# Use of Constructed Wetlands to Reduce Metals in Drainage from a High Altitude Mine System, SW Colorado: Mine Hydrology/ Chemistry

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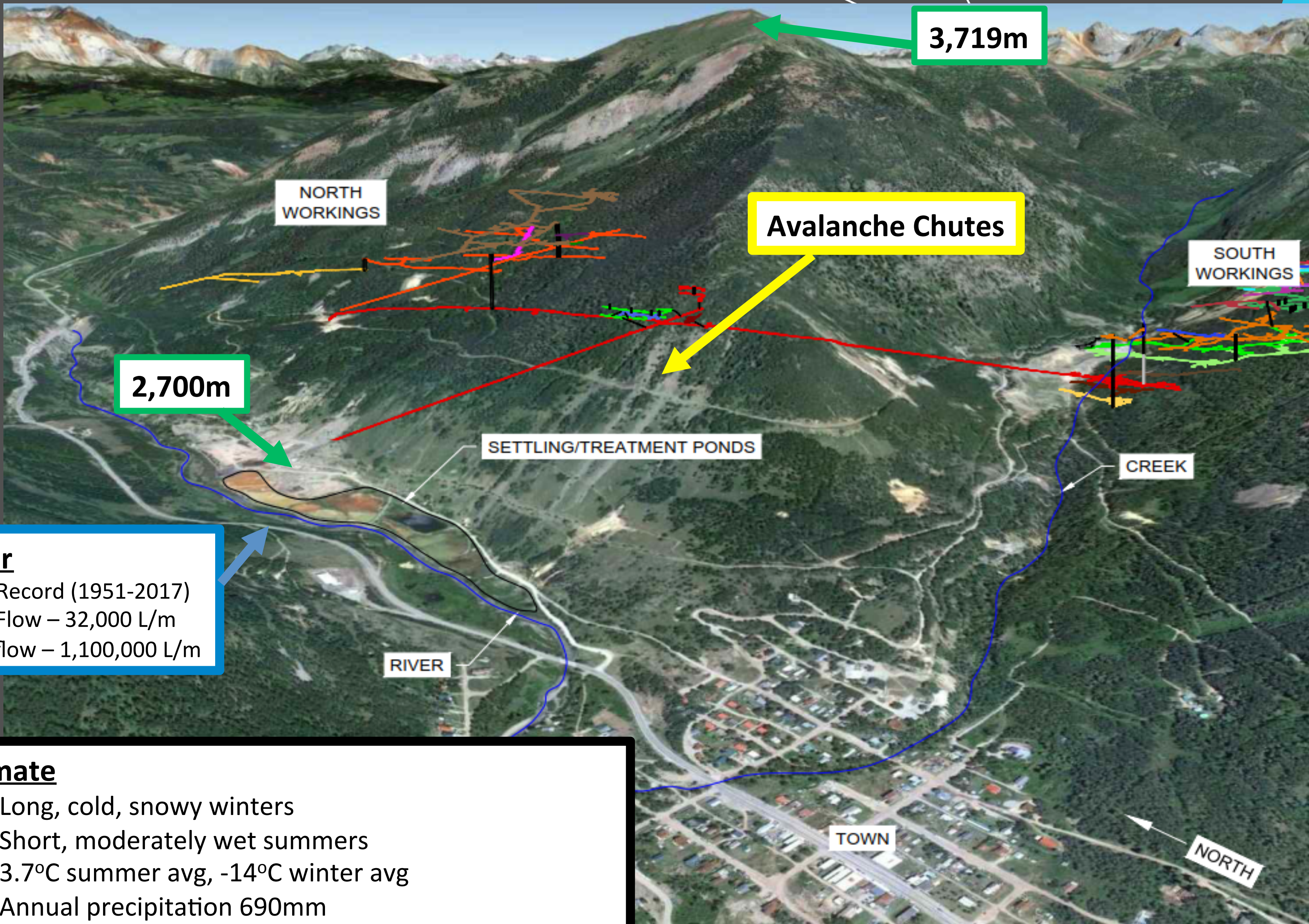
# Purpose:

Provide understanding of the seasonality of geochemistry and hydrology of mine water as an influent to passive wetland treatment systems

- Setting
- Geology and mineralogy
- Mine hydrology and seasonality
- Metals and acidity sources and migration
- Contaminant loading
- Advantages/Challenges

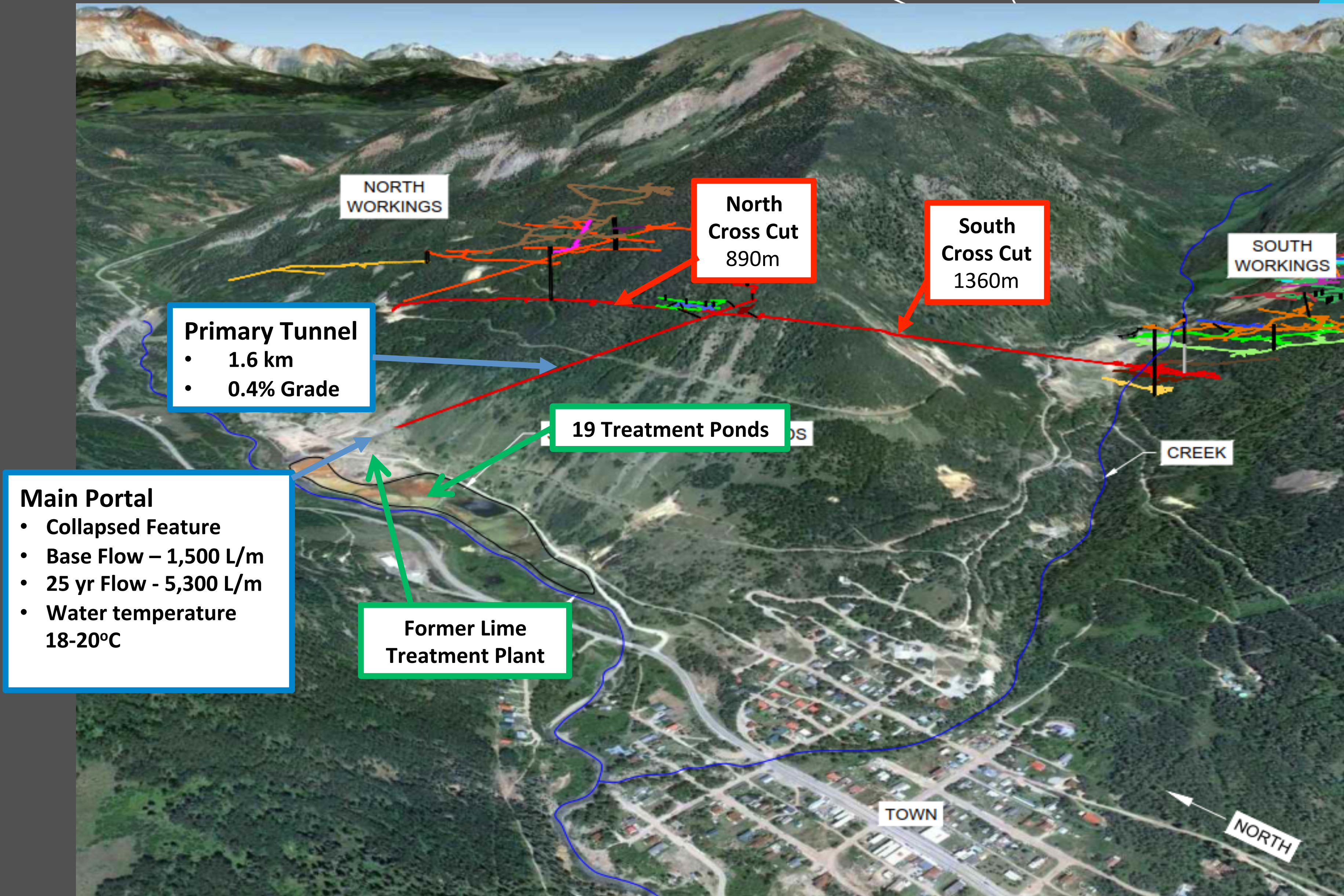



**River**

Flow Record (1951-2017)
Base Flow – 32,000 L/m
High flow – 1,100,000 L/m

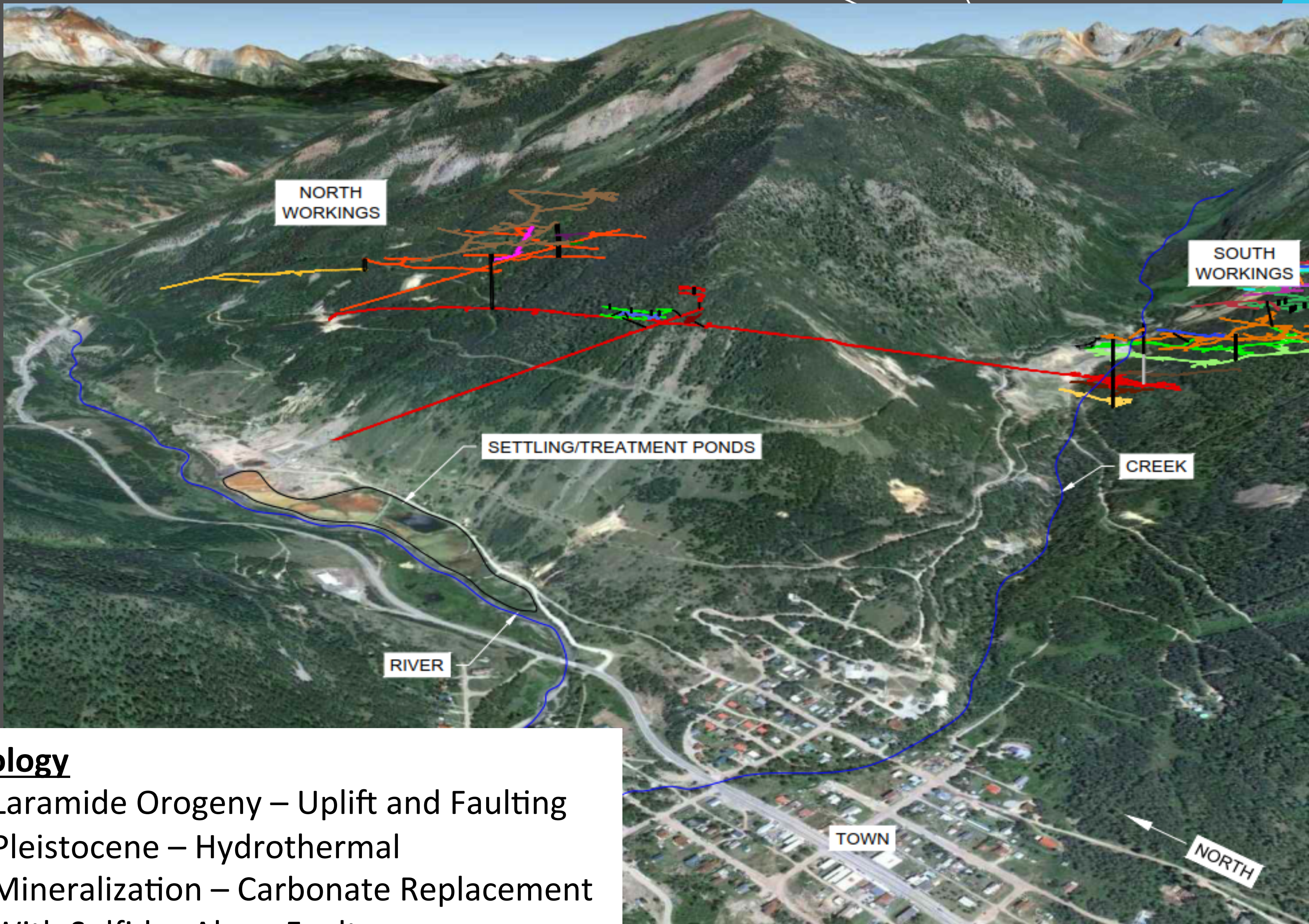
**Climate**

- Long, cold, snowy winters
- Short, moderately wet summers
- 3.7°C summer avg, -14°C winter avg
- Annual precipitation 690mm
- Annual snowfall 4,390mm


NORTH WORKINGS
North Cross Cut 890m
South Cross Cut 1360m
SOUTH WORKINGS
Primary Tunnel
• 1.6 km
• 0.4% Grade
19 Treatment Ponds
CREEK
Main Portal
• Collapsed Feature
• Base Flow – 1,500 L/m
• 25 yr Flow - 5,300 L/m
• Water temperature 18-20°C
Former Lime Treatment Plant
TOWN
NORTH

# Site History

- 1860's - mining started with silver and gold and transitioned to lead and zinc
- 1930 - 1931 – haulage/drainage tunnel driven
- Extensions in subsequent years connected drainage tunnel to area mine workings
- 1953 – 1965 - sulfuric acid plant operations
- 1971 - mining and mineral processing ceased & deeper workings beneath creek were allowed to flood
- 1984 - reclamation initiated with construction of lime treatment plant for mine water; water directed through series of 19 settling ponds
- 2012 - present: site characterization and tests of horizontal-flow and vertical-flow wetland technologies began. Discussed in next two presentations




## Geology

- Laramide Orogeny – Uplift and Faulting
- Pleistocene – Hydrothermal Mineralization – Carbonate Replacement With Sulfides Along Faults
- High Geothermal Gradient

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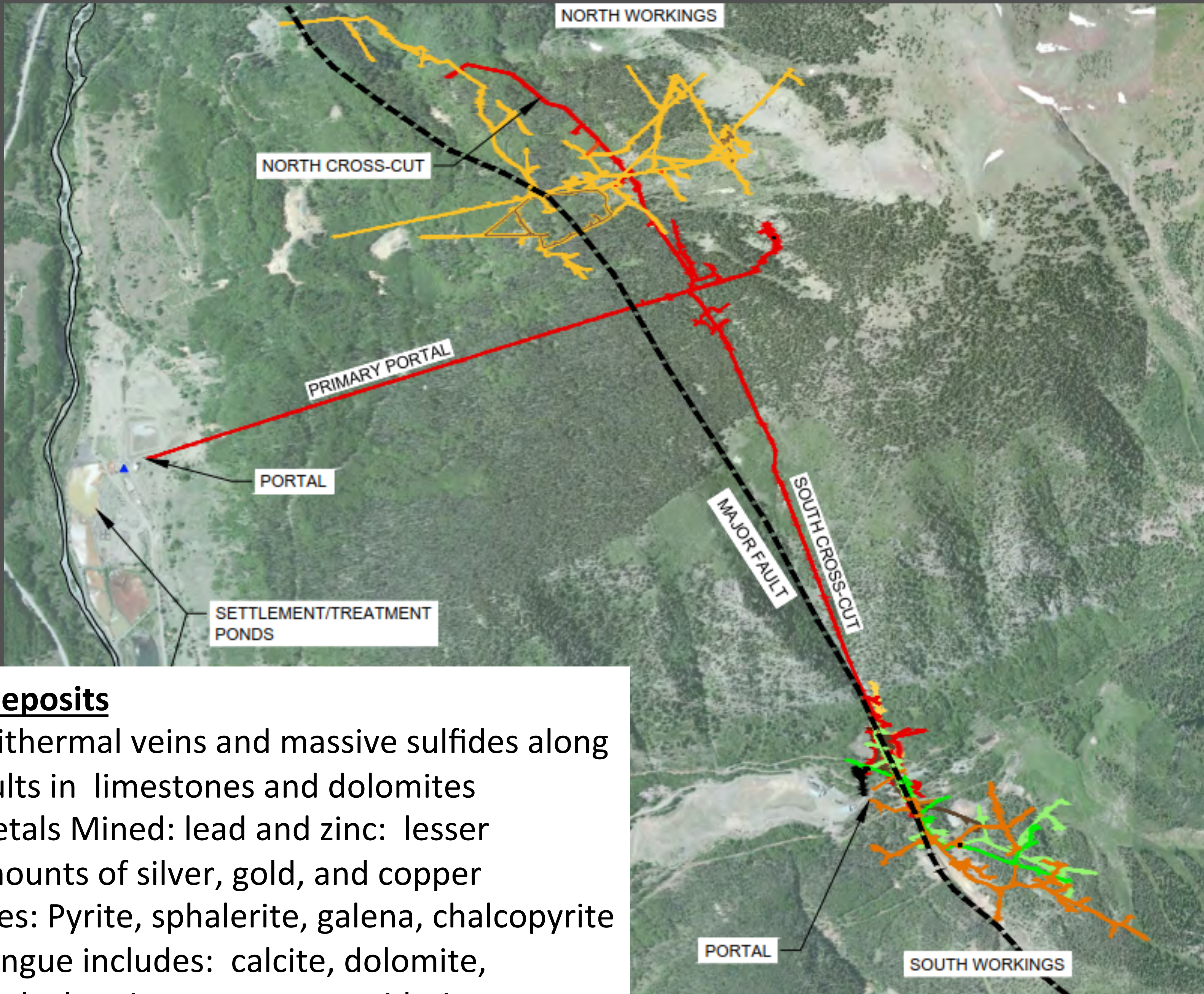



**Ore Deposits**

- Epithermal veins and massive sulfides along faults in limestones and dolomites
- Metals Mined: lead and zinc: lesser amounts of silver, gold, and copper
- Ores: Pyrite, sphalerite, galena, chalcopyrite
- Gangue includes: calcite, dolomite, rhodochrosite, manganoan siderite

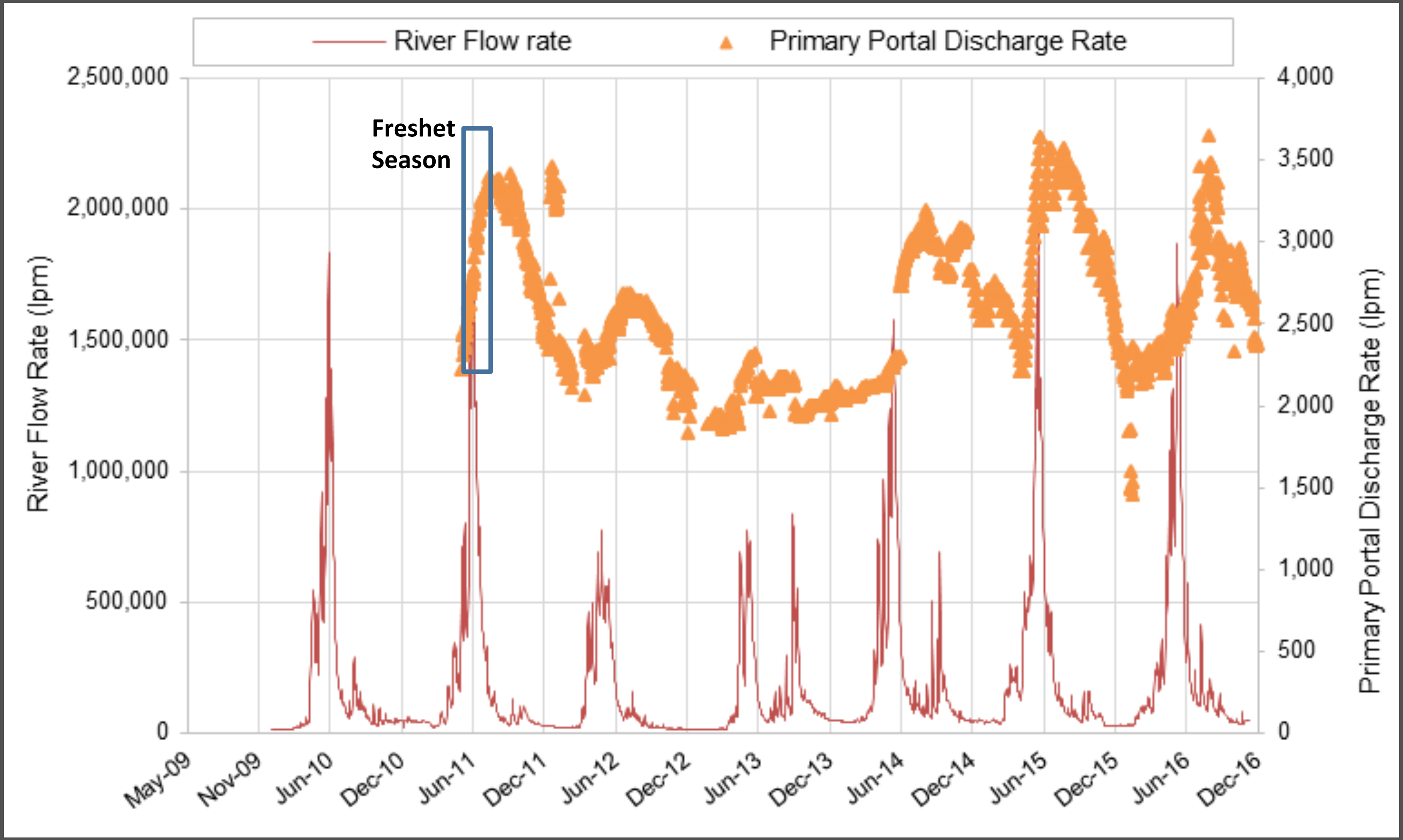
# Acidity/Metals Generation

- Sources of metals and acidity are ore minerals (mainly sulfides) within replacement deposits and surrounding rock
- Minerals are exposed to water and oxygen migration along faults, fractures, and mine workings resulting in oxidation, acidity formation, and enrichment in dissolved sulfate and metals (Cd, Cu, Fe, and Zn)
- Acidic dissolution of common gangue minerals - dolomite, manganoan siderite, and rhodochrosite - results in addition of manganese to mine water
- During winter, secondary, soluble acid-metals salts may form on fractures and drier mine surfaces
- Freeze-concentration of acid water can lead to increased acidity and metal contents
- Acidic products stored in disconnected pools of the mine during low flow periods

# Mine Hydrology

- Water originates from infiltration of snowmelt and rainfall
- Host rock conduits
  - Interconnecting fractures, fault planes
- Mine working conduits
  - Intersections of workings with natural fractures/ fault planes
  - Tunnels and shafts driven to explore for mineralized carbonates
  - Cross cuts and main drainage tunnel and convey mine drainage to the primary portal

# Primary Portal Seasonal Discharge Pattern



# Attenuation

Baseline portal discharge water is neutral (pH mostly 6.5 – 7) and decreased metal concentrations

- Neutralization of acidity by interaction with carbonate rocks, the host rock for mineralization
- Neutralization of acidity enhances attenuation of metals through adsorption and precipitation
- Carbonate dissolution results in elevated carbon dioxide in the mine air (primary form of acidity)
- Dilution - continual input of water from summer rains

# Attenuation between Upper Workings and Mine Portal

| | Sulfate | Iron | Cadmium | Copper | Manganese | Zinc | pH (protons) |
|---|---|---|---|---|---|---|---|
| | mg/L | ug/L | ug/L | ug/L | ug/L | ug/L | s.u. |
| Upper Workings | 6,180 | 1,950,000 | 12,000 | 349,000 | 294,000 | 2,460,000 | 2.25 |
| Portal Discharge | 618 | 445 | 52 | 55 | 4,270 | 10,200 | 6.70 |
| Decrease | 90.0% | 100.0% | 99.6% | 100.0% | 98.5% | 99.6% | 100.0% |

# Mine Water Cycle

Late fall and winter

- minimal infiltration due to frozen conditions
- seepage collects in disconnected pools within the mine
- oxidation and acid formation stored during low flow periods

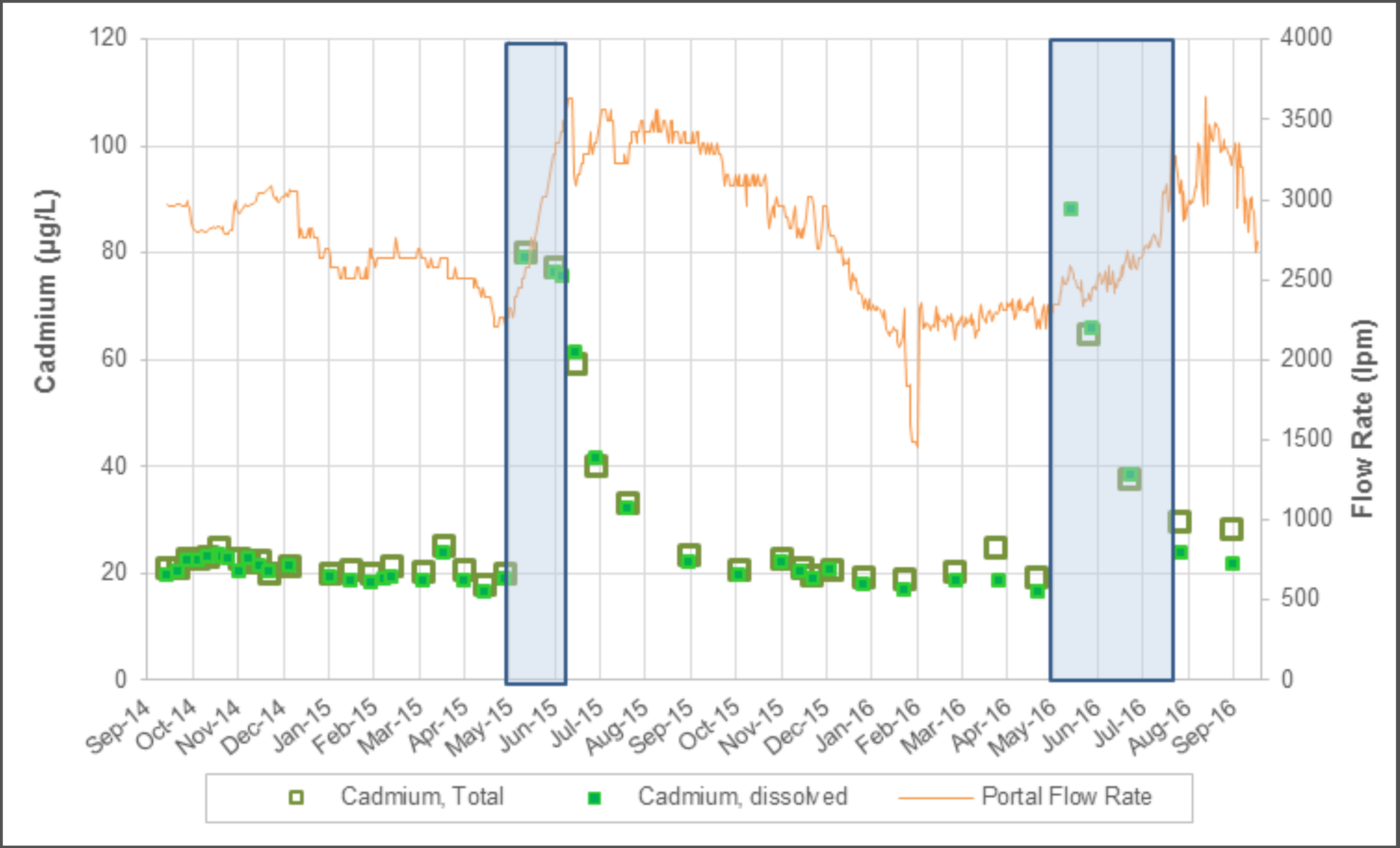
Spring thaw and freshet

- infiltrating water moves through fractures and down the mine walls
- dissolves accumulated acid-metal salts; collects in pools
- infiltration connects pools, moving acidic, metals-laden water through mine workings
- Flowing mine water carries metals and acidity through crosscuts, primary tunnel, and to mine portal

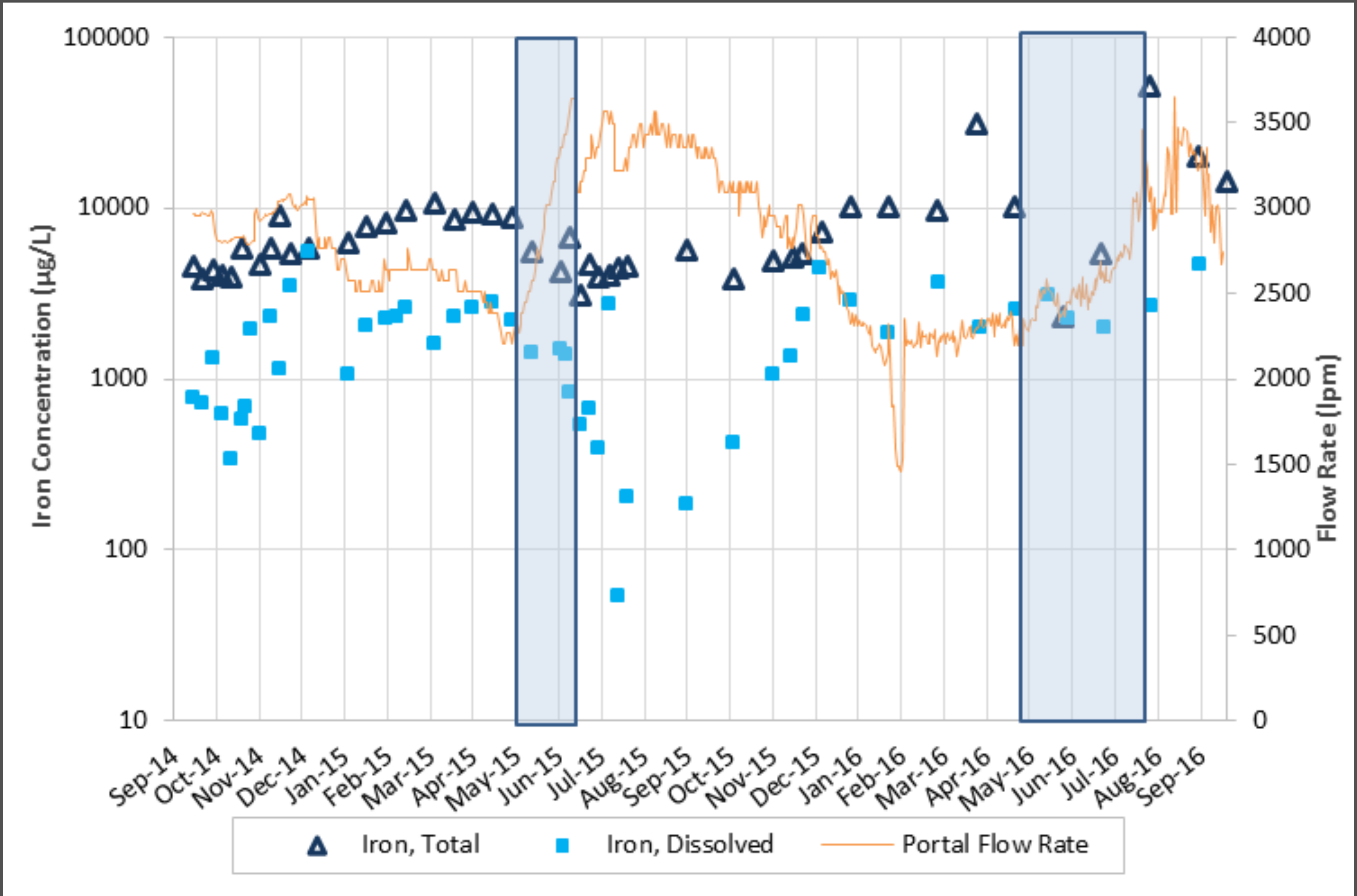
Summer

- continued infiltration dilutes water remaining in pools
- decreased metals concentrations in water moving through mine
- gradual return to baseline conditions

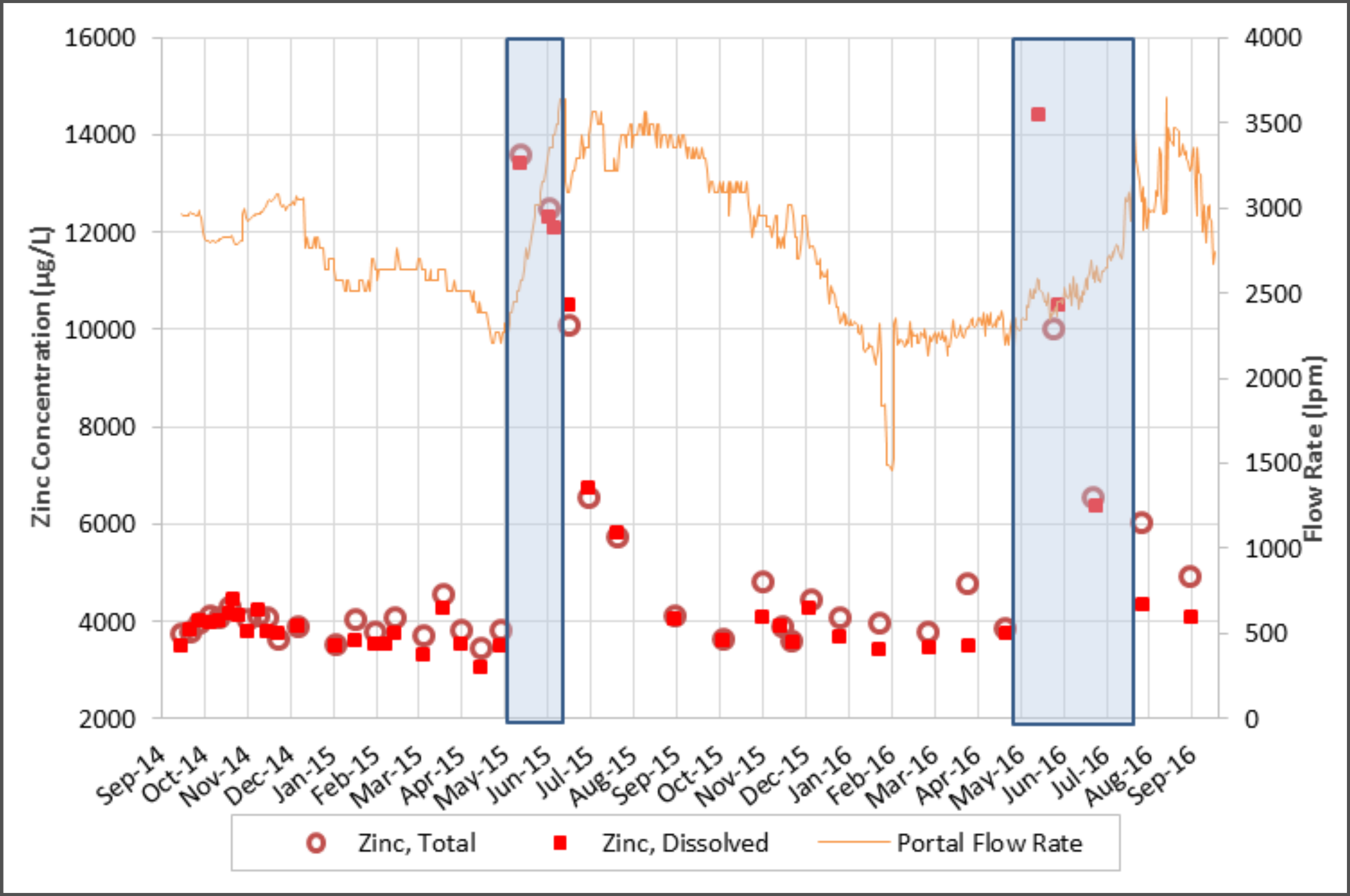
# Cadmium Increase from Freshet



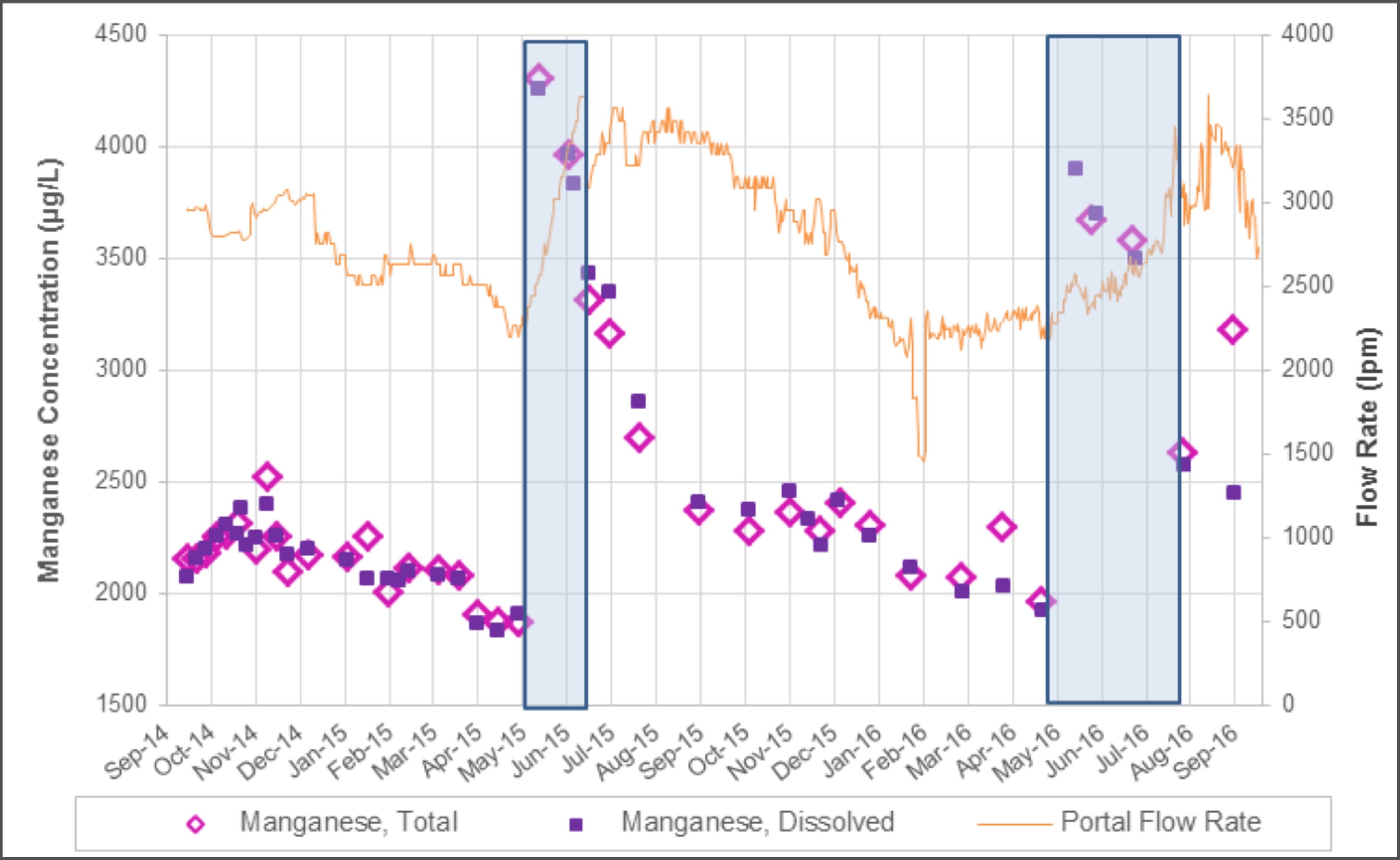
# Seasonal Iron Precipitation and Dilution



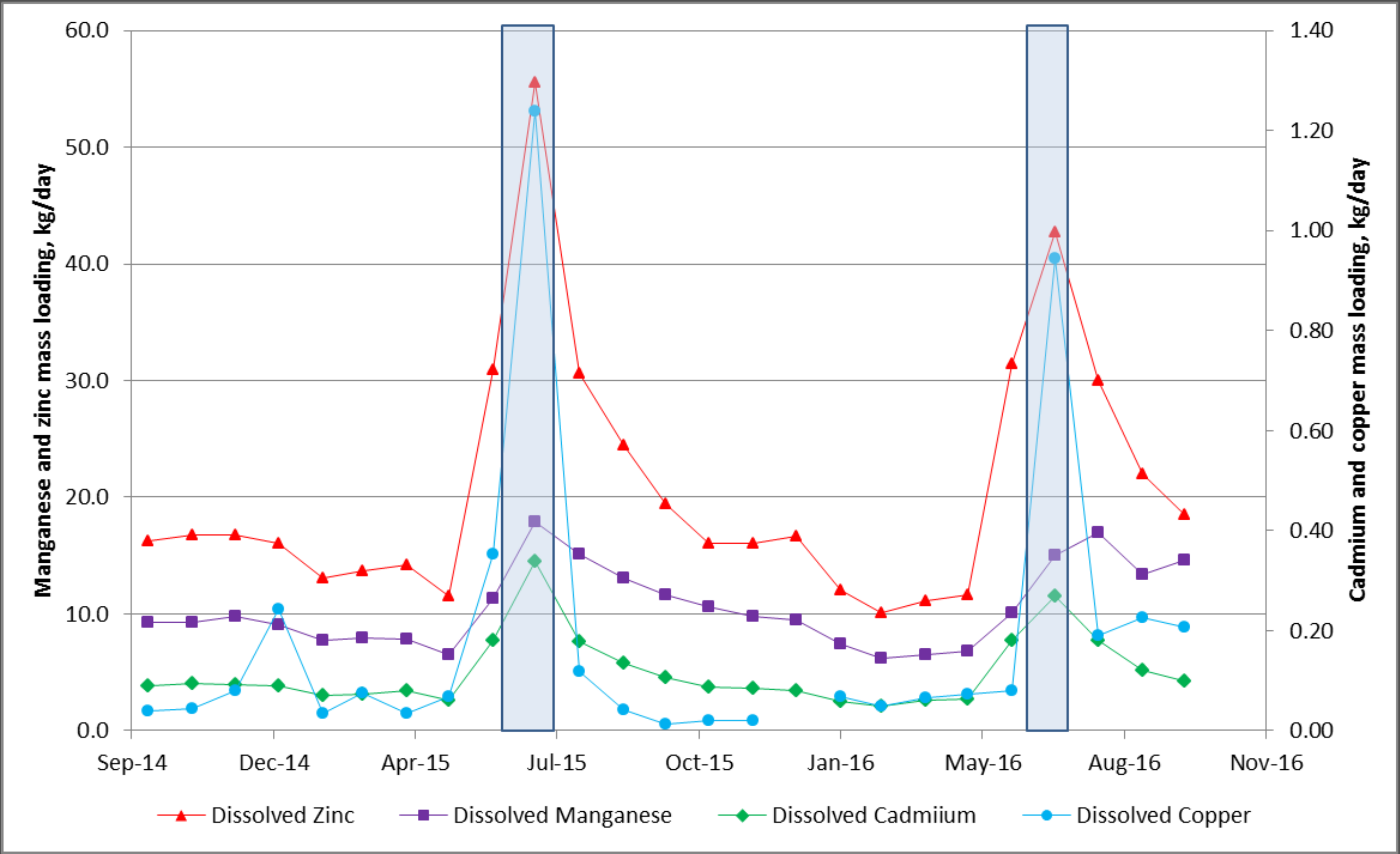
# Zinc Concentration Peaks from Freshet



# Seasonal Manganese Trends Due to Freshet



# Metals Mass Loading



# Summary

- Mine discharge and metals concentrations vary seasonally
  - Dry season (late fall & winter) - metals and acidity accumulate within fractures and mine pools
  - Spring snowmelt freshet - infiltration flushes acidity and metals through the mine
  - Summer – continued infiltration/dilution and return to base flow
- Attenuation of acidity and metals results from reaction of acidity with carbonate rocks in the mineralized zone and from dilution from infiltration of summer rains;
- Cd, Mn and Zn in mine drainage are typically above ambient surface water criteria
- Range of mass loading varies more than metals concentrations

# Implications for Treatment

**Advantages for Wetlands Treatment of Mine Drainage**

- Limited site access favors passive treatment
- Metals are attenuated inside the workings to a large extent
- Circumneutral mine drainage ($CO_2$ is the primary acid)
- Geothemal warming of mine drainage (18-20$^{o}$C)
- Presence of existing ponds for wetlands and polishing

**Challenges for Wetland Treatment of Mine Drainage**

- Seasonality causes wide range of mine water metals loading to wetlands
- Particulate iron and aluminum oxides affect wetland permeability

# Thank You!

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