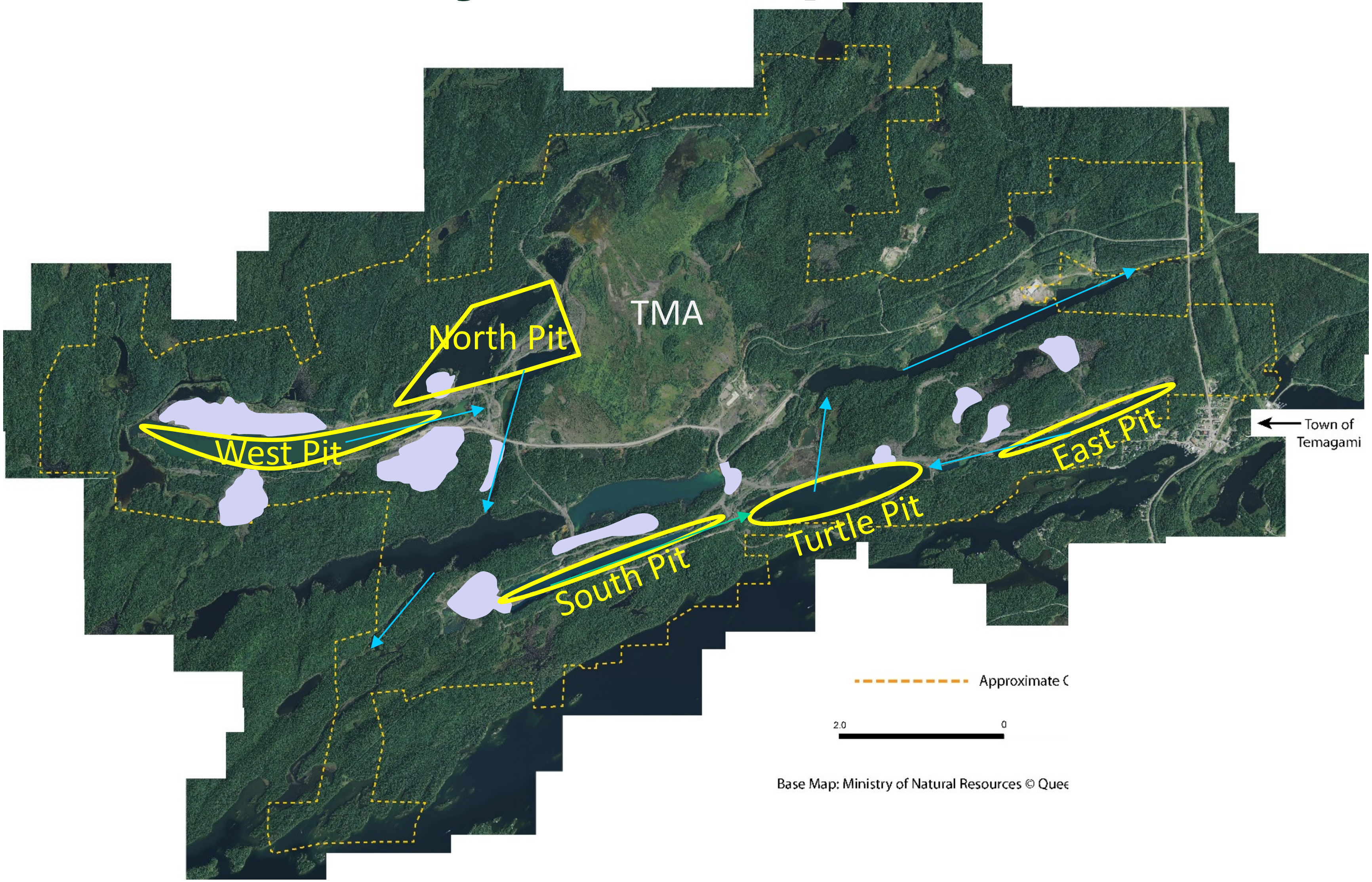
Water Quality in the Open Pits



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Water Quality in the Open Pits

- Acidic waters in the South and West Pits when filling after closure

- Chemical signature of ARD developed and most conspicuous in South Pit, especially in bottom water
  - pH – 3.5 to 4.5 throughout
  - low alkalinity (< 0.1 mg/L as $CaC0_3$) and high acidity (200 to 300 mg/L as $CaCO_3$)
  - Iron up to 300 mg/L

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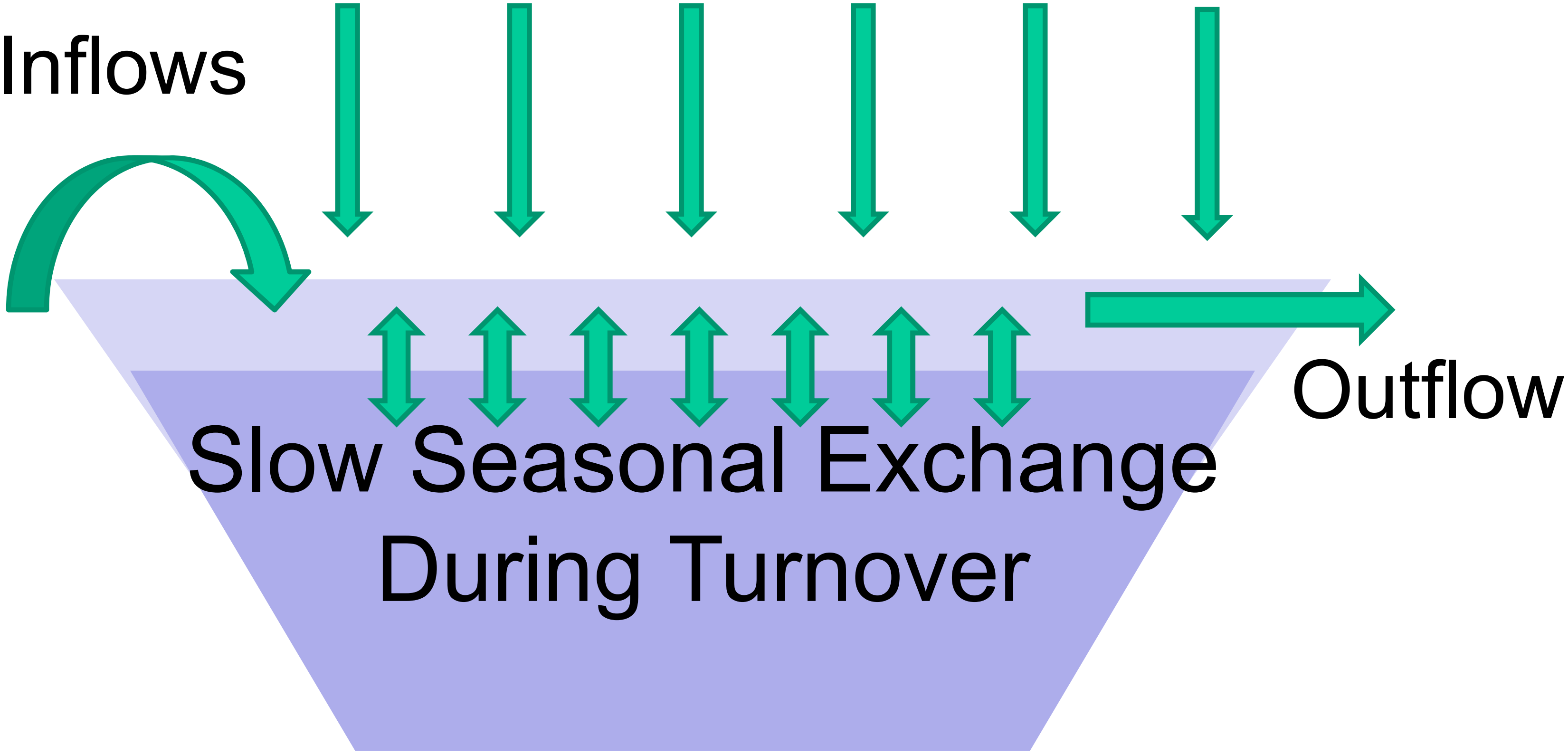
Water Quality in the Open Pits



Residence time of upper layer is decades and results in slow decline in concentrations over time

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Water Quality in the Open Pits

- <u>Stratification</u>
  - Four the of five pits have become strongly stratified because of density differences
  - Water below ~ 15 to 20 m is isolated from the upper layer
  - Water quality in the bottom layer
    - characterized by high TDS and lower pH
    - higher iron (ferrous) concentrations
    - stable chemistry over time
    - legacy of operations and early pit filling

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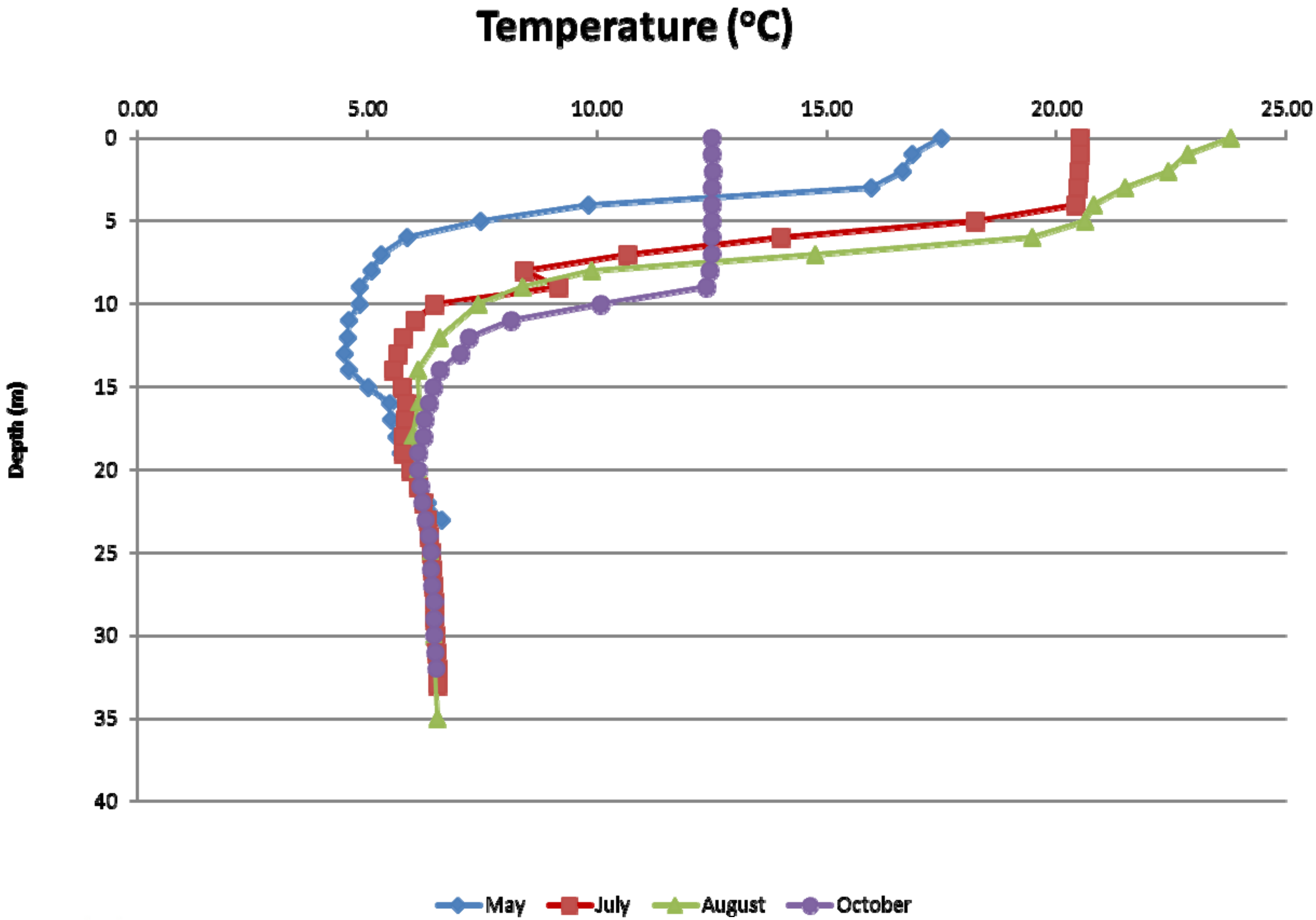
Water Quality in the Open Pits



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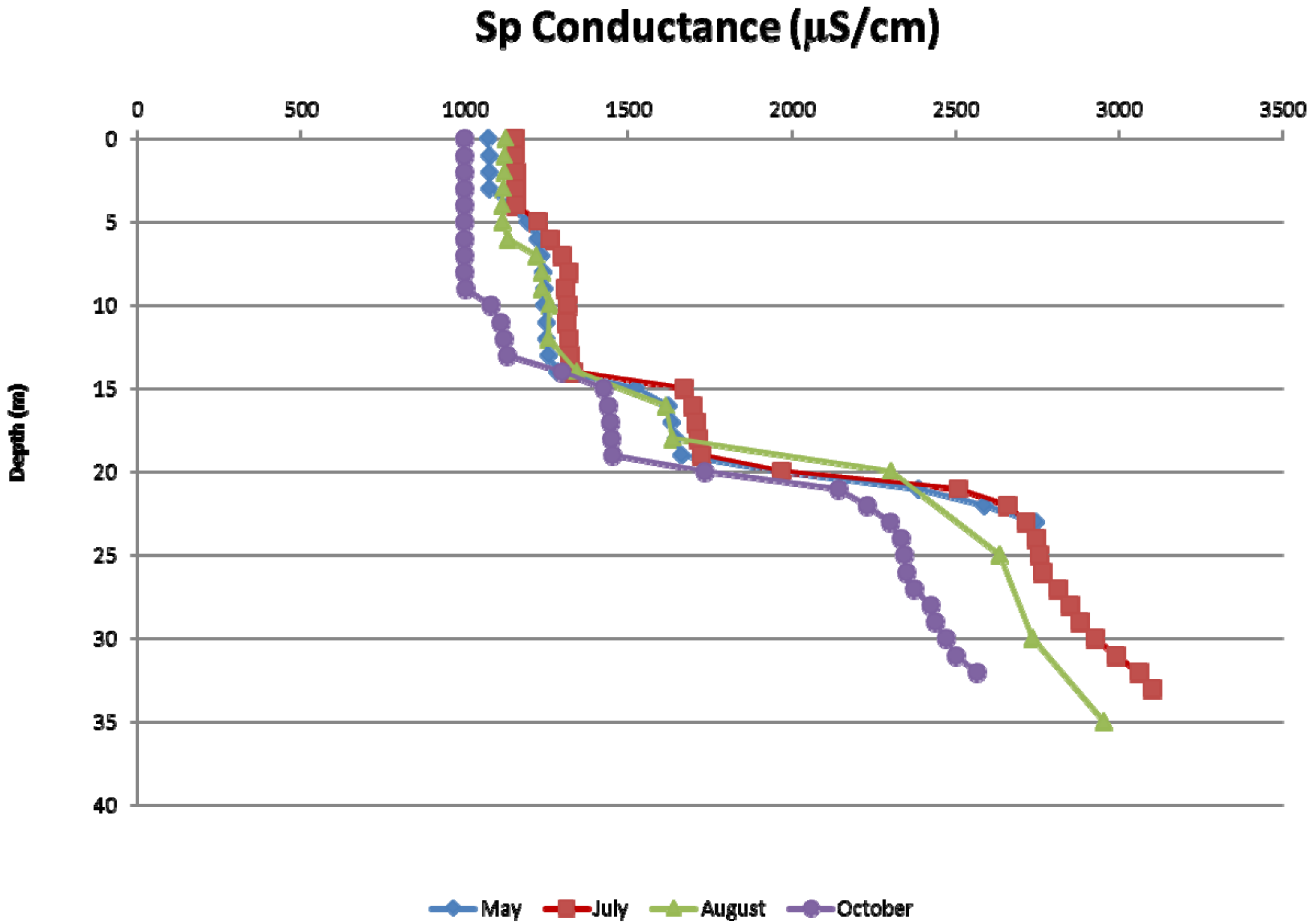

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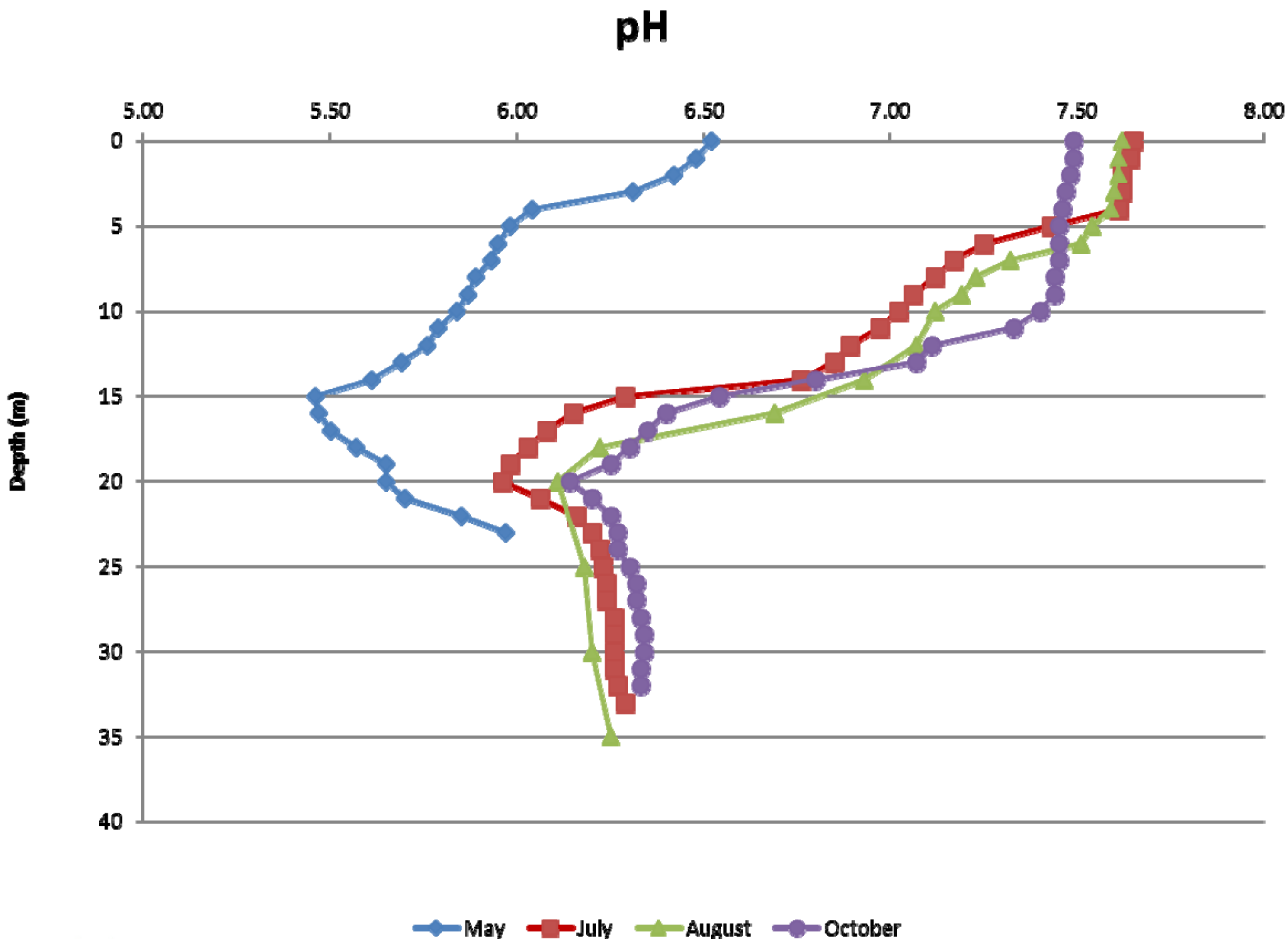

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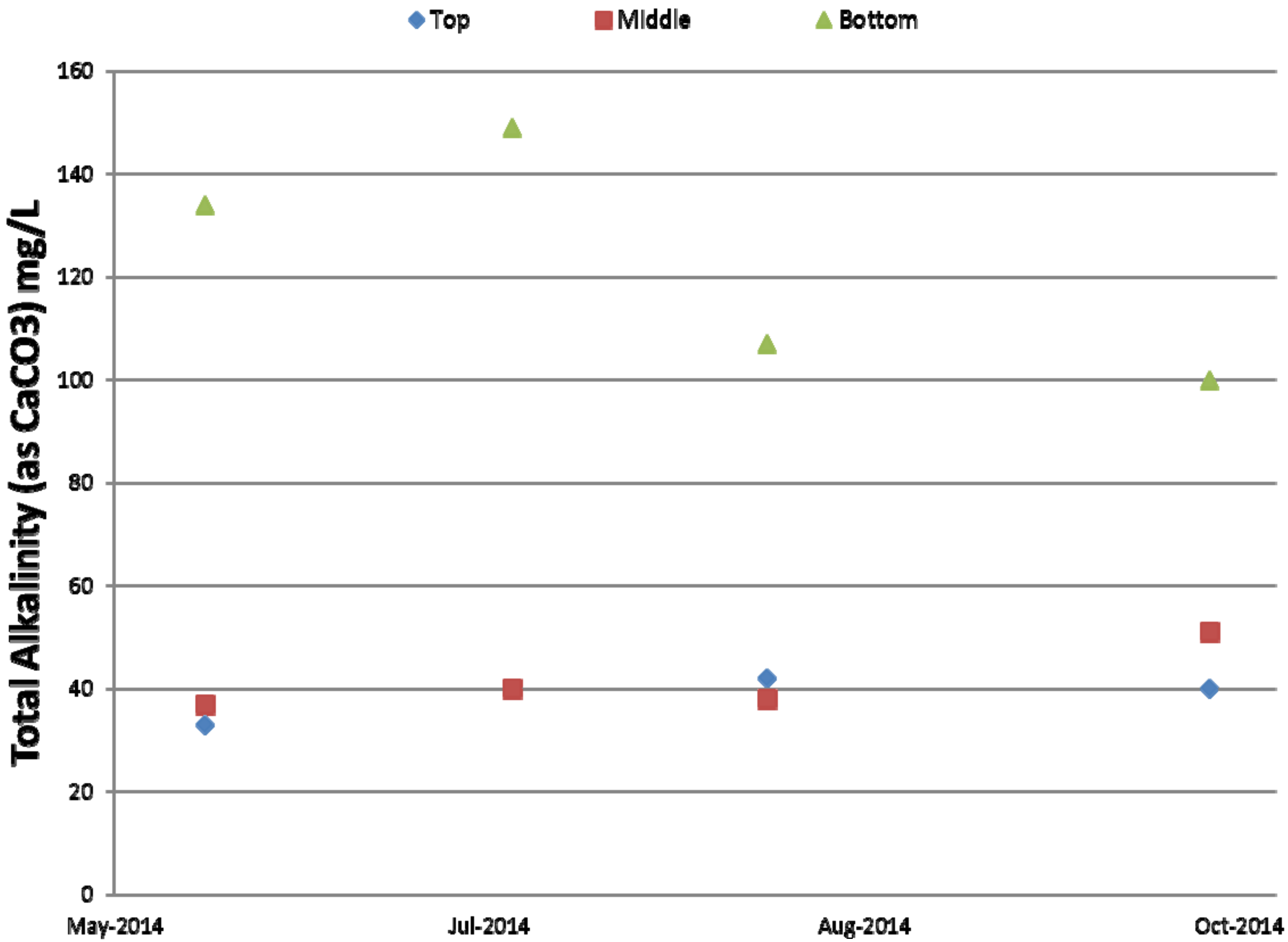

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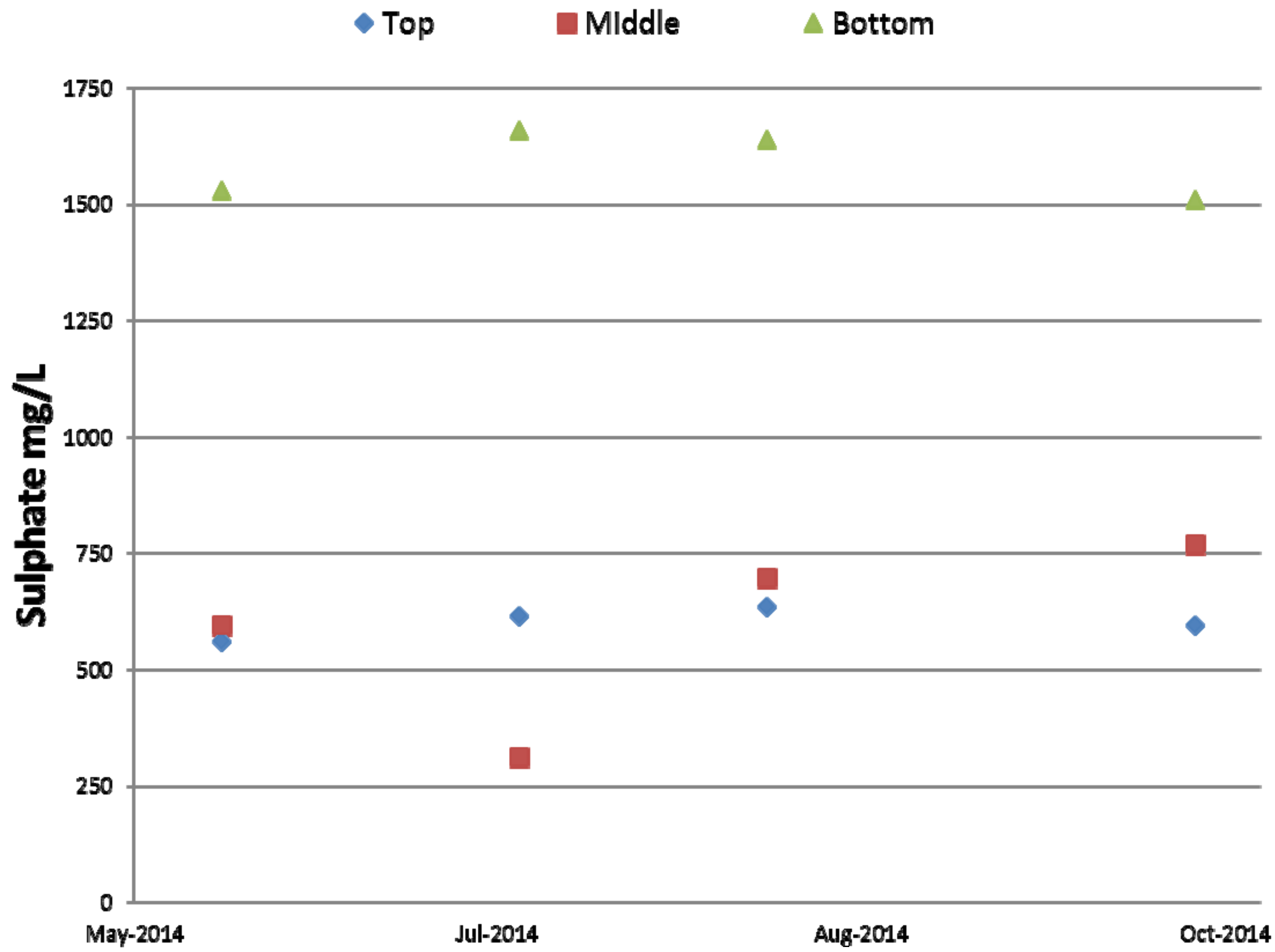

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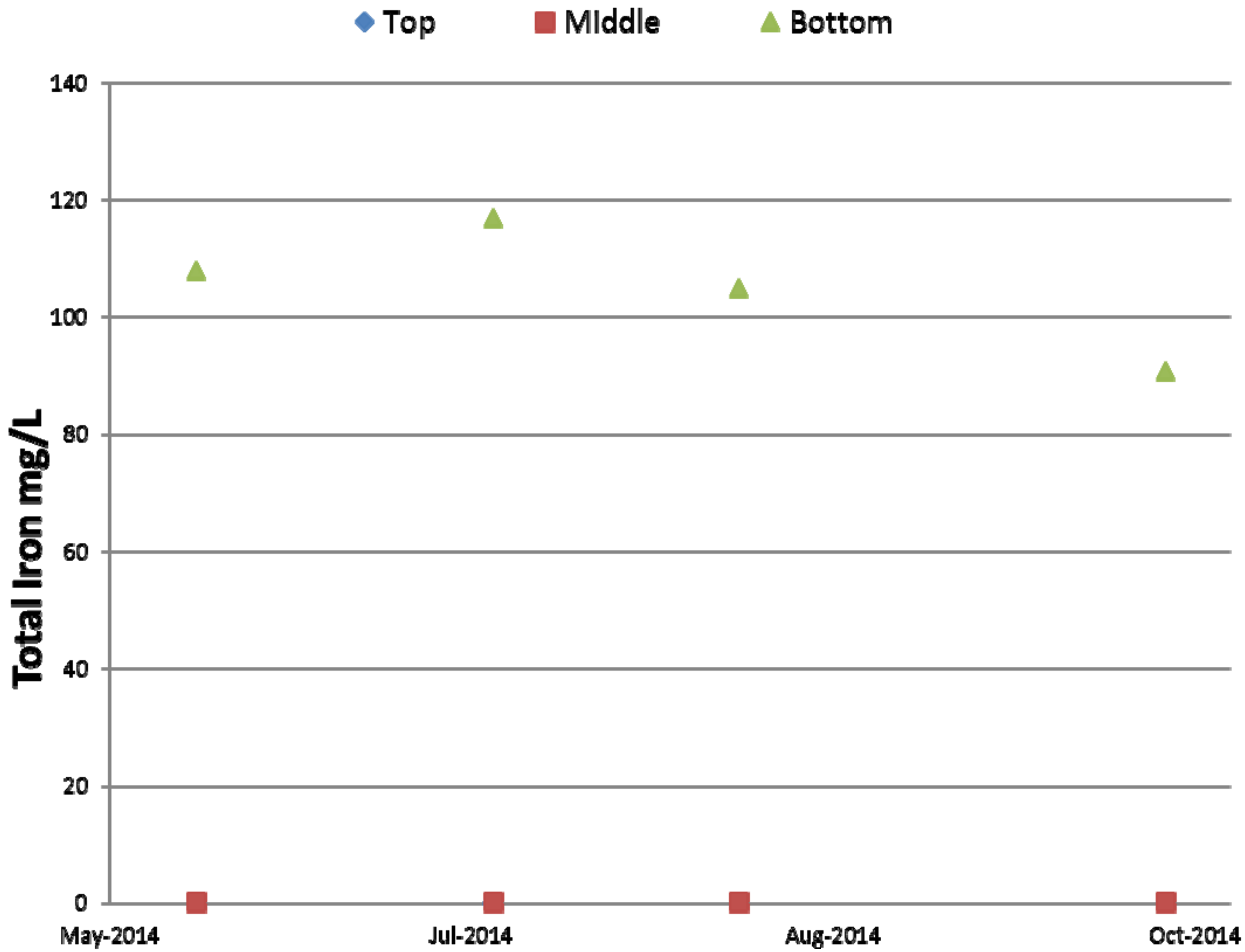

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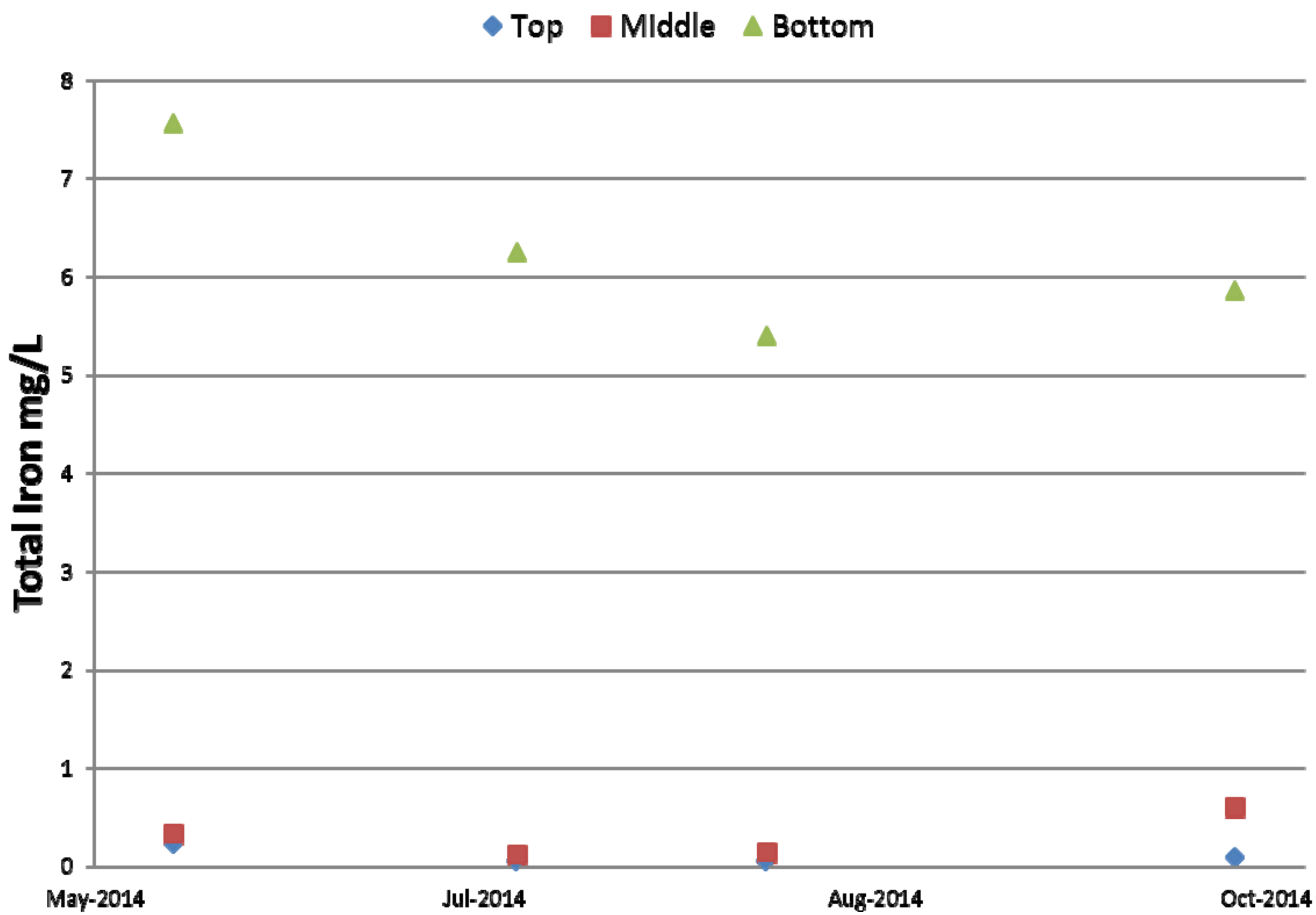

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Water Quality in the Open Pits

- Temporal trends
  - Slow and steady improvement in both surface and bottom waters
  - Water quality at or approaching water quality objectives in the surface layer
  - Open pits have small watersheds and relatively long residence times

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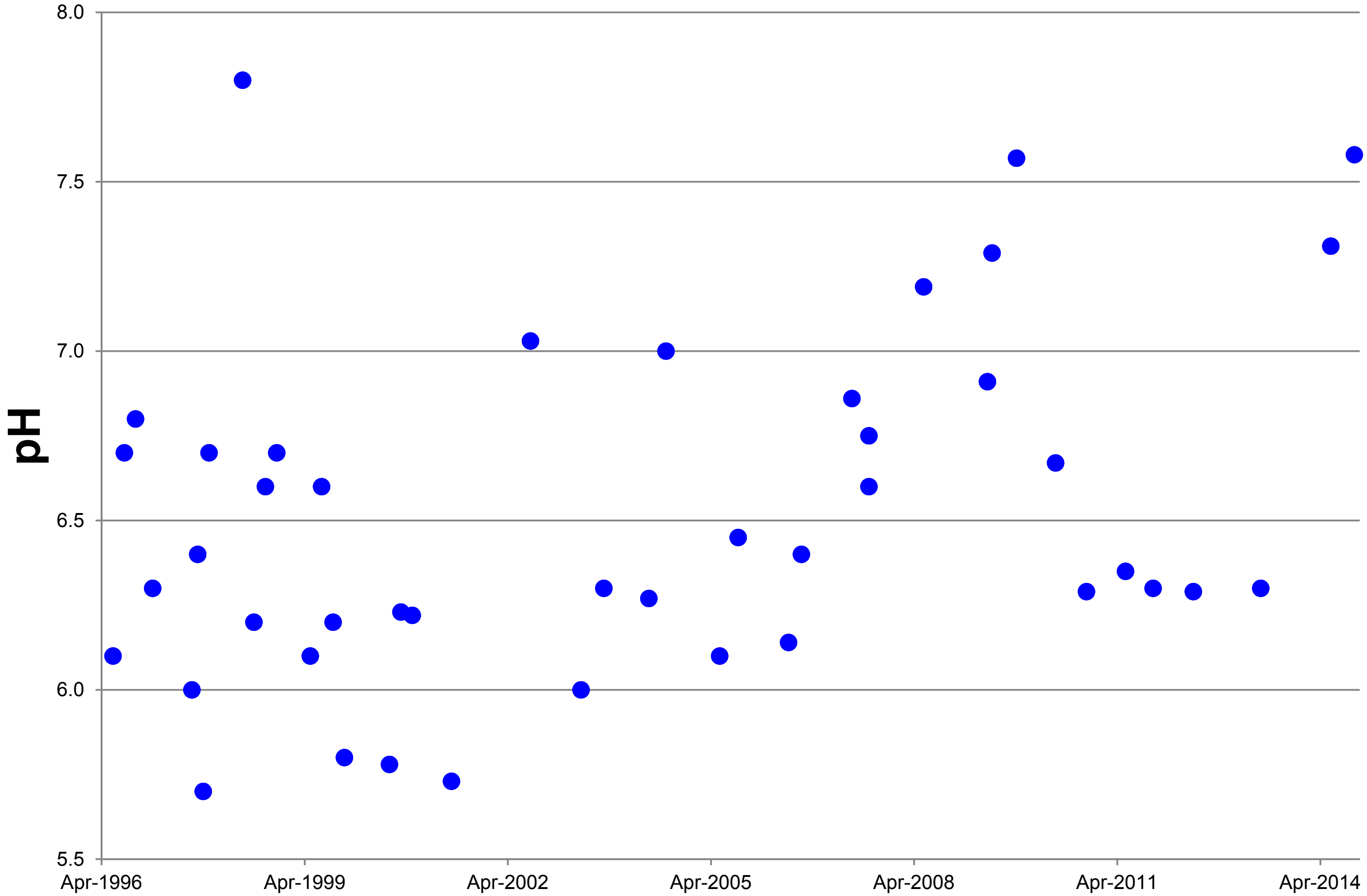
Water Quality in the Open Pits



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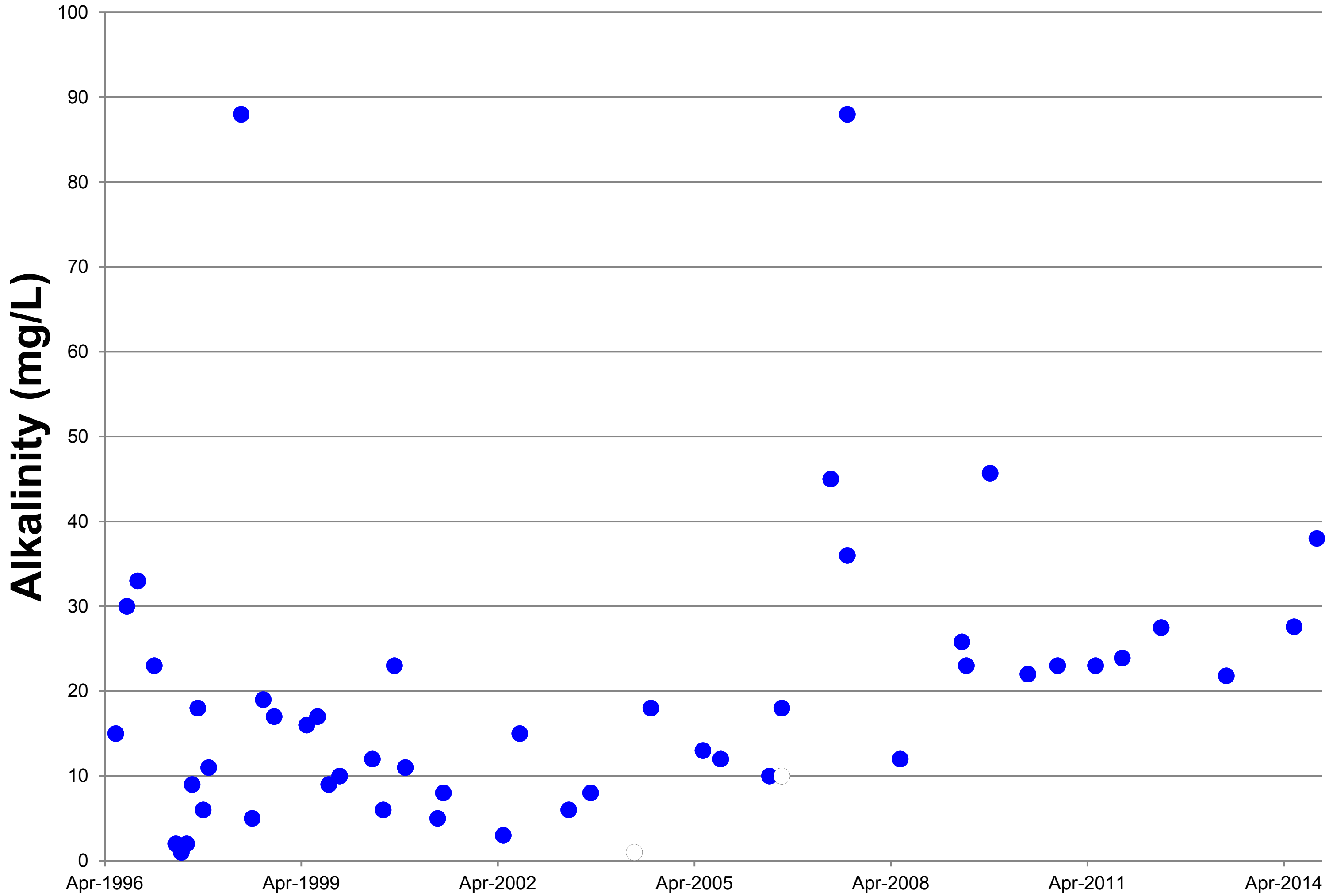

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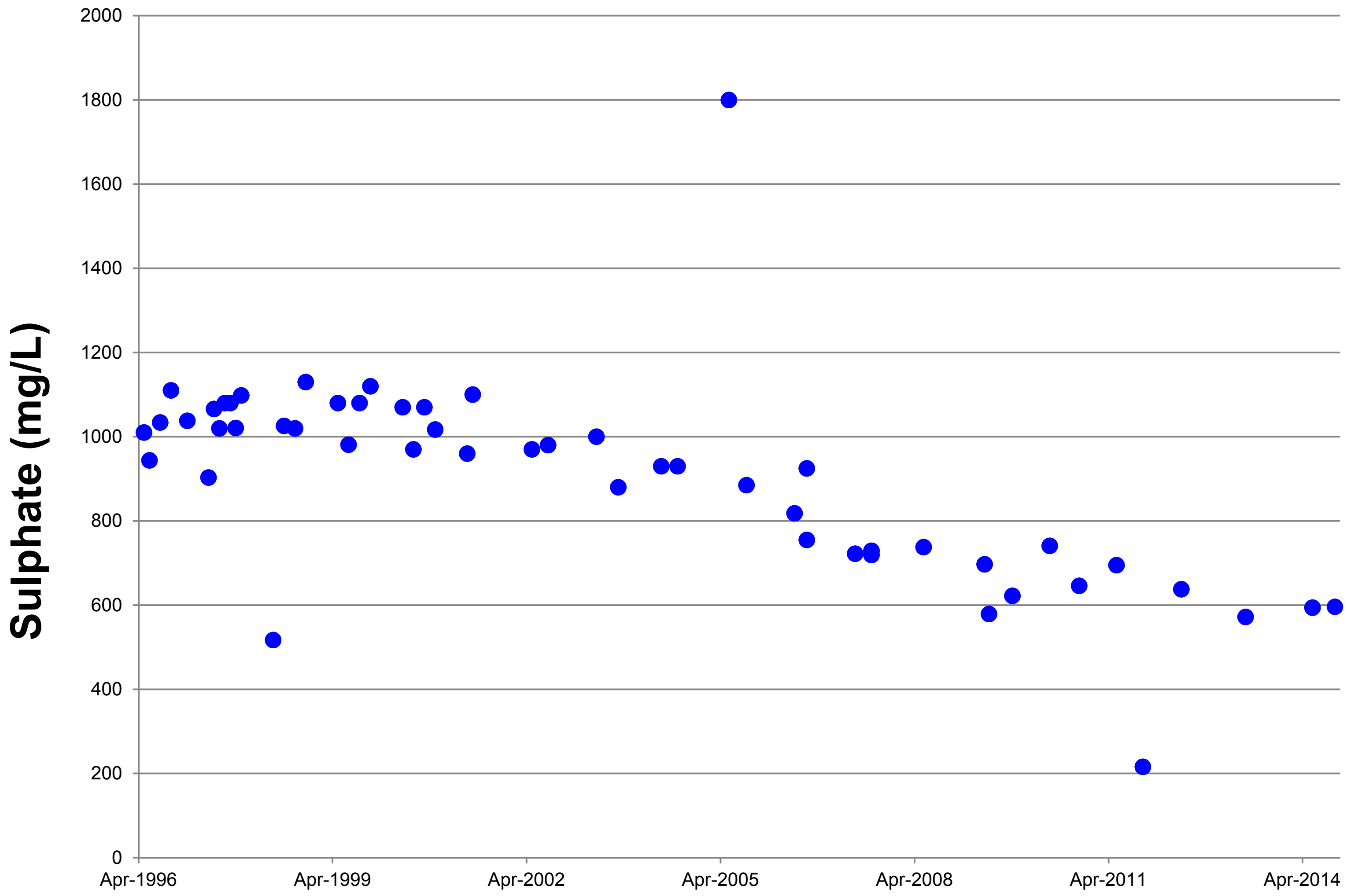

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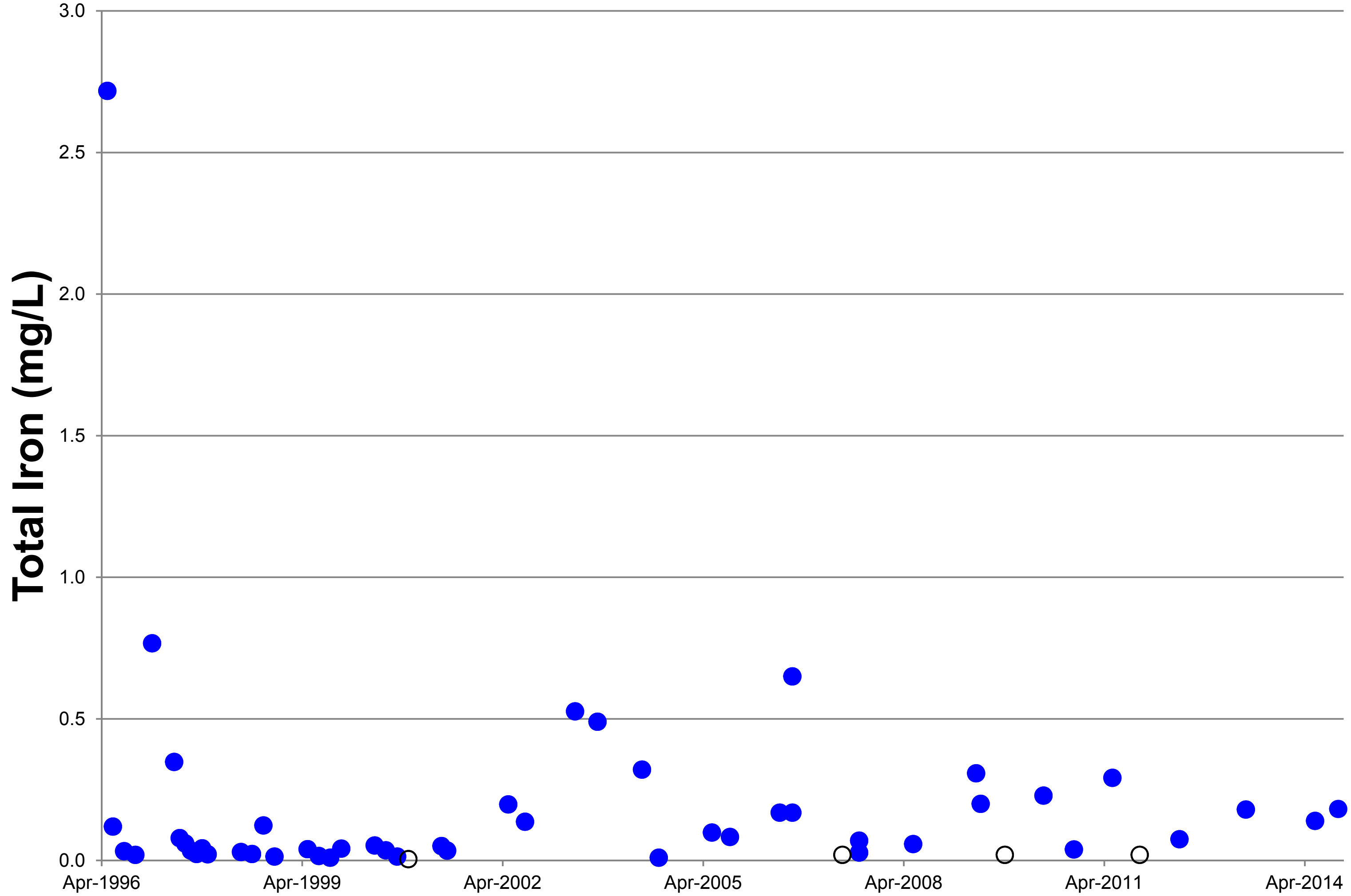

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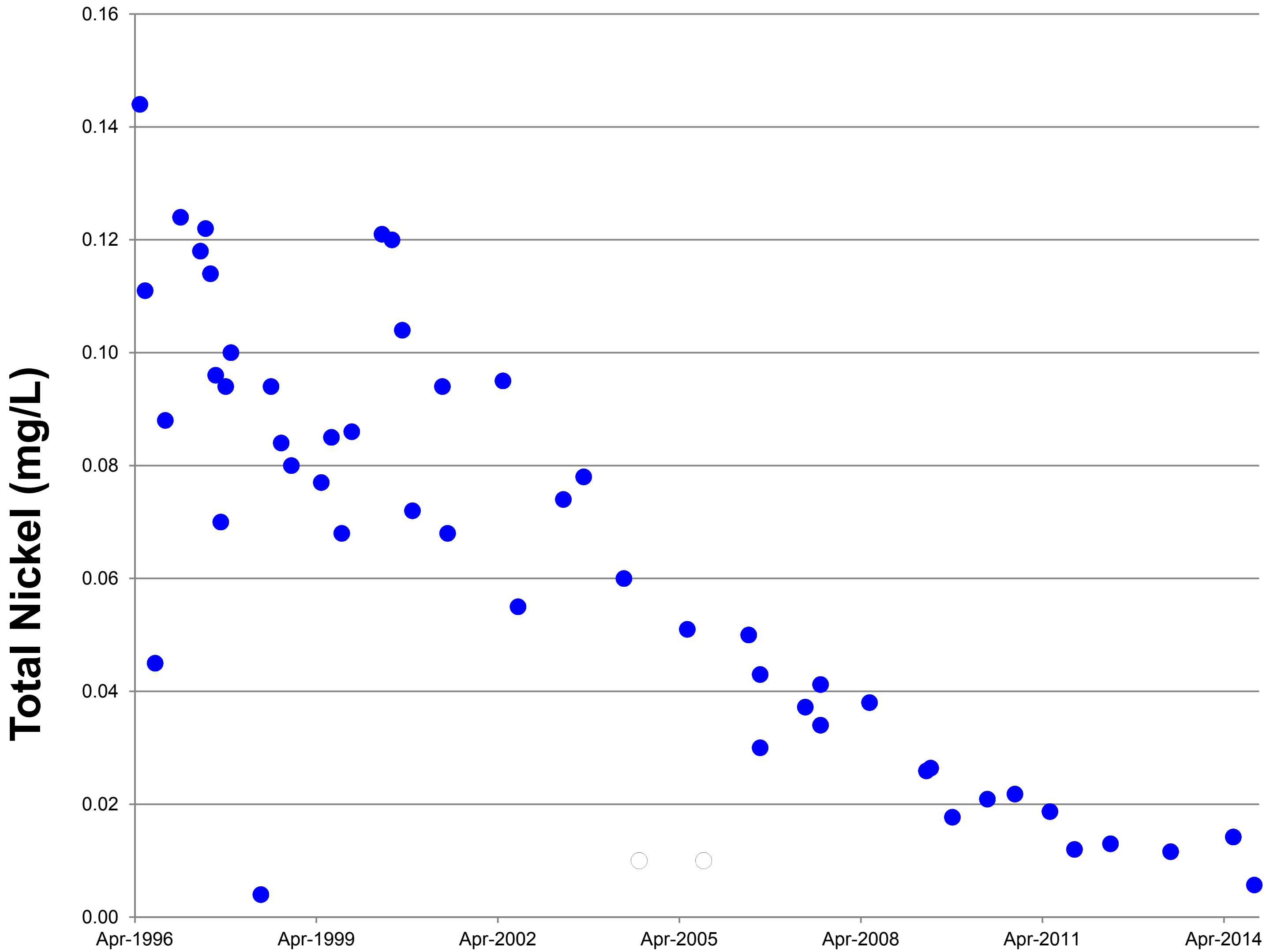
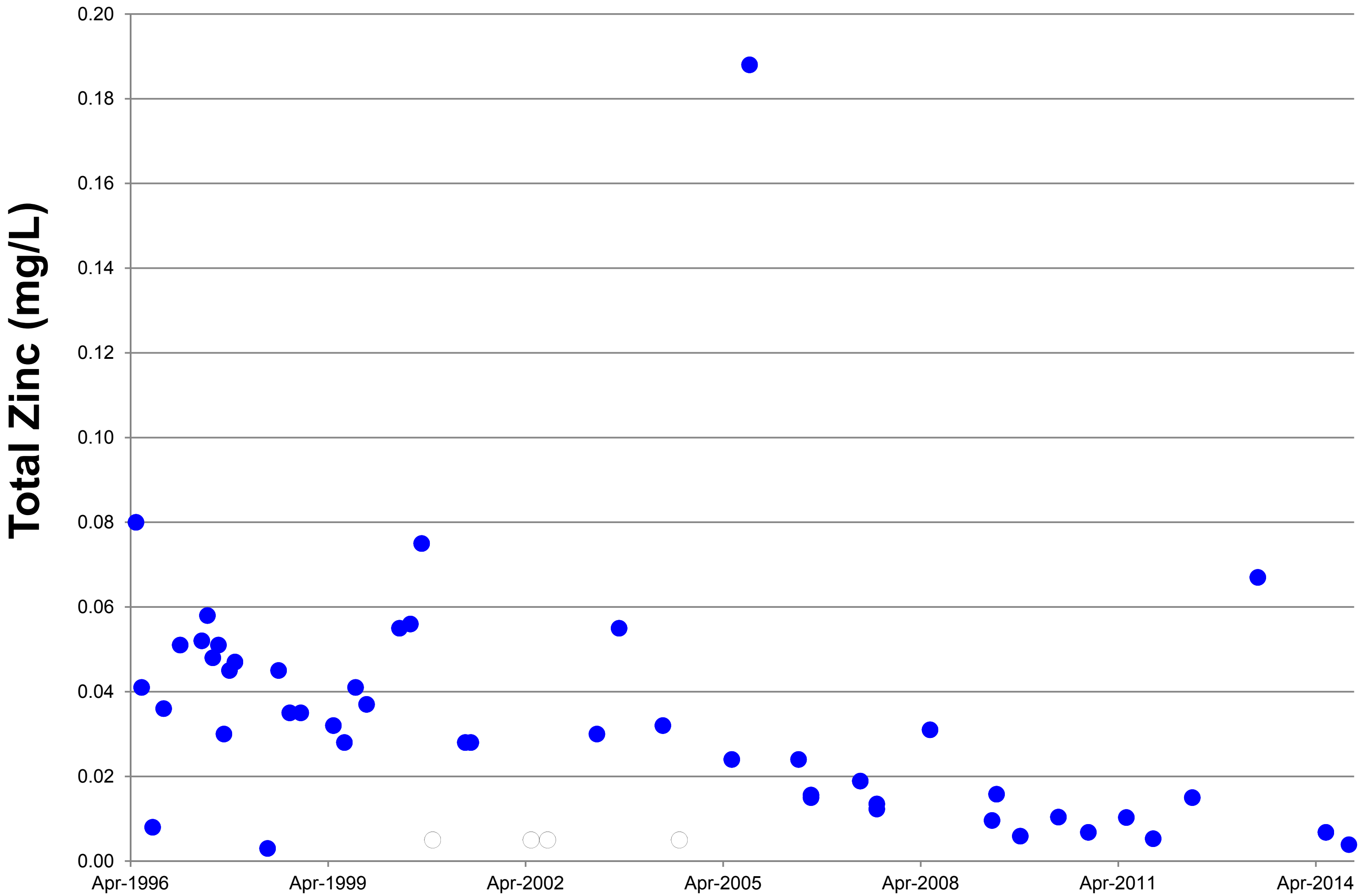


Water Quality in the Open Pits



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Water Quality in the Open Pits

- Future Prognosis
  - Water columns are stratified and relatively stable
  - Slow exchange between bottom and upper layers during seasonal turnovers
  - No expectation of bottom and upper layers mixing rapidly
  - Continued slow overall decrease in concentrations in both layers

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Water Quality in the Open Pits

- Future Prognosis
  - What is risk associated with rapid mixing?
    - Ferrous iron oxidized, precipitate and acid generation
    - Three of the four pits have sufficient alkalinity to neutralize pH
    - Additional mitigation will be required in South Pit
    - Low flow and monitoring will allow mitigation before effects in downstream

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Effects to the Downstream Receiving Environment

- Also assessing potential effects associated with the site on downstream receiving environment

- Surface water quality, sediment quality, biological communities

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Effects to the Downstream Receiving Environment

- Surface water
  - Trends in water quality off site mirror those on site
  - Water quality meets surface water quality objectives
  - No expectation of effects on biological communities due to exposure to surface water

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Effects to the Downstream Receiving Environment

- Sediment quality
  - Legacy of site source loadings seen in sediments
  - Sediment profiles - COPCs load up and then recover
  - Surficial sediment quality improving over time
  - Recovery modelled and is on-track
  - COPC concentrations above sediment quality guidelines but no impact resident biological communities

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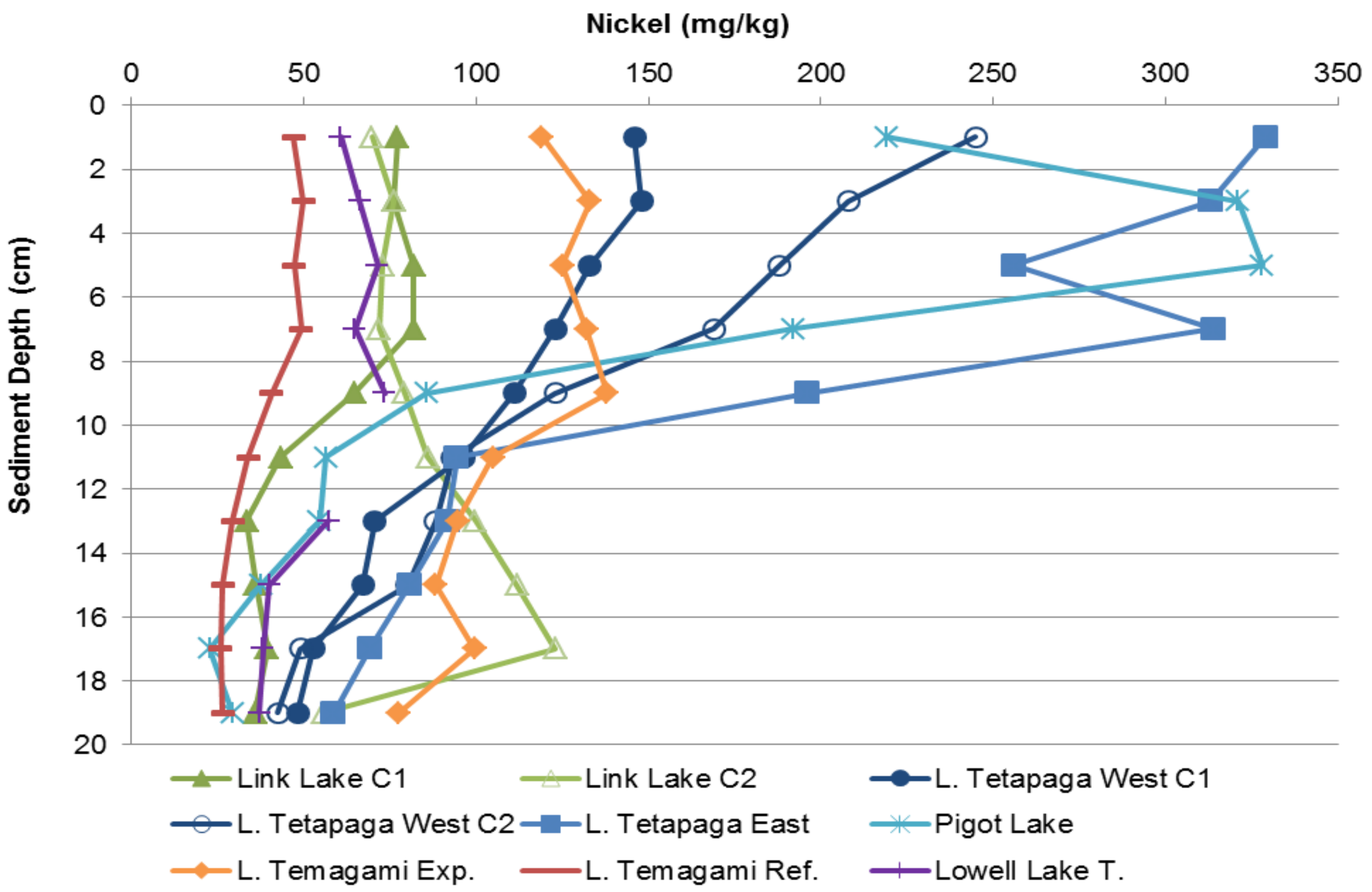
Effects to the Downstream Receiving Environment



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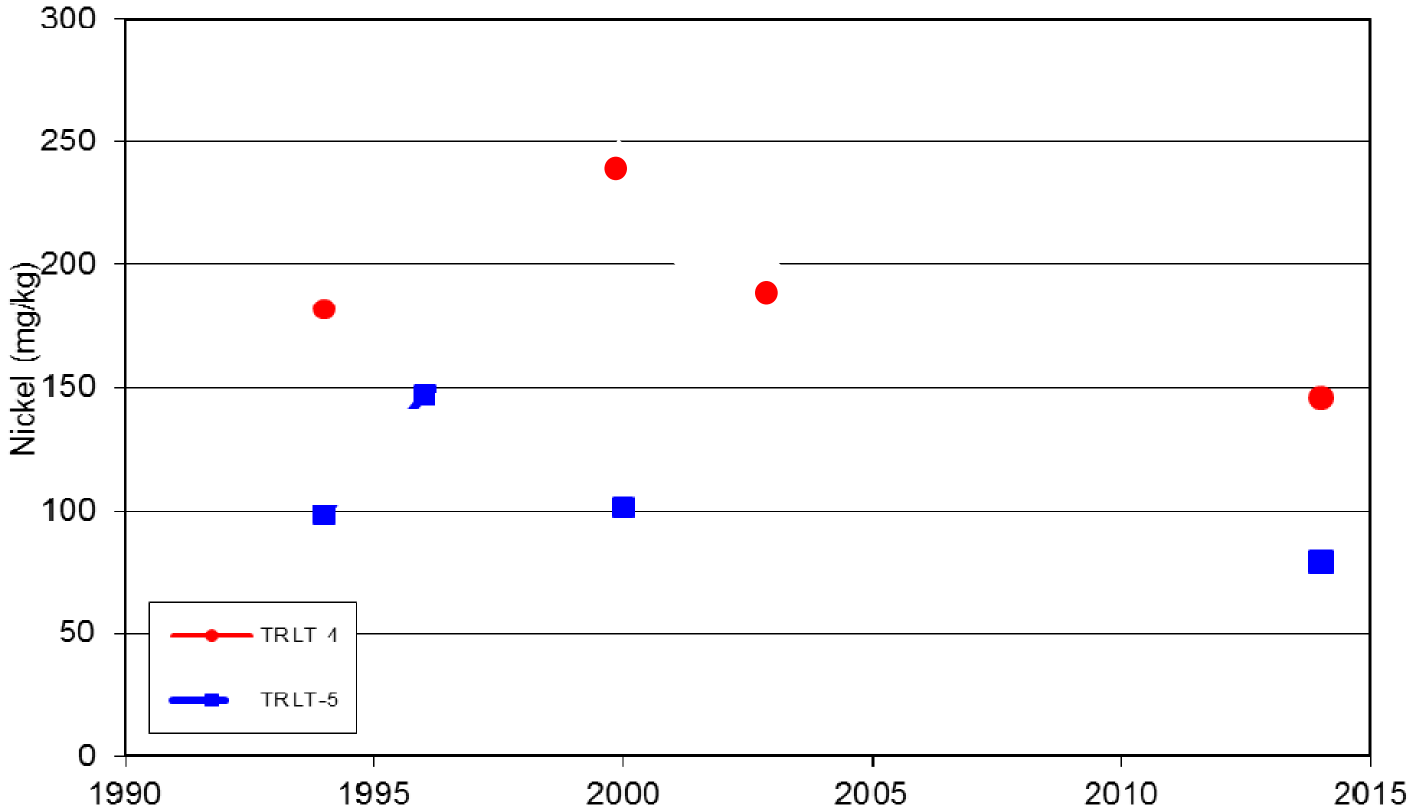
Effects to the Downstream Receiving Environment



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Effects to the Downstream Receiving Environment

- Biological communities
  - Benthic invertebrates (invertebrates in bottom sediments) integrate and respond to environmental conditions in predictable way
  - Survey data indicate no impacts downstream of mine sources

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Effects to the Downstream Receiving Environment

- Forward looking
  - Status quo
    - ➢ continued slow improvement in water quality
    - ➢ further improvements to sediment quality
    - ➢ no impacts to biological communities

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Effects to the Downstream Receiving Environment

- Forward looking
  - What if the open pits mix rapidly?
    - ➢ Issues can be mitigated on site
    - ➢ No expectation of adverse effects to downstream receiving environment
    - ➢ Biological receptors protected

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Summary

- Where did the acid (acidity) go?
  - Acid (acidity) is a legacy issue
  - Surface layer - neutralized by alkalinity
  - Bottom layer - some neutralized by alkalinity; some stored as ferrous iron (e.g., South Pit)
- Open pits are stratified and stable
- Water quality improving steadily
- No effects in downstream receiving environment
- Rapid mixing not expected but effects are mitigatable and downstream receiving environment can be protected

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QUESTIONS?

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