Relationship between Water Chemistry and Geology

Water / Rock Interactions
Important in Mine Drainage

Oxidation

$$FeS_{2(s)} + 3.75\ O_2 + 3.5\ H_2O = Fe(OH)_{3(s)} + 2\ SO_4^{2-} + 4\ H^+ + heat$$

Pyrite **Air** **Water** **"Yellowboy"** **Sulfate** **Acid**

Dissolution

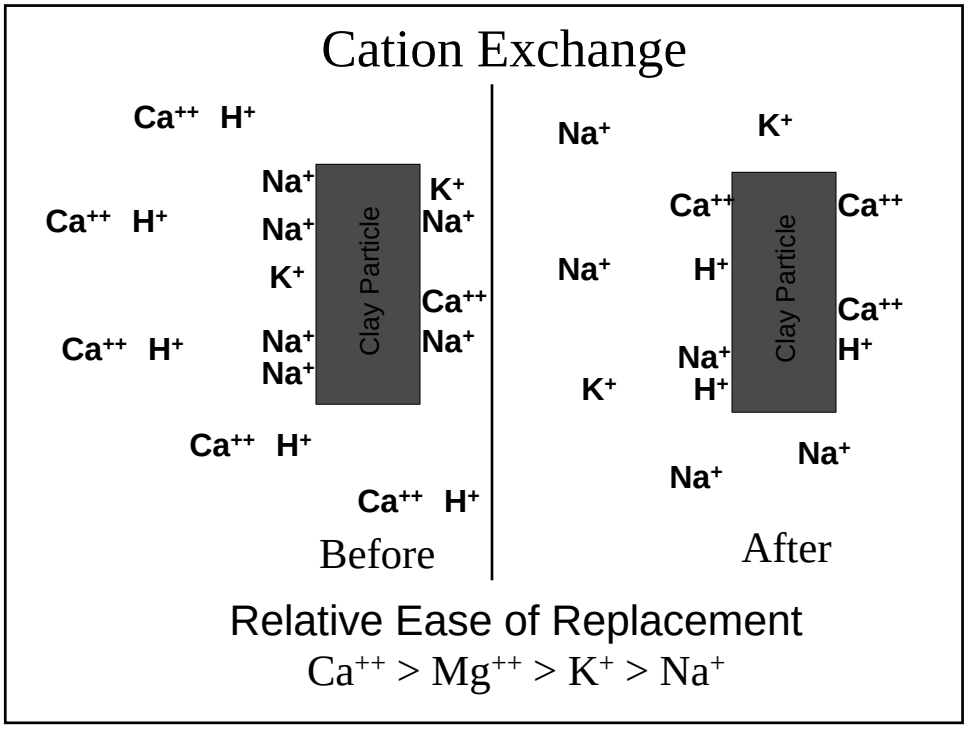
$$CaCO_3 + H^+ = Ca^{2+} + HCO_3^-$$

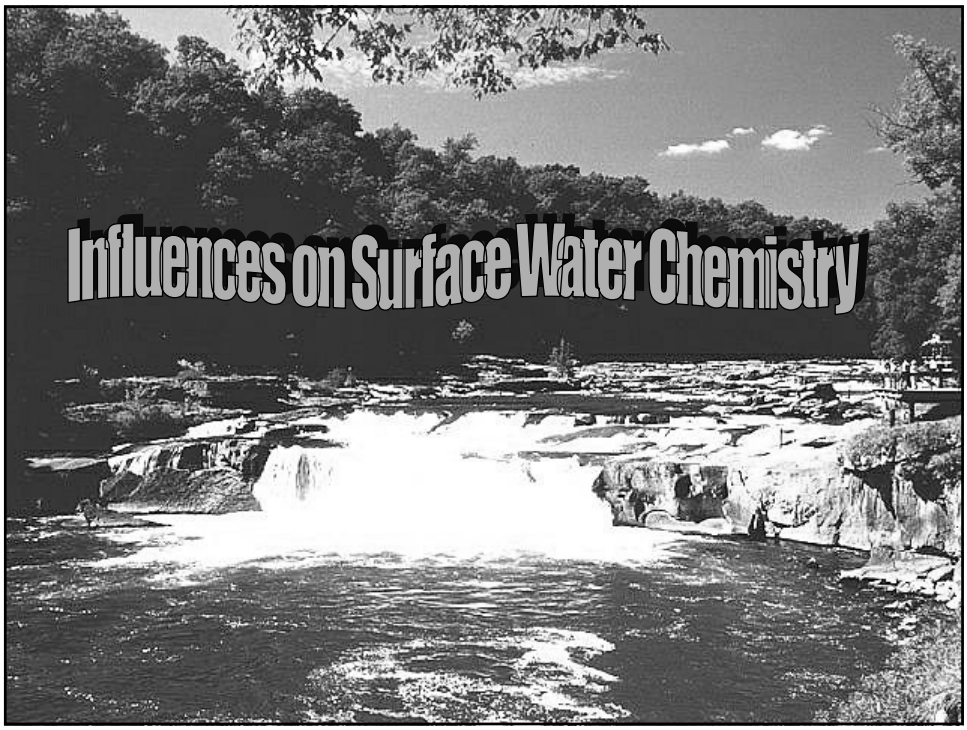
Calcite **Acid** **Calcium** **Bicarbonate**

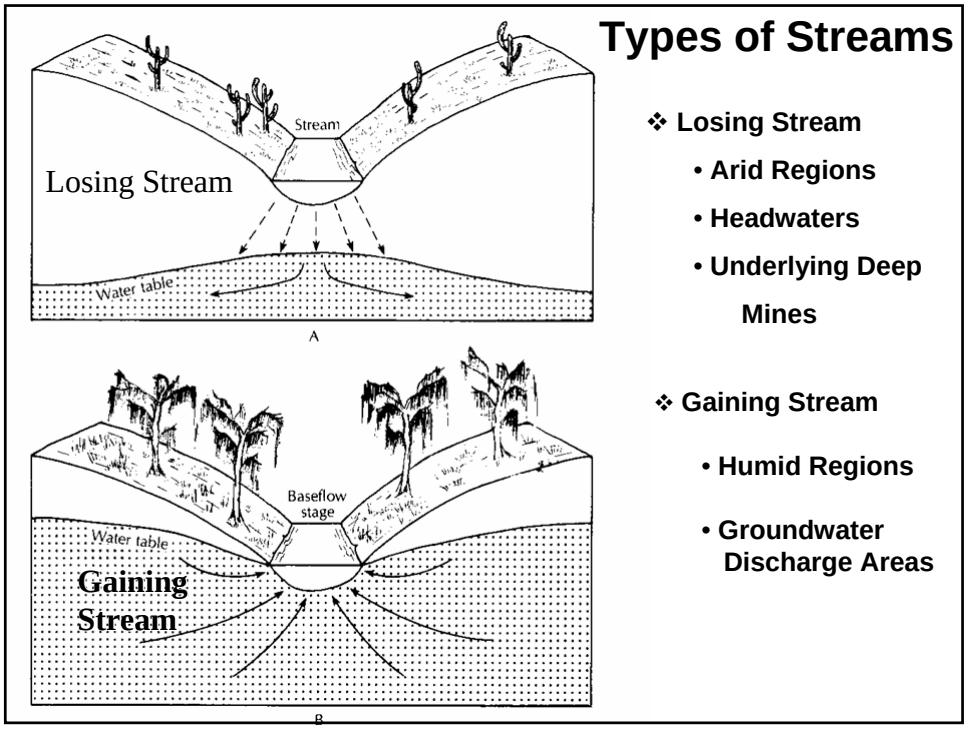
Precipitation

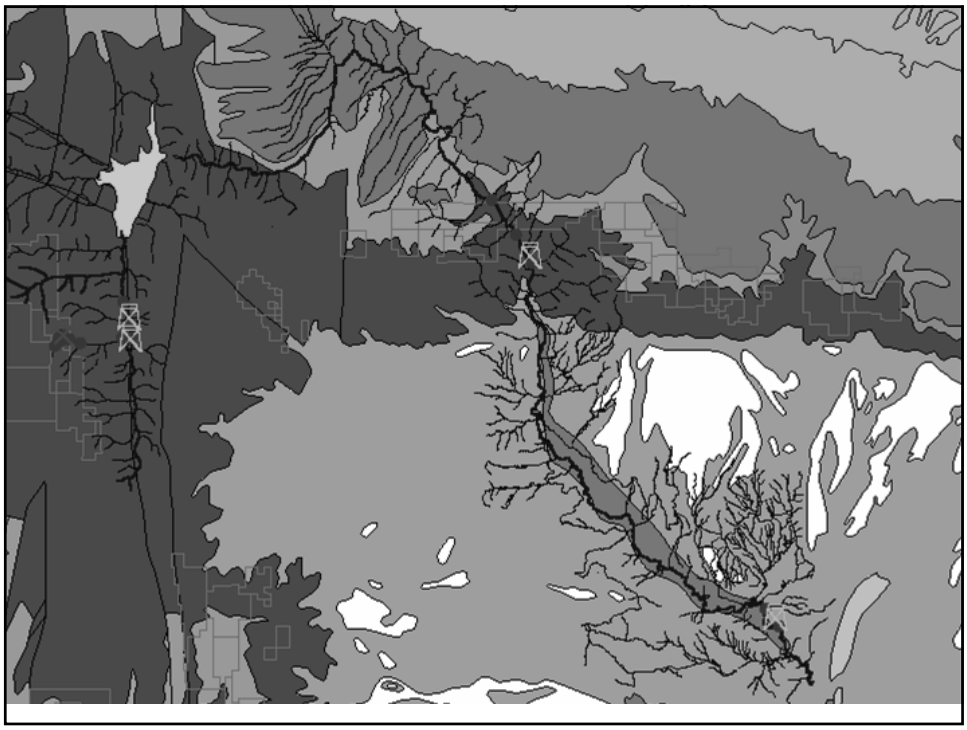
$$Al^{3+} + 3\ H_2O = Al(OH)_{3(s)} + 3\ H^+$$

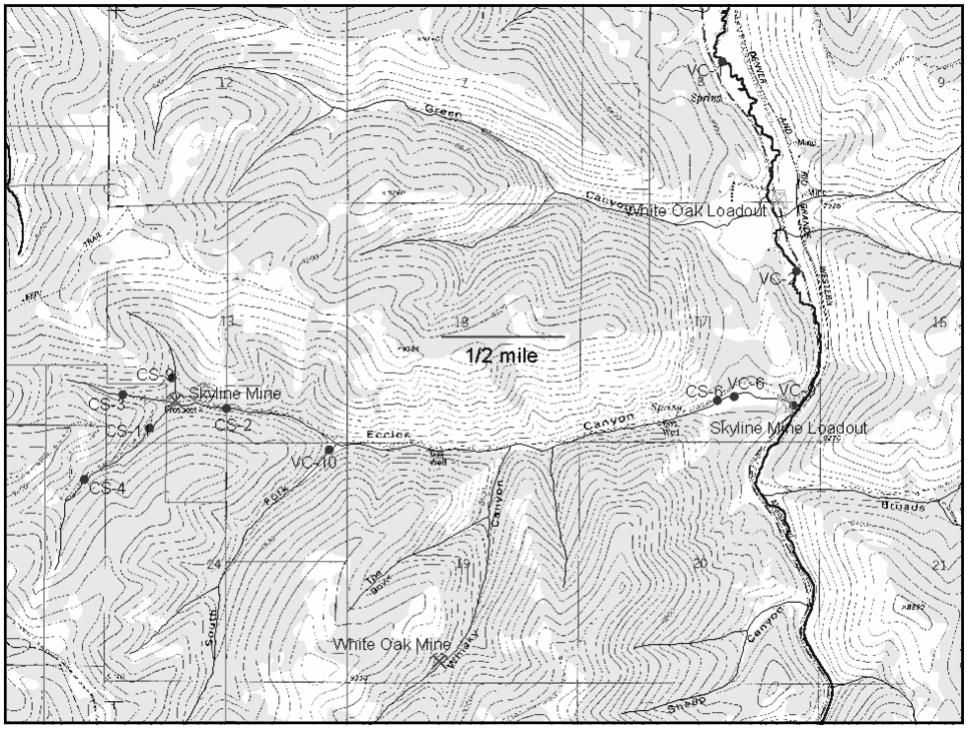
Aluminum **Water** **Gibbsite** **Acid**

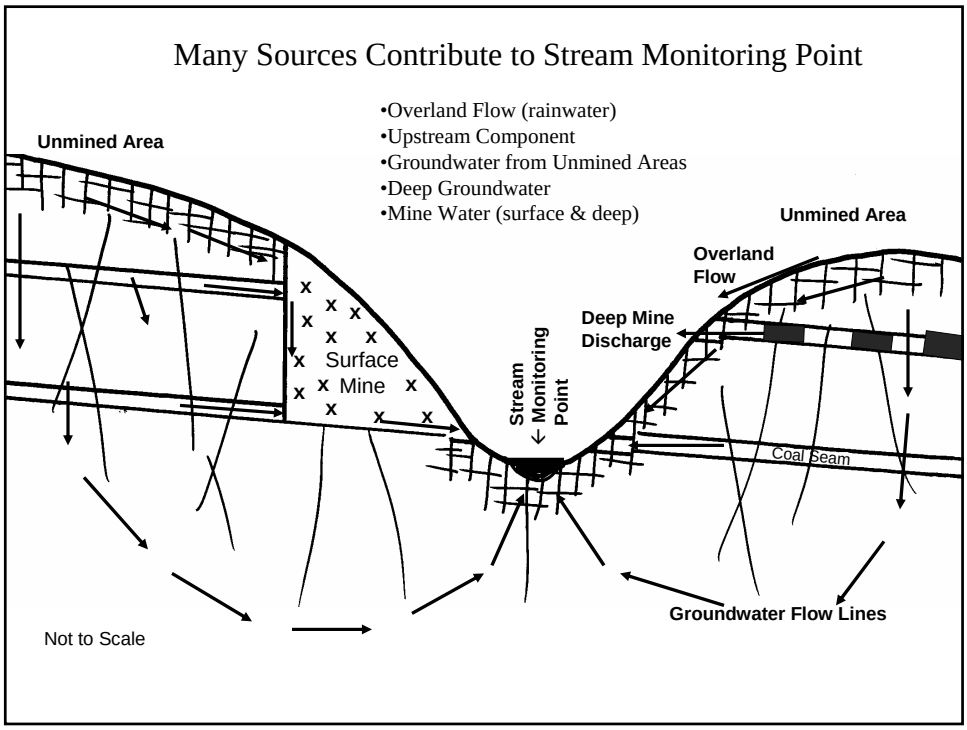

Cation Exchange
Ca++ H+
Na+
K+
Na+
Ca++ H+
Na+
K+
Clay Particle
Ca++
Na+
Ca++ H+
Na+
Na+
Ca++ H+
Ca++ H+
Before
Na+
K+
Ca++
Ca++
Na+
H+
Clay Particle
Ca++
H+
Na+
H+
K+
Na+
Na+
After
Relative Ease of Replacement
Ca++ > Mg++ > K+ > Na+

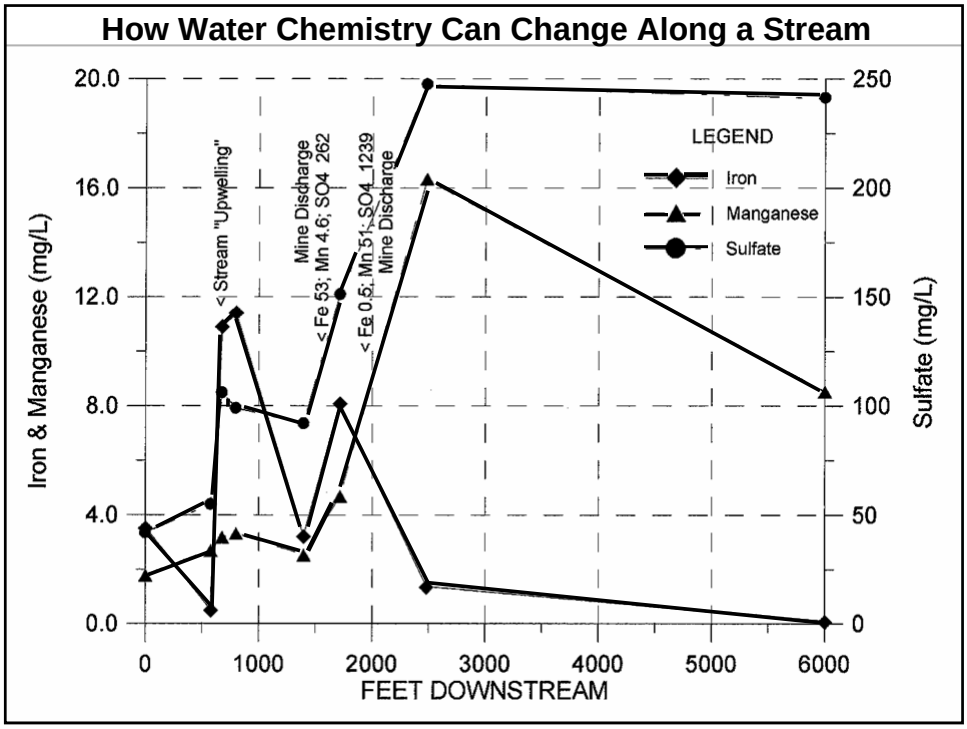

Influences on Surface Water Chemistry

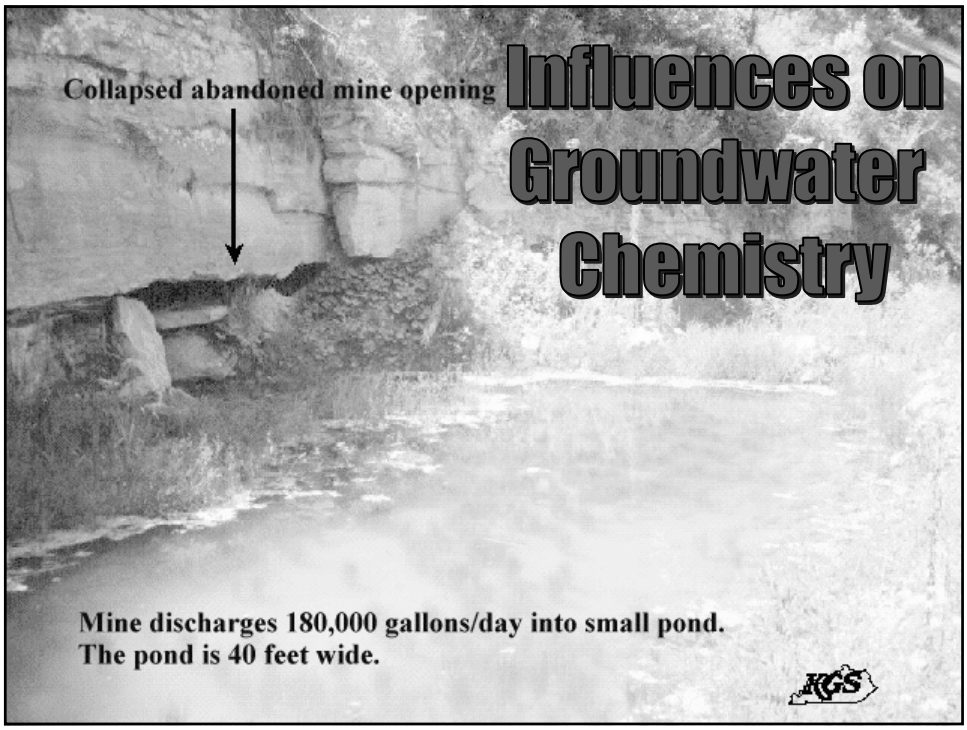

Types of Streams
Losing Stream
Stream
Water table
A
Baseflow stage
Water table
Gaining Stream
B
❖ Losing Stream
• Arid Regions
• Headwaters
• Underlying Deep Mines
❖ Gaining Stream
• Humid Regions
• Groundwater Discharge Areas

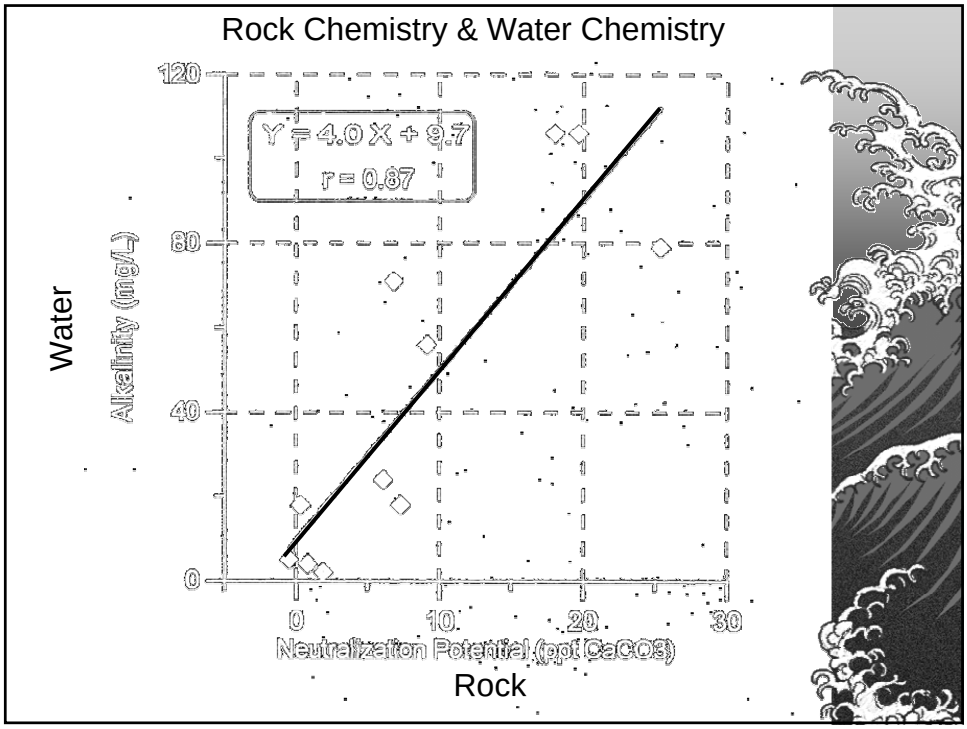


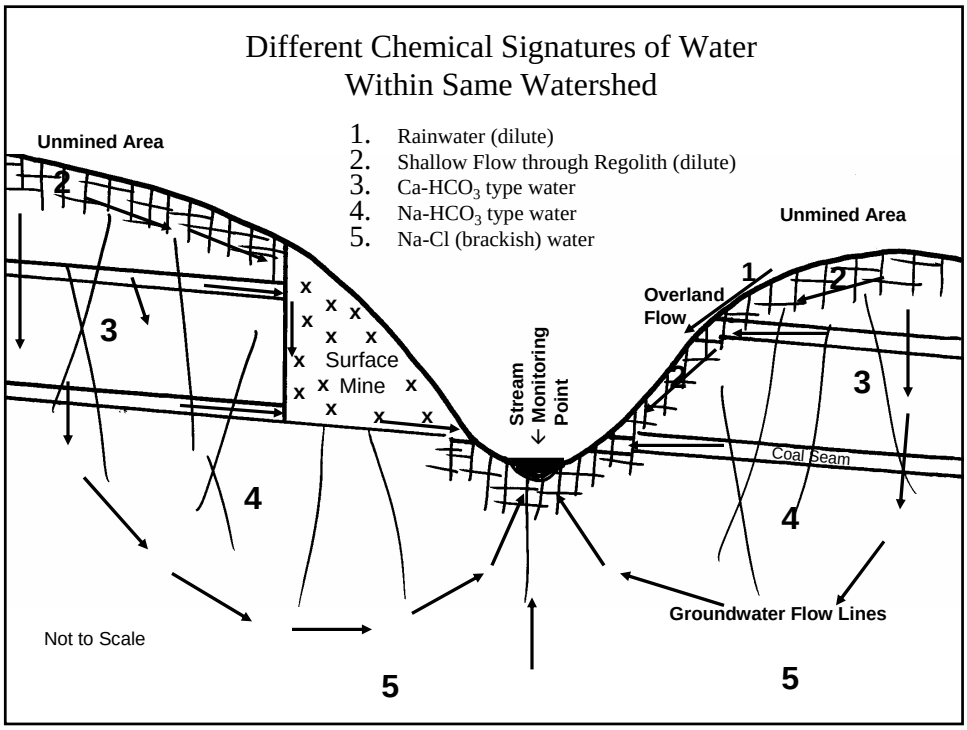

White Oak Loadout
1/2 mile
CS-5
Skyline Mine
CS-3
CS-1
CS-2
CS-4
VC-10
CS-6
VC-6
Skyline Mine Loadout
White Oak Mine


Many Sources Contribute to Stream Monitoring Point
•Overland Flow (rainwater)
•Upstream Component
•Groundwater from Unmined Areas
•Deep Groundwater
•Mine Water (surface & deep)
Unmined Area
Unmined Area
Overland Flow
Deep Mine Discharge
Surface Mine
Stream Monitoring Point
Coal Seam
Groundwater Flow Lines
Not to Scale


How Water Chemistry Can Change Along a Stream
Iron & Manganese (mg/L)
Sulfate (mg/L)
FEET DOWNSTREAM
LEGEND
Iron
Manganese
Sulfate
< Stream "Upwelling"
Mine Disdharge
< Fe 53; Mn 4.6; SO4 262
< Fe 0.5; Mn 51; SO4 1239
Mine Discharge
20.0
16.0
12.0
8.0
4.0
0.0
250
200
150
100
50
0
0
1000
2000
3000
4000
5000
6000

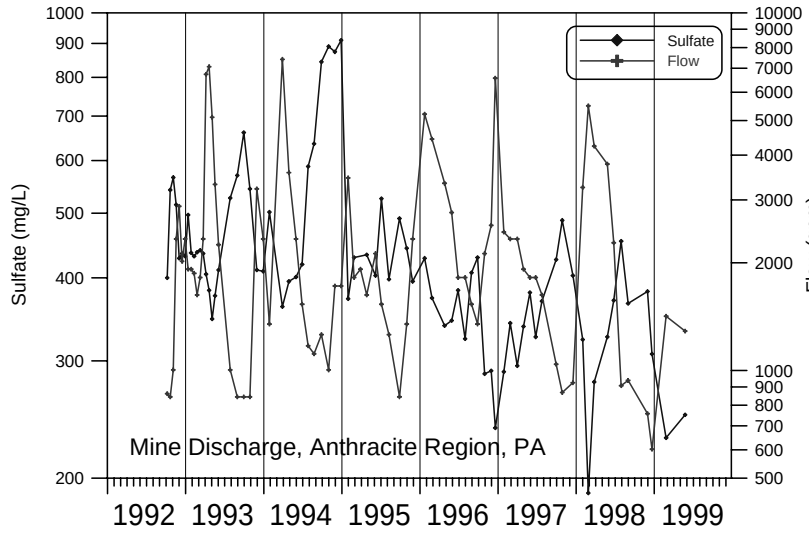

Influences on Groundwater Chemistry
Collapsed abandoned mine opening
Mine discharges 180,000 gallons/day into small pond.
The pond is 40 feet wide.
KGS

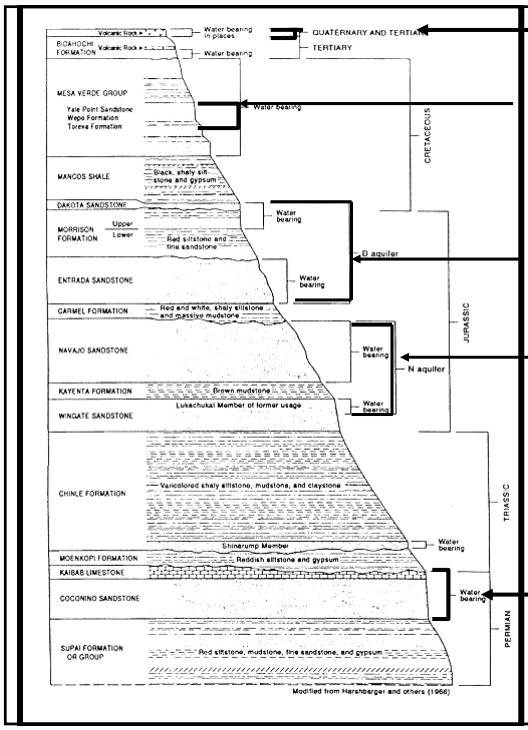

Rock Chemistry & Water Chemistry
Y = 4.0 X + 9.7
r = 0.87
Water
Alkalinity (mg/L)
120
80
40
0
0
10
20
30
Neutralization Potential (ppt CaCO3)
Rock


Different Chemical Signatures of Water
Within Same Watershed
1. Rainwater (dilute)
2. Shallow Flow through Regolith (dilute)
3. Ca-HCO3 type water
4. Na-HCO3 type water
5. Na-Cl (brackish) water
Unmined Area
Unmined Area
Overland Flow
Surface Mine
Stream ← Monitoring Point
Coal Seam
Groundwater Flow Lines
Not to Scale
1
2
3
4
5

Seasonal Variation

- High flow spring; Low flow summer
- Low concentration spring; High concentration summer





Quaternary Alluvium

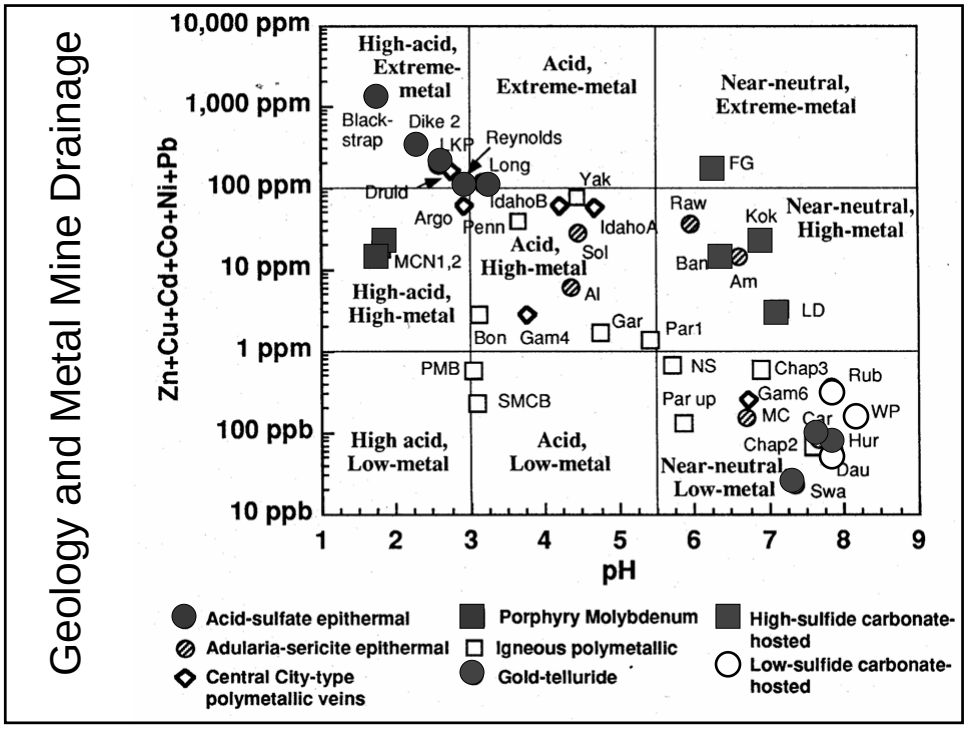
Wepo / Toreva
pH 7.34
Alk 557
SO_4 713
TDS 1809

D Aquifer
pH 8.2
Alk 230
SO_4 352
SC 1326

N Aquifer
pH 8.6
Alk 137
SO_4 66
SC 482

C Aquifer

Black Mesa, Arizona



Some Concluding Thoughts

- Stream Waters
  - Steam waters have multiple sources.
  - Some ions more conservative than others
  - Different looking samples may have had same source
- Ground Waters
  - Groundwater chemistry is related to rock chemistry.
  - Groundwater chemistry related to location within flow system (in East)
  - GW chemistry related to aquifer (in West)
  - Water quality often shows seasonal variations.