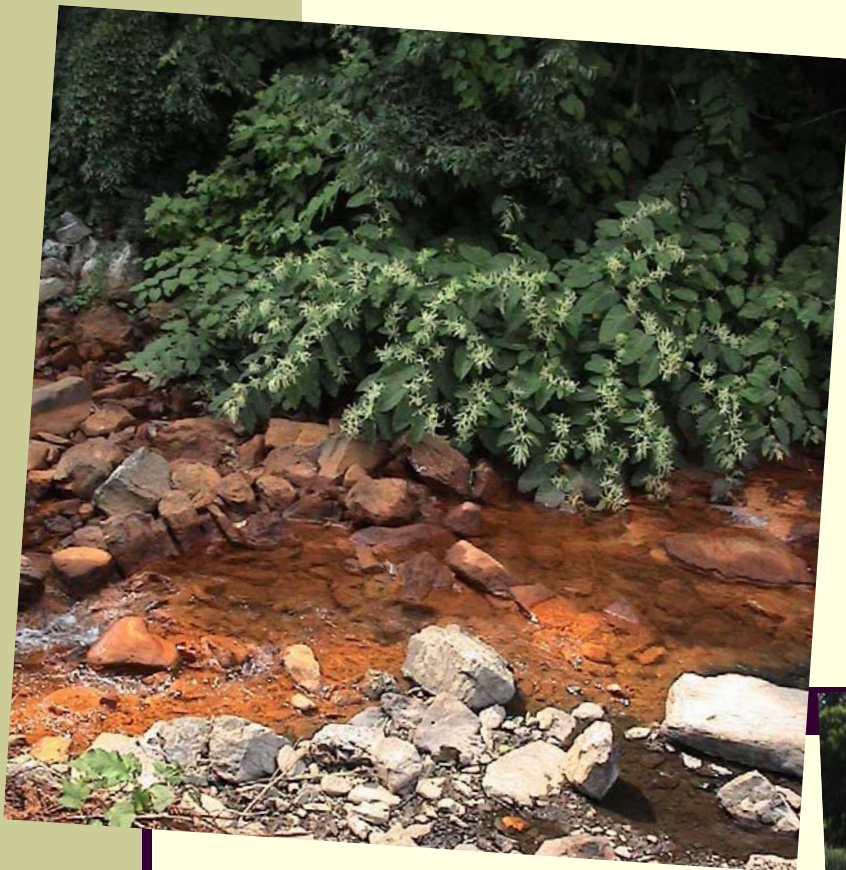


Ask me about
pyrite!

The formation of polluted mine water





Abandoned Mine Drainage

How it happens
How we can fix it



Bruce Golden

Western PA Coalition for Abandoned Mine Reclamation

What we'll cover

- Brief Discussion about Mining
- How mine water pollution forms
 - Central role of the mineral pyrite
 - How the pollution impacts the environment
- How polluted water can be treated
- What you can do



What is mining?

- Mining is the extraction or removal of a resource from the earth.

Why do we mine?

- To get the benefits the resource can provide.

If it's not grown...
...it's got to be mined.

Every American Born Will Need ...



3.5 million pounds of minerals, metals, and fuels in a lifetime

Why is COAL mined?

Coal is a concentrated source of energy.

Coal can be...

- burned to produce electricity,
- used in producing iron and steel,
- transformed into hundreds of useful compounds.

Coal Tree



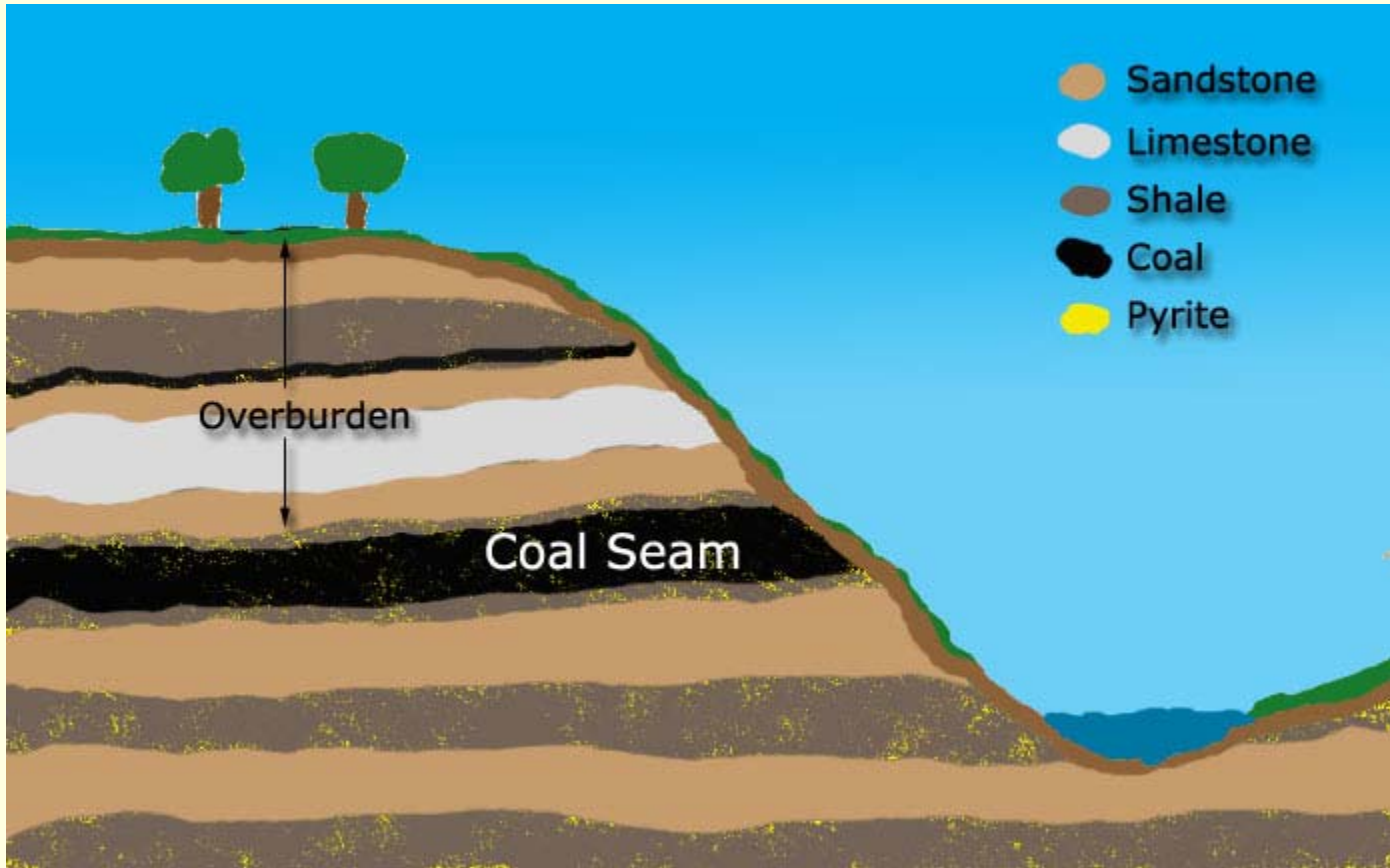
How is coal mined?

■ Underground

- Room and pillar ... leaves some coal behind to support mine roof
- Longwall ...removes all coal from a "panel" (hundreds of acres) ... causes controlled subsidence

■ Surface Mining

- Removes all earth above coal seam (overburden) to get to the coal... laws now require that the land be returned to original contour following mining.



What is Abandoned Mine Drainage?

Mine Drainage

Polluted Water caused by mining activities, appearing on the earth's surface or in surface waterways.



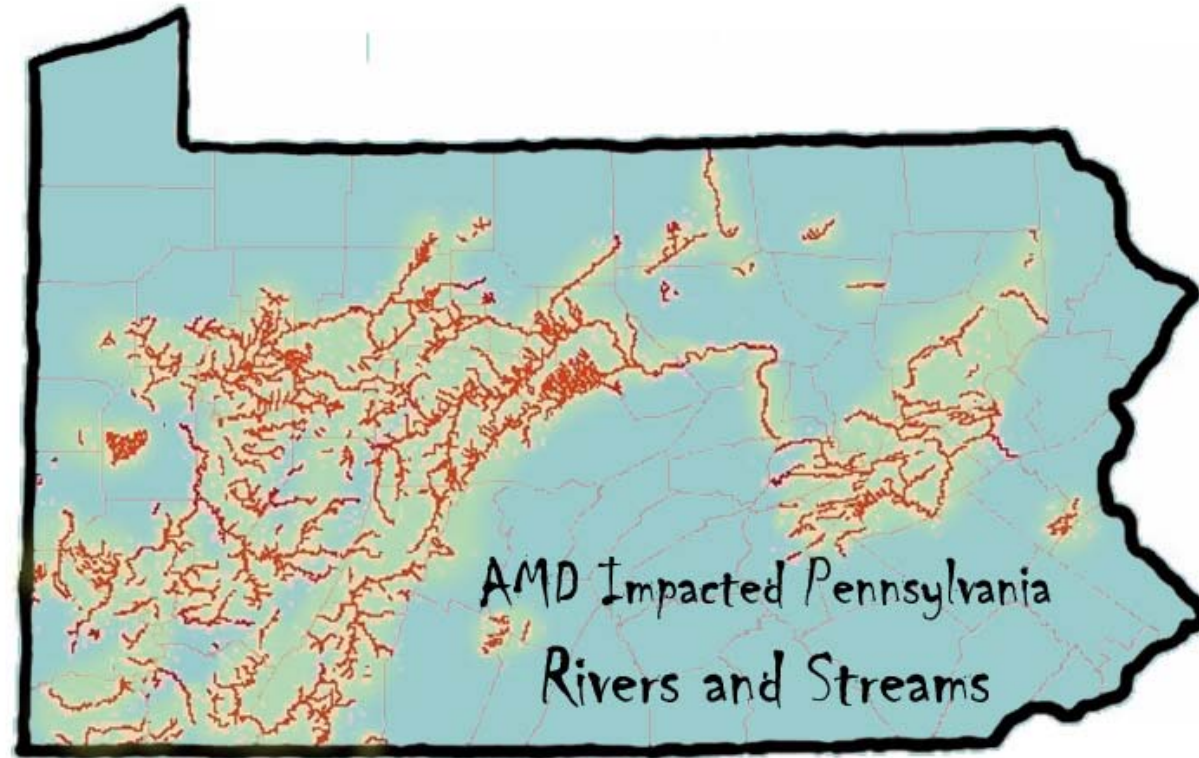
Abandoned Mine Drainage

- (1) mine drainage from abandoned coal mining operations;
- (2) Mine drainage from practices of another era that became society's problem because of a lack of adequate environmental laws.

The environmental legacy

- The old mines have long since been abandoned, but the conditions that create the pollution live on.
- Thousands of old underground mines, un-reclaimed strip mines, and coal refuse piles are all active AMD pollution factories on duty 24/7.
- The price tag in PA for fixing the problems from 150 years of past coal mining is \$\$ BILLIONS \$\$

AMD is the biggest water pollution problem in Pennsylvania



AMD pollutes over 4,200 stream-miles...
... that we know about.

Explain the difference



No rust

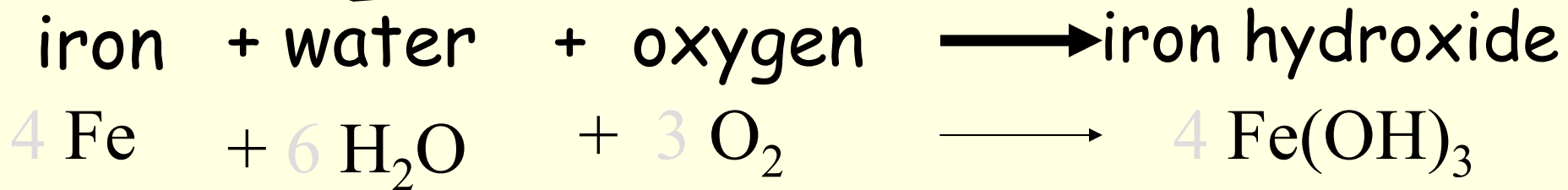
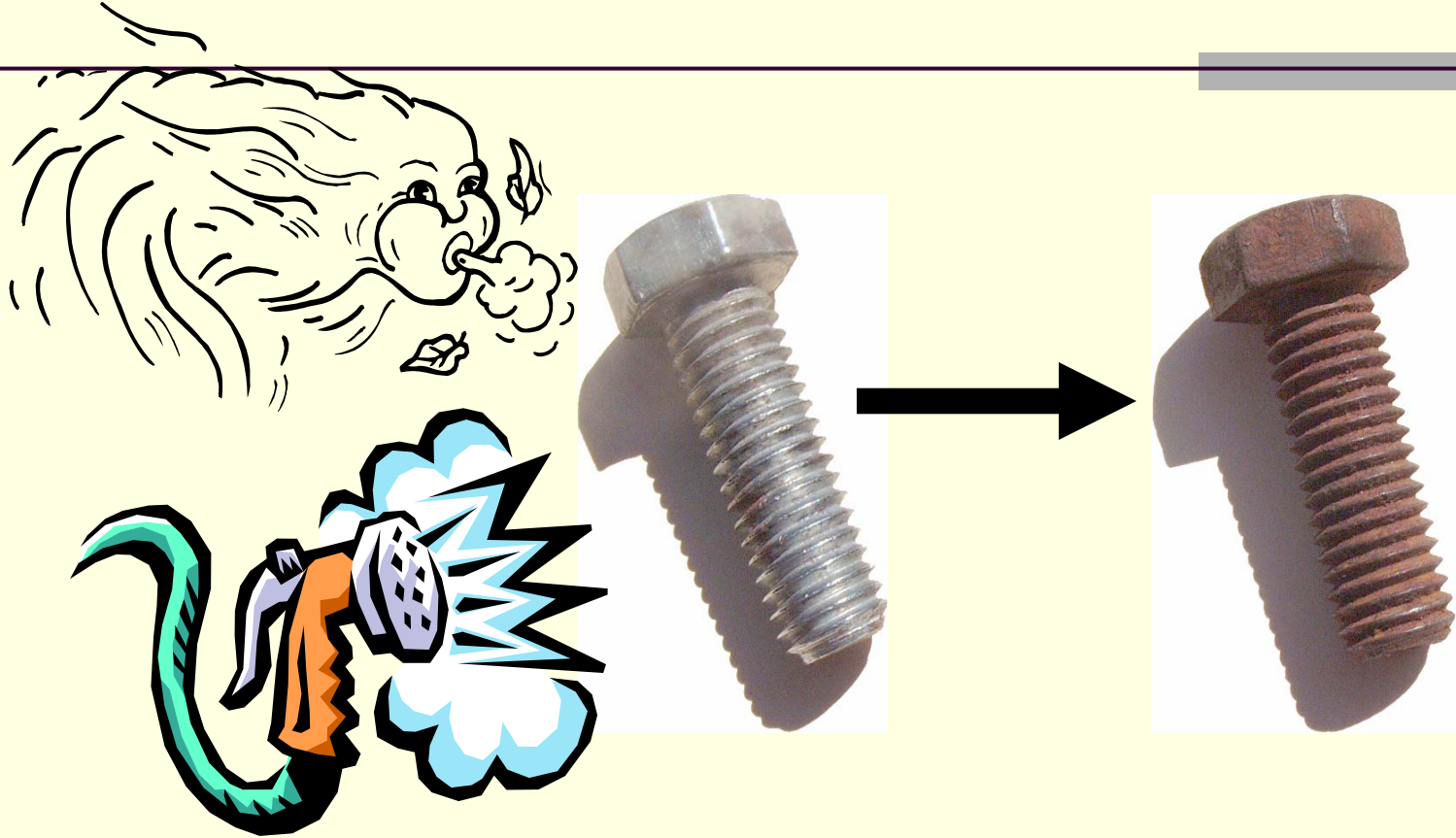
Protected
from air
and water



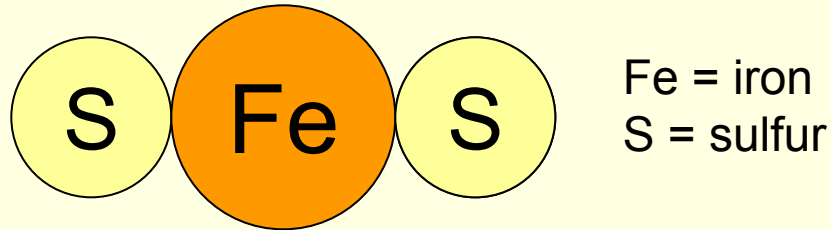
Rusted

Exposed
to air
and water

Rusting - the chemical reaction



AMD: it starts with Pyrite



Chemical Name: **Iron sulfide**

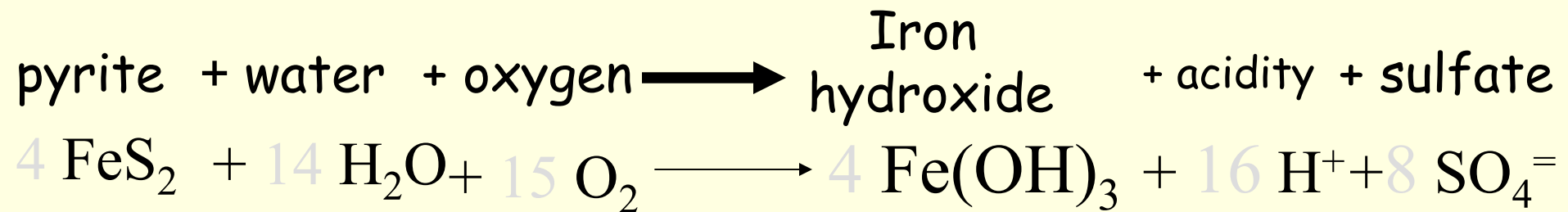
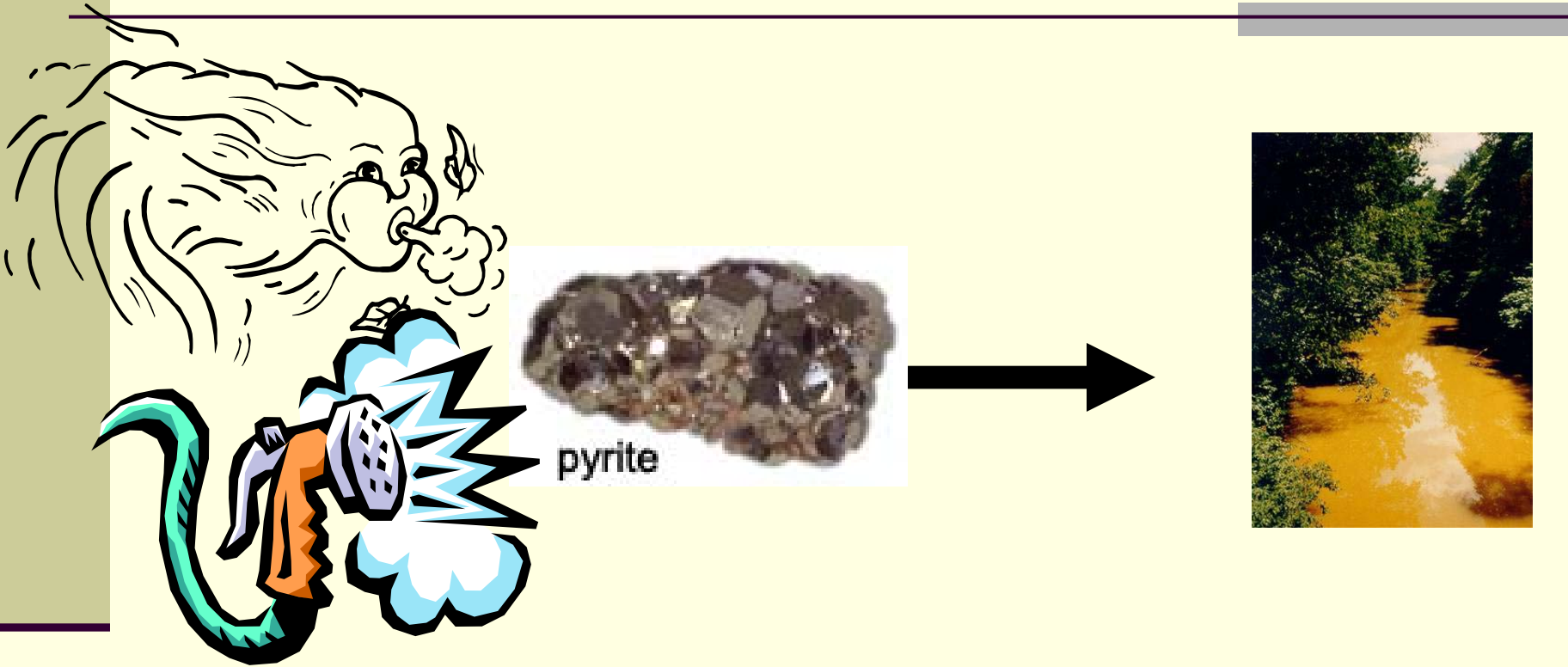
Mineral name: **Iron Pyrite**

Common Name: **Fool's Gold**

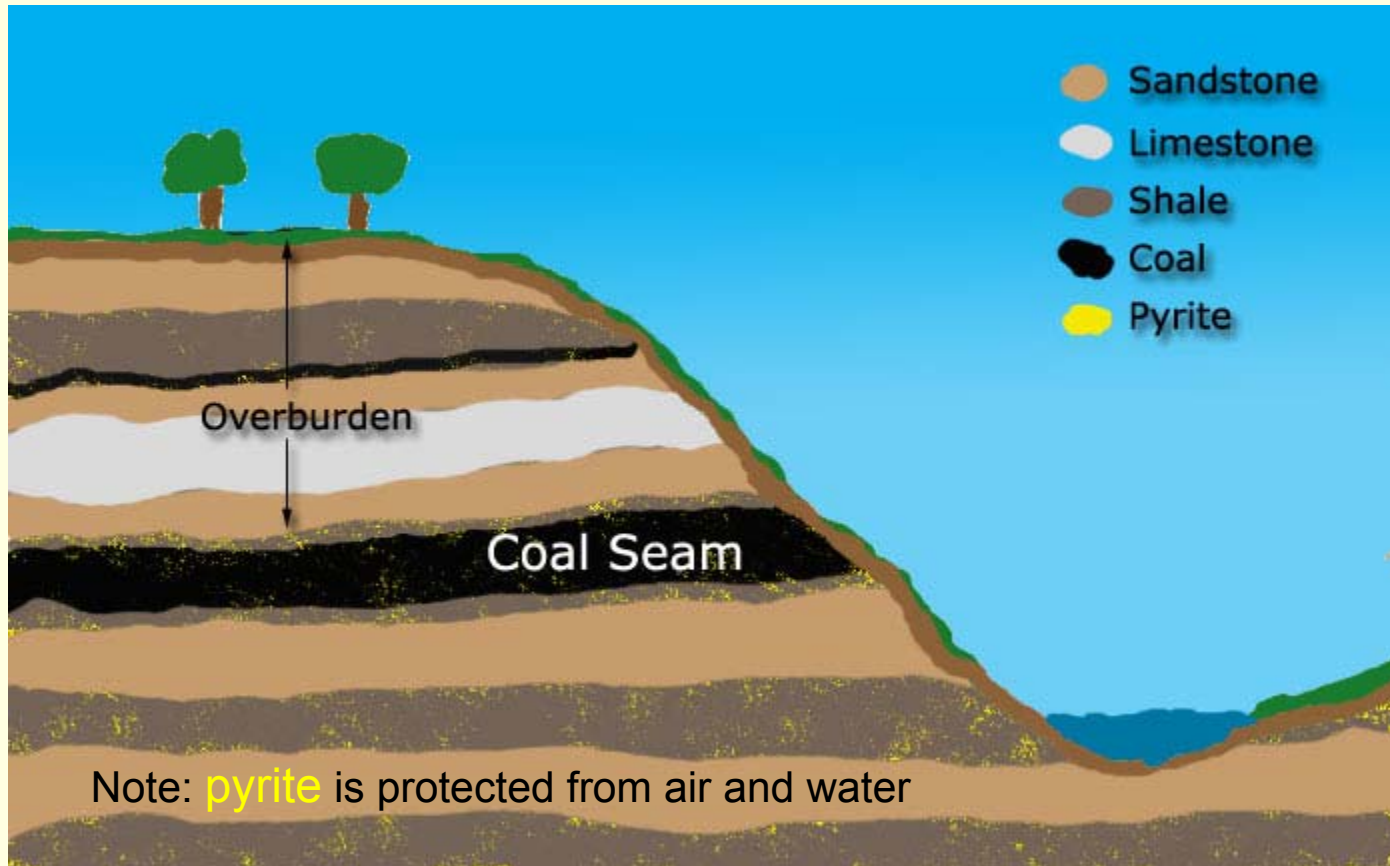
Pyrite is a very common mineral almost universally found in and adjacent to coal deposits.

Pyrite is protected from chemical reactions unless disturbed by mining activities.

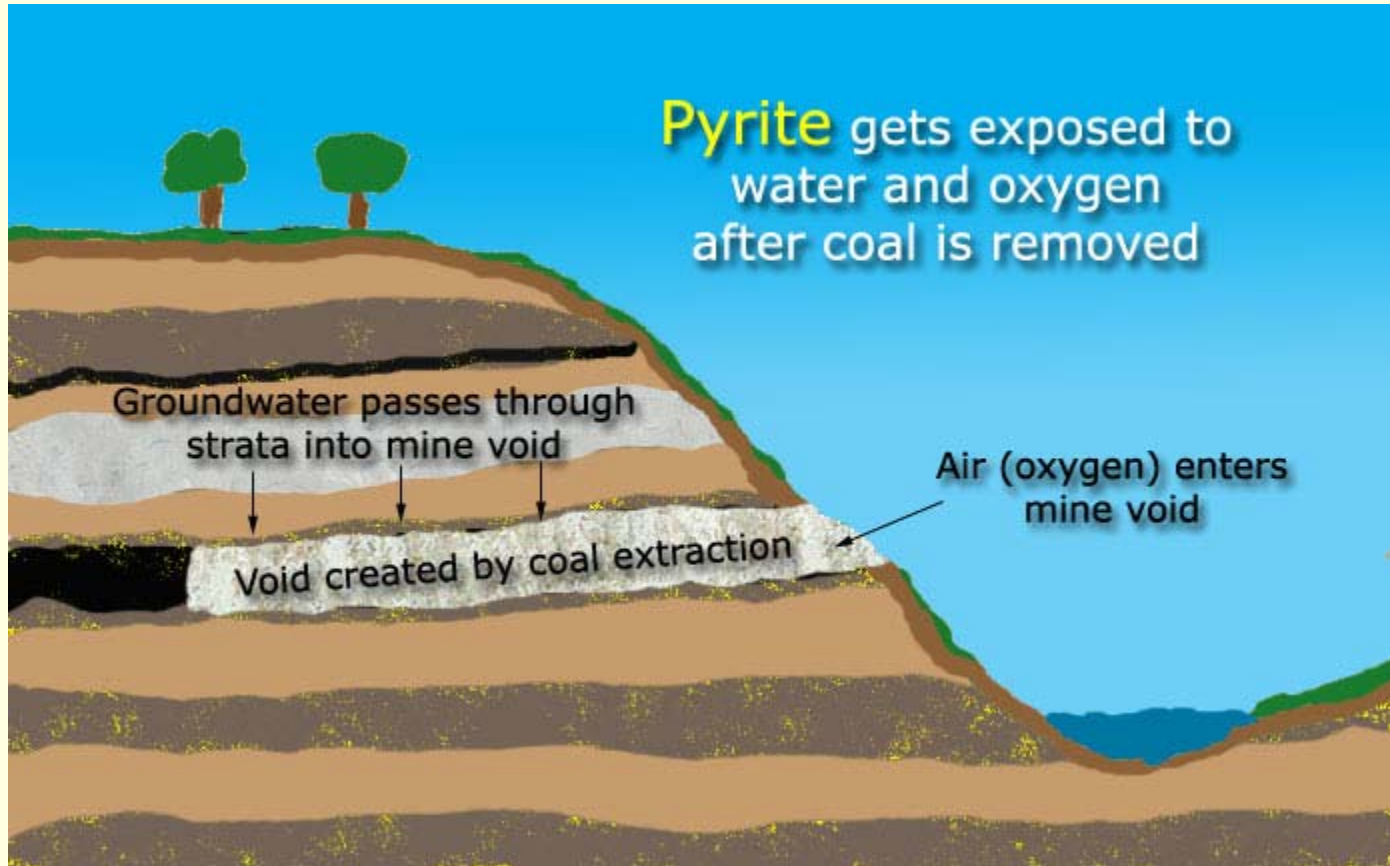
Pyrite's chemical reaction



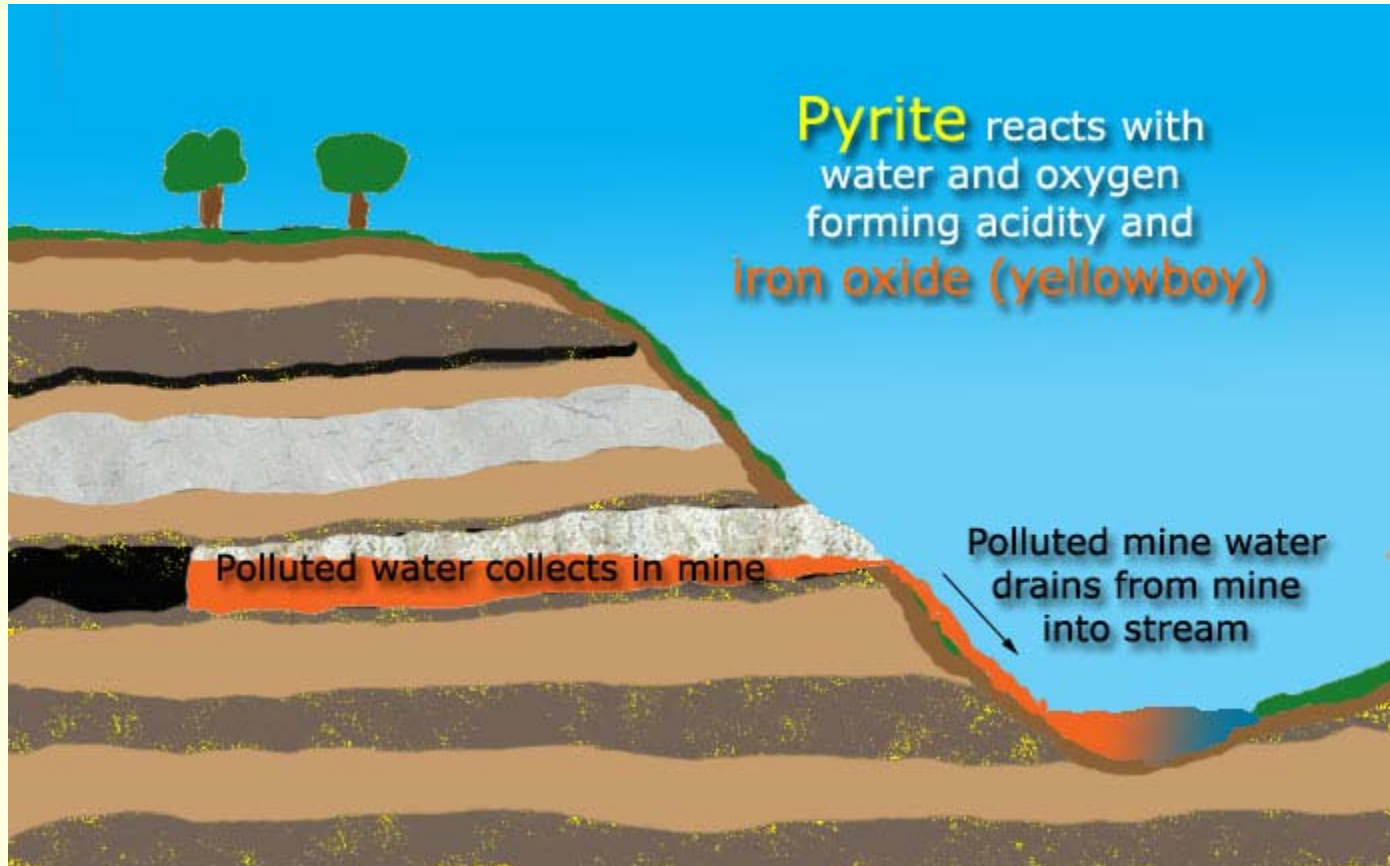
Before Mining



After mining



Pollution formed



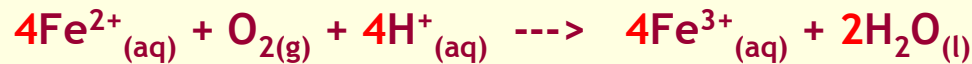
Pyrite reaction is a 3 step process

- (1) **Pyrite reacts with water and oxygen forming dissolved ferrous iron, acidity and sulfate**



Often, this is the only reaction that has occurred as an AMD discharge emerges from underground (if underground oxygen is limited)

- (2) **Ferrous iron is oxidized to ferric iron**



Constructed sedimentation ponds and aerobic wetlands promote this reaction

- (3) **Ferric iron is hydrolyzed to insoluble iron hydroxide (yellowboy)**



This reaction happens very quickly after (2). Sedimentation ponds & aerobic wetlands provide space for the solid iron hydroxide to be collected.

-
- (4) **Net reaction**



Pollution products from pyrite:

iron

- Dissolved iron (ferrous or Fe^{+2})
 - Present mainly when dissolved oxygen is low (as it often is emerging from underground)
 - Dissolved iron is not visible in water
 - Converts to solid (iron hydroxide) with oxygen & water
- Iron hydroxide (and similar rust-like solids)
 - Orange sediment coats bottoms of streams, limits light into stream
 - Smothers much aquatic life, destroys stream habitat

Streams polluted with Iron



Pollution products from pyrite:

Acidity

- Acidity is the ability to neutralize alkalinity
- Usually associated with lower pH's (less than pH 6 and as low as pH 2)
- Can be toxic to aquatic organisms
- May cause other metals to dissolve, making polluted water worse.

Aluminum - a common AMD pollutant indirectly caused by pyrite

- Clays are common and rich in aluminum
- Clays can be dissolved by acidity, releasing aluminum
- The acidity formed by pyrite reactions can drive clay dissolution. (Acid rain, too!)
- Aluminum is toxic to many aquatic organisms.
- Aluminum hydroxide is white solid and often visible as a coating on rocks or cloudiness in water if $\text{pH} > 4.5$
- Similar dissolution with other minerals can release other metals.



AMD polluted streams containing Aluminum



Aluminum
is toxic

Aluminum appears as
a white coating on rocks or
a white cloudiness in streams.

Limestone dissolution - a beneficial reaction

- Limestone is an alkalinity producing material
- Limestone counteracts acidity
- Limestone is calcium carbonate (CaCO_3)
- Limestone is sometimes found near coal seams
- Limestone can be dissolved by acidic water, tending to neutralize the acidity and raise pH
$$\text{CaCO}_3 + \text{H}^+ \rightarrow \text{HCO}_3^- + \text{Ca}^{++}$$
- AMD can be improved by limestone
- Water having dissolved limestone is said to be "buffered"

Not all AMD is alike

Possible pollutants:

- Acidity
- Metals
 - Iron
 - Aluminum
 - Others
- Sulfate
 - Not a pollutant, but an indicator of mine drainage

The concentrations (and flow) of these pollutants is what makes a particular AMD discharge unique.

AMD Treatment strategies

Active vs. Passive Treatment

Passive Treatment strategies are based upon

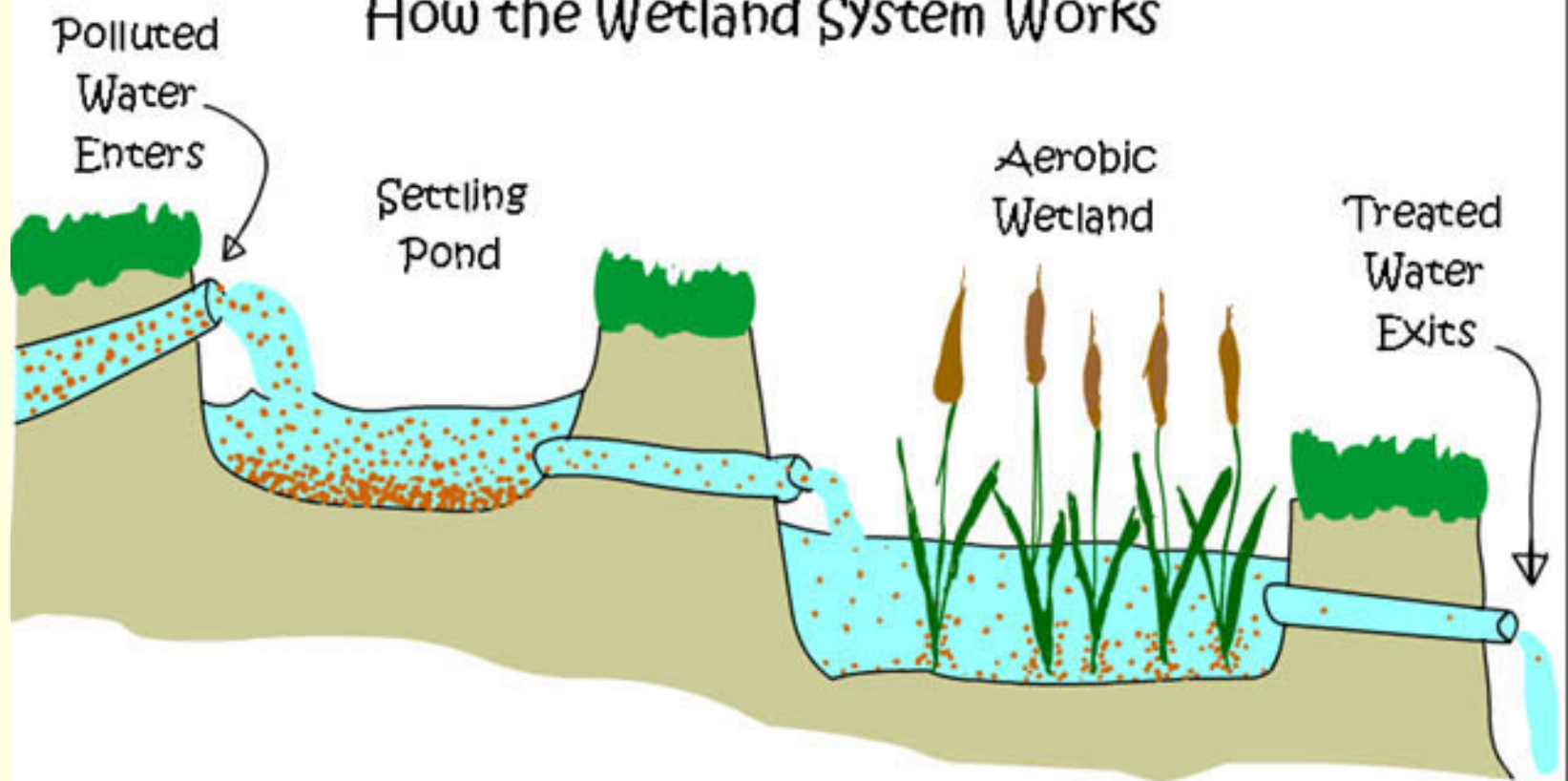
- Concentrations of individual pollutants
- Flow rate
- Characteristics of the site

All treatment strategies have two common elements

If acidity is present, neutralize it.

If metals are present, capture and retain them.

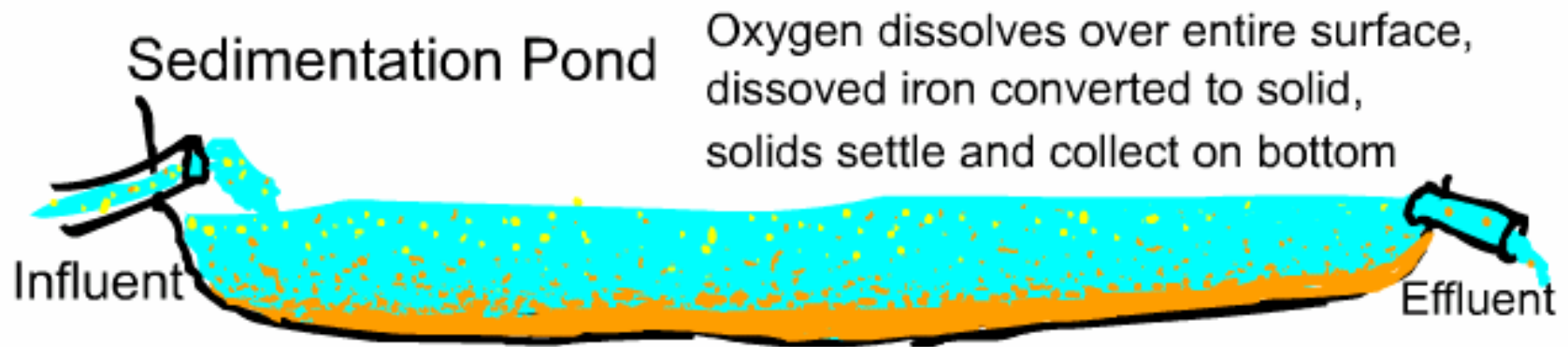
How the Wetland System Works



Treatment BMP's removing metals

Sedimentation ponds

- A.k.a settling or oxidation ponds
- Adds oxygen (to convert dissolved iron to rusty solid)
- Allows enough time for particles to settle
- Allows enough space for metals to accumulate
- Effectiveness increases with increasing pH



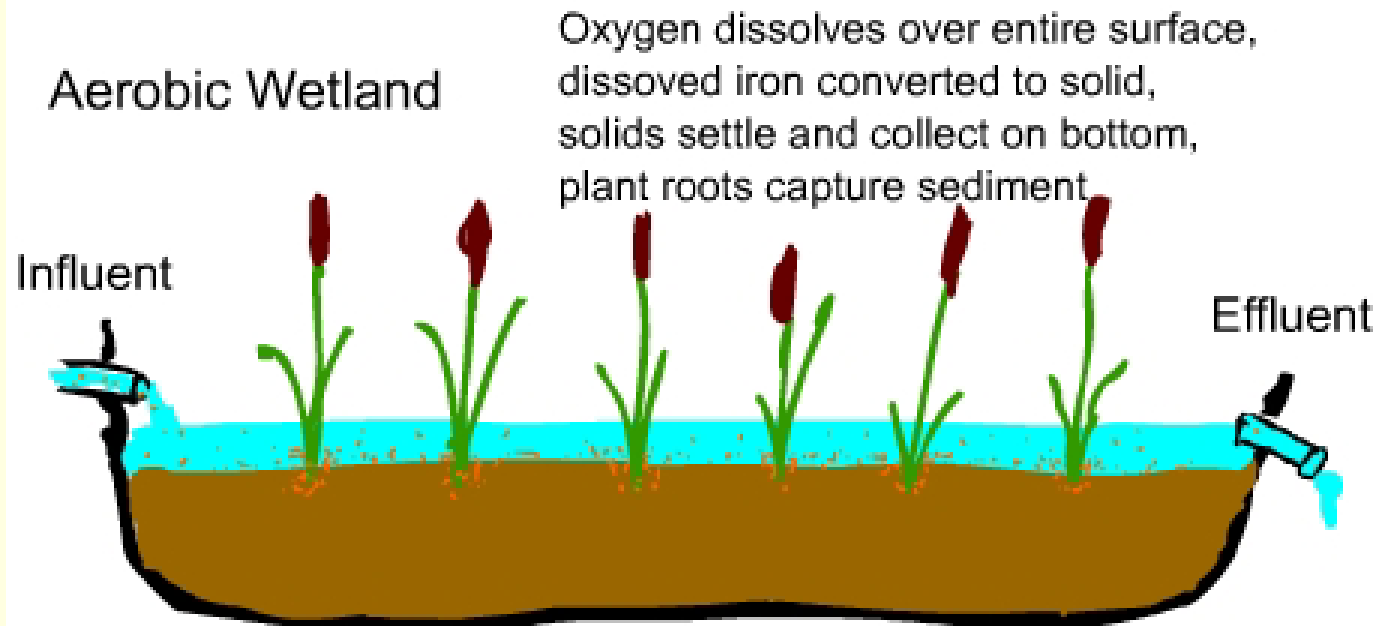


Sedimentation Pond

Treatment BMP's removing metals

Aerobic wetland (polishing pond)

- Adds oxygen (to convert dissolved iron to rust-like solid)
- Allows enough time for particles to settle
- Common to follow sedimentation pond
- Water should be net alkaline to work well
- Adds some alkalinity



Monastery Run Treatment System

Alkaline discharge
with high Iron

1st Sedimentation Pond
2nd Sedimentation Pond
3rd Sedimentation Pond

1st Aerobic Wetland
2nd Aerobic Wetland



Treatment BMP's adding alkalinity

Limestone

- For passive systems, dissolving limestone is almost always used to add alkalinity.
 - Cheap, safe

Disadvantages

- Armoring
coating limestone surface with iron hydroxide sediment, inhibiting dissolution
- Slow to dissolve



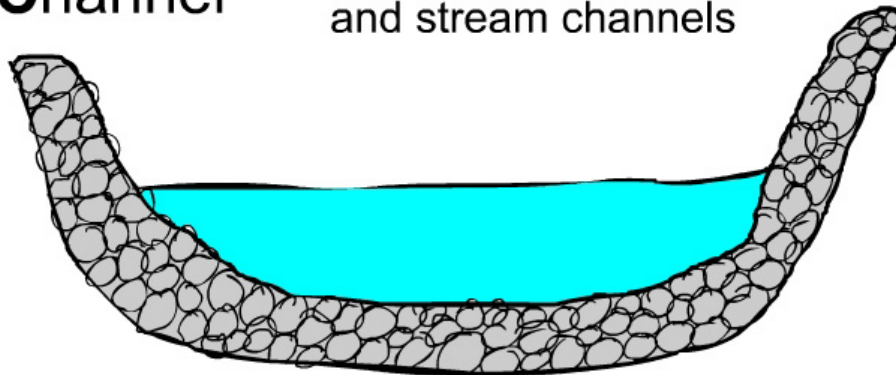
Treatment BMP's adding alkalinity

Open Limestone Channels

- Simple way of adding alkalinity
- Armoring can be a problem
- Best for low iron and low aluminum discharges
- Often placed on hillsides to get higher velocities

Open Limestone Channel

Small or large sized limestone placed along sides and bottom of culverts, diversions, ditches, and stream channels



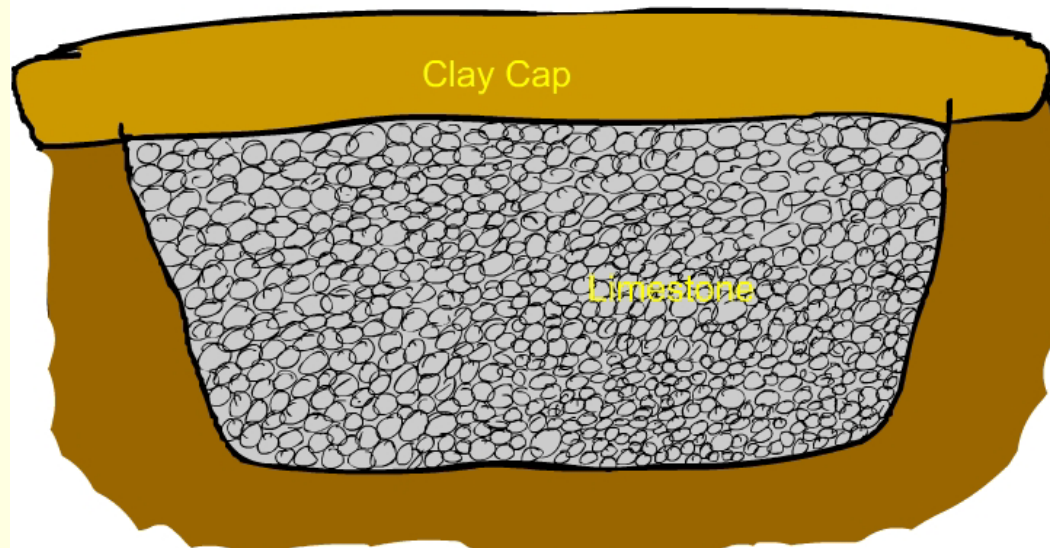
Treatment BMP's adding alkalinity

Anoxic Limestone Drain

- Good choice for discharge having only acidity and dissolved iron
- Keeping oxygen out prevents armoring, protecting limestone
- Buried structure

Anoxic Limestone Drain

Suited for discharges with acidity & dissolved iron,
but very low in dissolved oxygen, ferric iron & aluminum



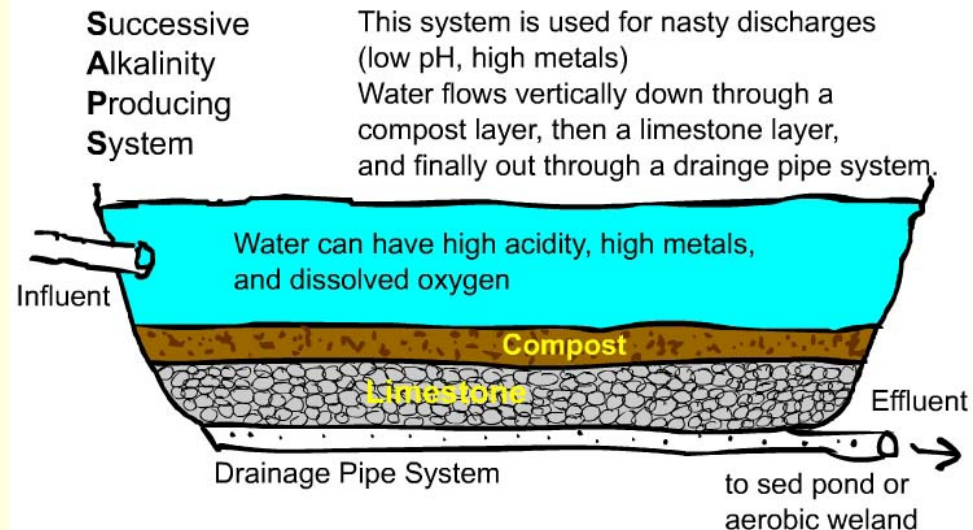
Cross section of long trench filled with limestone, sealed from air.

Treatment BMP's adding alkalinity

Successive Alkalinity Producing Systems

SAPS, a.k.a. Vertical Flow Reactors (VFR)

- Big gun - used when no other passive system will do the job
- Compost layer protects the limestone layer
 - strips oxygen from water (anaerobic) and reduces ferric iron to ferrous while producing alkalinity
- Limestone layer adds alkalinity
- Perforated pipes at bottom collect water to convey to a sedimentation pond or aerobic wetland



Treatment BMP's are used in combination to capture metals and neutralize acidity



Treatment BMP's adding alkalinity

Limestone Sands

- The simplest way to add limestone alkalinity to a stream
- Dump piles of limestone sand along stream bank
- High water events wash sands into stream;
conveyed and dissolved downstream
- Hastens metal precipitation in stream
- Best if metals concentrations are low
- Replenish once or twice
per year



How you can help

- Get involved with environmental issues.
- Get educated about the problems and possible solutions.
- Spread the word.
- Join your local watershed organization.
- Capstone project???

For more information

The website

<http://AMRCClearinghouse.org>

has lots of useful information about and links to abandoned mine reclamation issues.

Bruce Golden, Regional Coordinator

Western PA Coalition for Abandoned Mine Reclamation

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