

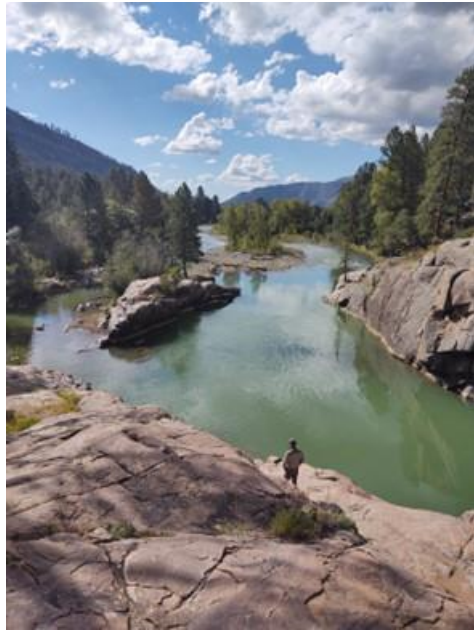
# Animas/San Juan River Monitoring Under the WIIN Program

Watershed Scale Patterns of Water Quality Related to Metals and Nutrients

Kate Sullivan

US EPA Office of Research and Development

Athens, Georgia



## Congress allocated 5 Years of funding to States and Tribes following the Gold King Release (administered by EPA)

*Water Infrastructure Improvements for the Nation Act (WIIN Act)*

WIIN Program has sponsored projects to learn more about:

- ❖ Status of water quality conditions
- ❖ Where materials originate (particularly metals and nutrients)
- ❖ Where materials end up
- ❖ Defining risk and informing management
- ❖ Predicting where or when adverse levels occur

*Projects designed by:*

- Colorado Dept Public Health and the Environment
- New Mexico Dept. of Environment
- Utah Dept Environmental Quality
- Navajo Nation
- Southern Ute Indian Tribe
- Ute Mountain Ute Tribe



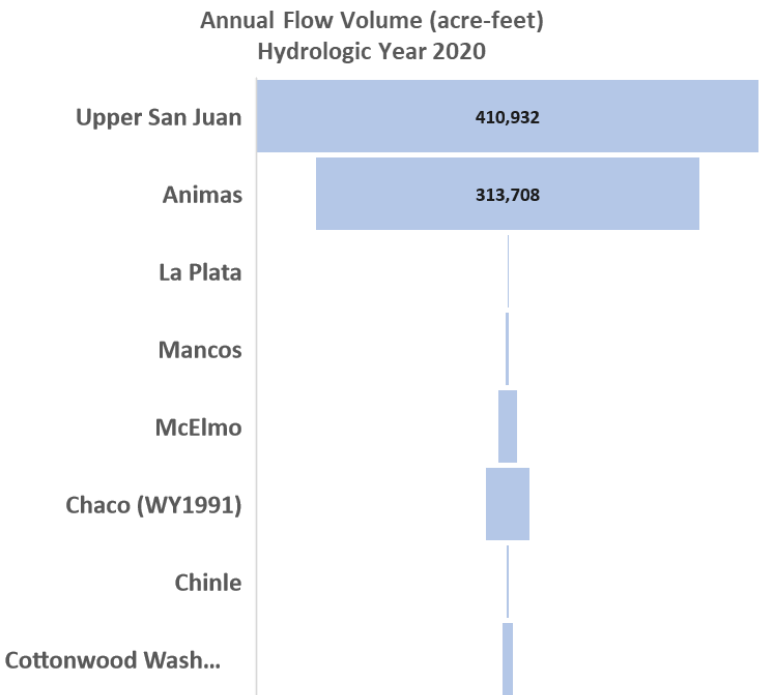
***Visit: [epa.gov/sanjuanwatersheds](https://epa.gov/sanjuanwatersheds) to learn more about current and completed projects***

# San Juan Watershed Tributaries

| Tributary              | Area (mi <sup>2</sup> ) | % SJ Basin |
|------------------------|-------------------------|------------|
| Upper SJ at Navajo Dam | 3,260                   | 9%         |
| Animas                 | 1,360                   | 4%         |
| La Plata               | 602                     | 2%         |
| Mancos                 | 785                     | 2%         |
| McElmo                 | 705                     | 2%         |
| Chaco                  | 4,353                   | 11%        |
| Chinle                 | 3,725                   | 10%        |
| Washes and Arroyos     | 23,510                  | 61%        |

Total Area 38,300

## Contribution to Annual Flow Volume



The Animas is the largest free-flowing perennial river in the watershed



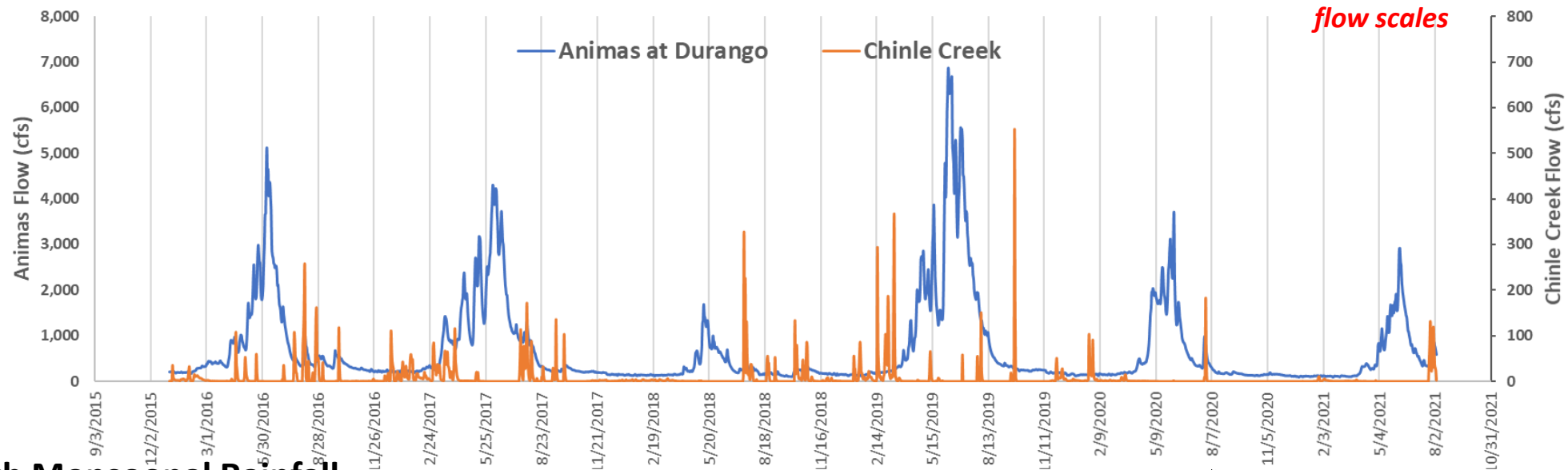
Most of the San Juan tributaries are intermittent or nearly so and contribute very little water to the San Juan River on an annual or daily basis

# Climate influence on flow volumes and timing

Compare River Flow in Time (note difference in flow scale)

## Snowmelt Regime

- Prolonged higher flows from April-July

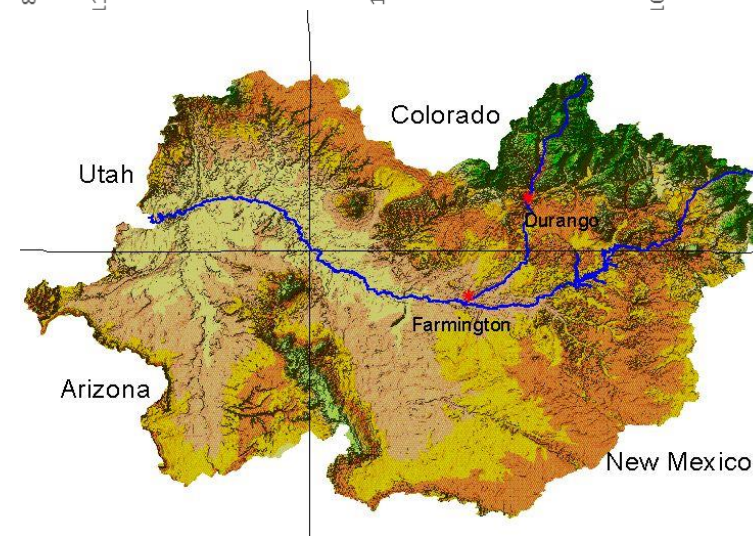


## Intermittent flow with Monsoonal Rainfall

- Short, rapid flow spikes associated with intense rain events
- Flow often retreats to near 0 between events
- May be very local involving one tributary or “widespread” involving many.



- Chinle Creek is one of the larger intermittent tributaries
- Can contribute as much as 40% of the flow in SJ at Mexican Hat during the largest events



# WIIN Water Quality Monitoring Data

WIIN funded San Juan Watershed Monitoring 2018-2021

39 sampling locations

10 sampling campaigns

Fall 2018 through Snowmelt 2021

Sampled a variety of flow conditions

Fall and winter baseflows

Spring snowmelt

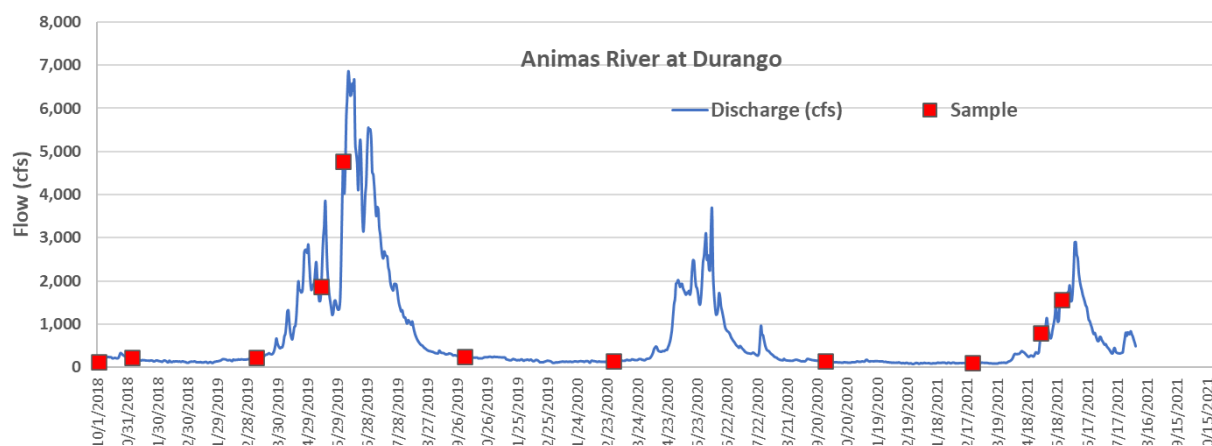
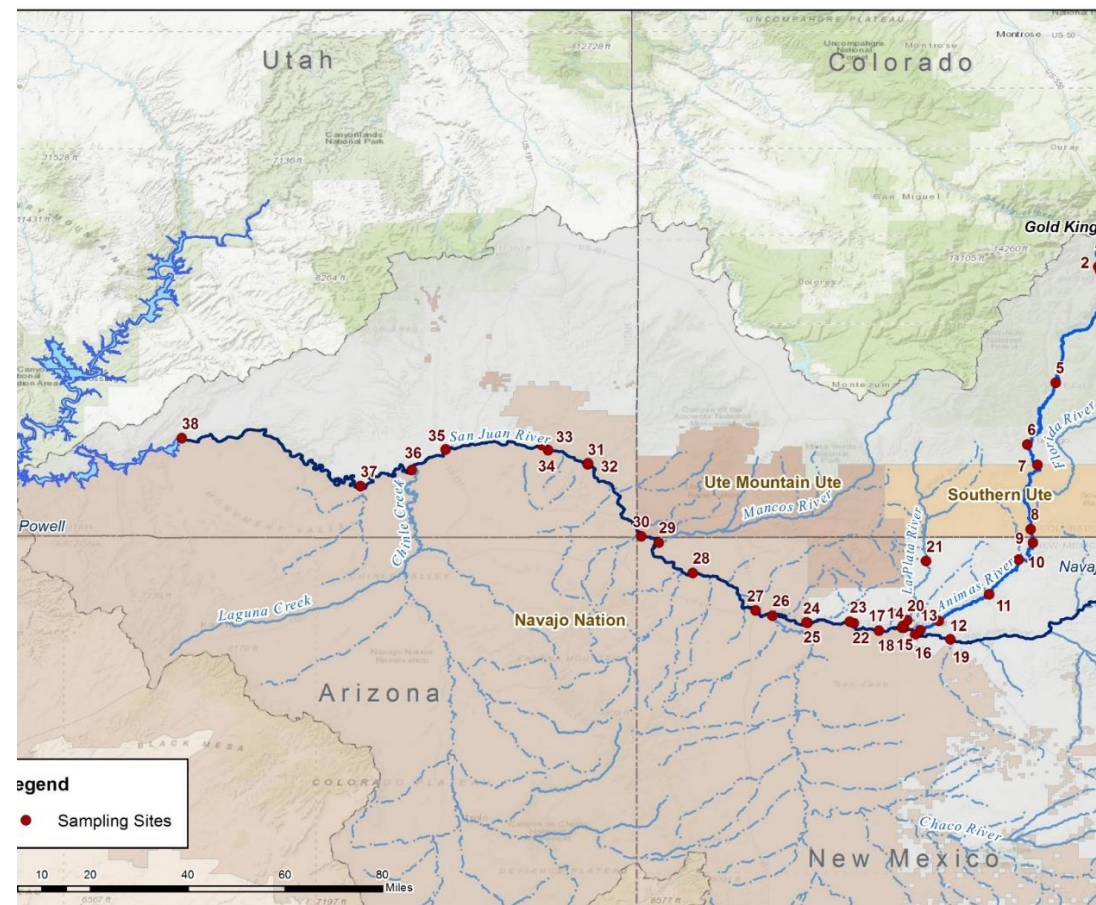
Regional storm

318 individual samples

**Metals in sediment and water**

Nutrients

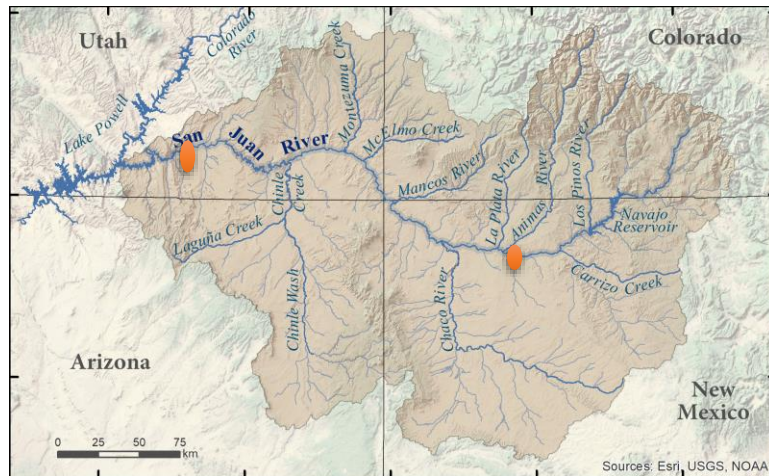
Other water chemistry parameters



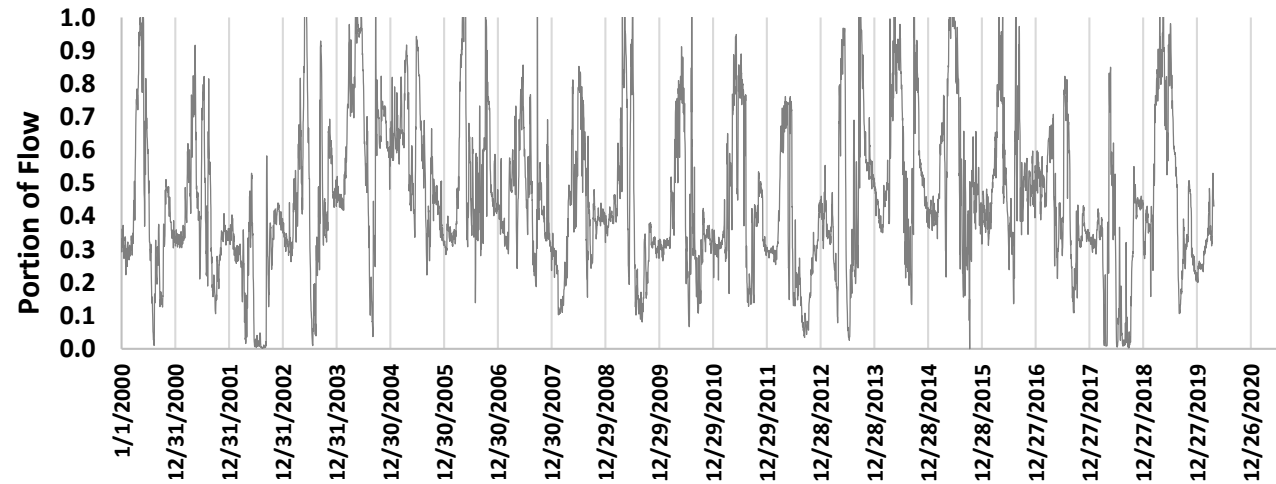
EPA involvement is winding down but the program will be going forward under leadership of cooperating States and Tribes

# Animas River is a significant contributor to flow in the San Juan River at Farmington most of the time

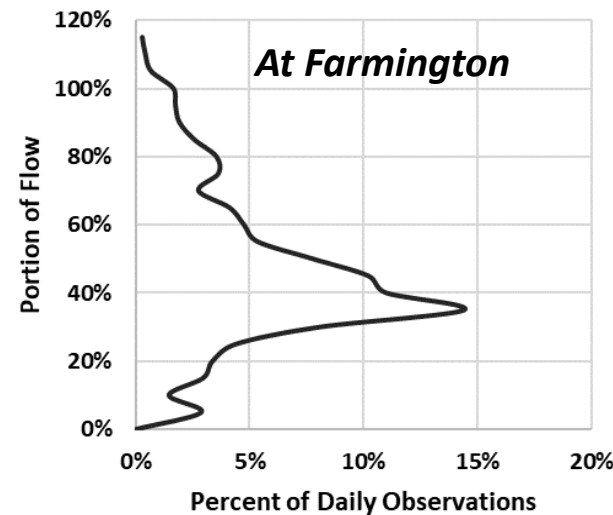
- Below confluence in Farmington:
  - Median: 40%
  - Commonly: 30-60%
  - As high as 95%
- At Mexican Hat 250 km downstream before entering Lake Powell
  - Same



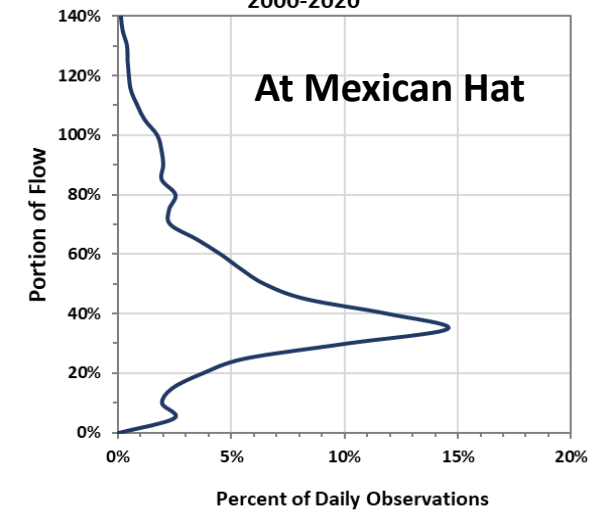
Animas as Portion of San Juan Flow at Farmington



Animas Portion of Flow in the San Juan River at Farmington 2000-2020

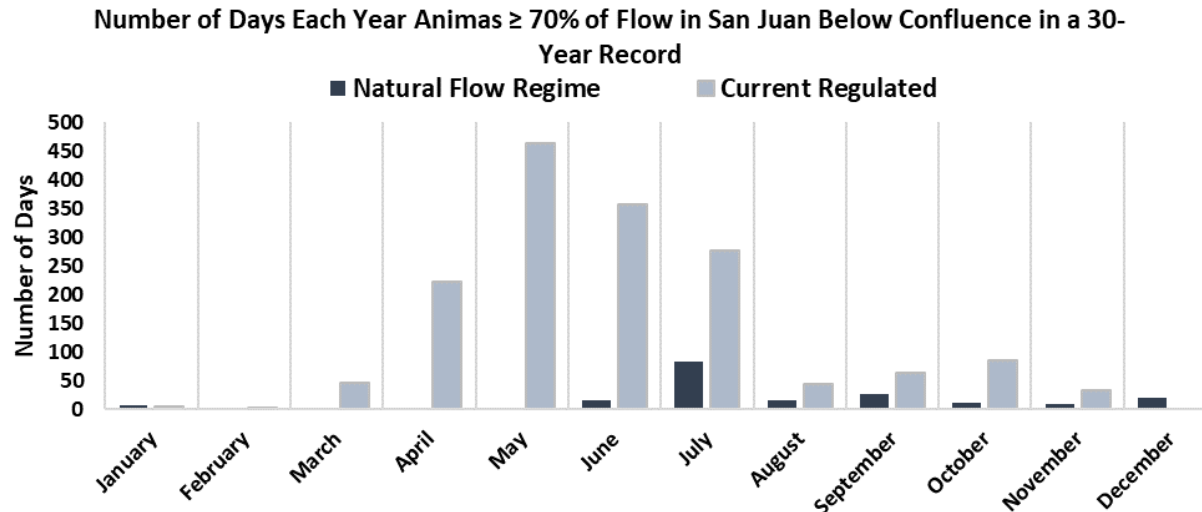
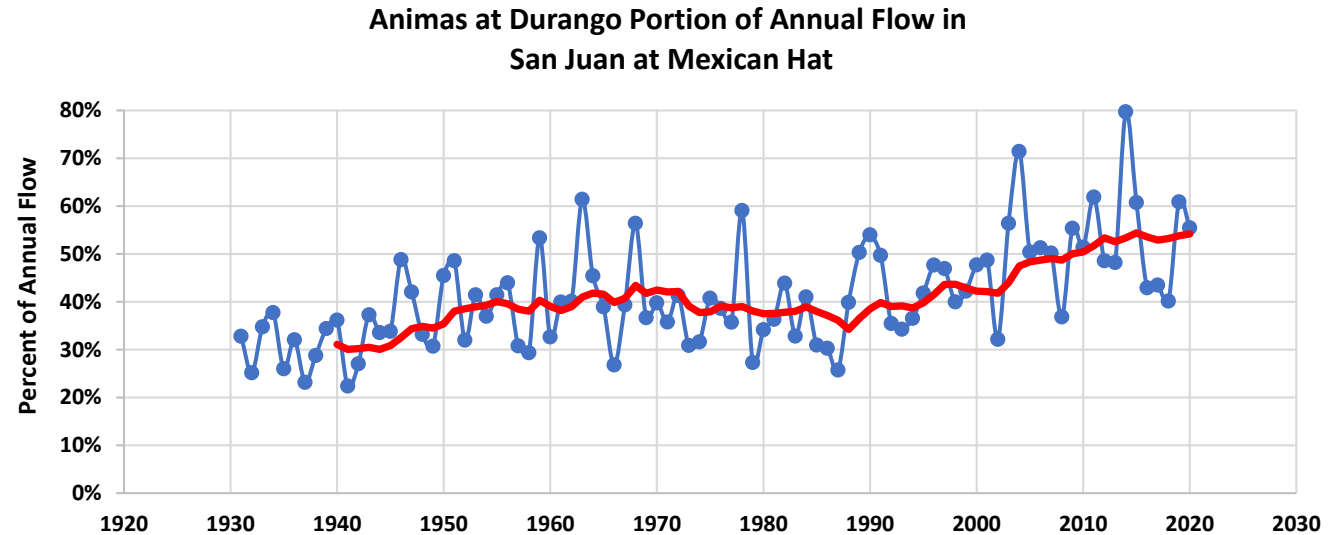


Animas Portion of Flow in the San Juan River at Mexican Hat 2000-2020

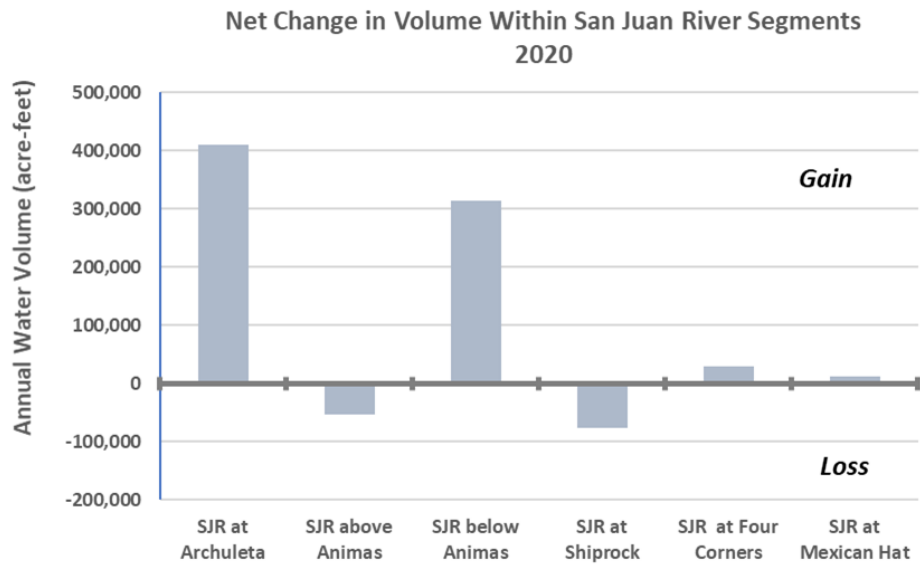
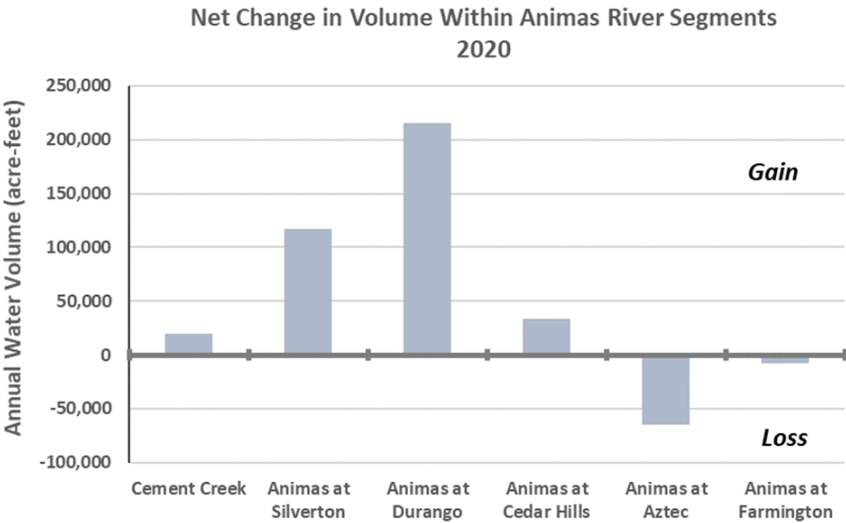
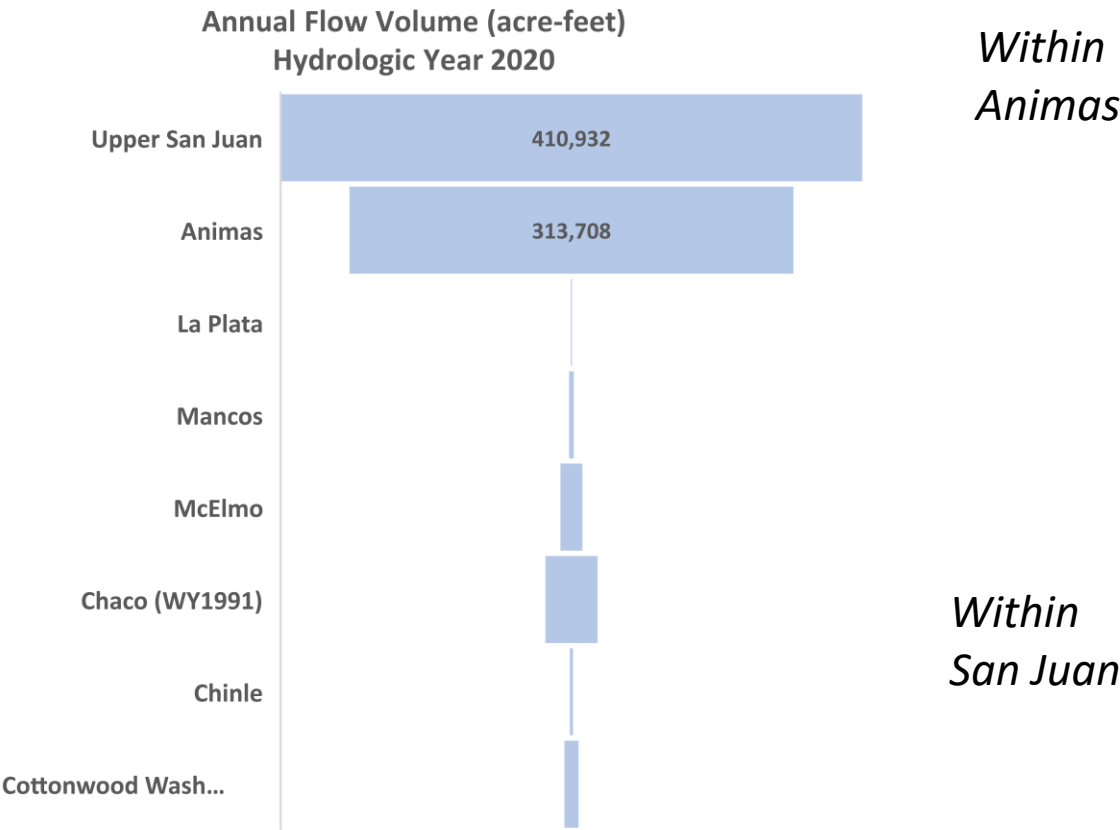


## The importance of the Animas River in maintaining flow in the San Juan has grown over time

- Animas portion of flow has grown over time since river management began in 1963
- Now far more days when Animas contributes at least 70% of flow
- Many of these days occur during snowmelt but increasingly occur much of the year
- Likely to further influence any Animas water quality effects in the San Juan

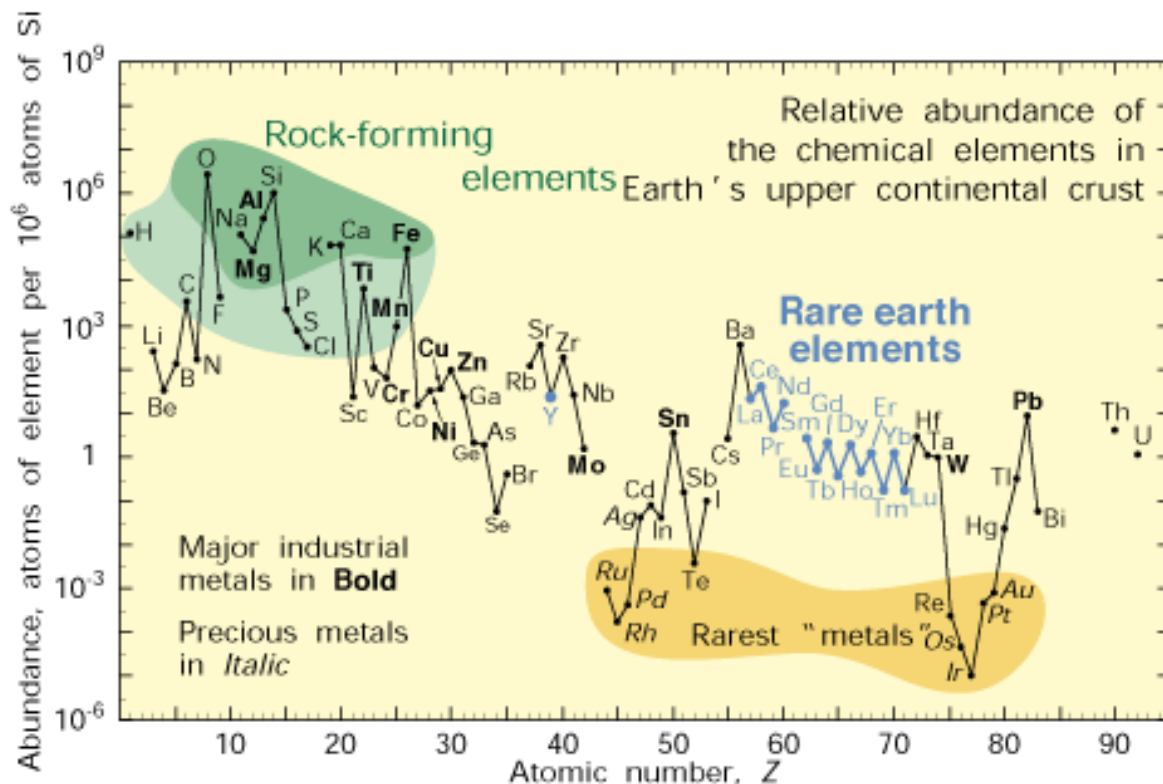


# Where does water come from on annual basis?

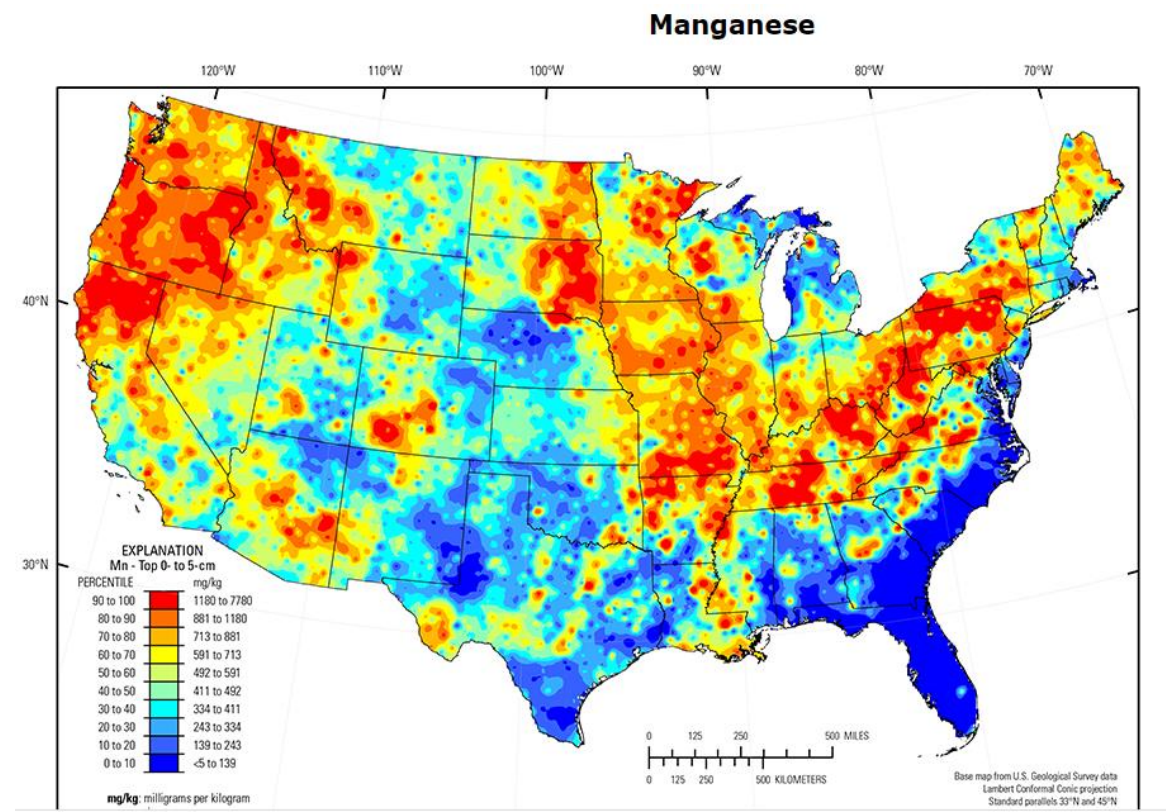


## Metals occur in all rocks and the soils that weather from them

## Average crustal abundance across earth



## Concentrations vary significantly at more local level reflecting rock origins



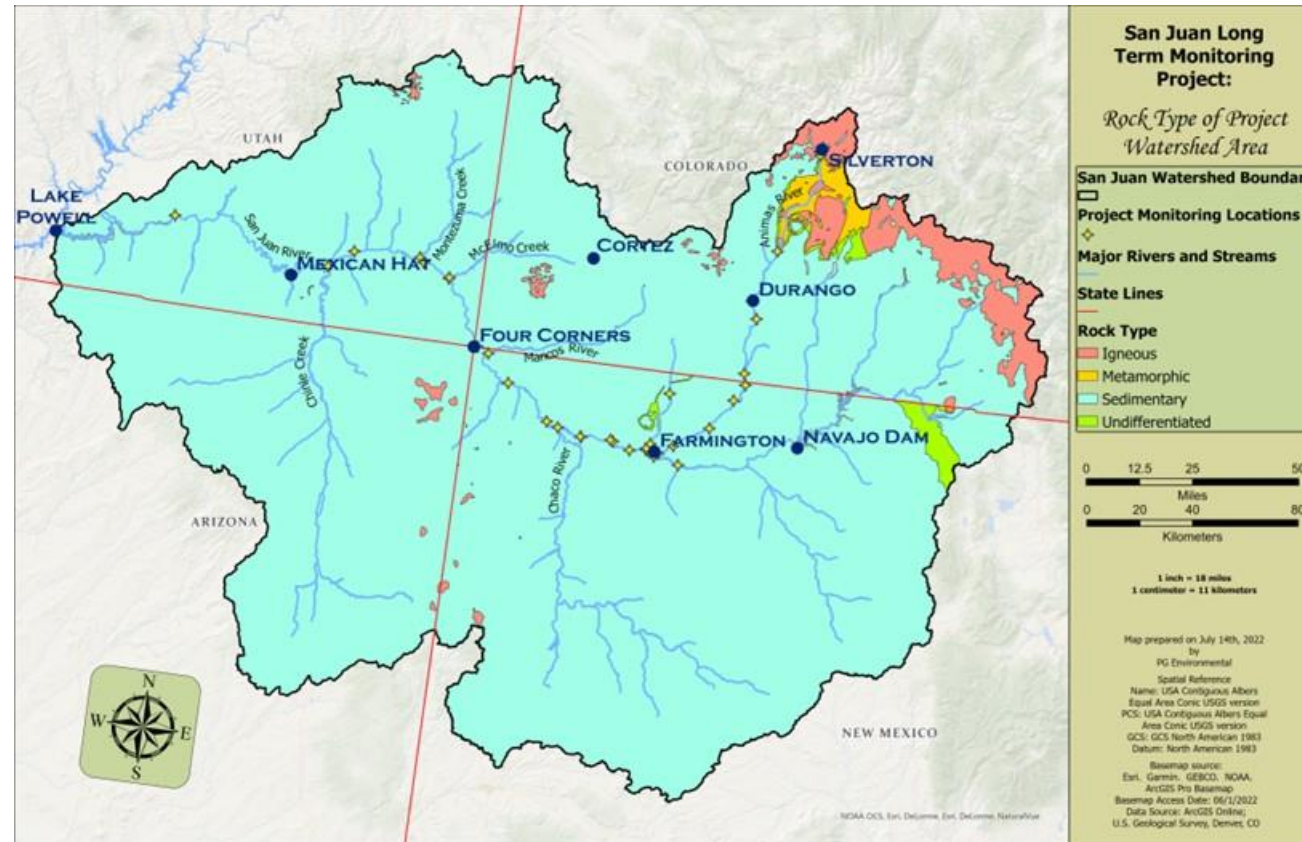
**Includes: Major, Trace, and Rare earths**

# Geology is the main source of metals in water

*All rocks are primarily comprised of metals  
Rock types vary in what metals are present*

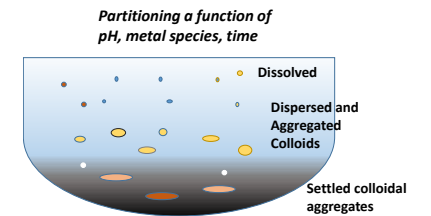
## Colorado Plateau Sedimentary

- Generally “silicate-bound”
- Rocks erode and enter stream as particles of varying sizes

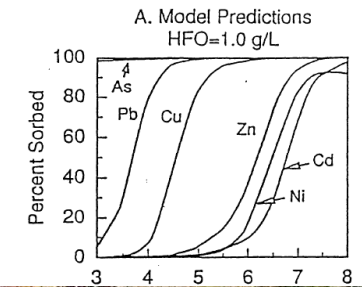


## San Juan Mountain Volcanics

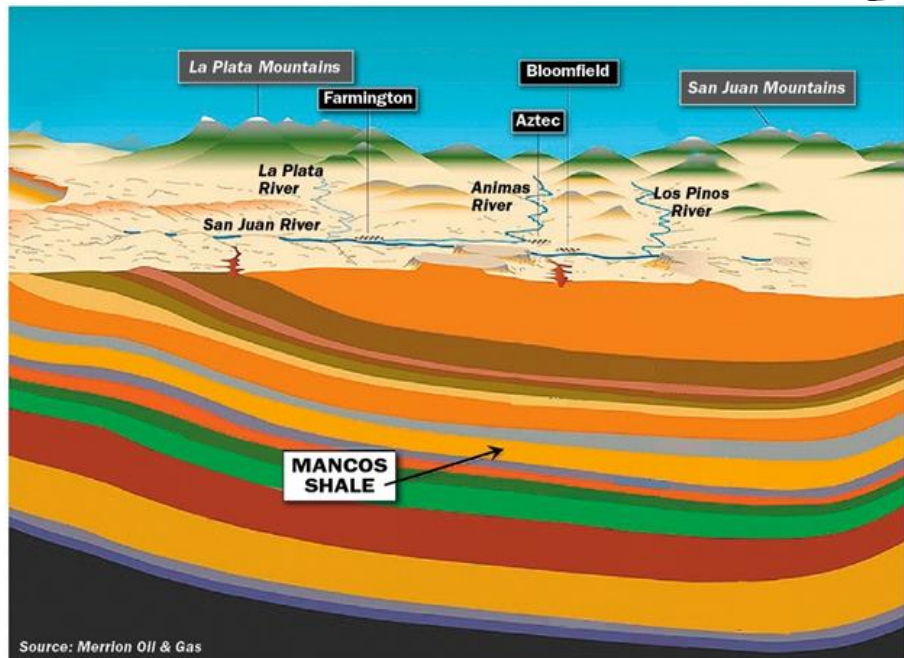
- Form of metal (dissolved or solid) is highly dependent on pH



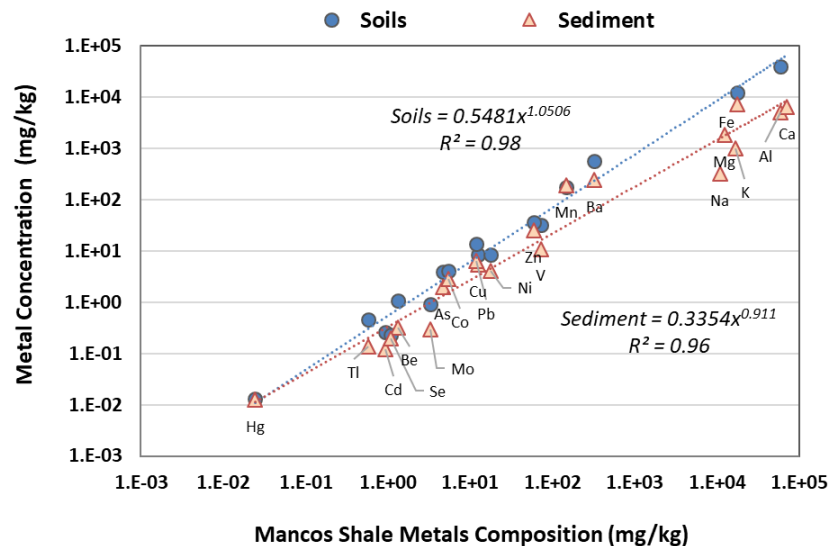
- Metals weather by groundwater leakage through sulfide-rich mineral ores and mining waste



# Metals in Sedimentary Rocks – Mancos Shale

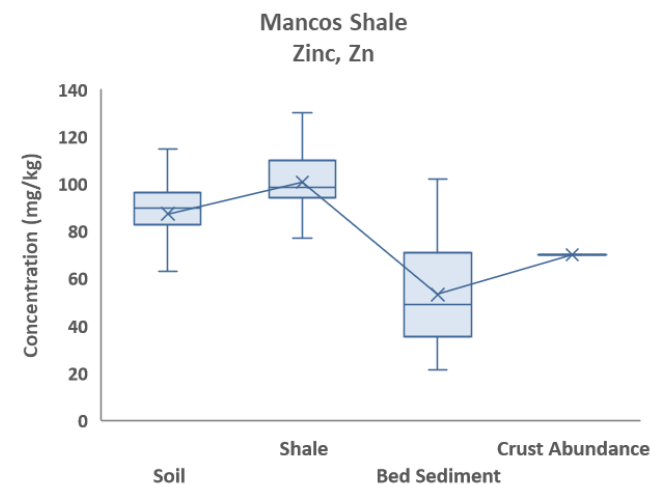
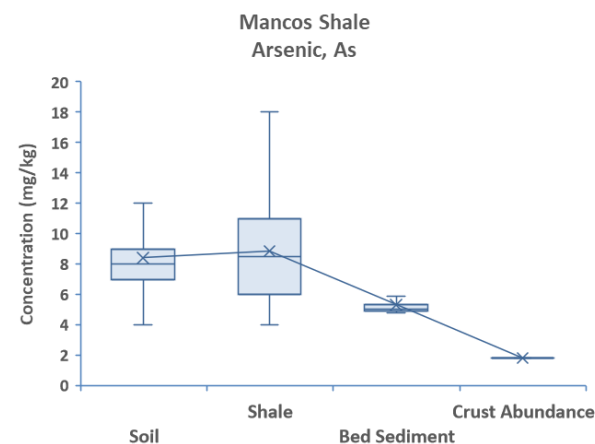
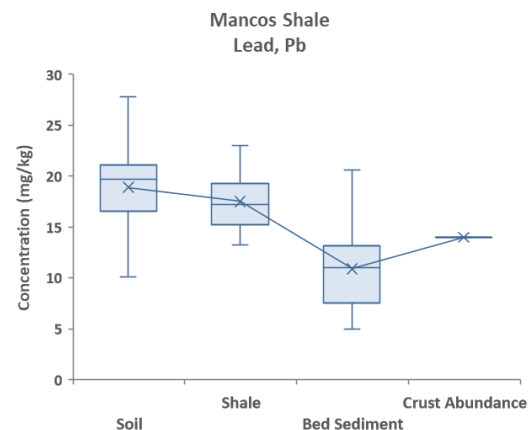


Relationship Between Mancos Shale Composition, Soils, and Sediment in the Upper San Juan River



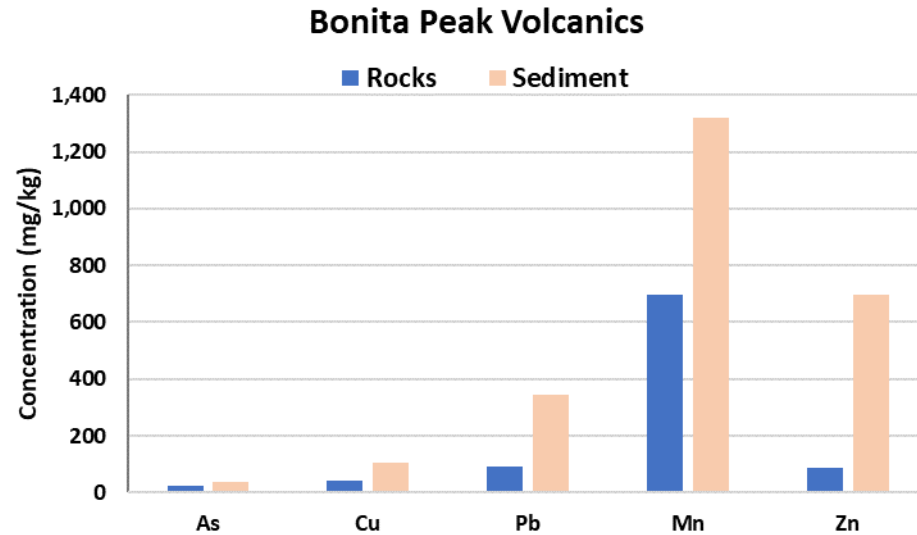
Metals in river sediments and water generally reflect their concentration in parent rocks

Rock → Soil → Eroded into streams



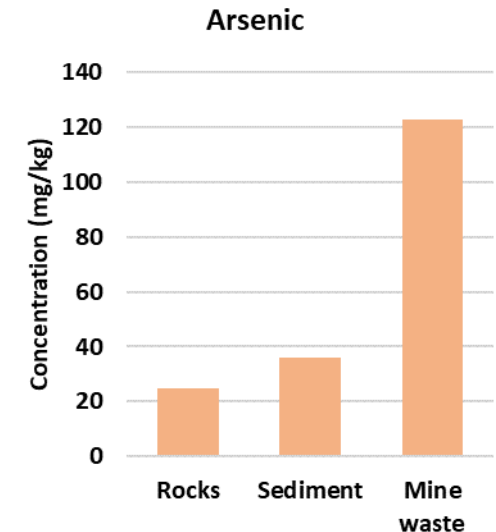
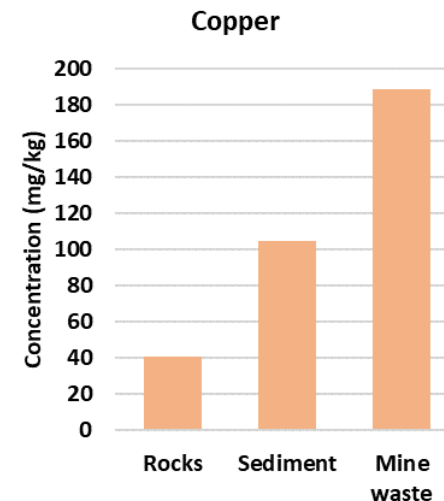
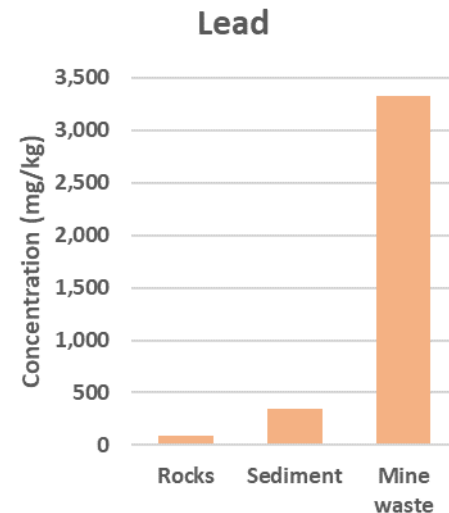
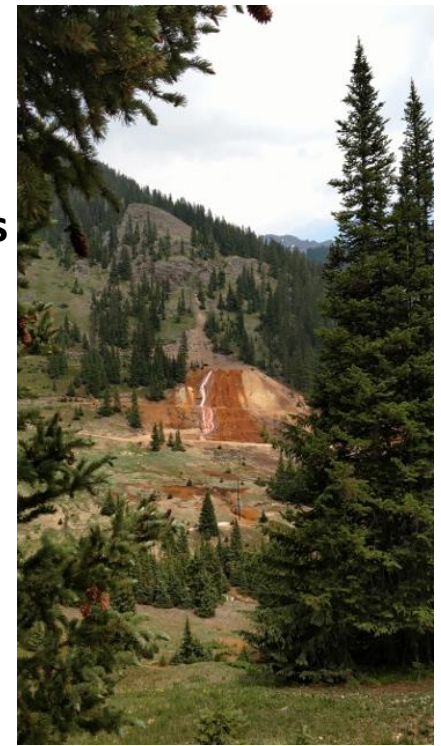
- Bonita Peaks has complex local geology associated with volcanic formations
- Ore veins create locally high concentrations of some metals which can affect much of the stream network in that area
- Metal availability has increased due to mine tunnels and wastes
- Target of remediation efforts

## Metals in Sediment Within the Bonita Peaks



### Ore-Related metals

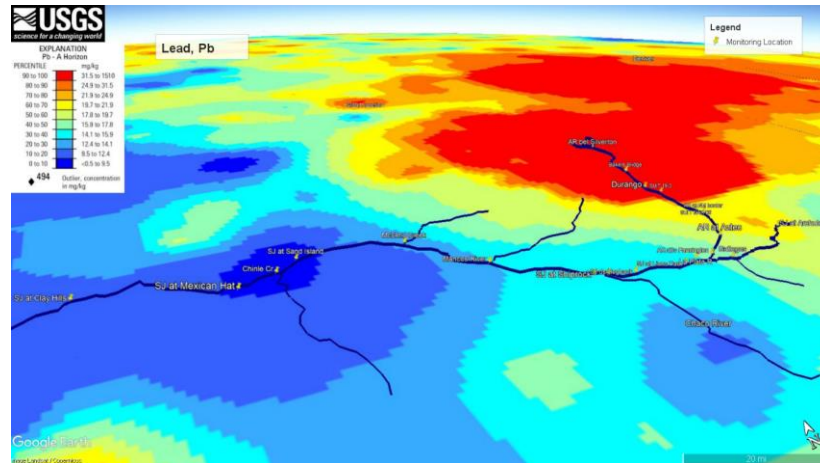
Lead  
Copper  
Zinc  
Arsenic  
Manganese  
Cadmium



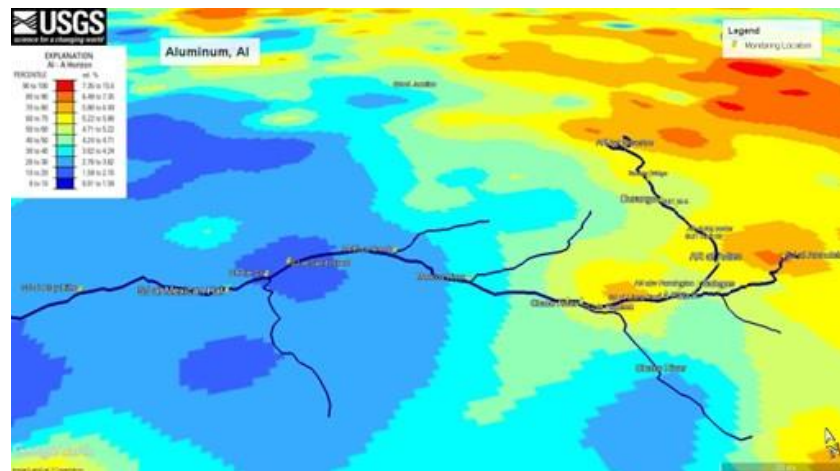
# Geology creates a longitudinal gradient of metals availability within the Animas/San Juan Rivers

USGS Soil Metal “Heat Maps”

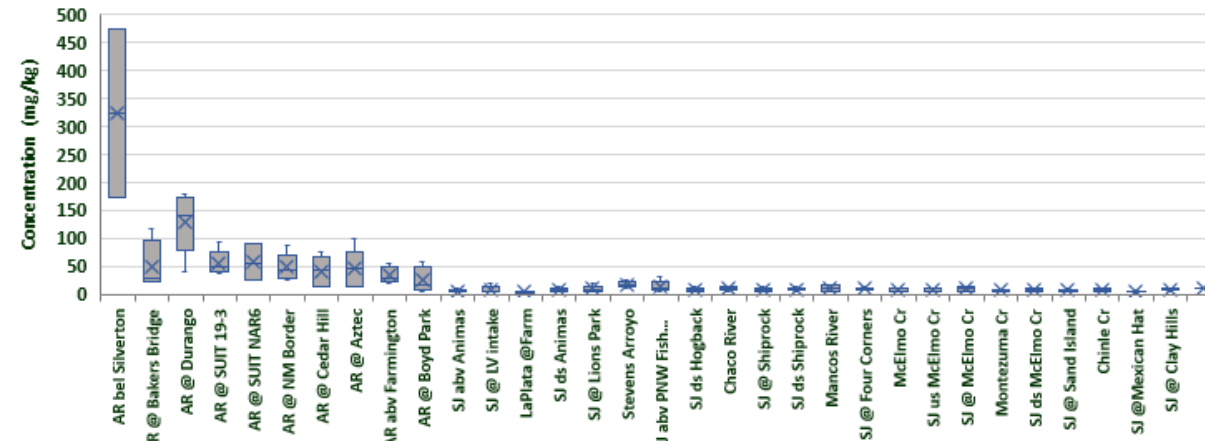
## LEAD



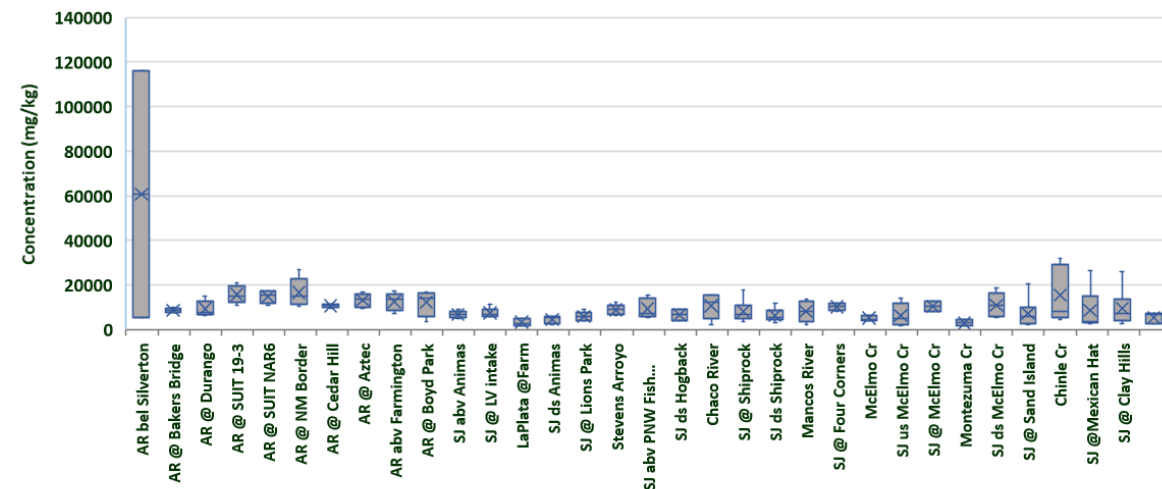
## Aluminum



Lead in Sediment in the Animas/San Juan

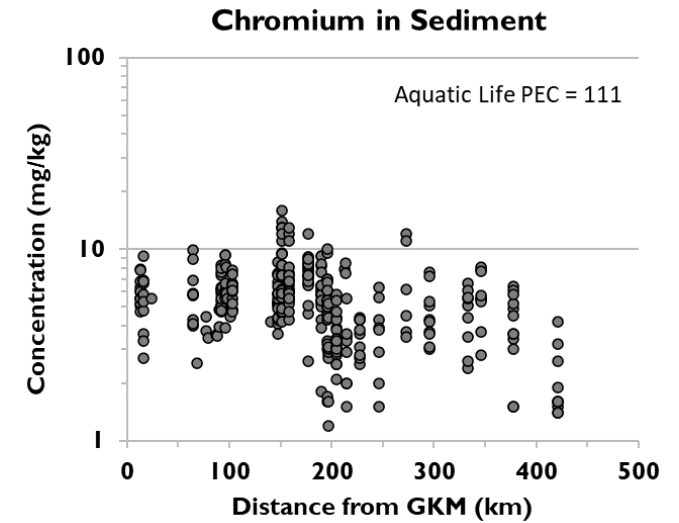
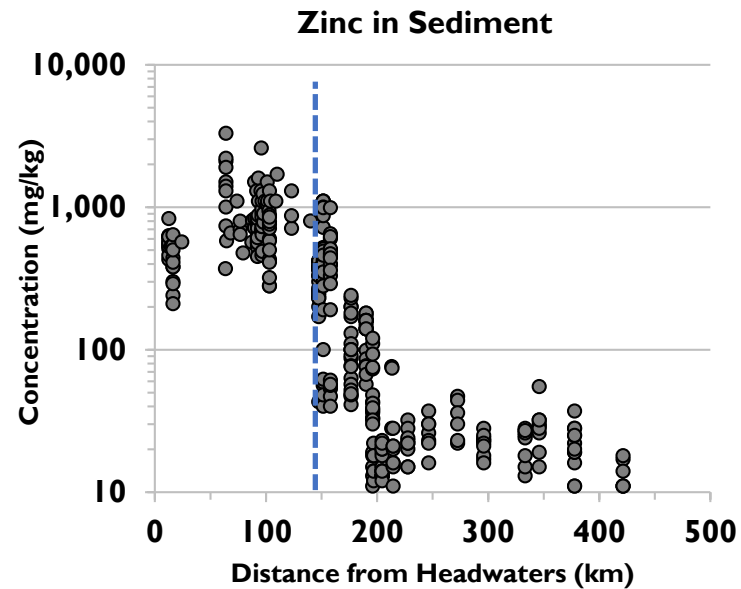
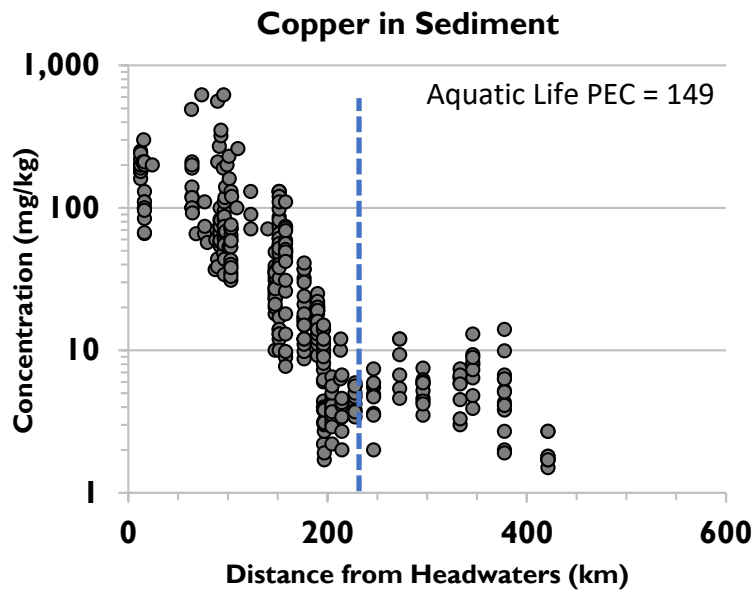
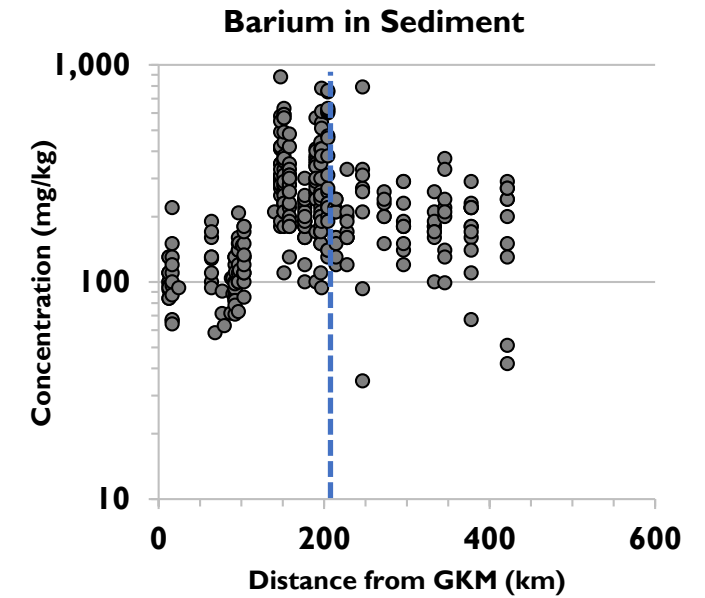
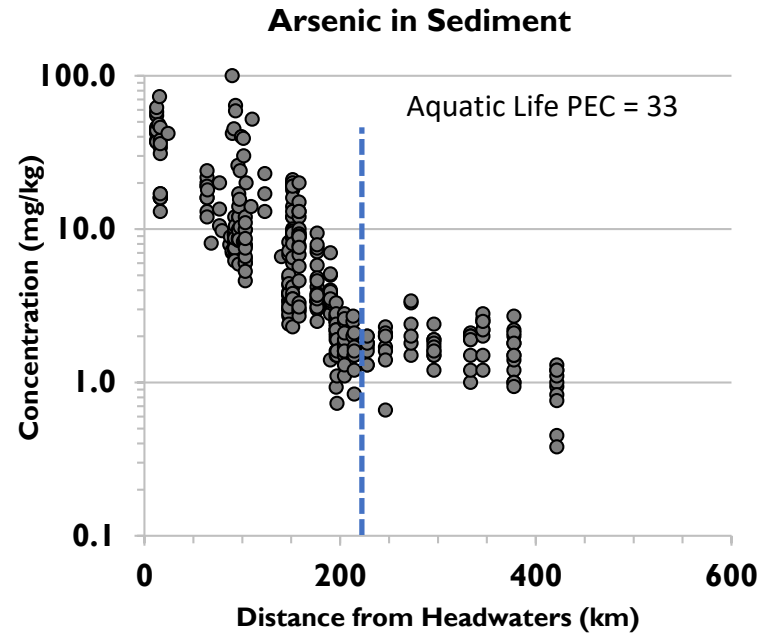
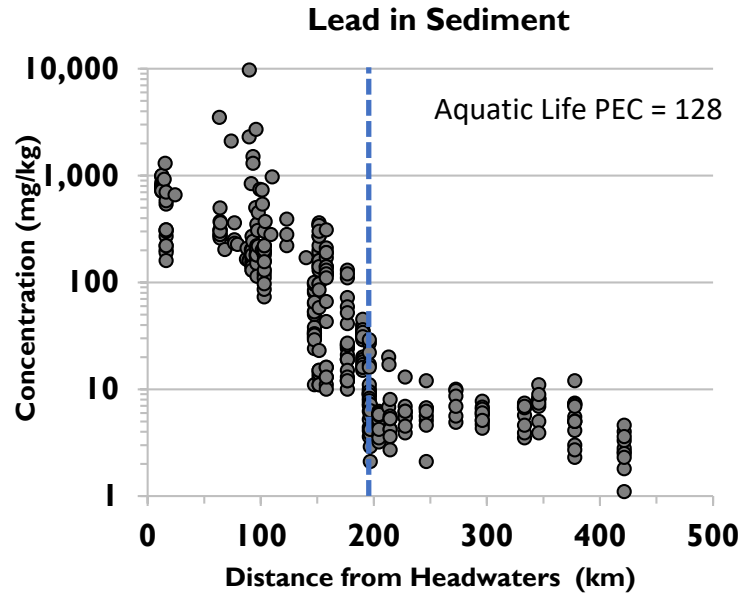


Aluminum in Sediment in the Animas/San Juan



Generally translates to similar patterns in streambed sediments and stream water

# Metals in Streambed Sediments

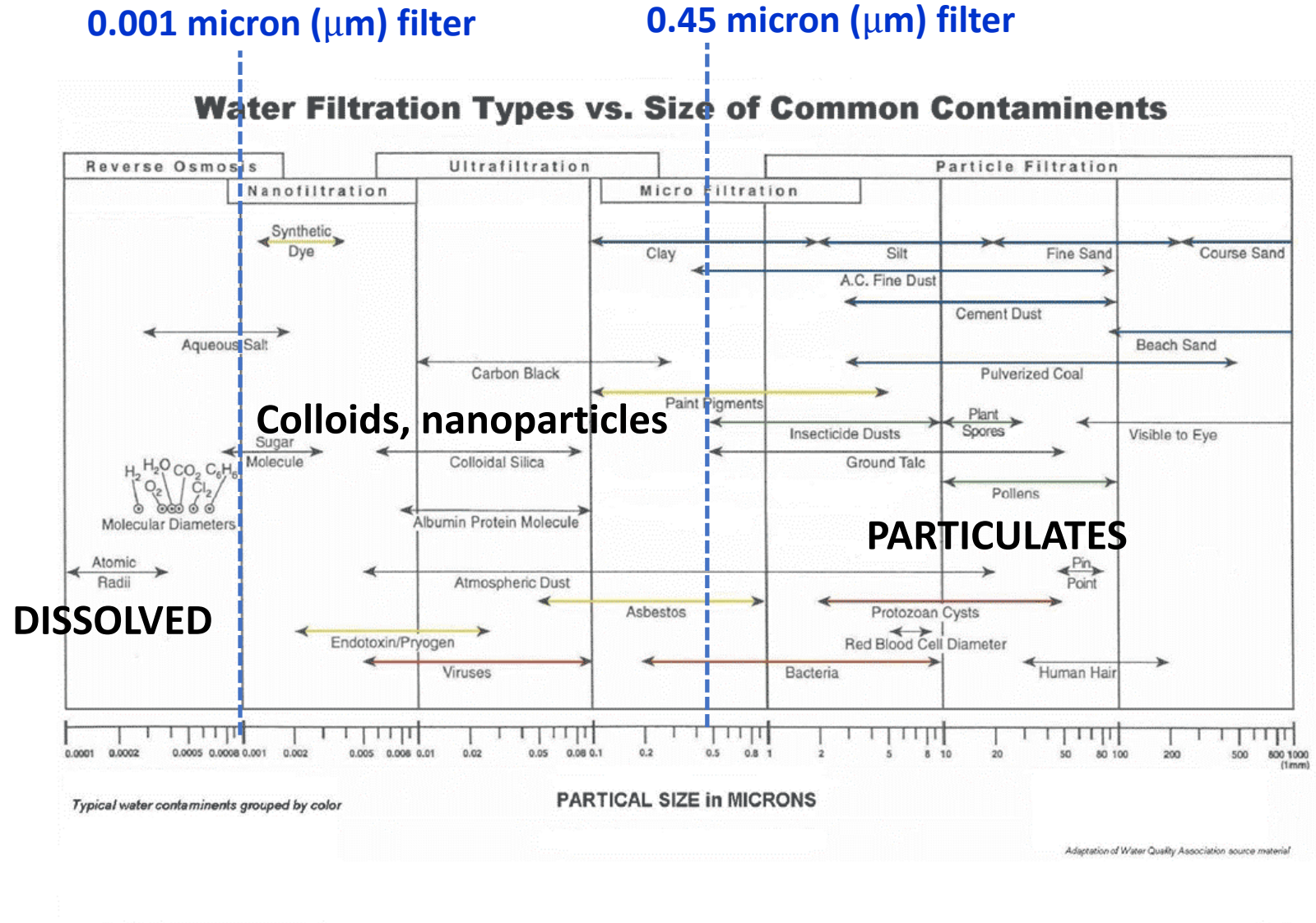
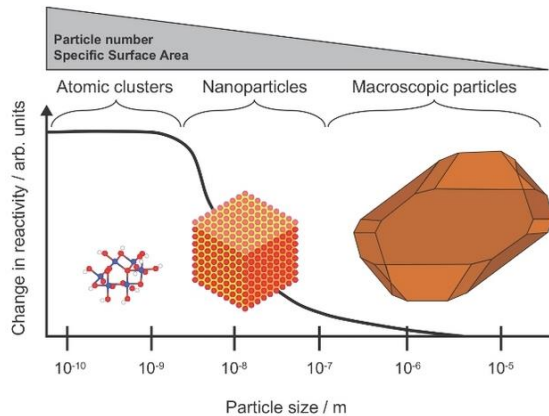


# **Status of benthic macroinvertebrate communities generally follow the trends in streambed sediments**

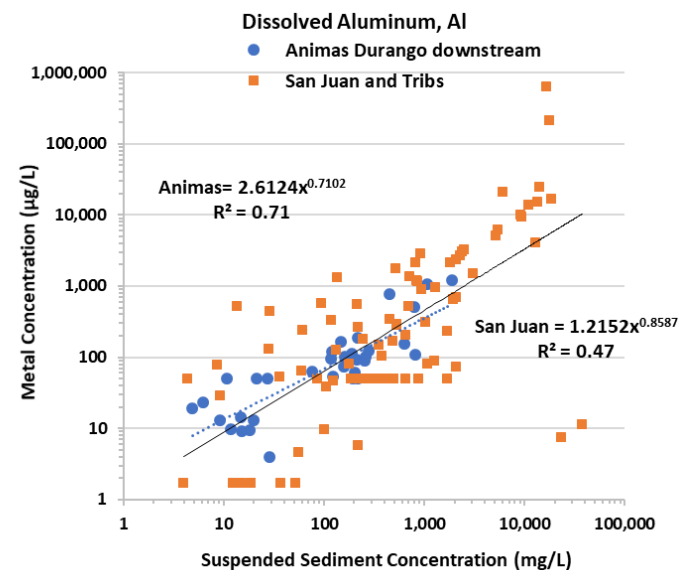
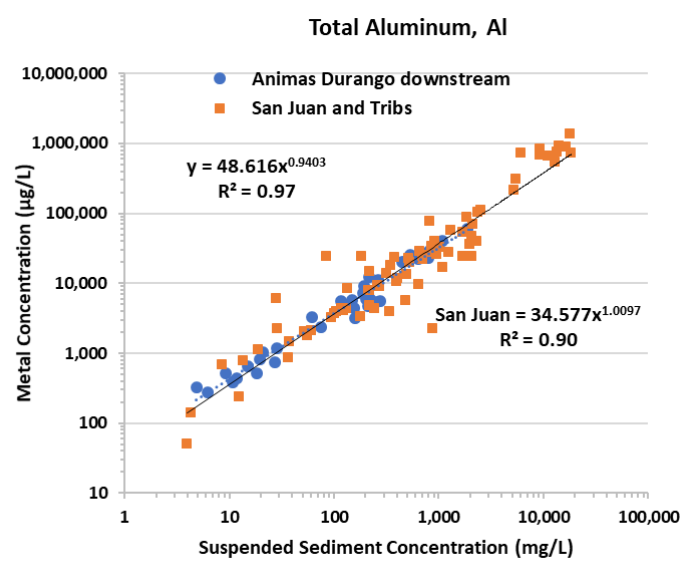
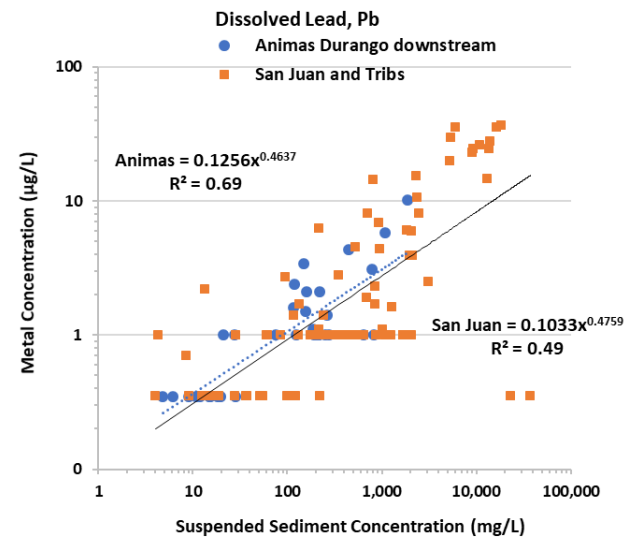
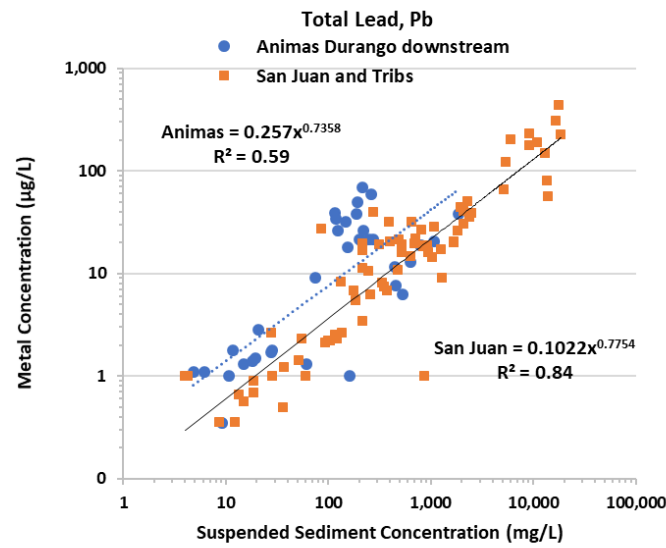
**NRSA Index  
assesses  
various  
components of  
the condition  
of a waterbody  
including  
aquatic  
invertebrate  
community**

# Water Quality Considers Dissolved and Total Metals

- Standard process to determine the dissolved fraction is to filter the sample through a 0.45 micron ( $\mu\text{m}$ ) mesh
- Dissolved metals more closely approximate the bioavailable fraction of metal in the water column
- Samples filtered with the standard 0.45 micron mesh may include some of the colloidal fractions within the dissolved category



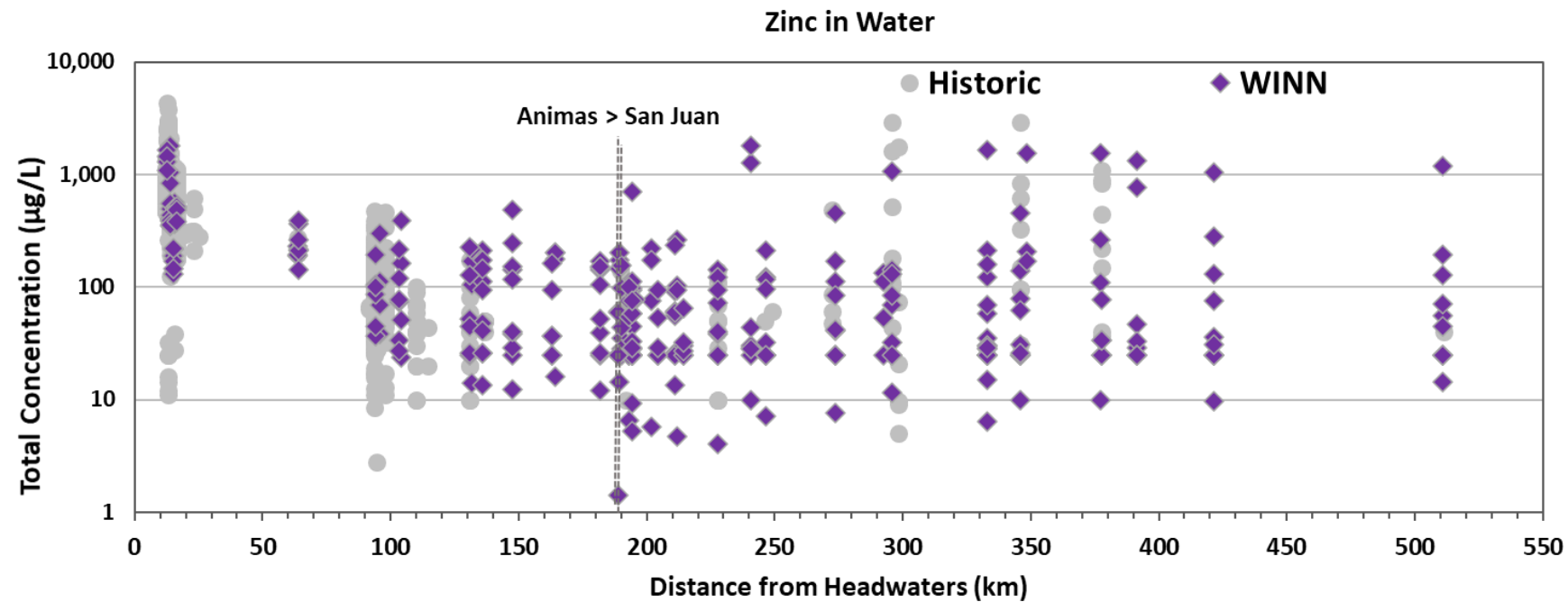
Total and Dissolved Metals are highly correlated with Suspended Sediment Concentrations–All Metal Groups



# Total Concentration in Water

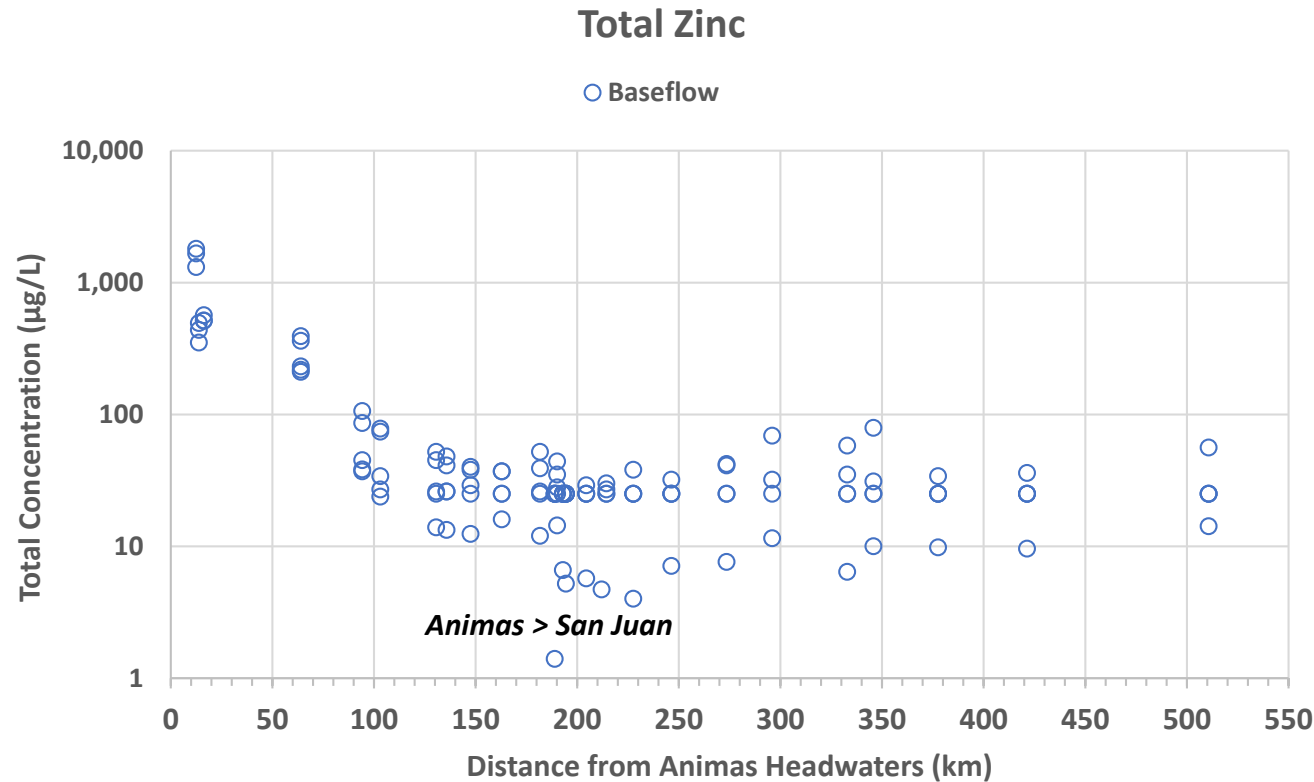
- Water concentrations in the Animas and the San Juan can vary widely during the year
- Water concentrations in the San Juan can be as high as in the Animas
- On any day:
  - The Upper Animas is largely geochemically processing ore-related metals delivered on a chronic basis
  - The middle and lower Animas have a mixture of ore- and sediment sources determined by hydrology
  - The San Juan has abundant sediment and associated metals with a low level influx from the Animas

*The mobility of metals from various sources and mechanisms along with the varying hydrology creates a wide range of metals concentrations at most locations in the watershed within the annual hydrologic cycle*



*The mobility of metals from various sources and mechanisms along with the varying hydrology creates a wide range of metals concentrations at most locations in the watershed within the annual hydrologic cycle*

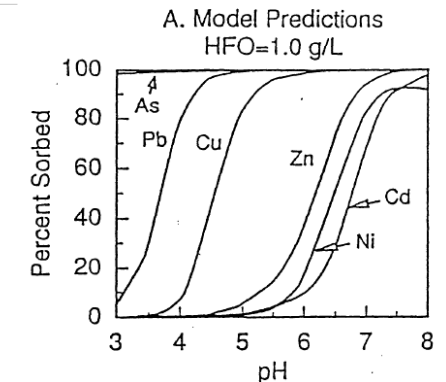
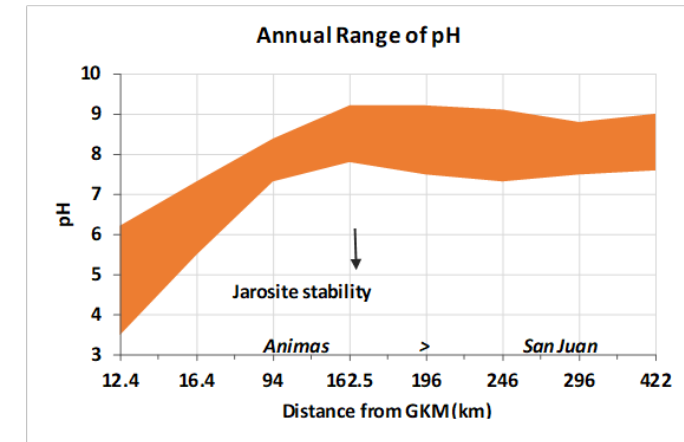
- At baseflow there is a strong downstream gradient from headwaters to Aztec



## Baseflow

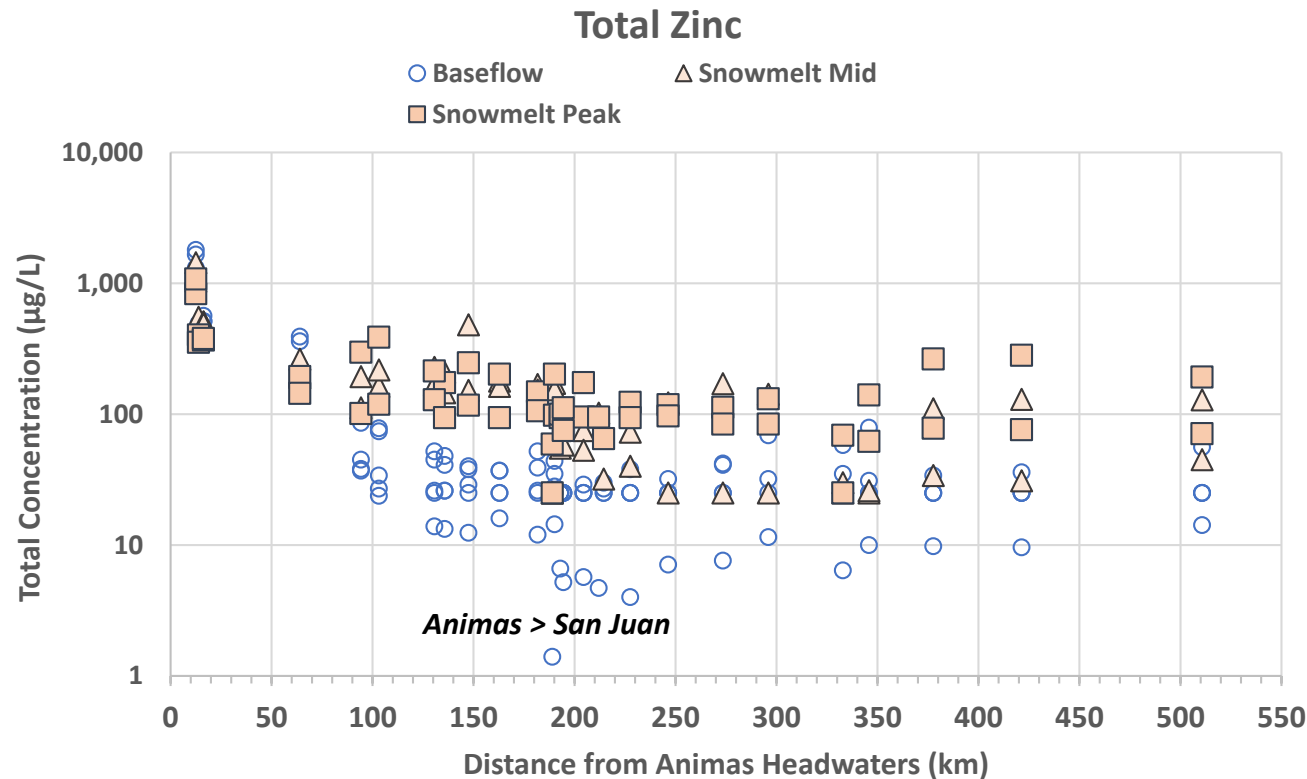
### Factors influencing:

- pH causing adsorption (dissolved to total)
- Low Flows causing deposition



*The mobility of metals from various sources and mechanisms along with the varying hydrology creates a wide range of metals concentrations at most locations in the watershed within the annual hydrologic cycle*

- At baseflow there is a strong downstream gradient from headwaters to Aztec
- **During snowmelt the general level of metals is higher and similar from the Animas through the San Juan**



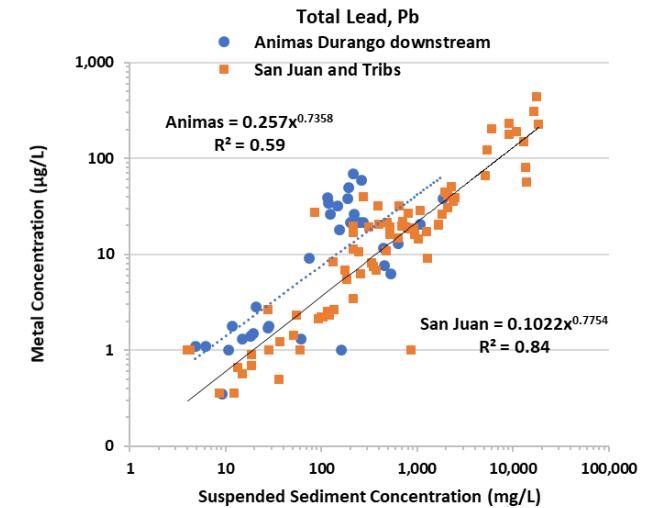
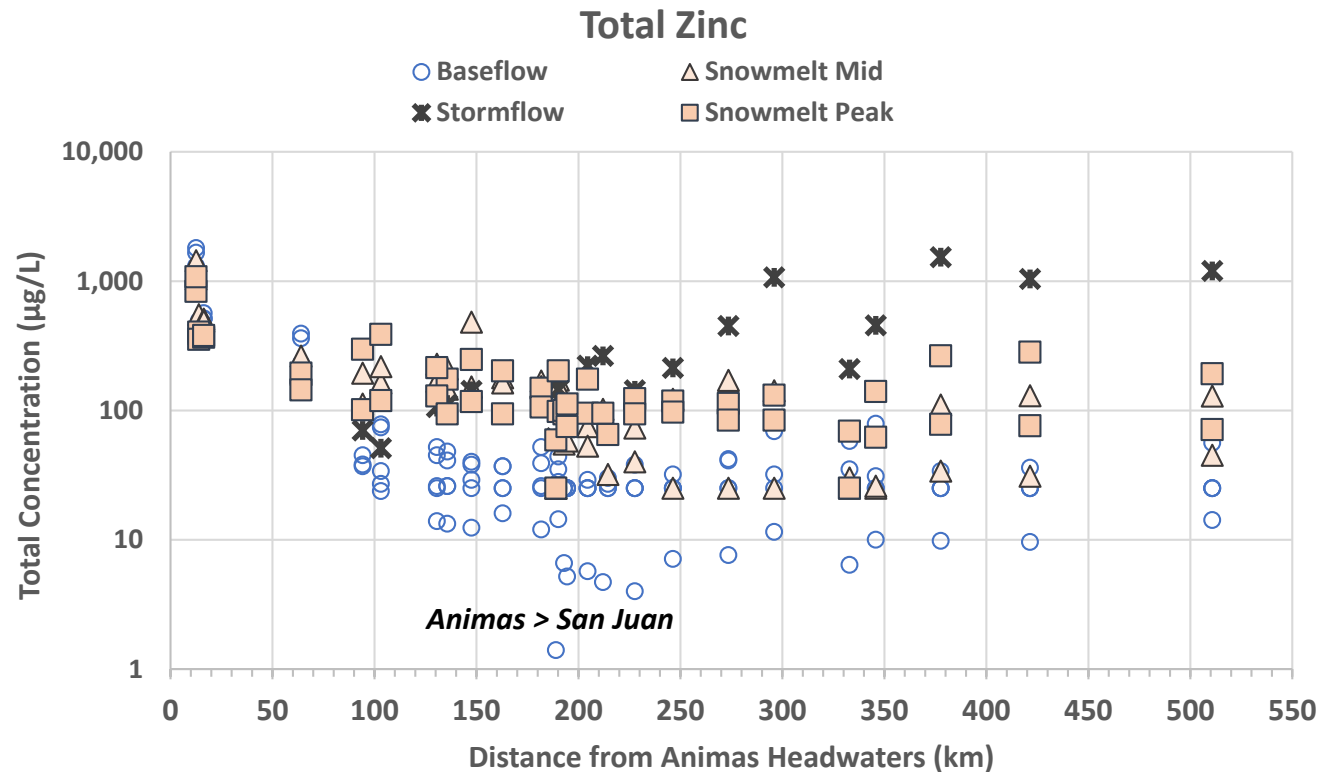
## Snowmelt

### Factors influencing:

- Dilution due to high flow volume
- Mobilization of previously deposited particulates
- High transport capability

*The mobility of metals from various sources and mechanisms along with the varying hydrology creates a wide range of metals concentrations at most locations in the watershed within the annual hydrologic cycle*

- At baseflow there is a strong downstream gradient from headwaters to Aztec
- During snowmelt the general level of metals is higher and similar from the Animas through the San Juan
- During stormflow there is a strong increase in metals through the San Juan associated with sediment

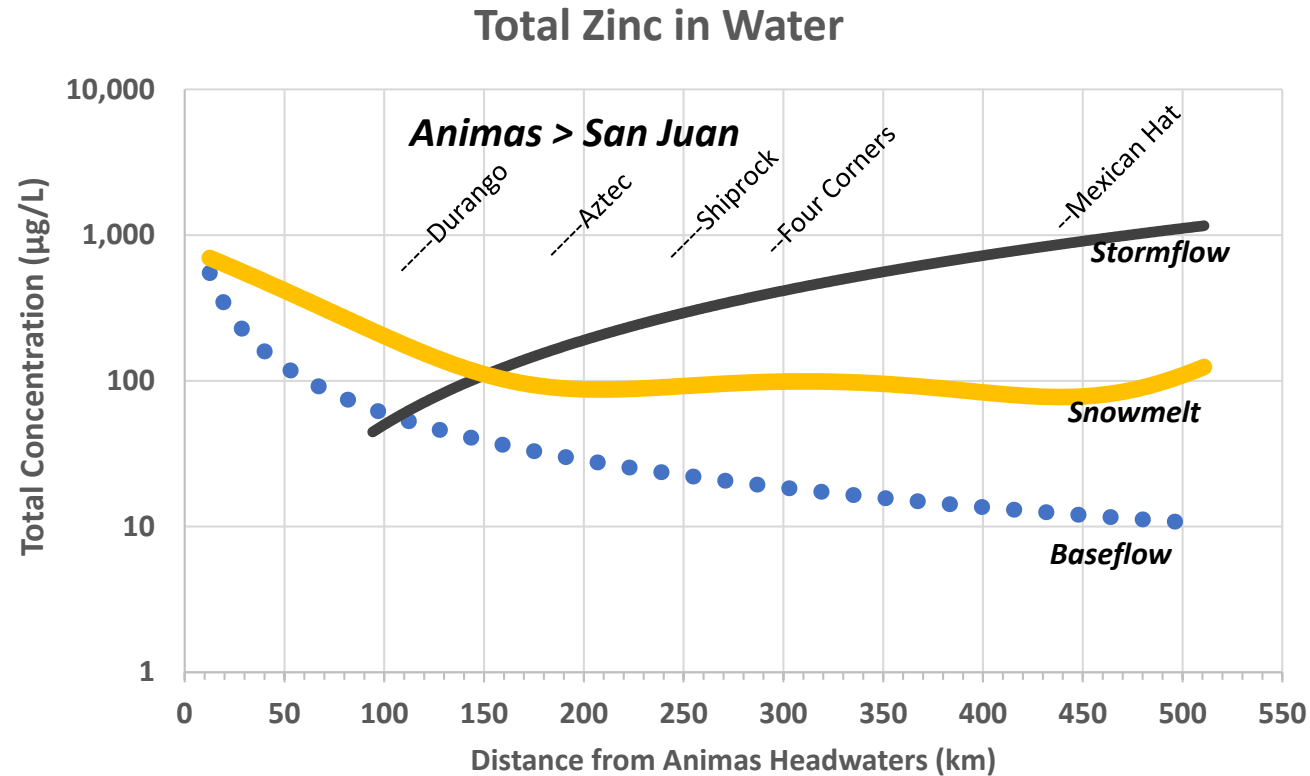


## Stormflow

### Factors influencing:

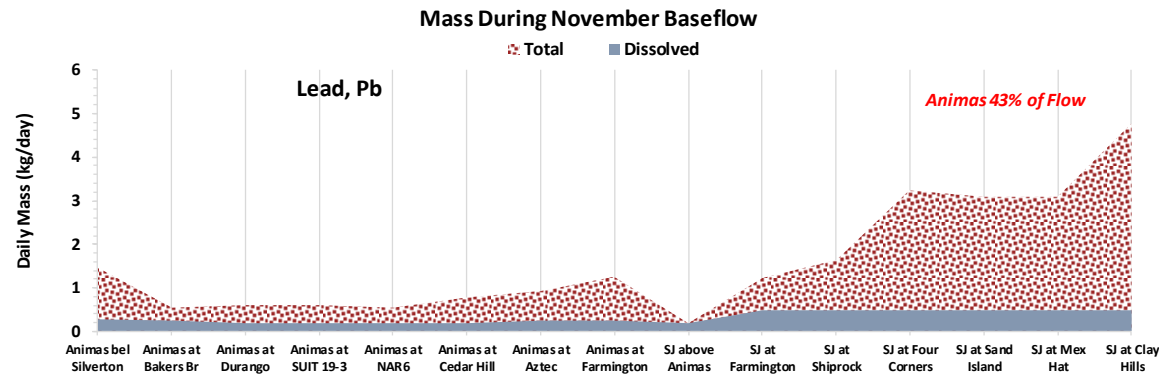
- High streamflow mobilizes sediment
- Monsoonal storms generally impact lower Animas/SJR

- At baseflow concentrations in the San Juan are low
- During snowmelt the metals delivered from the Animas determine the metals concentrations through the San Juan generally
- During stormflow metals are entirely related to sediment supply

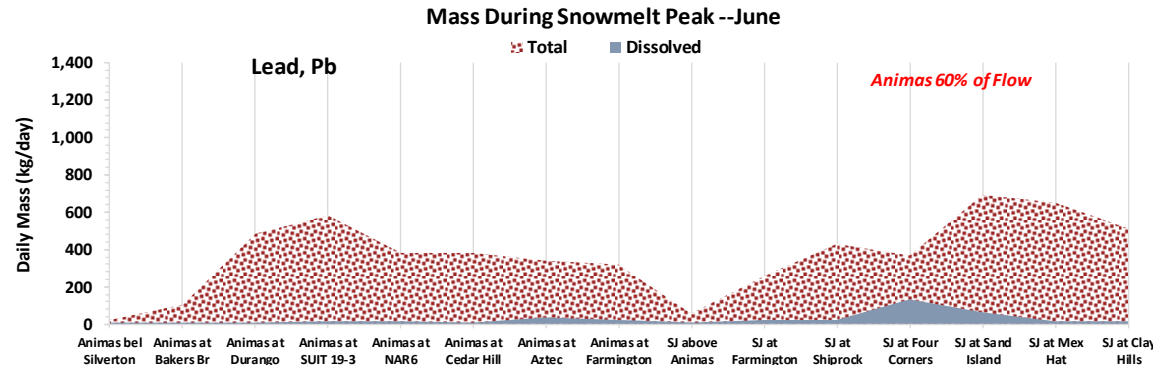


# Movement of Lead Mass through the Animas / San Juan Rivers

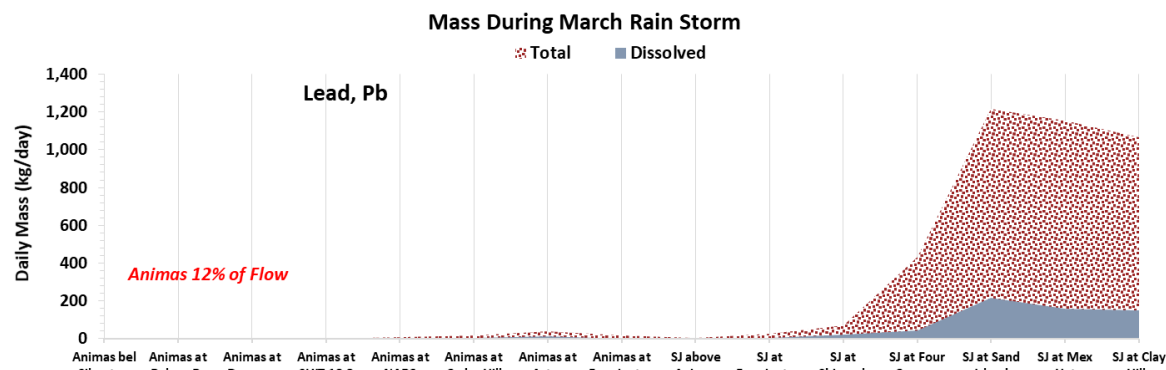
## Baseflow



## Peak Snowmelt

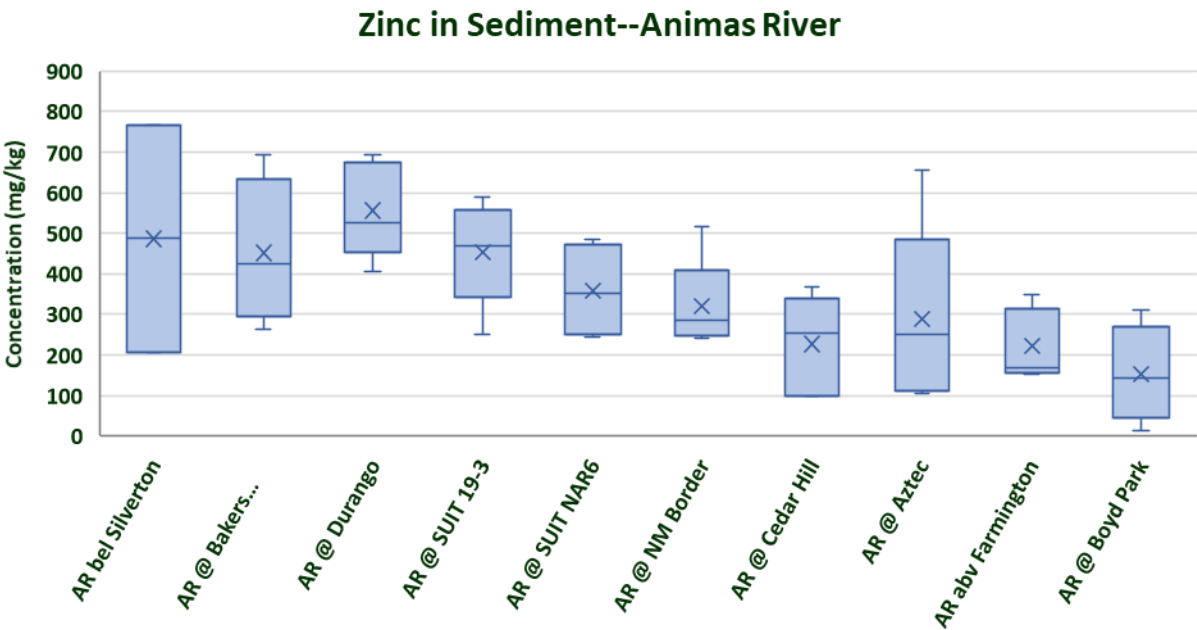


## Storm

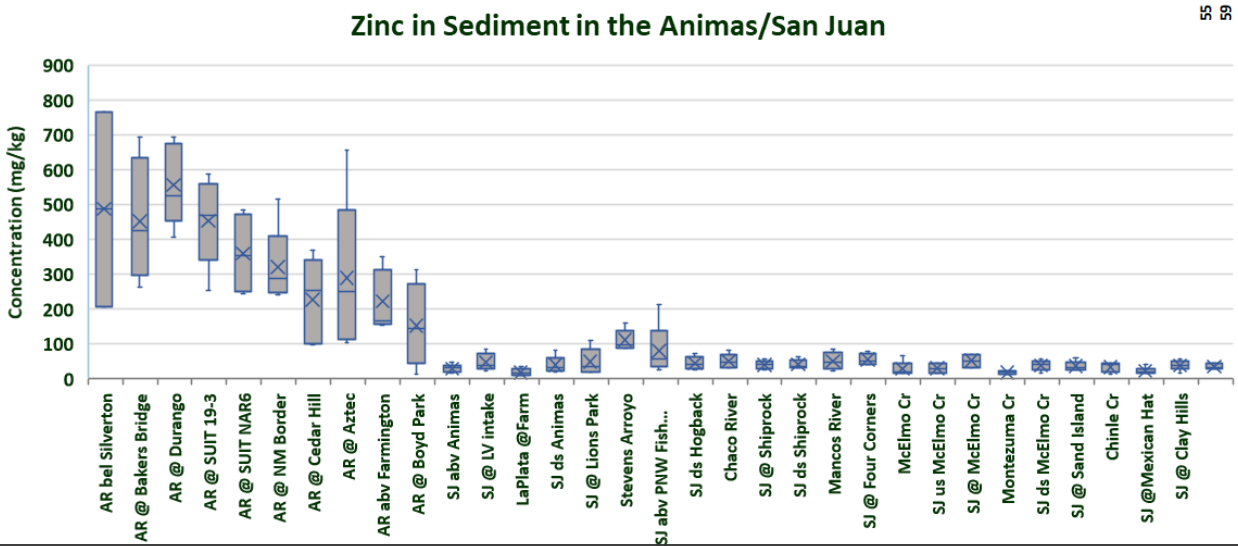
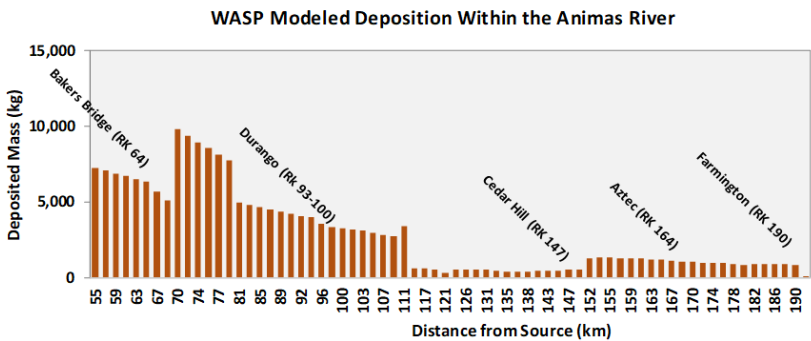


- Metals mass often gains in the San Juan at baseflow moving westerly due to increasing sediment load
  - Load of most metals is low
- During snowmelt, concentrations decrease but mass in transit increases through middle Animas and stays about the same all the way through the San Juan River
- During storms, mass increases wherever the storm affects rainfall as sediment is mobilized
- Mass in transport can be greater during storms than snowmelt

# Annual variability in metal concentrations in the bed sediments within the Animas River . . . .



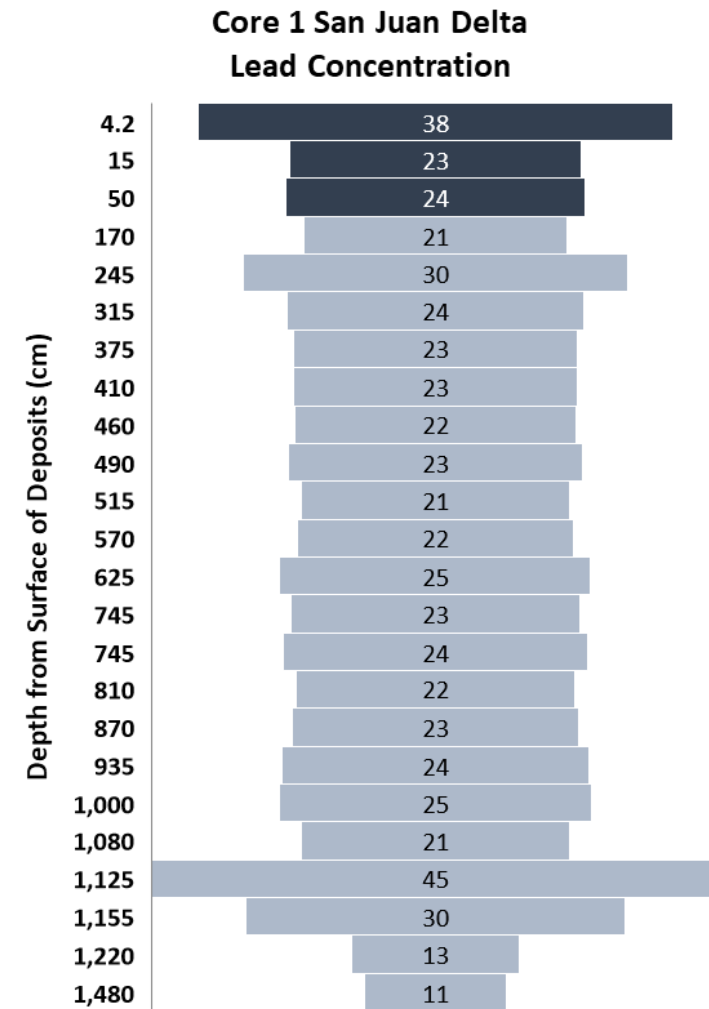
- The Animas River is “sticky” for the labile metals
- Temporary storage accounts for wide variation in metals at Animas sites on an annual basis



. . . but metals do not generally accumulate in the San Juan River sediments (move through)

# Lake Powell as a sink for sediments and metals from the San Juan Watershed

- Each hydrologic event produces another layer of sediment in Lake Powell
- Two WINN projects have looked at sediment cores in Lake Powell for evidence of metal sources in the watershed
  - Univ. of Utah looked at existing cores
  - USGS performed new coring to base of reservoir
- Both studies have concluded that some layers contain evidence of volcanic ore origin
- USGS most recent study: “The last century was much worse than this one”



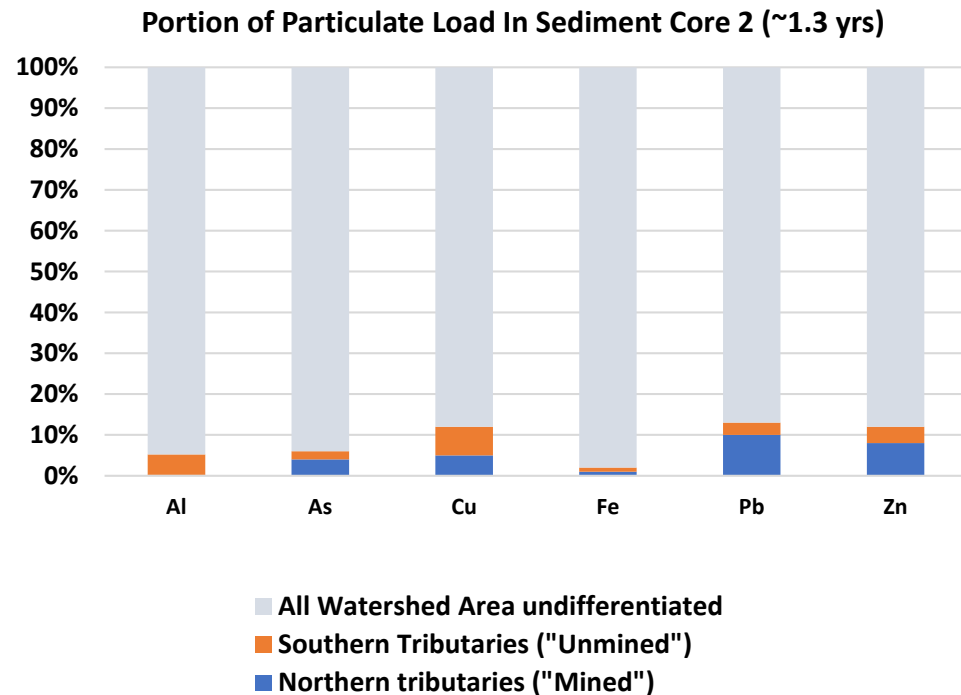
*The Mancos Shale concentration of lead is about 22 mg/kg*

**Lead, Pb**



# Source of Metals in Lake Powell Sediment Over the Course of a Year

## University of Utah Study



Metals apportioned at the sub-basin level over the annual climate cycle show reasonable balance with the mixture of geologies present in the watershed area

The Animas contribution stands out during snowmelt

Northern Tributaries 9% Area:

Animas, LaPlata, Mancos, McElmo

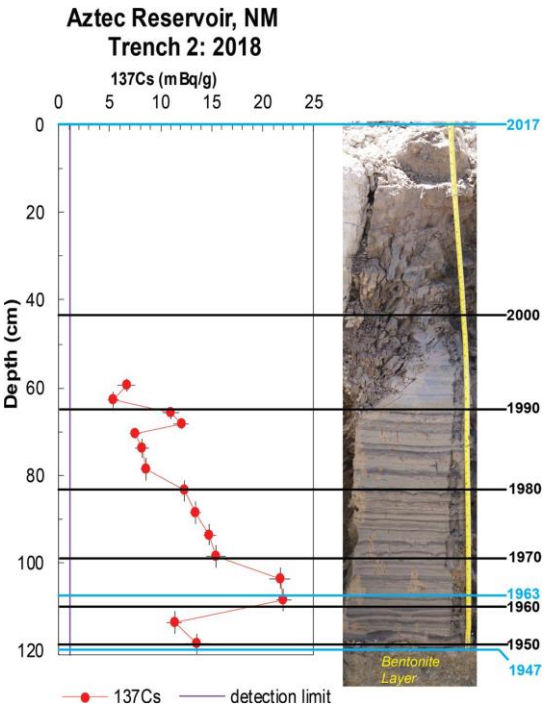
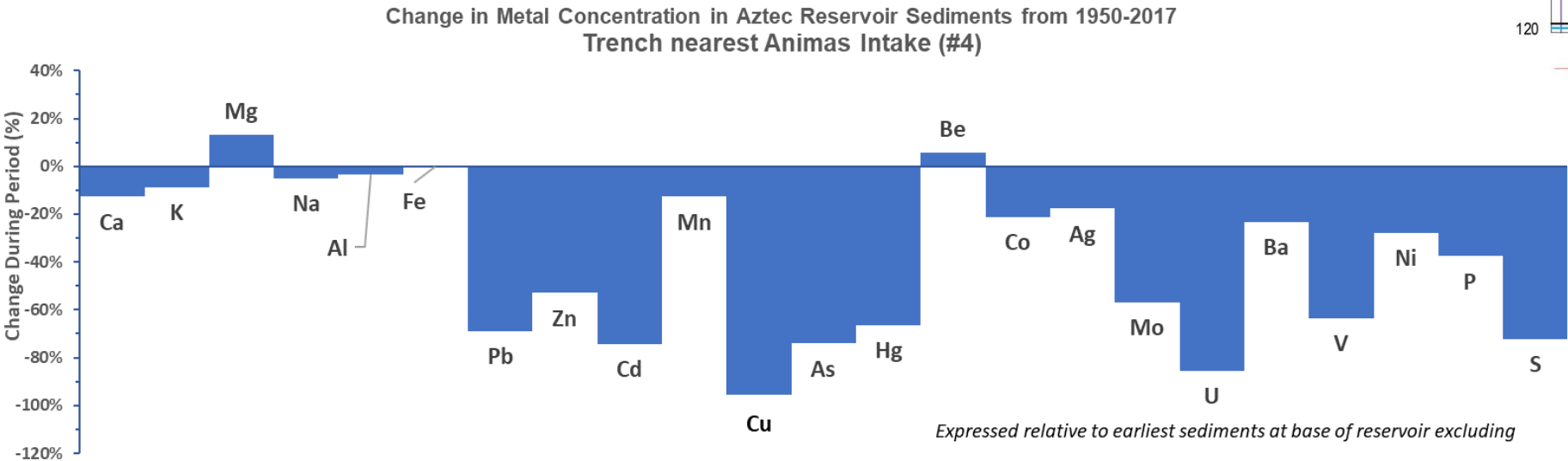
Southern Tributaries 21% of Area

Chaco, Chinle, Rest of Watershed Area:  
70%

There is some evidence that metals have declined in river water and/or sediments over the past 70 years

## Aztec Reservoir Coring Project—USGS 2020

*Up to 90% reduction in Copper, 60% reduction in Lead from base of reservoir sediments (1950) to top of sediments (2017)*



Blake et al. 2020 Environmental Earth Sciences 79:404 <https://doi.org/10.1007/s12665-020-09126-9>

# Water Quality

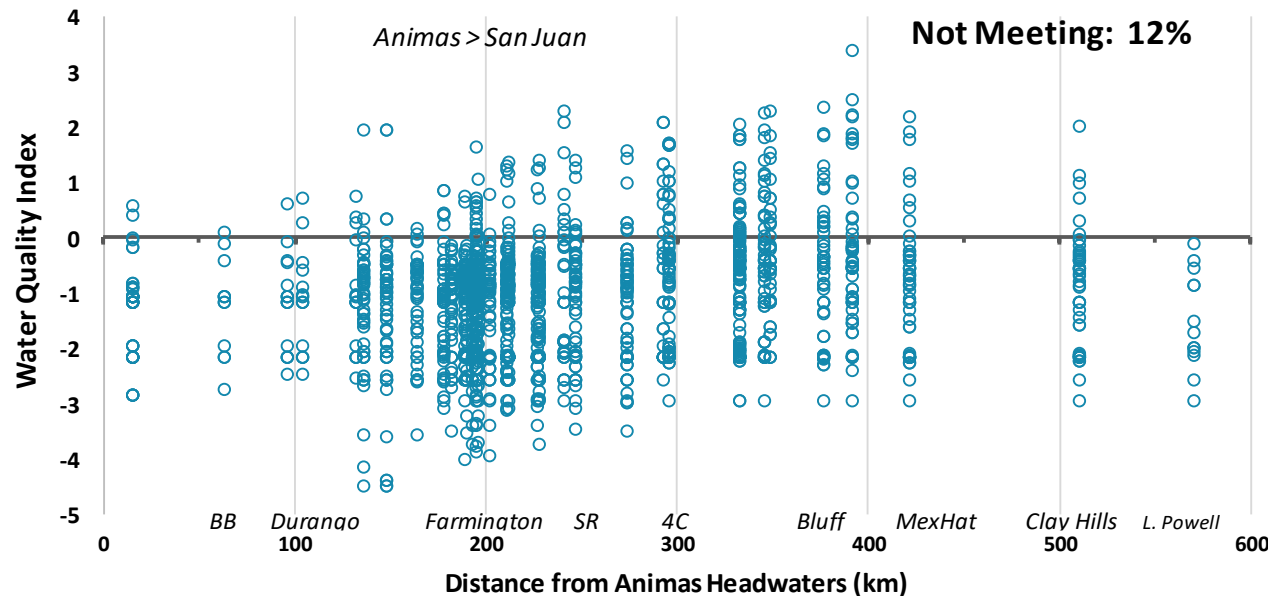
- State and tribal water quality criteria vary as to emphasis on dissolved or total metals
- Aquatic life criteria are most frequently not met
- Dissolved criteria are failed more frequently

$$WQI = \text{Log}_{10} \left( \frac{\text{Sample Value}}{\text{Criteria}} \right)$$

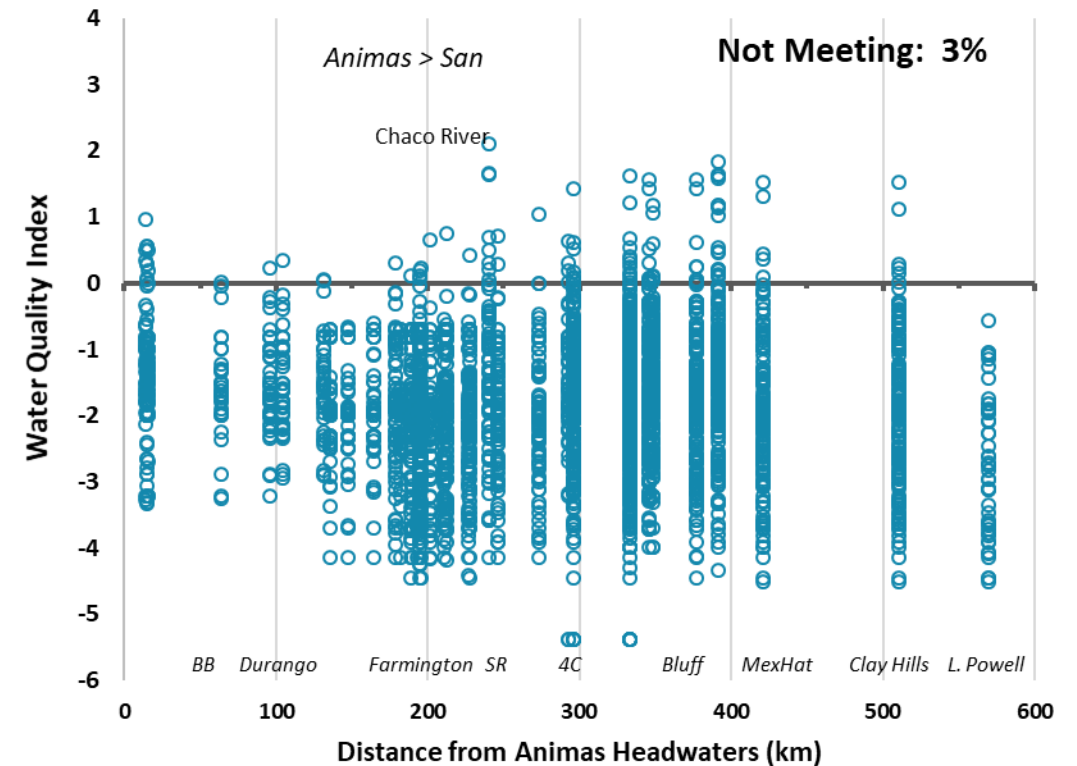
*WQI > 0 : Metal concentration exceeds goal*

*WQI < 0 : Metal concentration within goal*

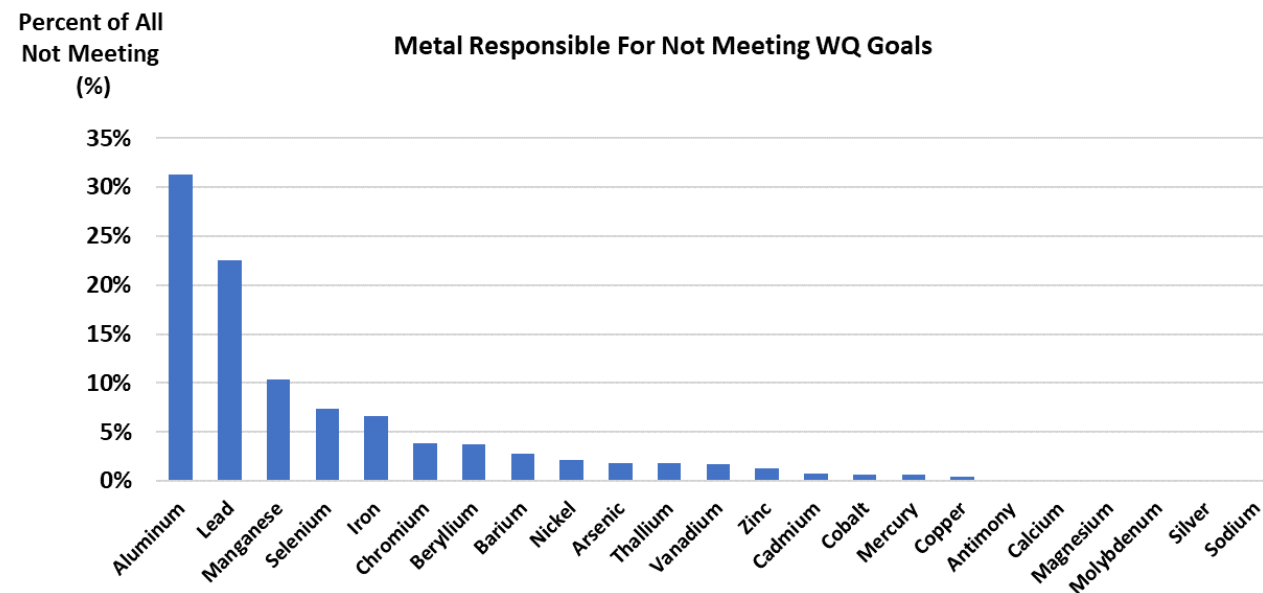
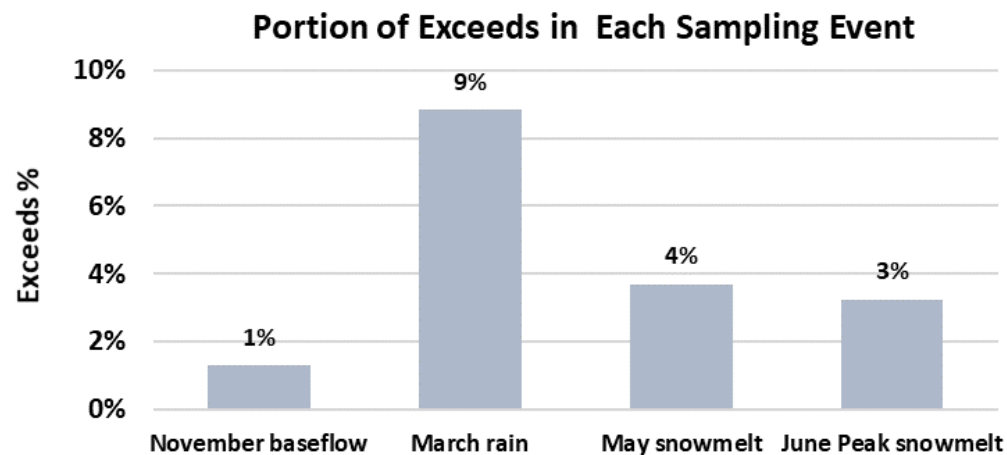
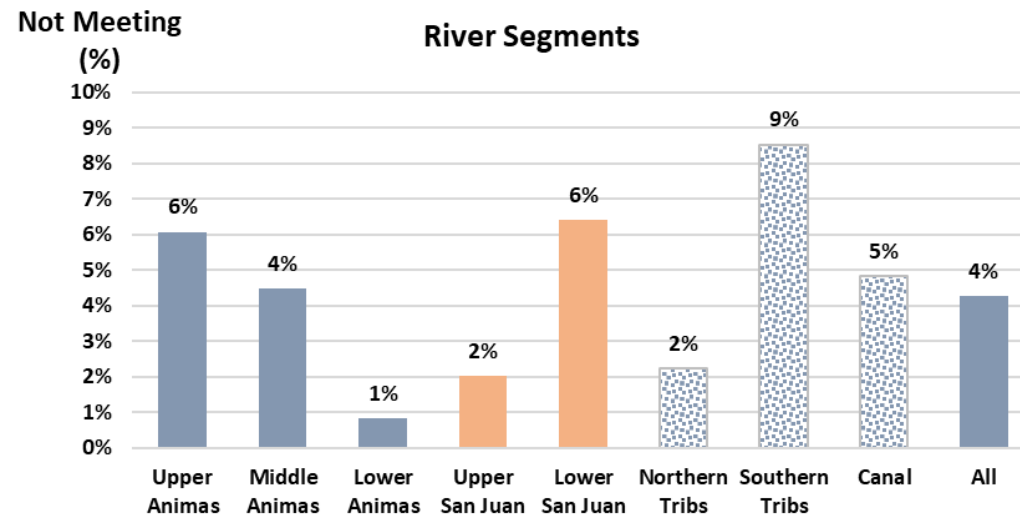
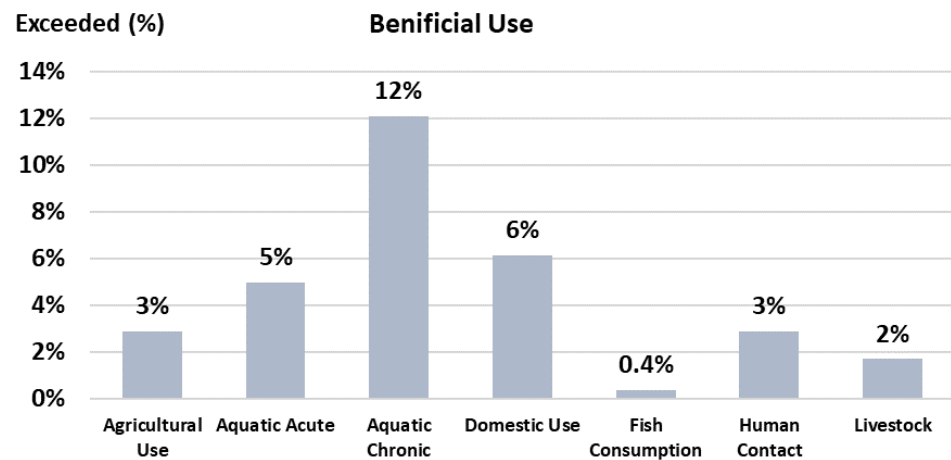
## Aquatic Chronic



## Agricultural Use

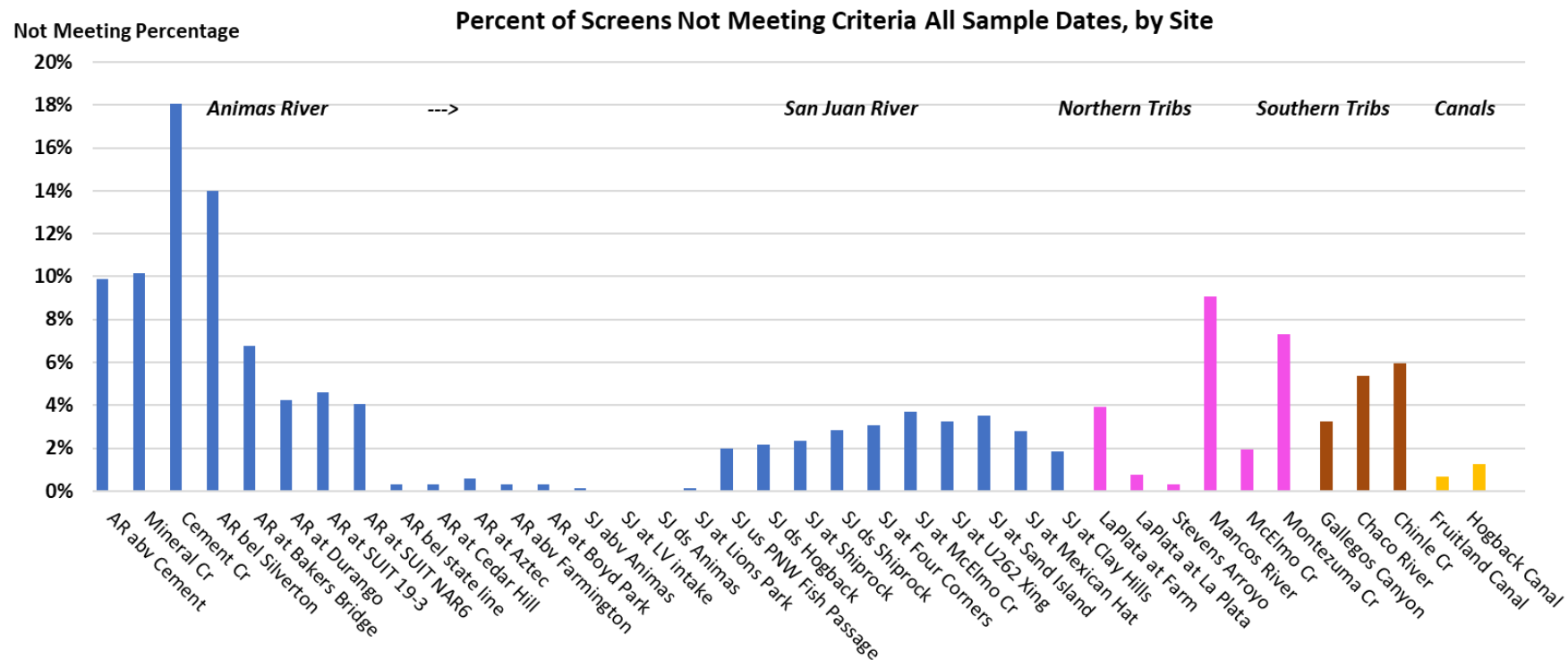


# Failure to Meet Water Quality Criteria



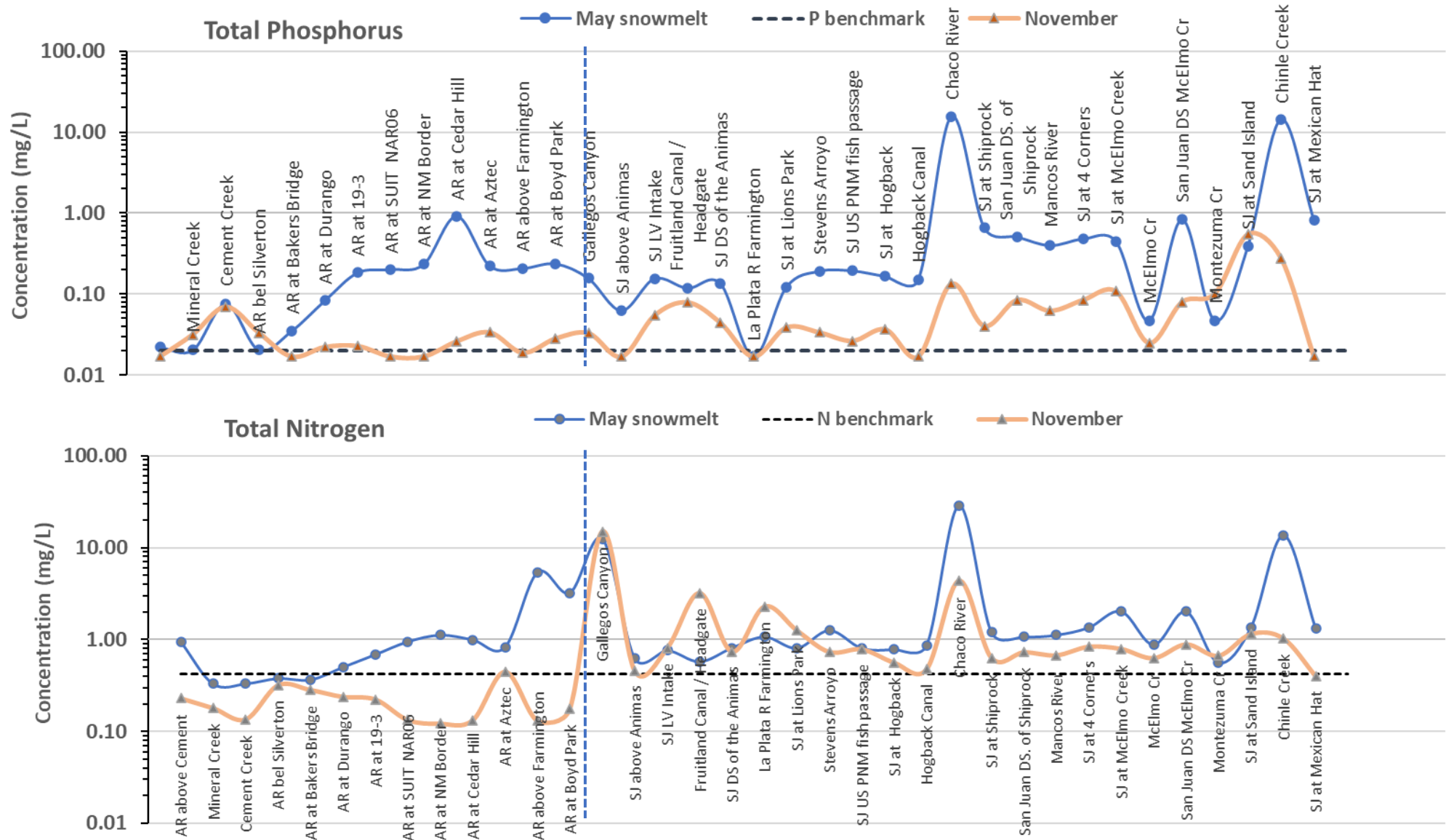
# Longitudinal Distribution of Exceedances

Note that differences in jurisdictional water quality criteria contribute to differences in exceedance rate between river segments



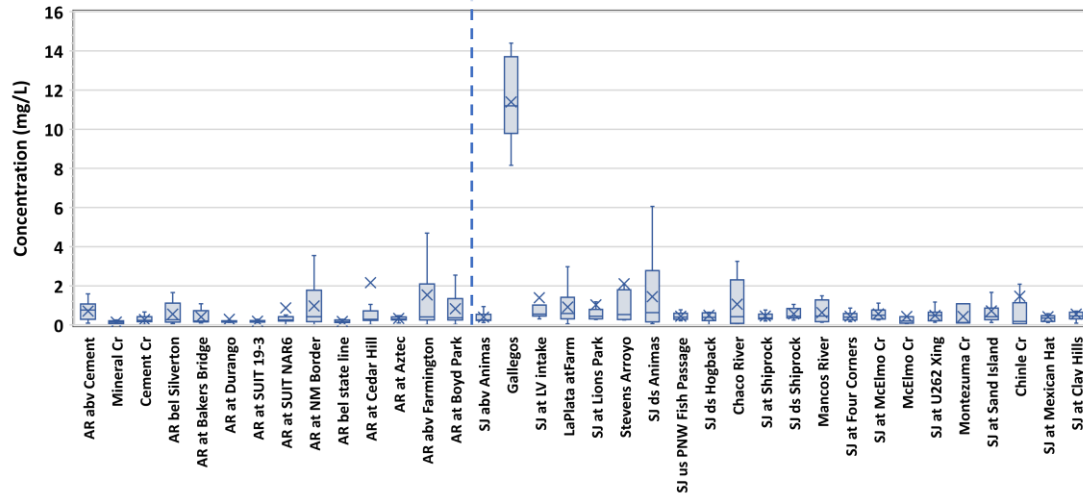
- Lower Animas in New Mexico is the “sweet spot”—few exceedances
- San Juan exceedances reflect Navajo and Utah criteria primarily
- Tributaries have greater number of exceedances

# Nutrients

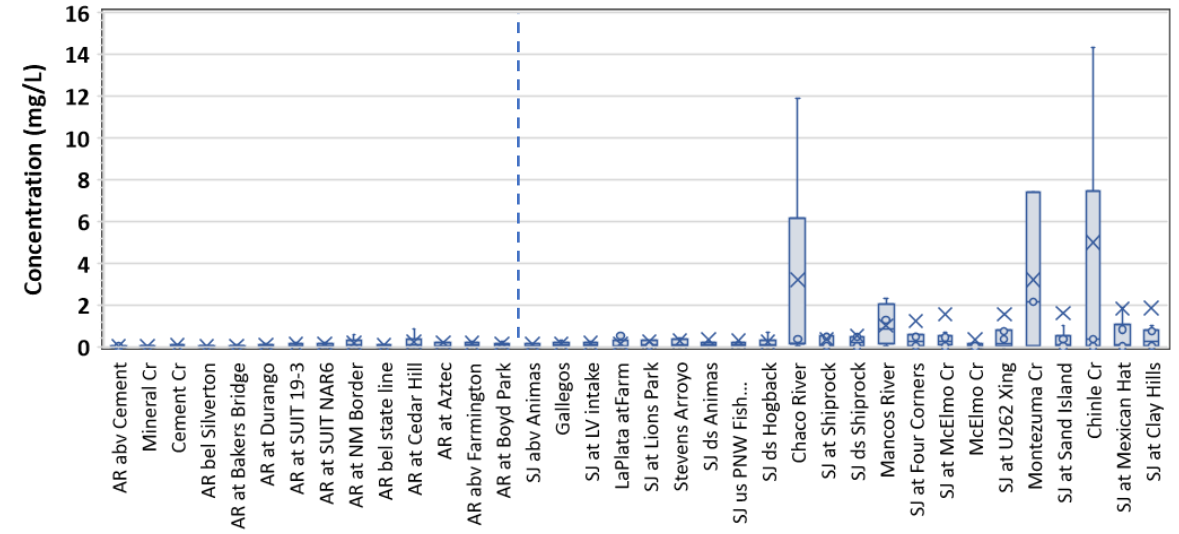


# Nutrients

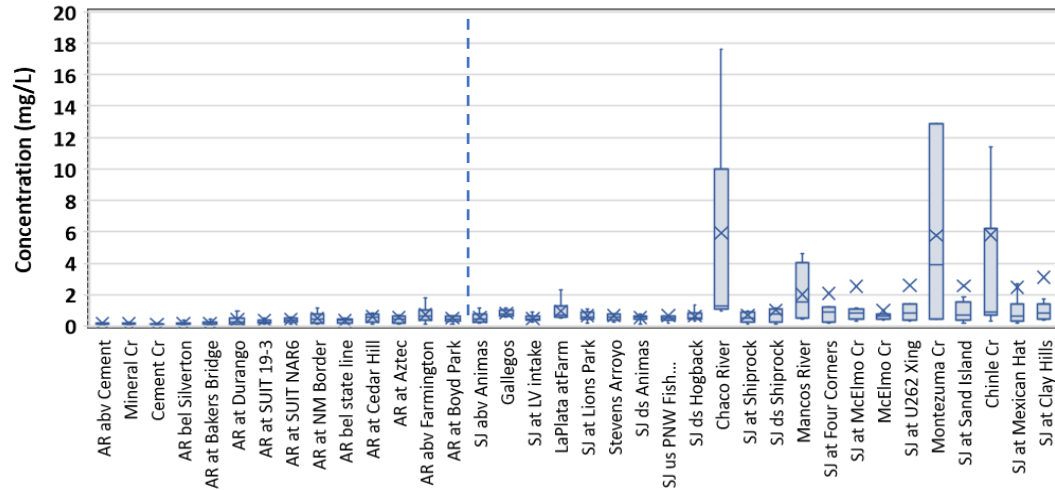
## Nitrate + Nitrite



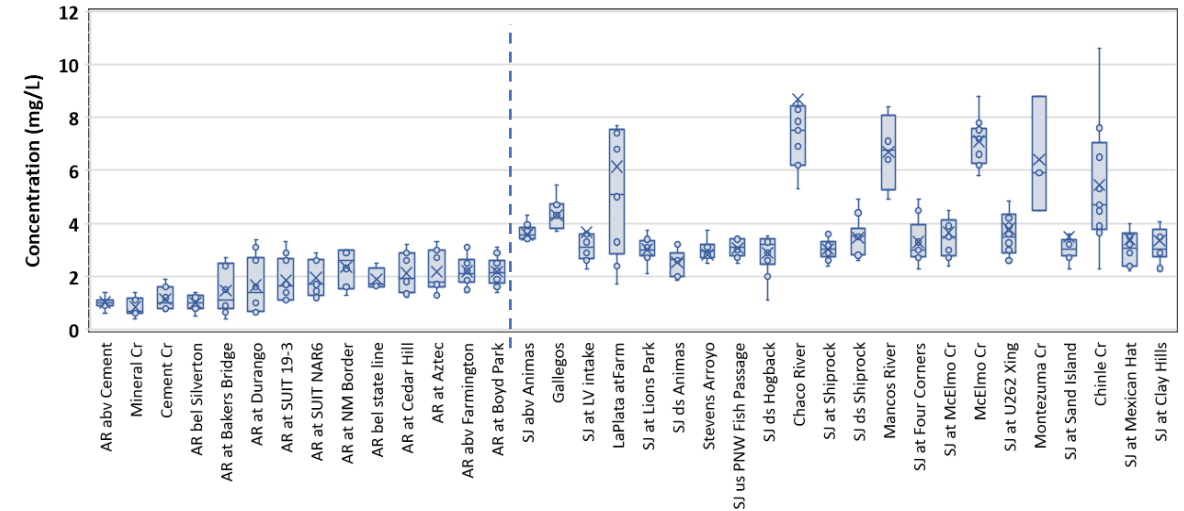
## Total Phosphorus



## Kjeldahl N

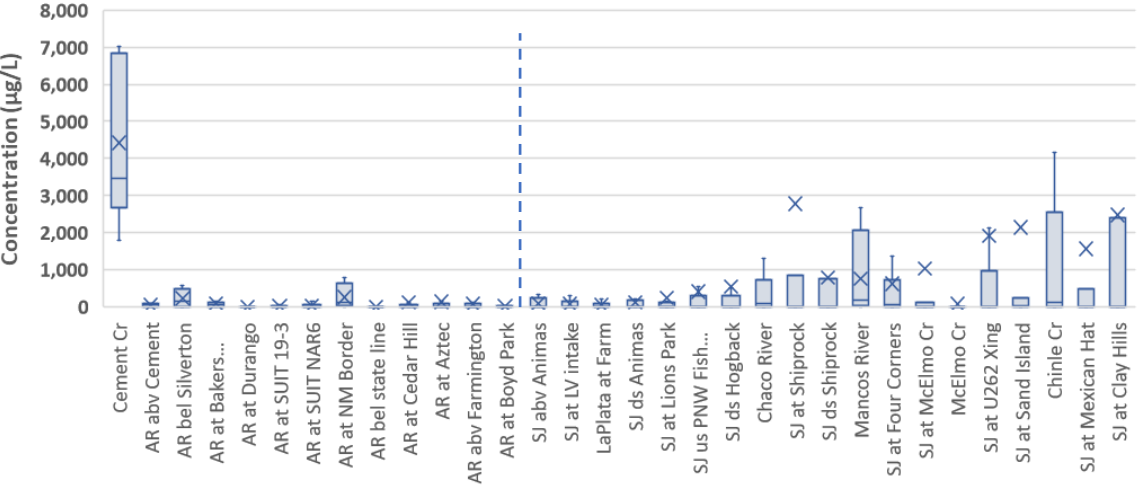


## Dissolved Organic Carbon

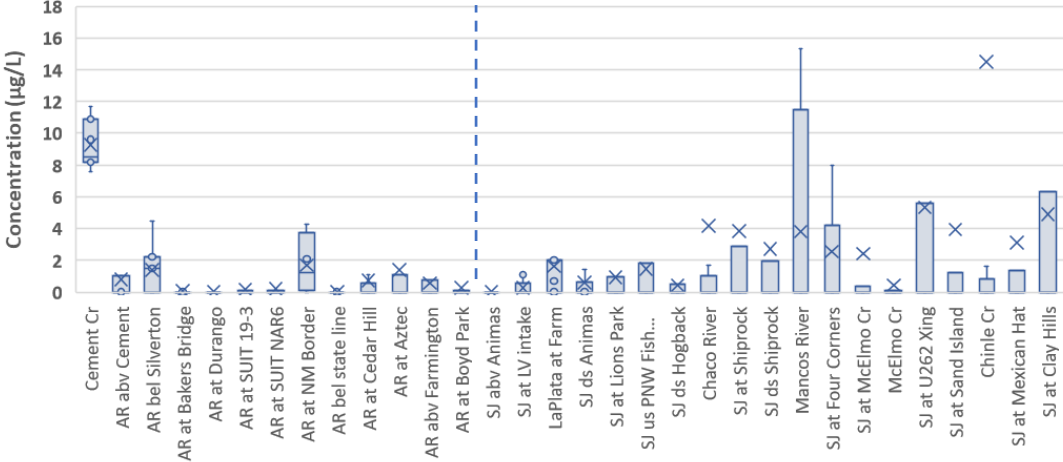


# Dissolved Metals

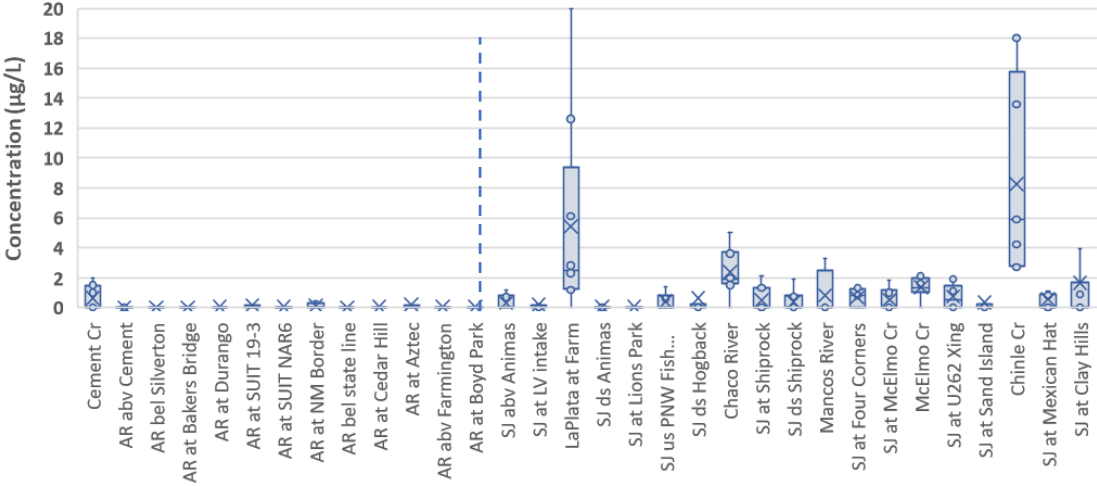
Dissolved Aluminum, Al



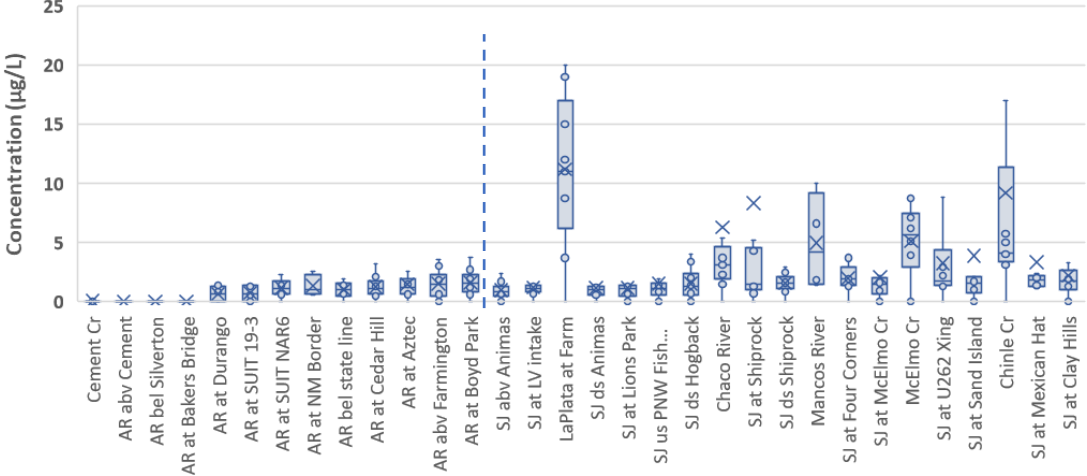
Dissolved Lead, Pb



Dissolved Arsenic, As

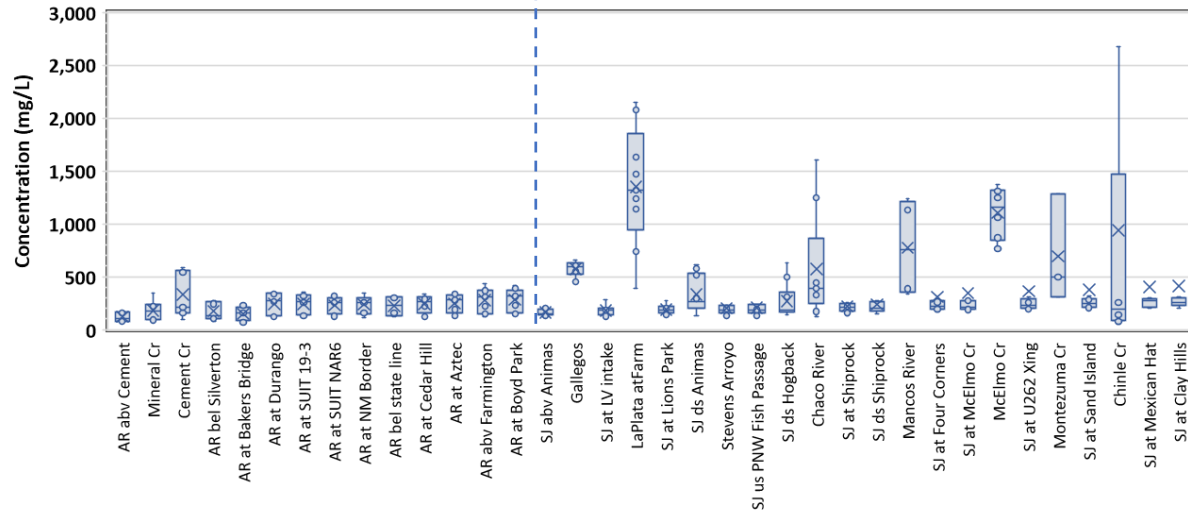


Dissolved Uranium, U

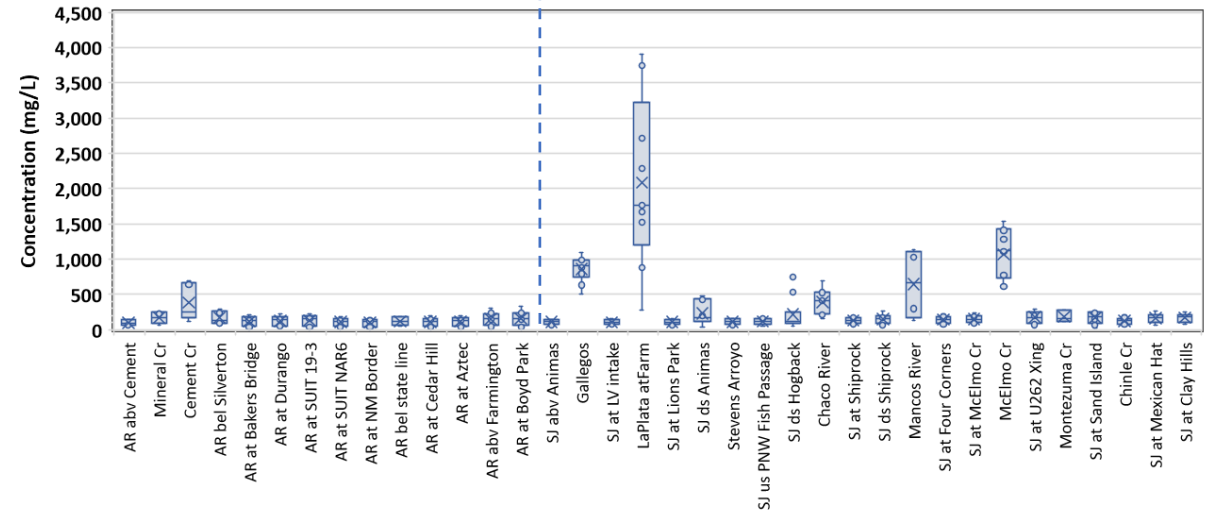


# Water Chemistry

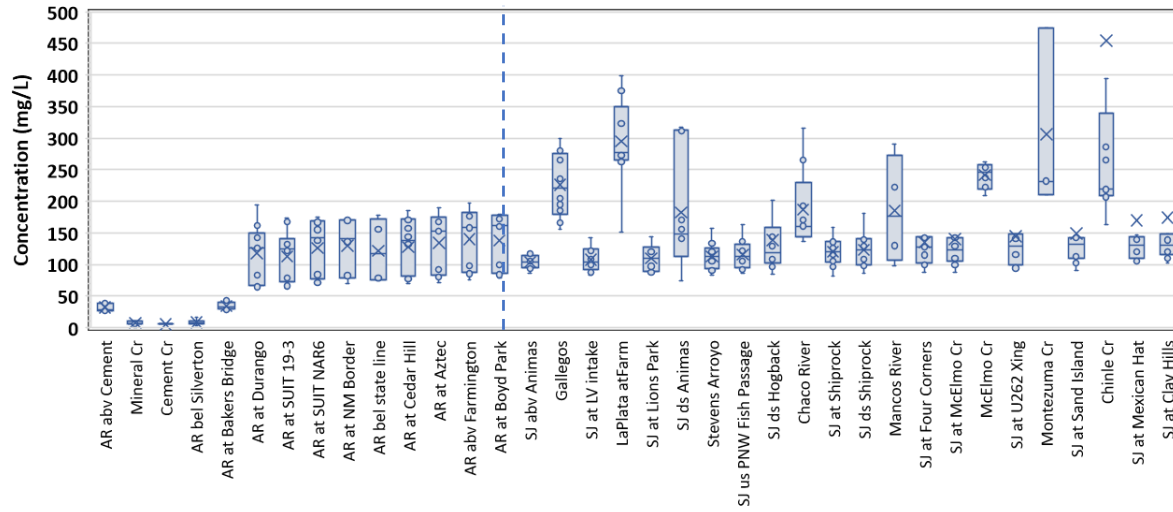
## Hardness



## Sulfate



## Alkalinity



## Chloride

