Watershed interactions and water quality assessment of previously mined mineralized areas
Willow Creek Demonstration Watershed, Madison Co., MT, 2006-2011

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Willow Creek Watershed

Introduction

- The drainage divide of the Tobacco Root Mts. bounds the upper watershed and is underlain by granite and granite-gneiss.

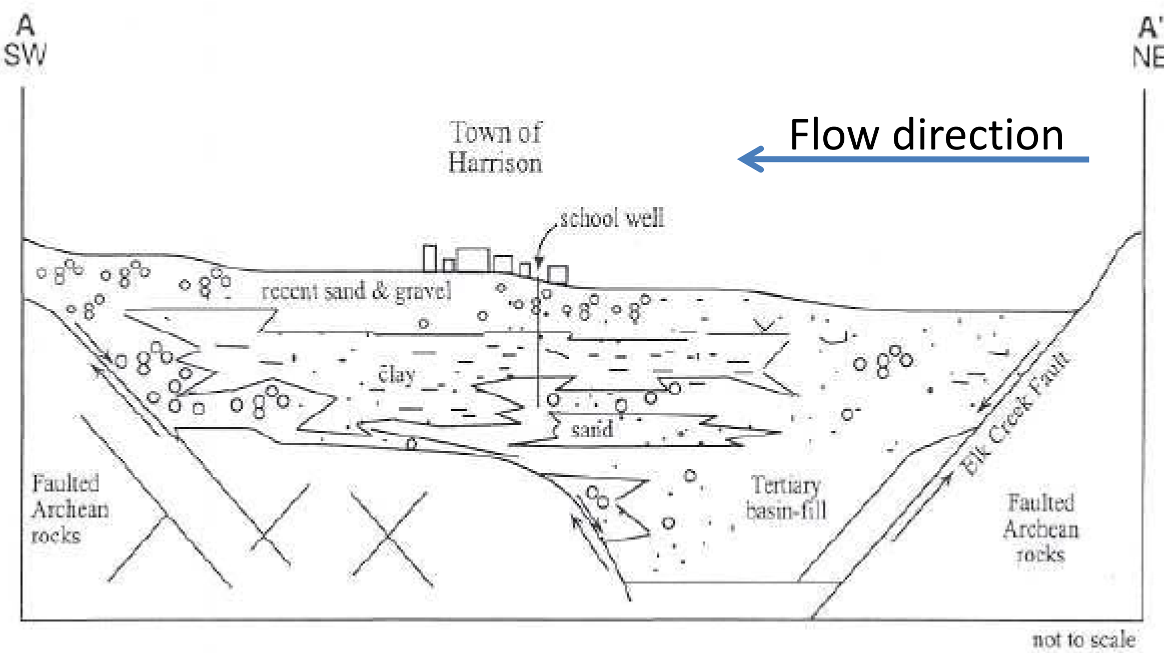
- Tertiary age deposits composed of weathered sediments fills in the lower watershed, and creates a dual aquifer system in the valley.

- Region has a long history of mining – gold, copper, iron, and zinc associated with the Tobacco Root Batholith. Most mines in the watershed are now abandoned.

- Glacial activity in the upper reaches of the watershed and freeze-thaw weathering produced silica-rich sediments from the igneous and metamorphic rock.

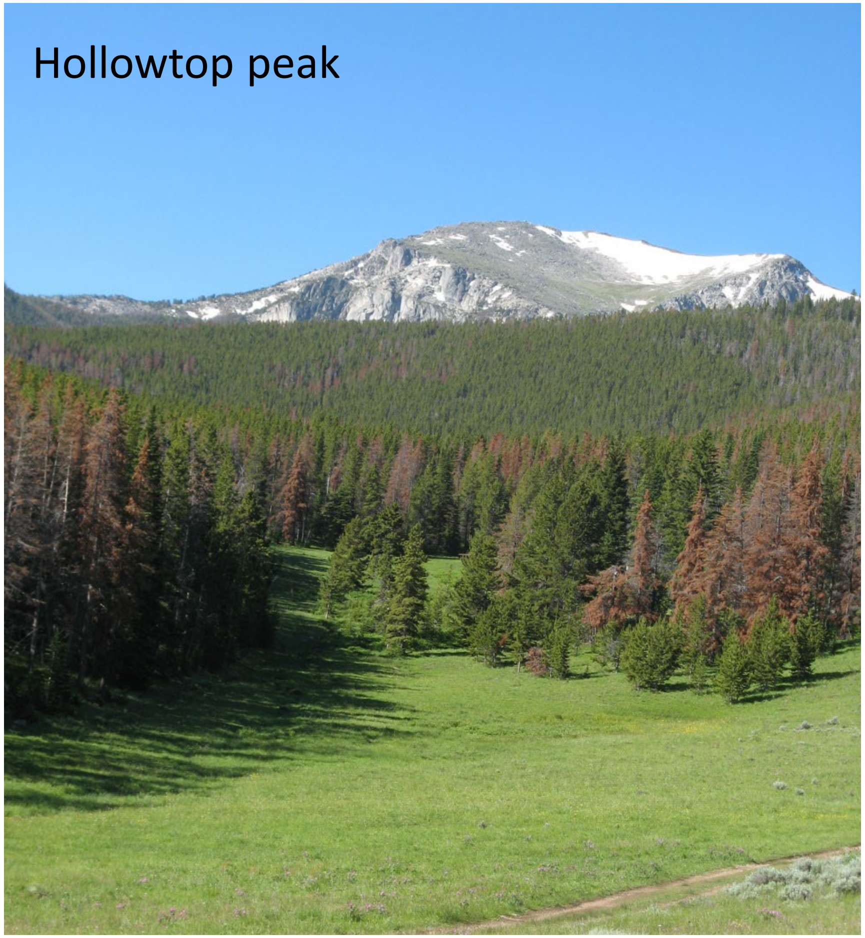
- The Tertiary fill in the lower reaches is composed of the weathered sedimentary materials carried down from the upper watershed and deposited by braided stream systems NE of the Elk Creek fault in the basin.

- Tertiary fill gravel, sand, silt and clay beds are well to poorly-sorted and variable in thickness.



Lower watershed, along flow path. (Harrison School District source water delineation and assessment report, 2005)

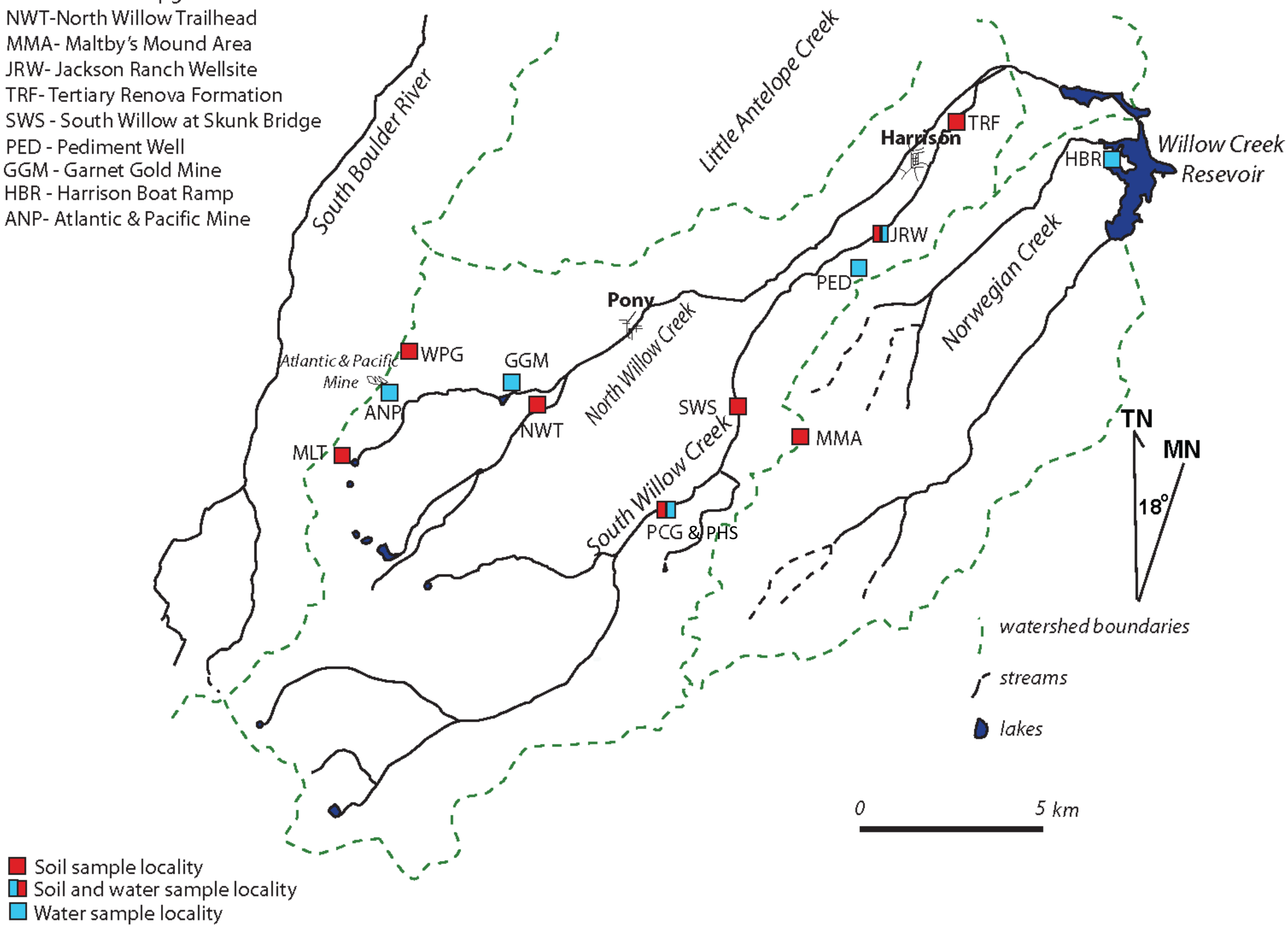
Research Questions



- Did previous mining have a long term impact on the watershed?
- How does the ground water interact with the local geology?
- What flow paths does the water take to the reservoir?
- Is the drinking water safe for agriculture and human use, given current EPA guidelines?

Willow Creek Sampling Sites

WPG - Windy Pass Granite
MLT - Mason Lake Transect
PCG - Potosi Campground
NWT-North Willow Trailhead
MMA- Maltby's Mound Area
JRW- Jackson Ranch Wellsite
TRF- Tertiary Renova Formation
SWS - South Willow at Skunk Bridge
PED - Pediment Well
GGM - Garnet Gold Mine
HBR - Harrison Boat Ramp
ANP- Atlantic & Pacific Mine



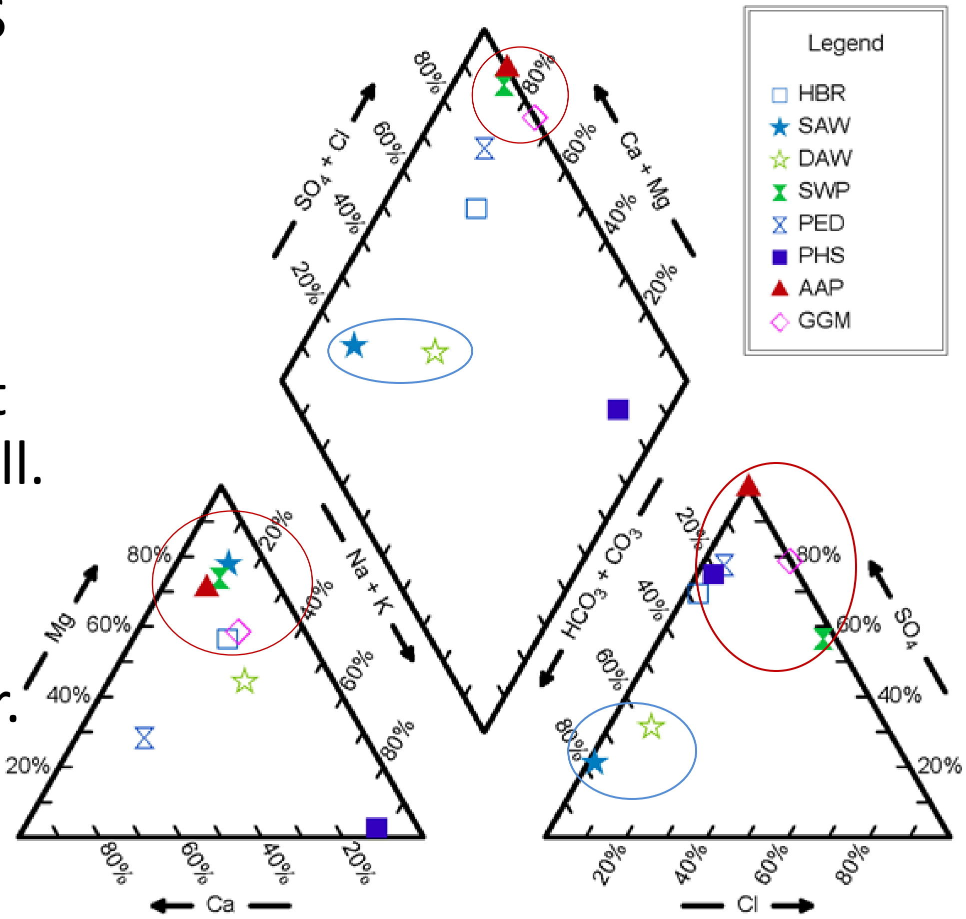
Methods

- **Sample Collection**:
  - Soil samples collected by the G329 class (2006)
  - Water samples collected by G329 classes (2006 and 2011)
- **Sample Analysis**:
  - Soil samples: Bulk XRF and sequential extractions (*after Sposito et al. 1982*)
    - exchangeable, sorbed, organic, and carbonate fractions analyzed
  - Water samples: Flame/Furnace atomic absorption and ion chromatography

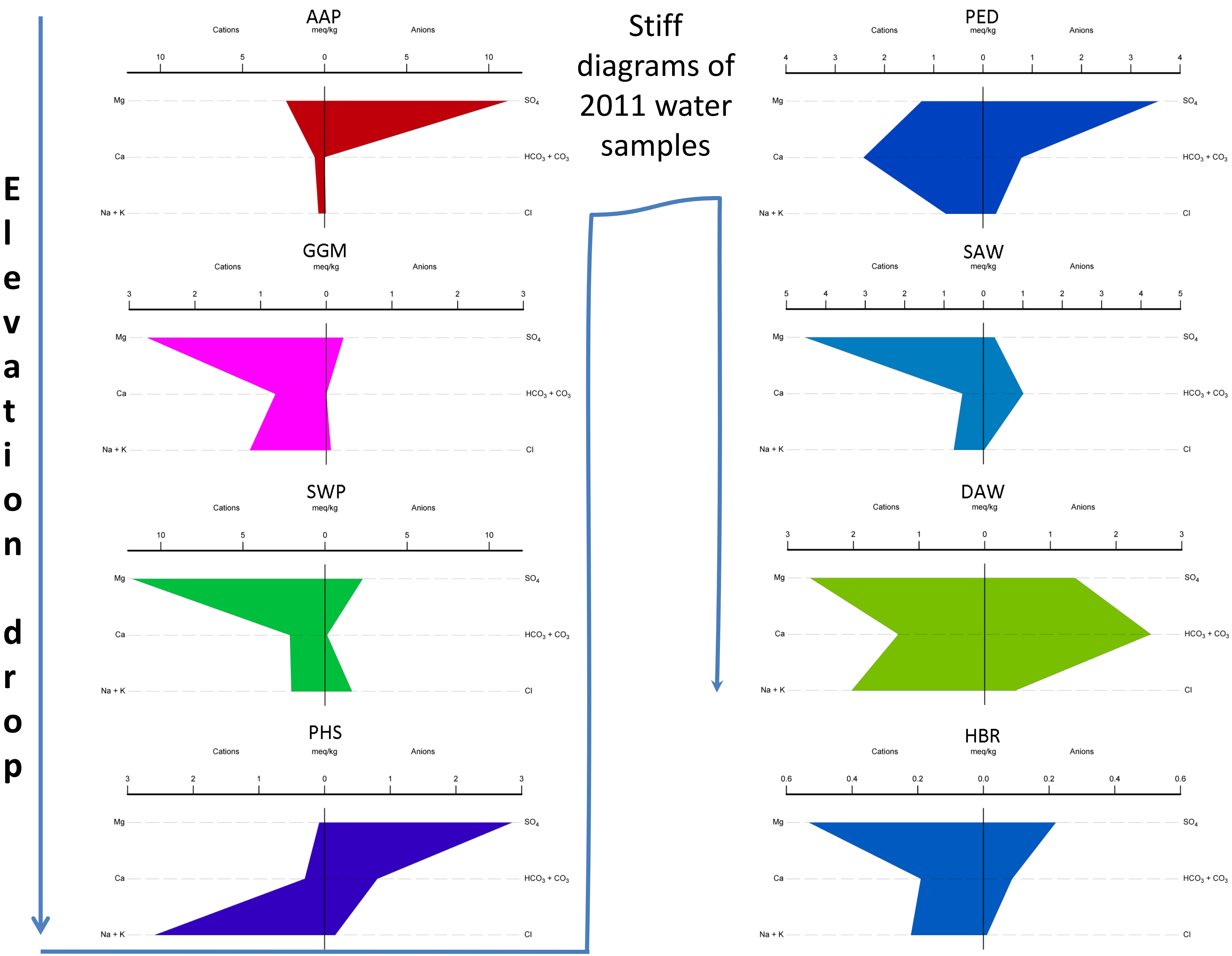
Results & Discussion

Piper diagram of hydrofacies.

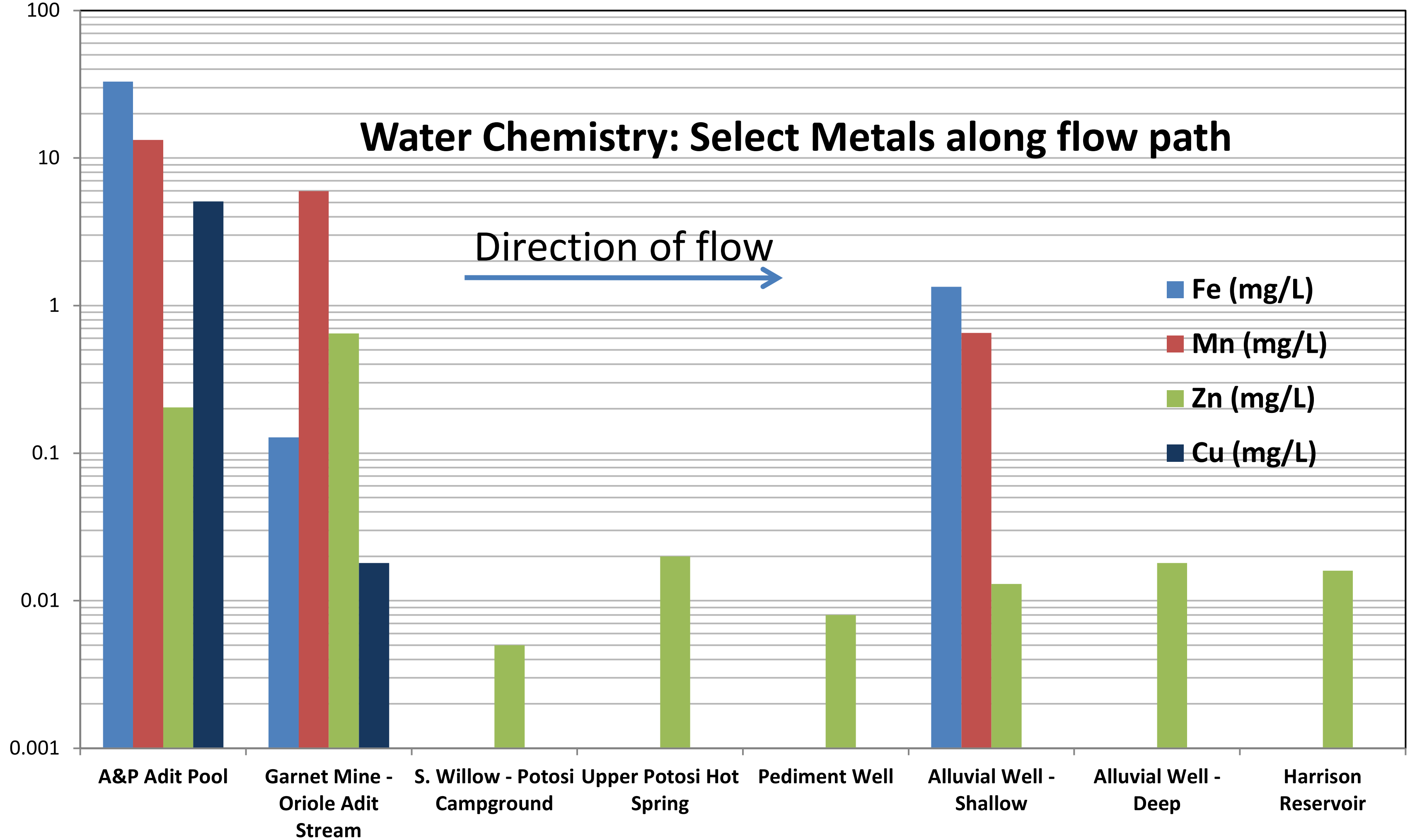
- A&P Mine, Garnet Mine, and South Willow Creek @ USFS Potosi campground are hydrochemically similar.
- Alluvial wells are hydrochemically similar, but different than pediment well.
- Pediment well and Harrison Reservoir are slightly similar.



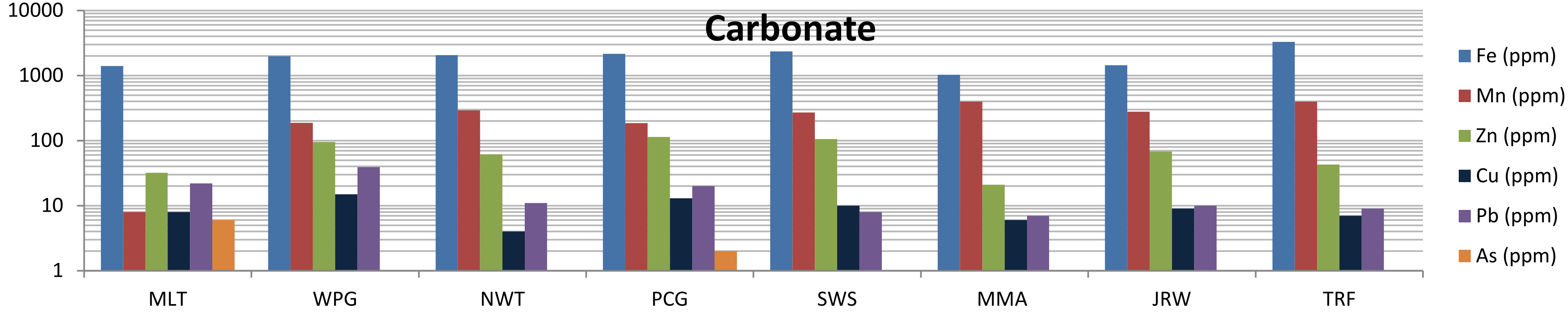
Piper Diagram

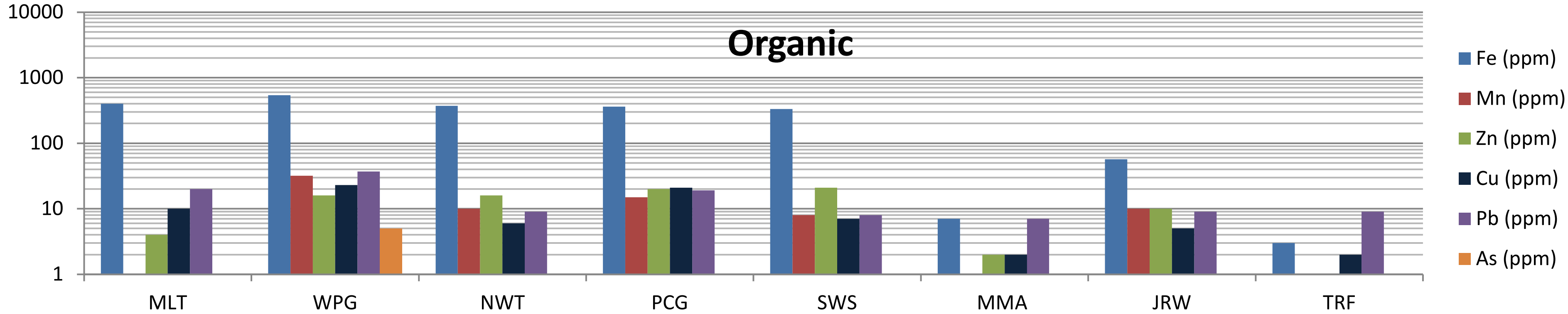


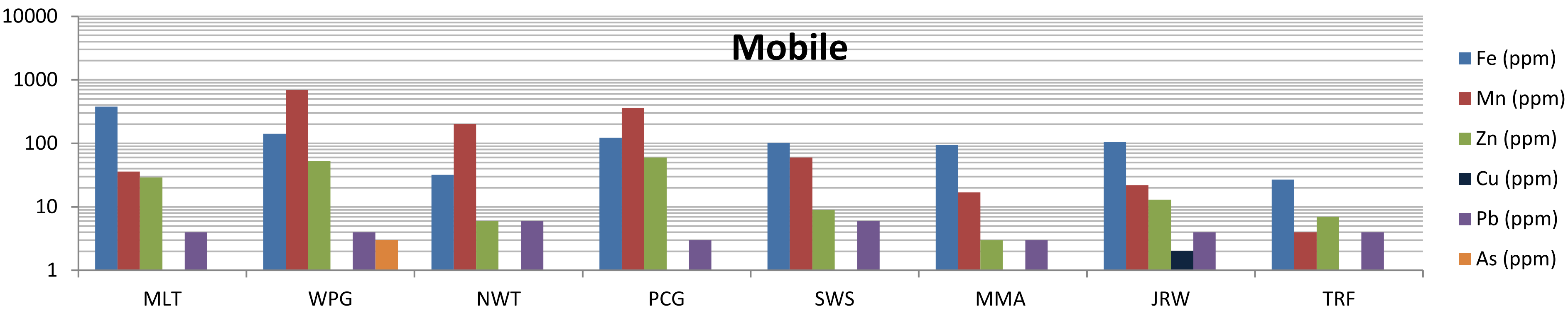
Stiff diagrams of 2011 water samples
Elevation drop
AAP
Cations
meq/kg
Anions
10 5 0 5 10
Mg
Ca
Na + K
SO_4
$HCO_3 + CO_3$
Cl
GGM
Cations
meq/kg
Anions
3 2 1 0 1 2 3
Mg
Ca
Na + K
SO_4
$HCO_3 + CO_3$
Cl
SWP
Cations
meq/kg
Anions
10 5 0 5 10
Mg
Ca
Na + K
SO_4
$HCO_3 + CO_3$
Cl
PHS
Cations
meq/kg
Anions
3 2 1 0 1 2 3
Mg
Ca
Na + K
SO_4
$HCO_3 + CO_3$
Cl
PED
Cations
meq/kg
Anions
4 3 2 1 0 1 2 3 4
Mg
Ca
Na + K
SO_4
$HCO_3 + CO_3$
Cl
SAW
Cations
meq/kg
Anions
5 4 3 2 1 0 1 2 3 4 5
Mg
Ca
Na + K
SO_4
$HCO_3 + CO_3$
Cl
DAW
Cations
meq/kg
Anions
3 2 1 0 1 2 3
Mg
Ca
Na + K
SO_4
$HCO_3 + CO_3$
Cl
HBR
Cations
meq/kg
Anions
0.6 0.4 0.2 0.0 0.2 0.4 0.6
Mg
Ca
Na + K
SO_4
$HCO_3 + CO_3$
Cl



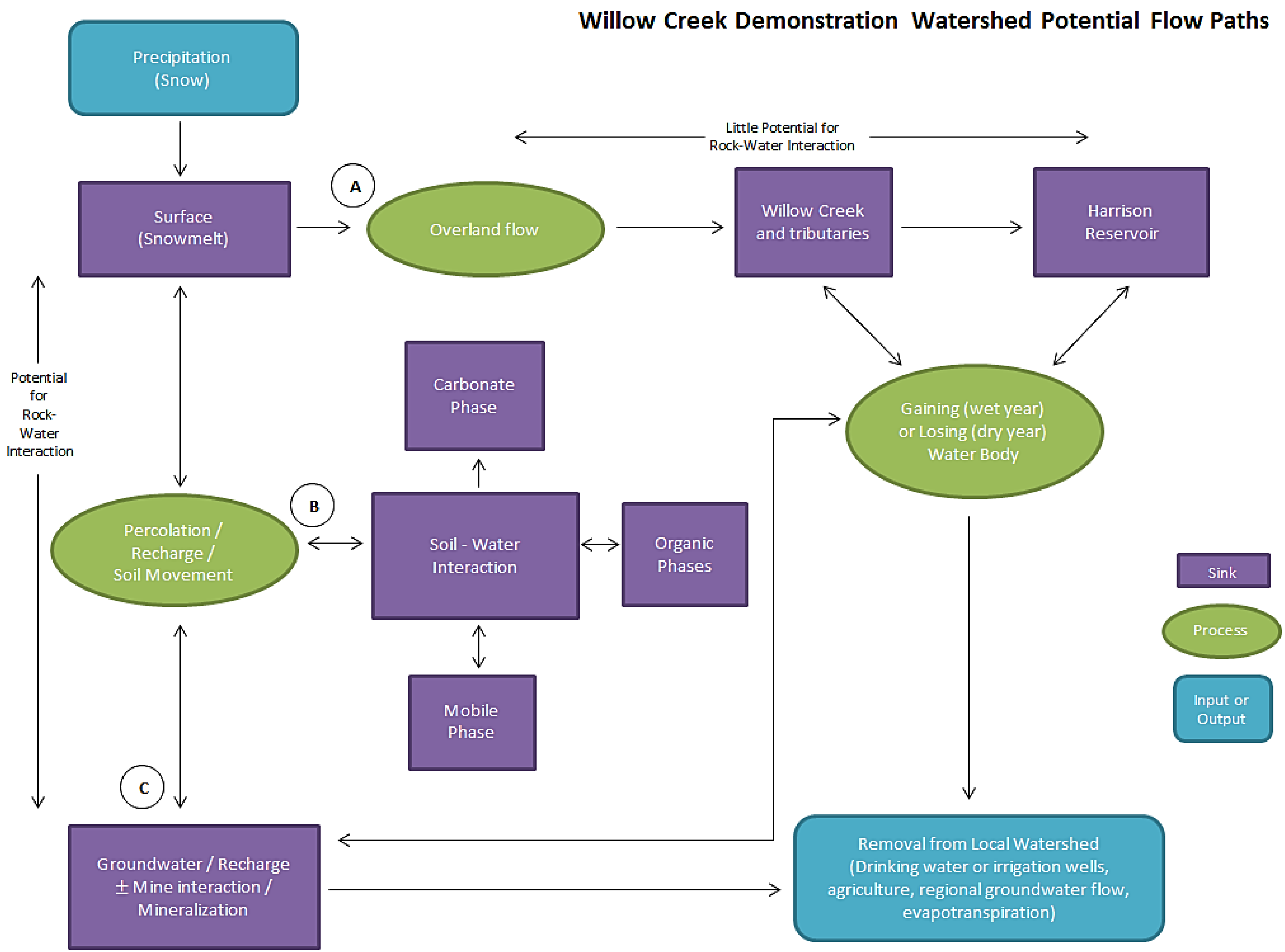
- Why is Fe/Mn in mines and shallow alluvial well but not elsewhere in watershed?
  - Found in areas of rock-water interaction near reaction boundaries
  - System very diluted at the time of sampling due to high snowfall
- Where does the Cu go?
  - Essential plant nutrient







- Most metals bound in carbonate forms – Ca substitution to Siderite ((Fe,Mn)CO3)
- Organic phase includes metals bound in oxides (FeO, MnO)
- Are the metals found in the mobile phase dangerous? → Not necessarily
  - As in soil well below dangerous levels ; metals are sorbed in non-toxic forms.


Willow Creek Demonstration Watershed Potential Flow Paths
Precipitation (Snow)
Surface (Snowmelt)
A
Overland flow
Little Potential for Rock-Water Interaction
Willow Creek and tributaries
Harrison Reservoir
Potential for Rock-Water Interaction
Carbonate Phase
Gaining (wet year) or Losing (dry year) Water Body
B
Percolation / Recharge / Soil Movement
Soil - Water Interaction
Organic Phases
Sink
Process
Input or Output
Mobile Phase
C
Groundwater / Recharge ± Mine interaction / Mineralization
Removal from Local Watershed (Drinking water or irrigation wells, agriculture, regional groundwater flow, evapotranspiration)

Drinking Water Safety

- **A&P Mine adit stream**:
  - copper (5.09 ppm) – 5x regulatory limit
  - pH 2.35
  - high Fe (110x rec.) and Mn
- **Garnet Mine adit stream:**
  - pH 2.7
  - high Mn
- **SW @ USFS Potosi Campground**
  - pH 4.98
- **Shallow alluvial well:**
  - high Fe and Mn
- **Fe and Mn**

  cause taste and coloration problems but are not harmful at these concentrations

Contaminant	Enforceable Concentration	Non-Enforceable Concentration (Recommended)
Aluminum		0.05-0.2 mg/L
Arsenic	10 ppb; 0.01ppm	
Chloride		250 mg/L
Copper	1.3 ppm	1.0 mg/L
Flouride		2.0 mg/L
Iron		0.3 mg/L
Lead	15 ppb	
Manganese		0.05 mg/L
Nitrate	10 mg/L	
pH		6.5-8.5
Zinc		5.0 mg/L

Source: EPA National primary drinking water contaminants, 2009

Conclusions

- Currently,

  - a dilute system with many metals removed or stored; not bio-available.

  - wells tested not harmful to human health.

- Rangeland water and vegetation near mines may be impacted.
- A preliminary study: more sampling and investigation of vegetation and soil is required near abandoned mines.