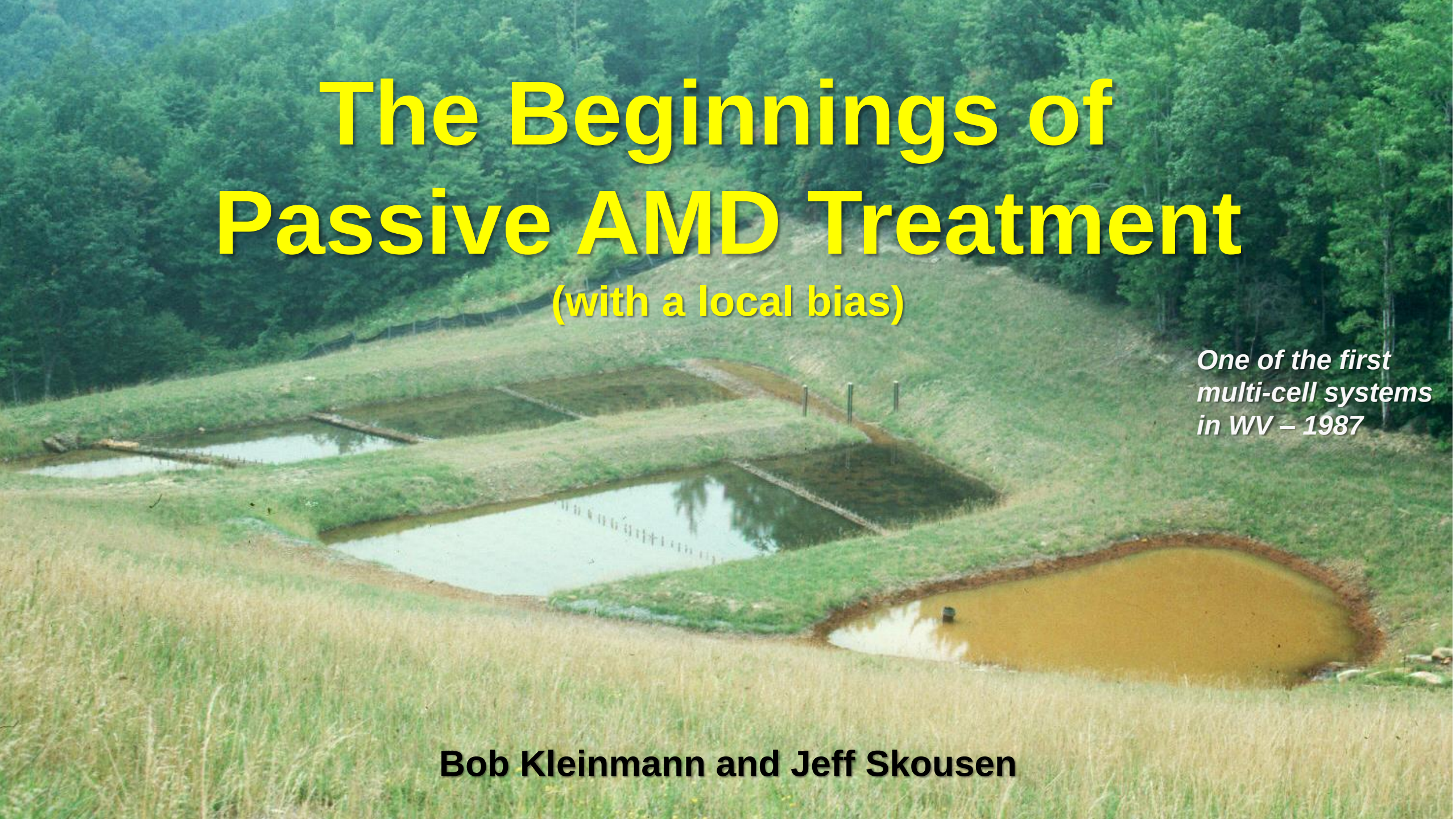
The Beginnings of Passive AMD Treatment

(with a local bias)



One of the first multi-cell systems in WV – 1987

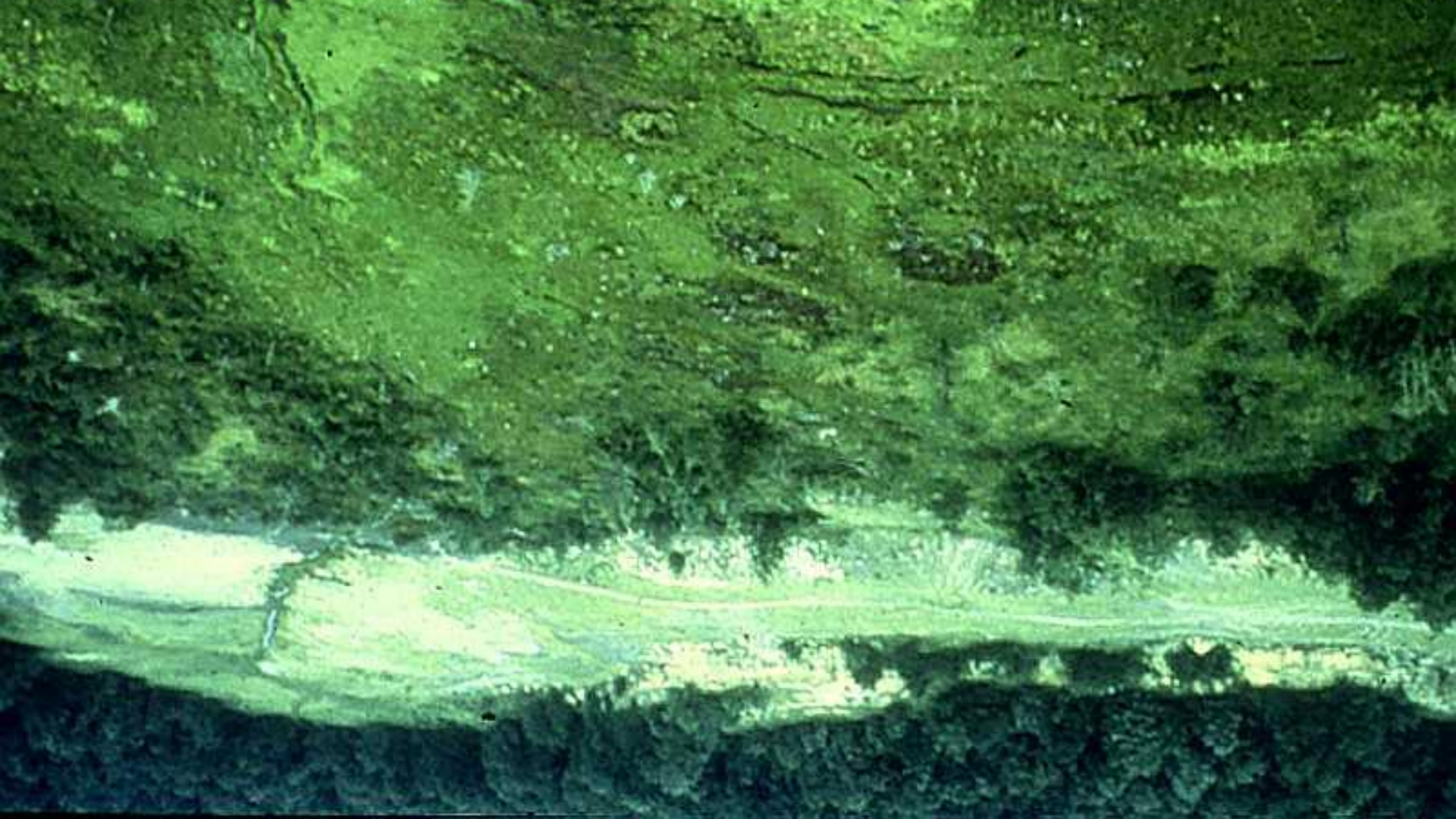
Bob Kleinmann and Jeff Skousen

Passive Mine WaterTreatment Systems

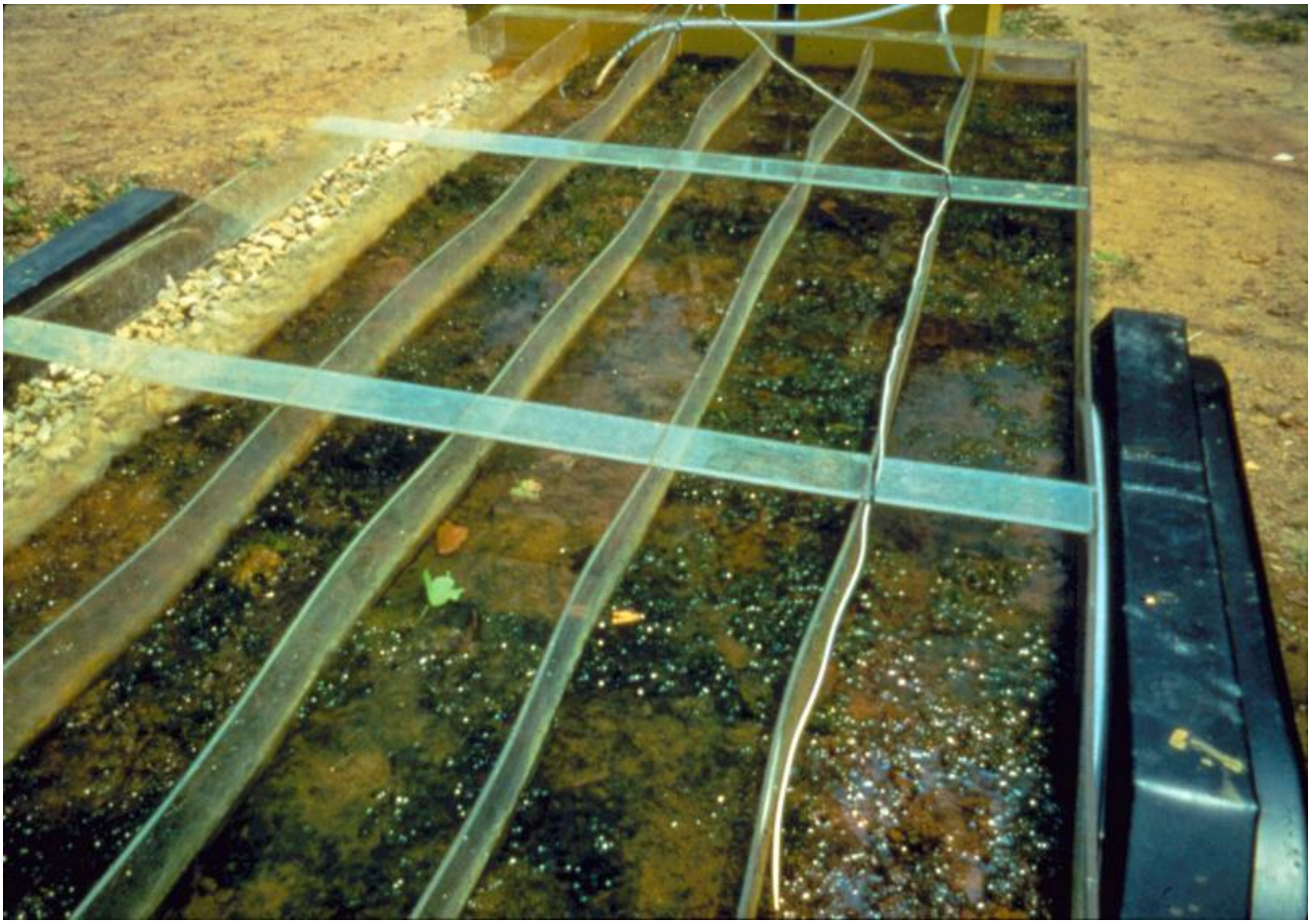
Two general categories:

1. Biological
   a. Aerobic/Anaerobic Wetlands
   b. Vertical Flow Wetlands
   c. Bioreactors
2. Geochemical
   a. Anoxic Limestone Drains
   b. Open Limestone Channels
   c. Alkaline Leach Beds
   d. Flushable Limestone Beds


Passive AMD Treatment
But how and where did it begin?



To test this concept, we created a miniature version of this Sphagnum moss bog (a port-a-bog) and mounted it on a flatbed trailer so that it could be tested at various mine sites.

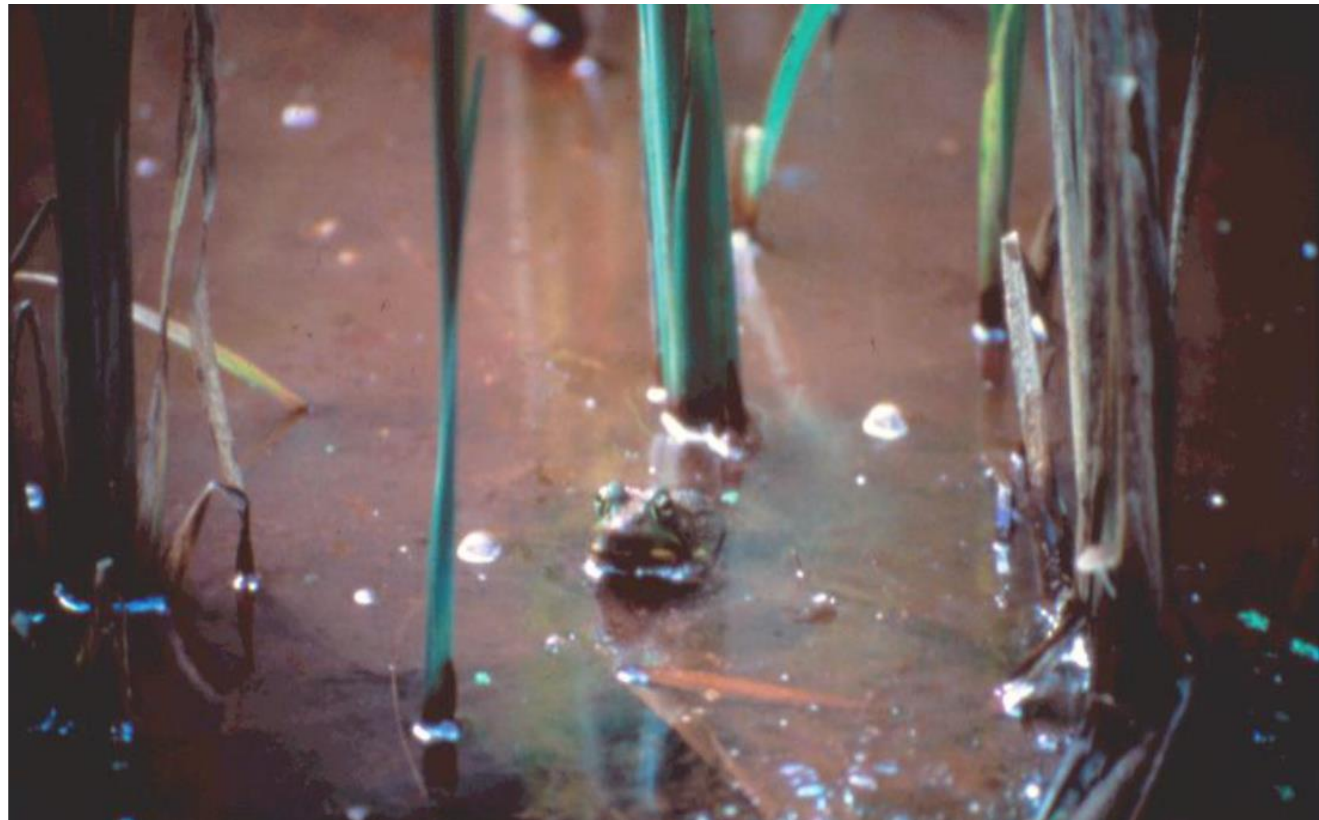


After testing the approach with our port-a-bog, we tried scaling it up at actual field sites.

However, we learned that while the Sphagnum moss systems could handle relatively mild coal mine drainage, high metal loads created an advancing wall of death unless there was large amounts of dilution available.


But others had also noticed MIW improving as it flowed through cattail wetlands.

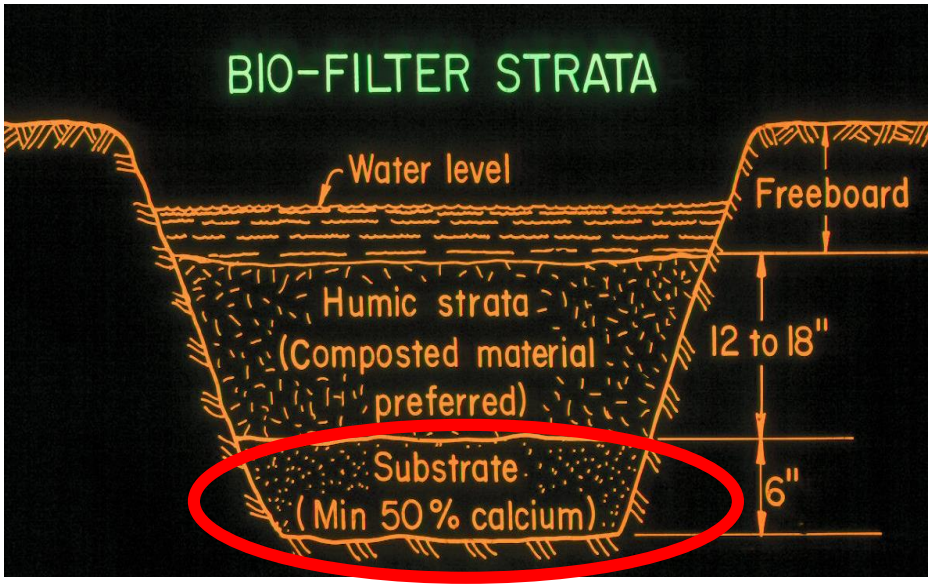
Typha (cattails) seemed much more tolerant of acid mine water than Sphagnum



<u>1984</u>

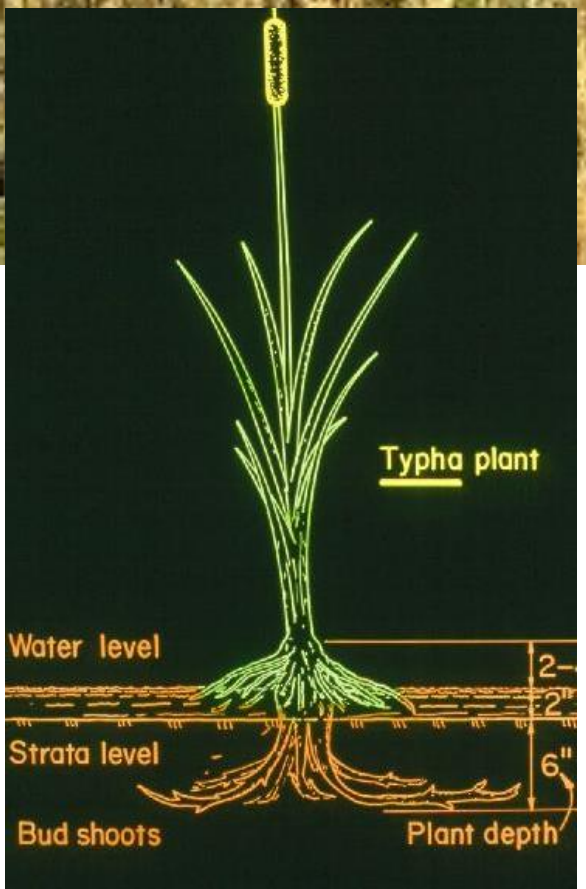
Friendship Hill, PA

Layered substrate



Aerobic Wetlands and Ponds

Typha (cattail) wetlands were being planted and thriving at inactive mine sites by 1985 and at active mine sites 5-10 years later.



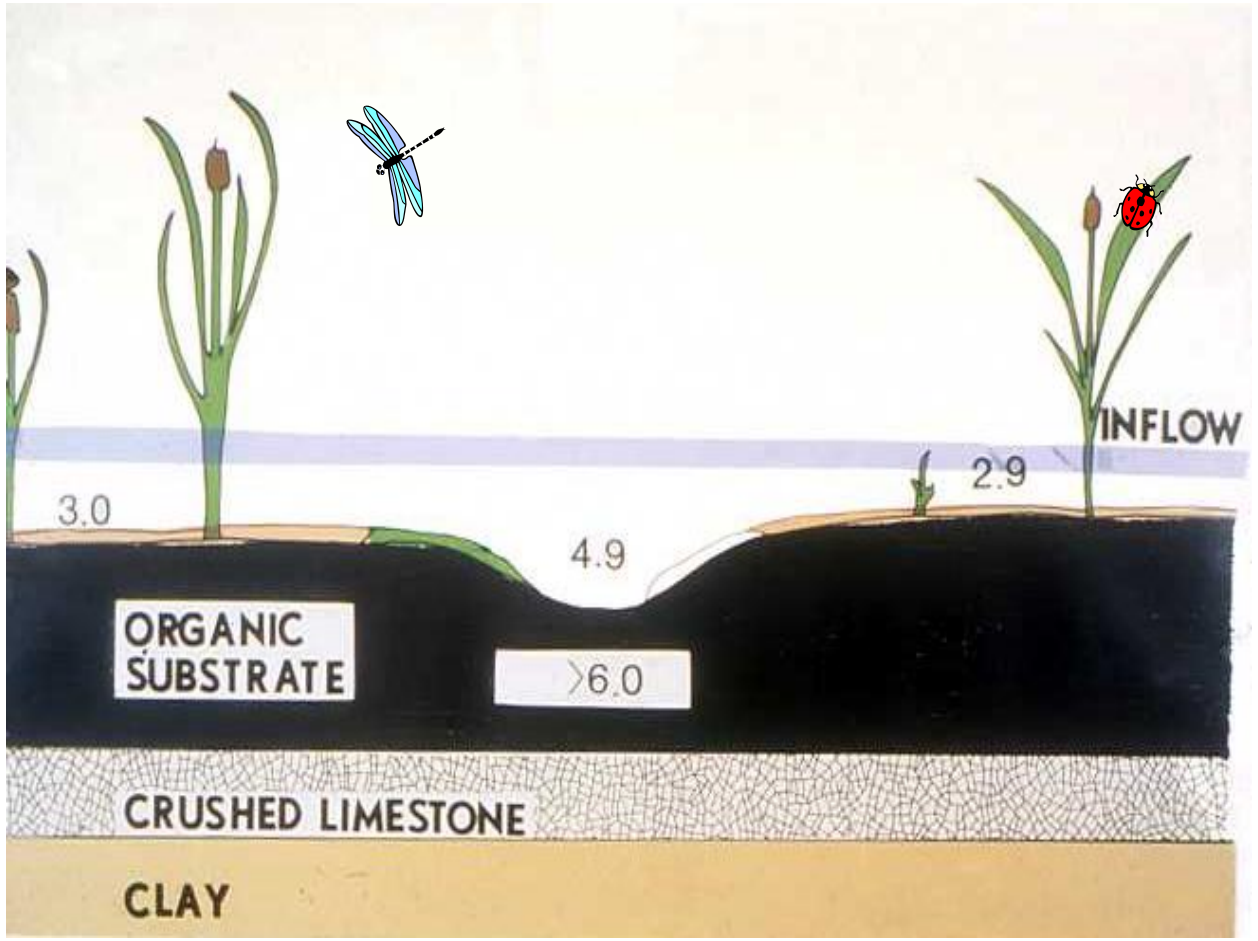
<u>1985</u> – Jeff's first system

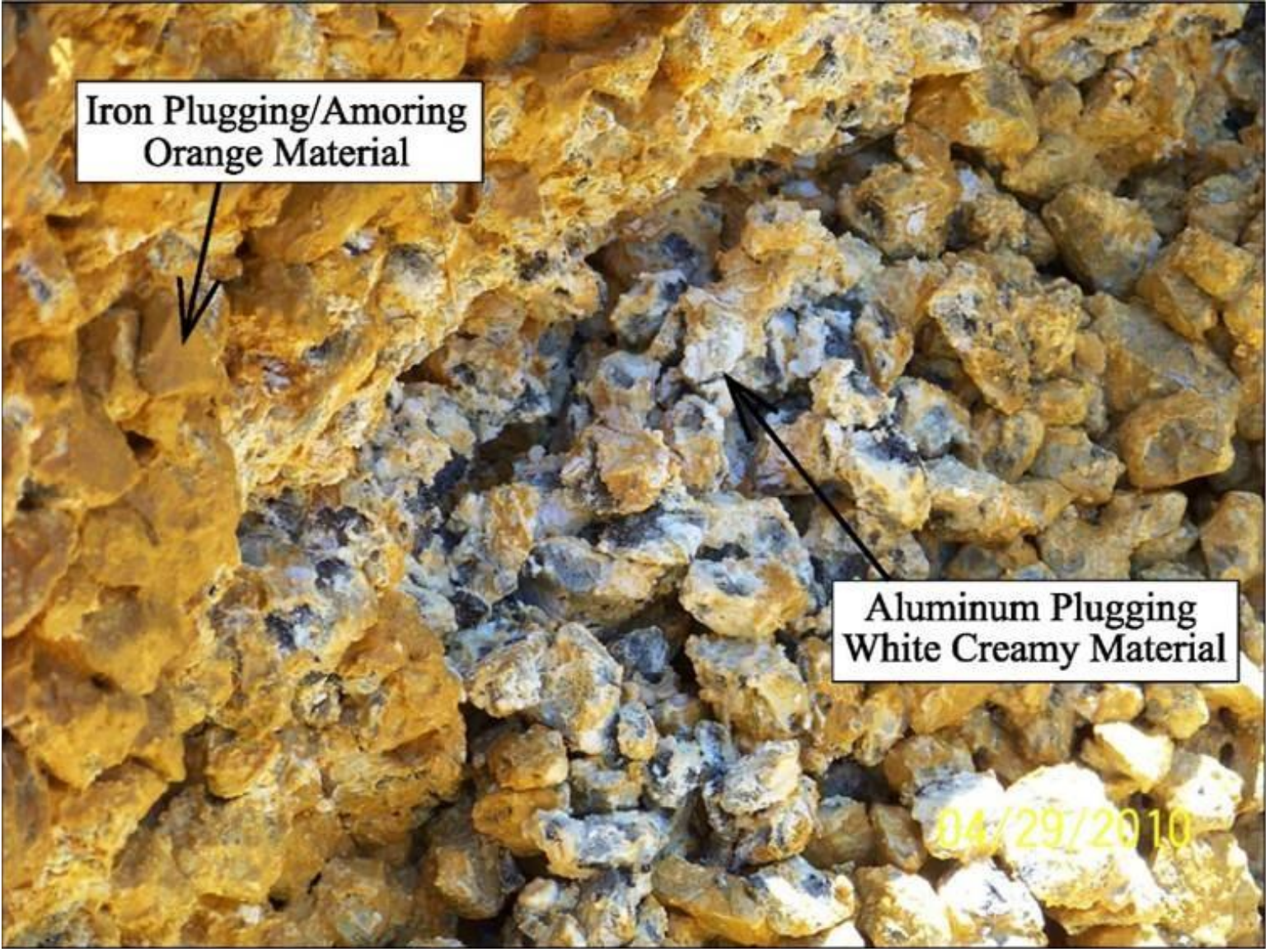
Small flow – Mod acid


1987 – early multiple-pond system
Six cells – sequential aerobic and anaerobic


2003 – still working after 16 years.

The Development of Anaerobic Wetlands

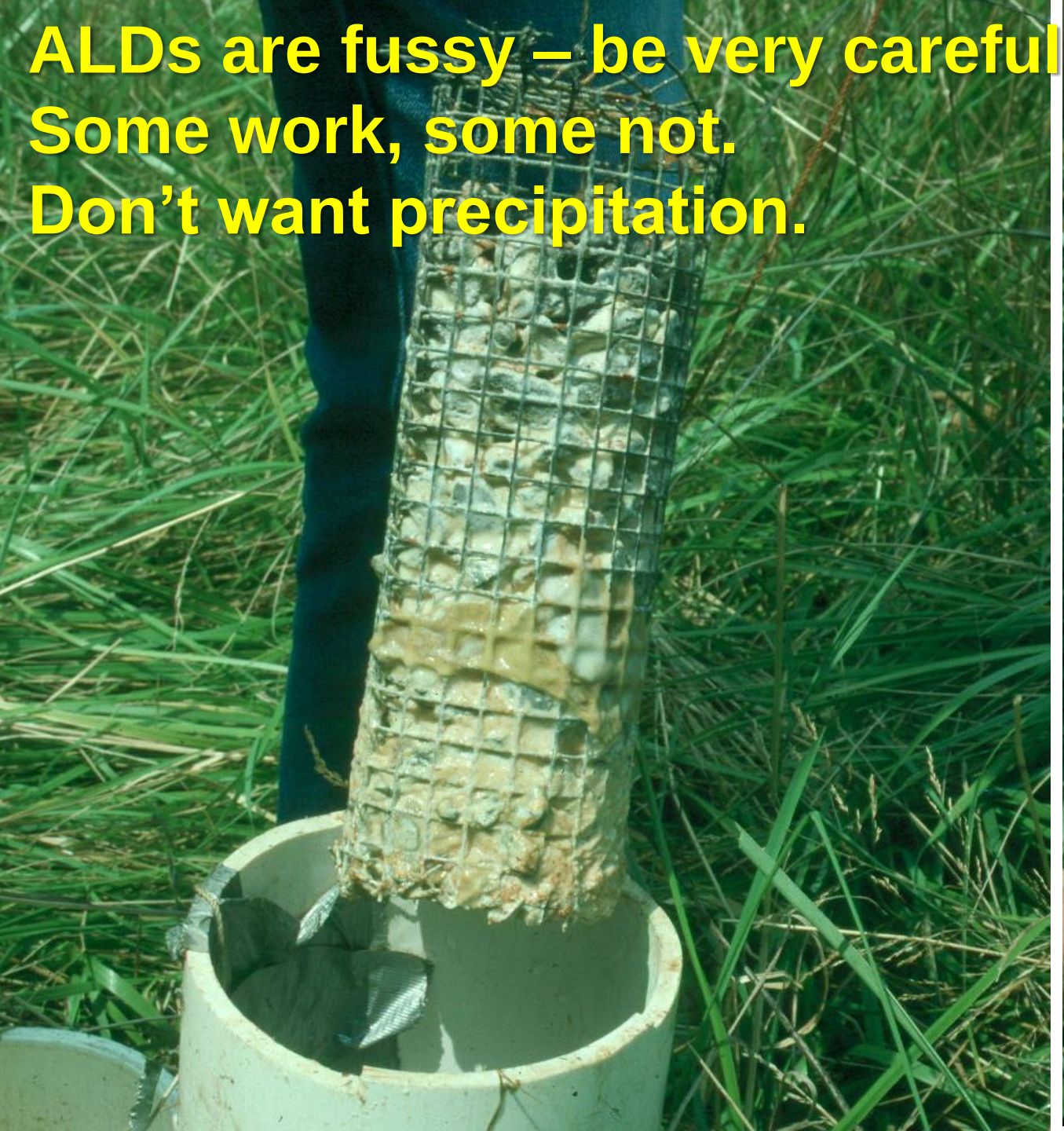




Fe coating of LS

Is there any way to keep the LS from becoming coated with iron hydroxide?


Great idea!
Keep LS anoxic – won't armor
Anoxic Limestone Drains


ALDs are fussy – be very careful
Some work, some not.
Don’t want precipitation.


Want clean LS

Figure 1. Excavation of the trench was followed by placing filter fabric in the trench, and then filling the trench with limestone.

Figure 2. Hay bales were placed on top of the filter fabric lined trench filled with limestone.

One idea was to add haybales to serve as a sink for oxygen, generate CO_2, and add alkalinity. **Nope!**

Figure 3. The limestone and hay in the trench were covered with plastic.

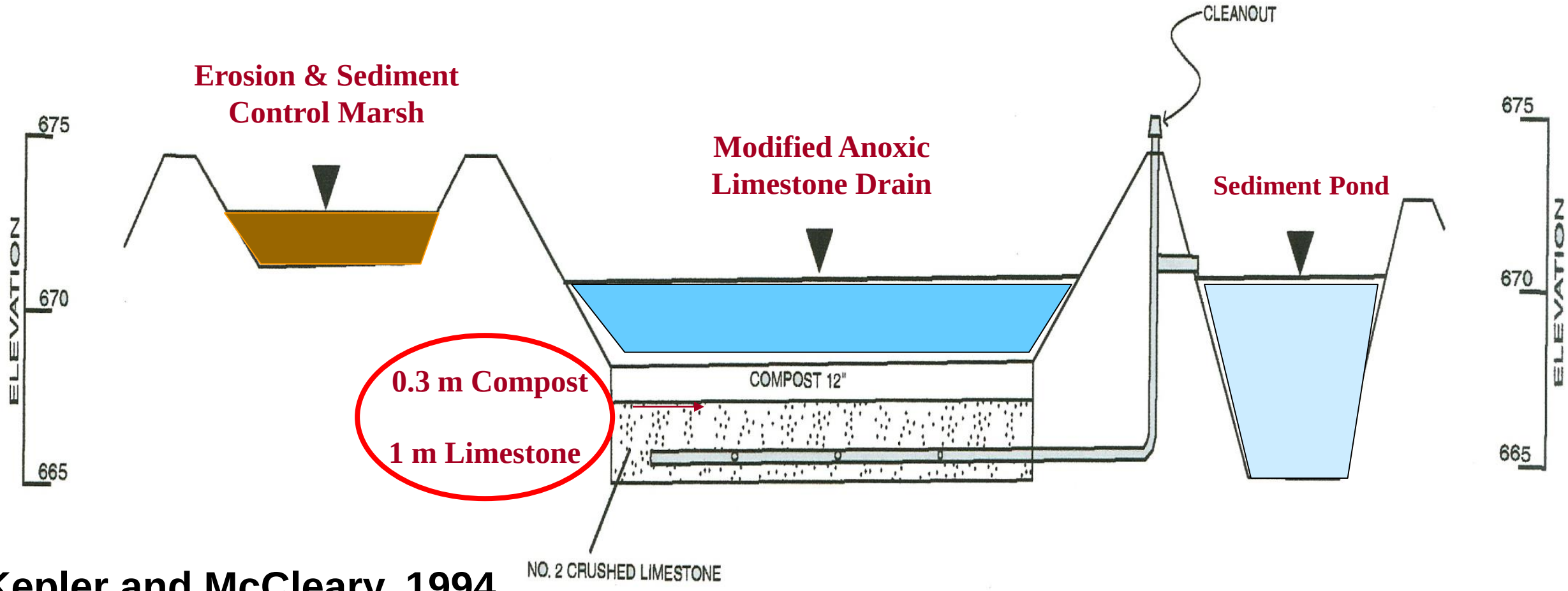
Skousen and WVDEP 1991

Can we pre-treat oxygenated mine water before it goes into an ALD?

SAPS or Vertical Flow Wetlands

Great idea!

Push water through OM, then into LS, out through pipes



Kepler and McCleary, 1994

SAPS were designed to remove O_2 from the water with a downflow system through OM then LS, out through pipes.

Does LS stop dissolving when armored?
Not completely! Typical dissolution continues at 20-30%

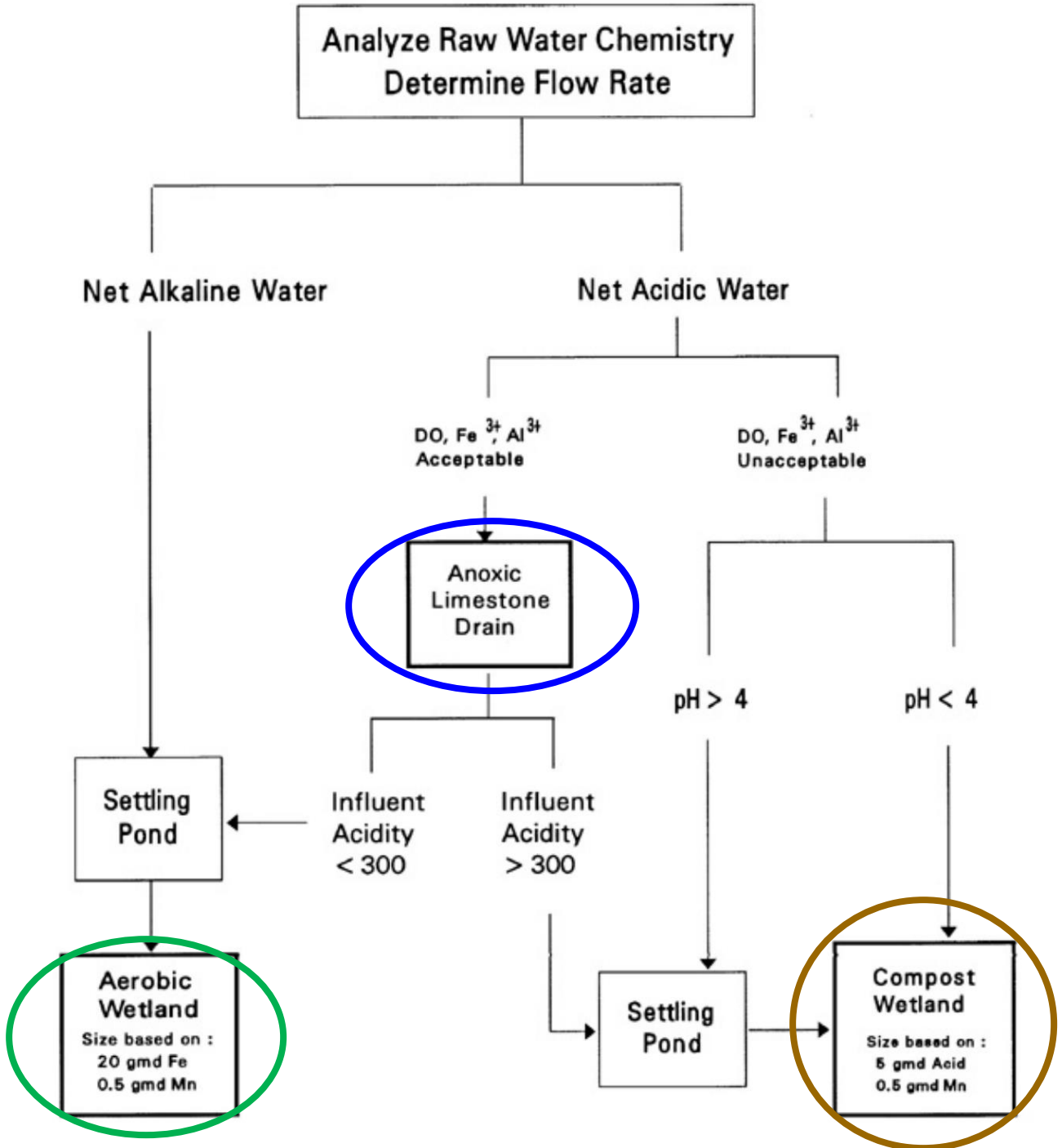
Good idea!

Build longer Open Limestone Channels!


Steel Slag Leach Bed

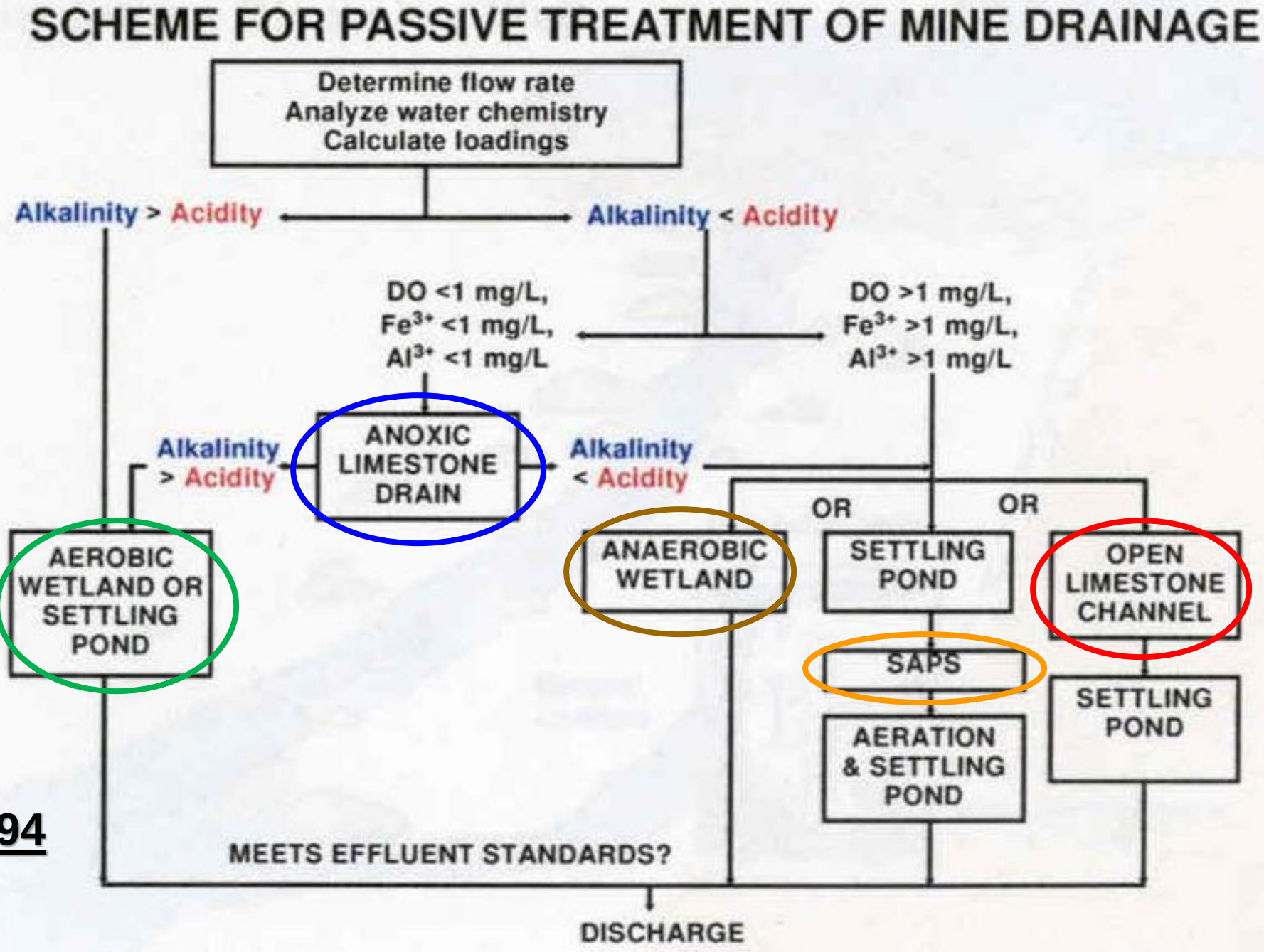
Here was the original decision tree…

three systems



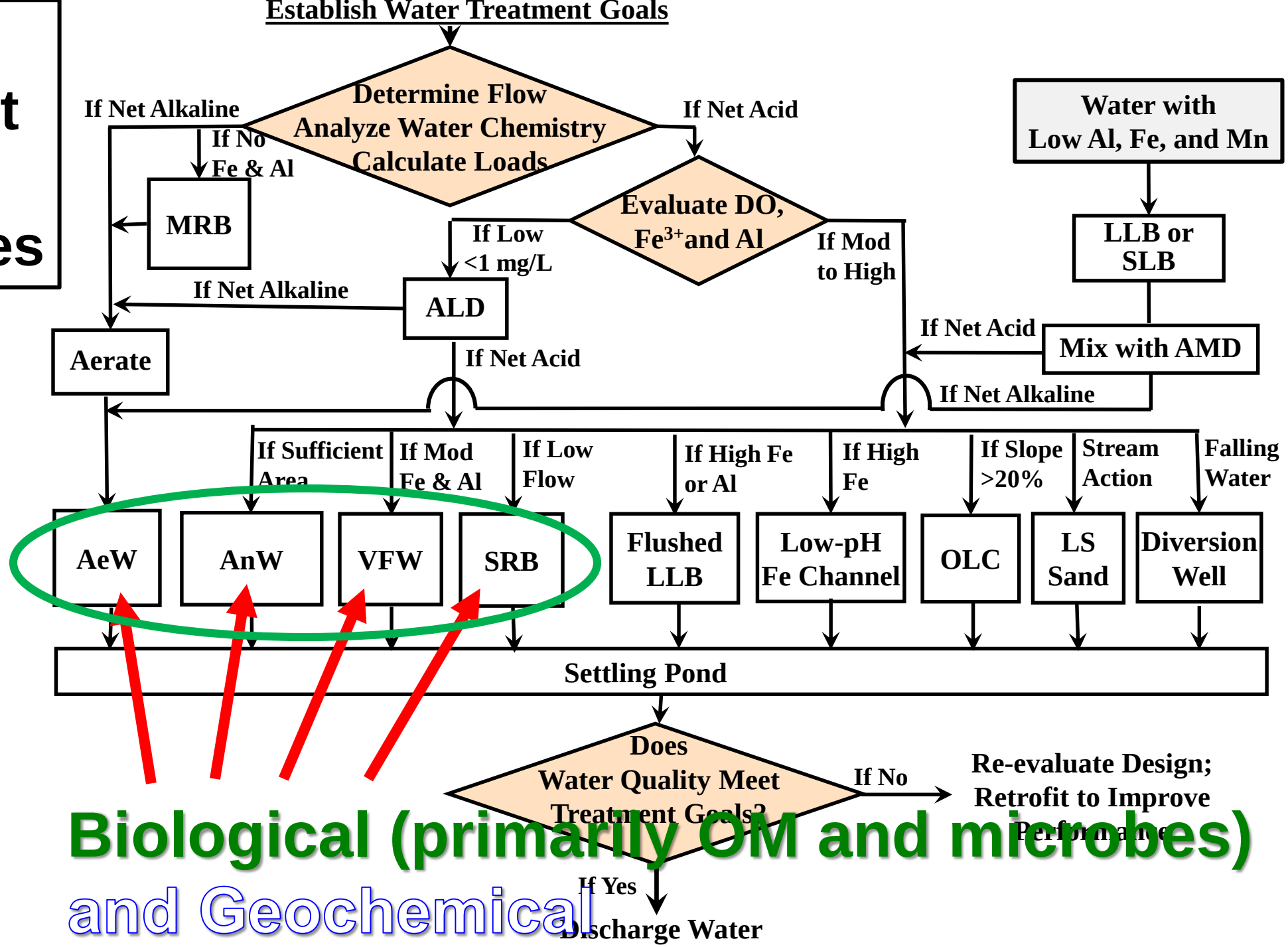
In 1994,
this was the
Decision Tree

with five choices

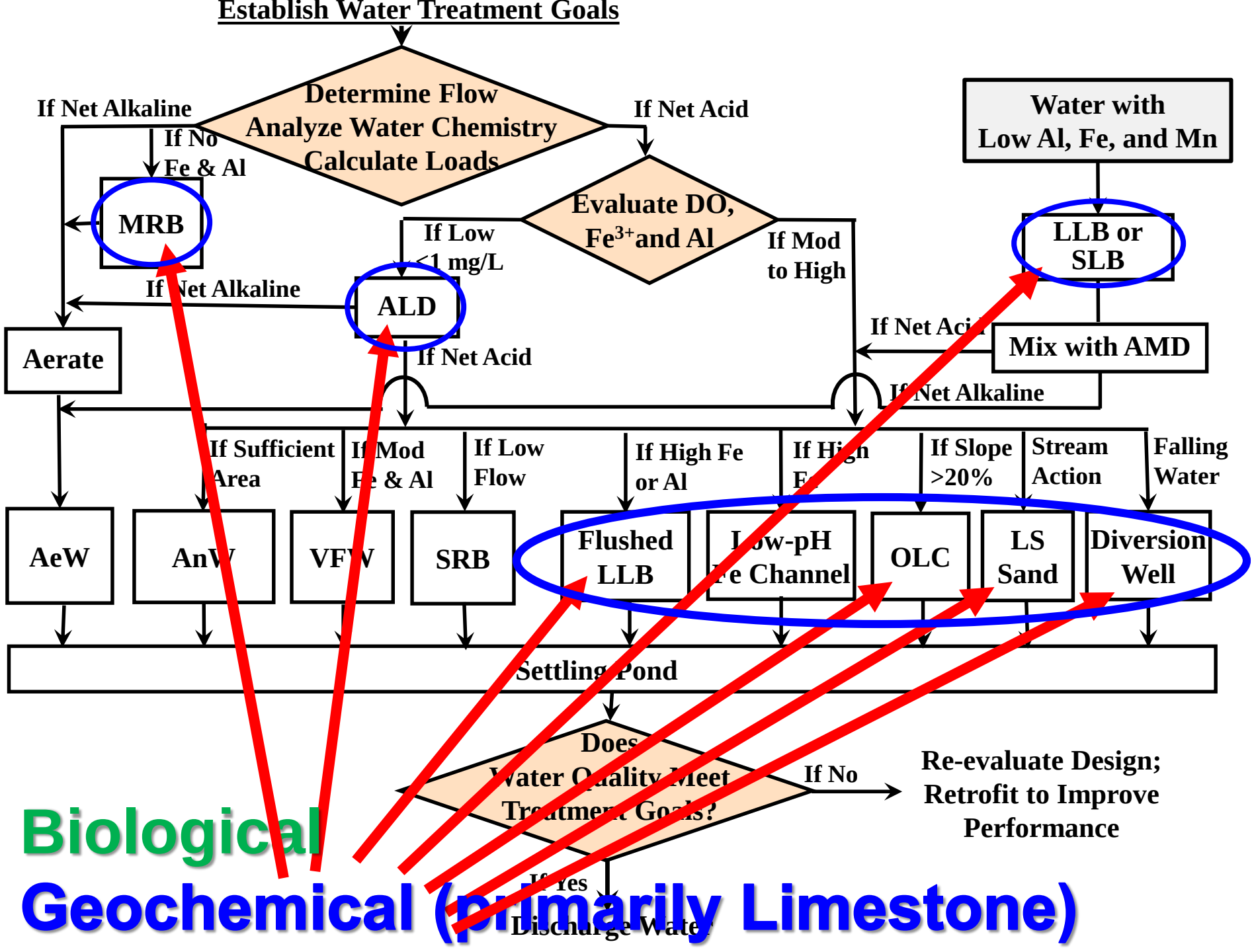


US Bureau of Mines 1994

Today at least 12 Choices



Biological (primarily OM and microbes) and Geochemical


Establish Water Treatment Goals
Determine Flow
Analyze Water Chemistry
Calculate Loads
If Net Alkaline
If No Fe & Al
If Net Acid
MRB
Evaluate DO, Fe3+ and Al
If Low <1 mg/L
If Mod to High
ALD
If Net Alkaline
Aerate
If Net Acid
Water with Low Al, Fe, and Mn
LLB or SLB
If Net Acid
Mix with AMD
If Net Alkaline
If Sufficient Area
If Mod Fe & Al
If Low Flow
If High Fe or Al
If High Fe
If Slope >20%
Stream Action
Falling Water
AeW
AnW
VFW
SRB
Flushed LLB
Low-pH Fe Channel
OLC
LS Sand
Diversion Well
Settling Pond
Does Water Quality Meet Treatment Goals?
If No
Re-evaluate Design; Retrofit to Improve Performance
If Yes
Discharge Water
Biological
Geochemical (primarily Limestone)

Here are the Major Points for Passive Treatment Systems

1. When appropriately designed and maintained, passive systems **can provide long-term, efficient, and effective treatment** for *many* acid mine drainage (AMD) sources.

2. Passive AMD treatment relies on **natural processes to neutralize acidity and to oxidize or reduce and precipitate metal contaminants**.

3. … are most suitable for **small to moderate AMD discharges of appropriate chemistry**. Periodic inspection and maintenance plus eventual renovation are generally required.

Here are the Major Points for Passive Treatment Systems

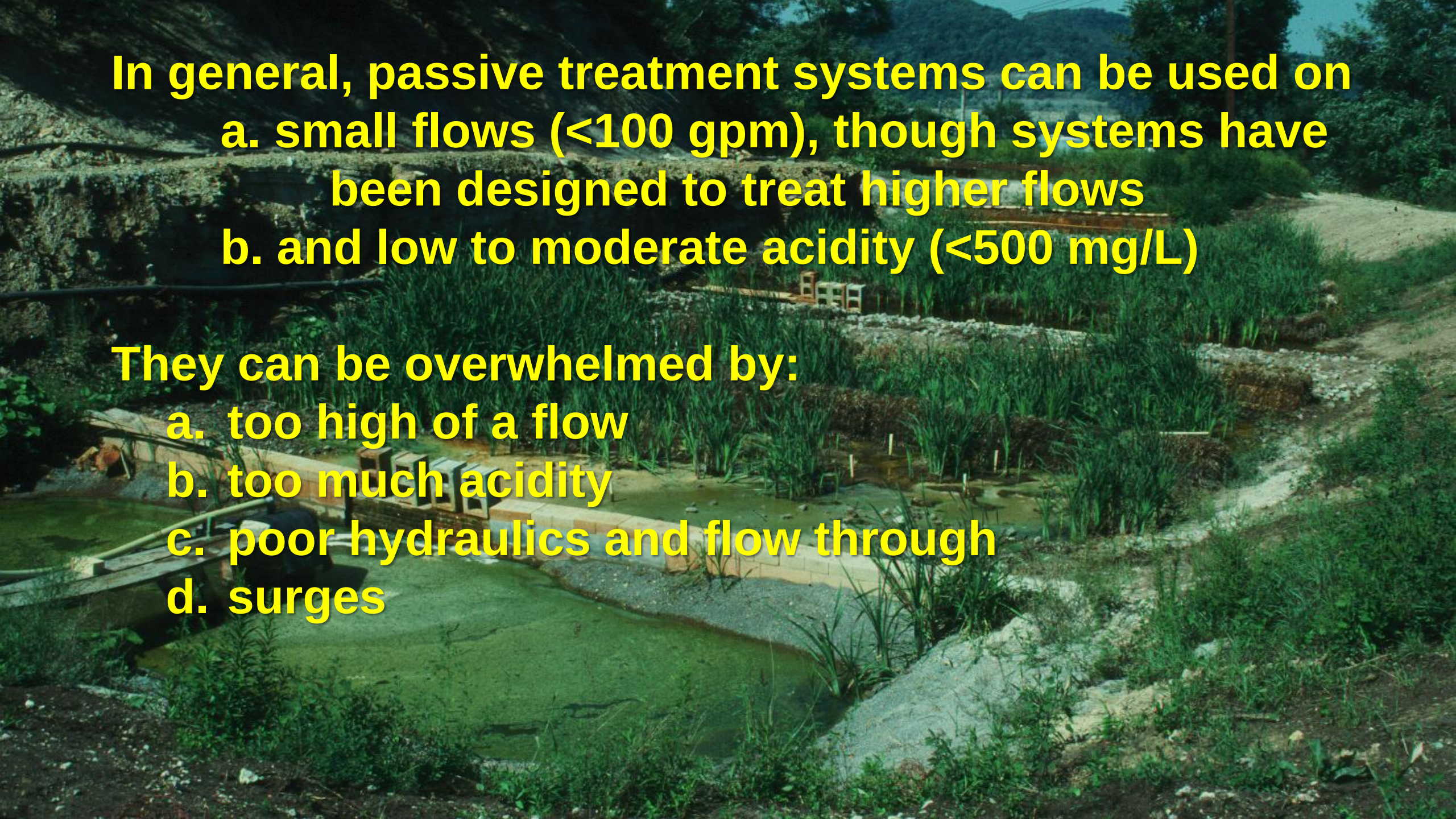
4. **Biological** passive treatment technologies rely on **bacterial activity and may use organic matter to stimulate microbial sulfate reduction and to adsorb contaminants.**

5. **Geochemical** systems place alkalinity-generating materials such as **limestone** in contact with AMD (direct treatment) or with fresh water upgradient of the AMD.

Here are the Major Points for Passive Treatment Systems

6. Most passive treatment systems **employ multiple methods**, often in series, to promote acid neutralization and oxidation and precipitation of the resulting metal flocs.

7. Before selecting an appropriate treatment technology, the AMD conditions and chemistry must be characterized. **Flow, acidity and alkalinity, metal, and dissolved oxygen concentrations** are critical parameters for selection and design.



In general, passive treatment systems can be used on
a. small flows (<100 gpm), though systems have been designed to treat higher flows
b. and low to moderate acidity (<500 mg/L)

They can be overwhelmed by:
a. too high of a flow
b. too much acidity
c. poor hydraulics and flow through
d. surges

Conclusions

Many researchers developed ideas.
A technology whose time had come.

Discovery order:

1. **Aerobic**
2. **Anaerobic**
3. **Anoxic Limestone Drains**
4. **Open Limestone Channels**
5. **Vertical Flow Wetlands**
6. **Sulfate-Reducing Bioreactors**

Thank you ! Any questions?

What came next? Semi-passive systems!
Flushable Limestone Bed Drainage System


Flushable Limestone Bed
LS filled


Flushable Limestone Bed
Control box releases water


Flushable Limestone Bed
Flushed material settled

How many drainage pipes?

Spacing?

Do they really remove particulates?

Some say 20%, some 70%


Big Five Tunnel CO – metal mine drainage
Bioreactors – sulfate reduction

What came next?

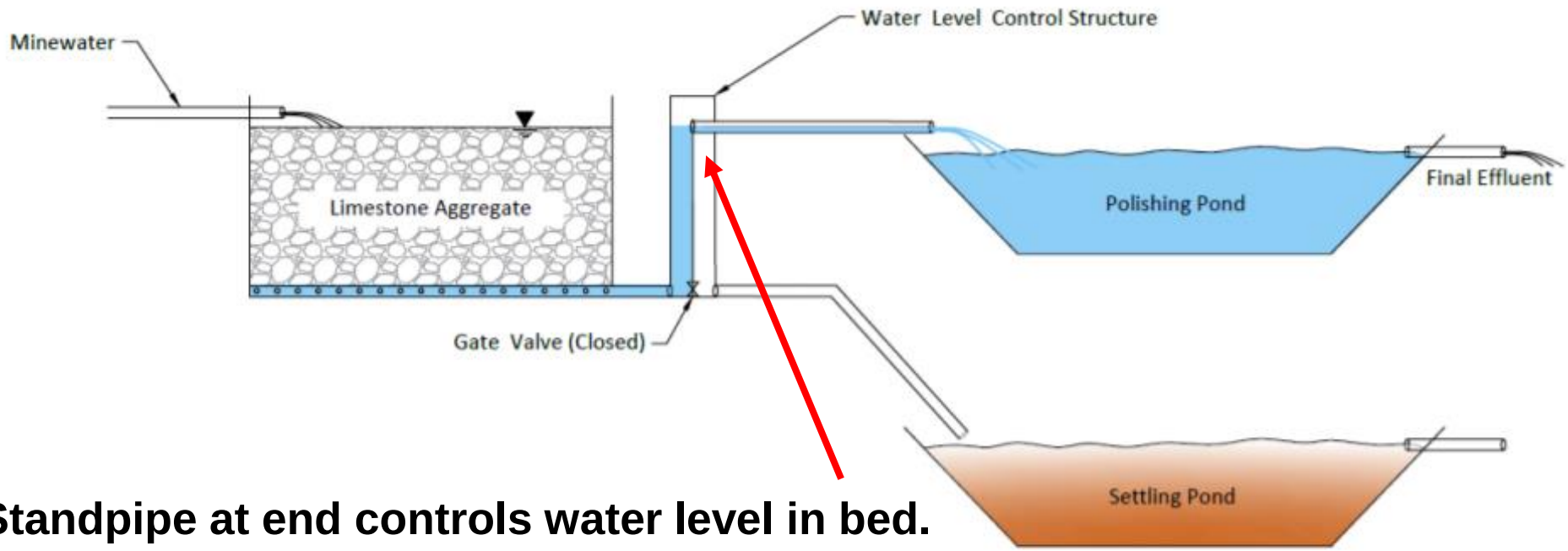
Semi-passive systems


Capture sediments and estimate amount
Tim Danehy

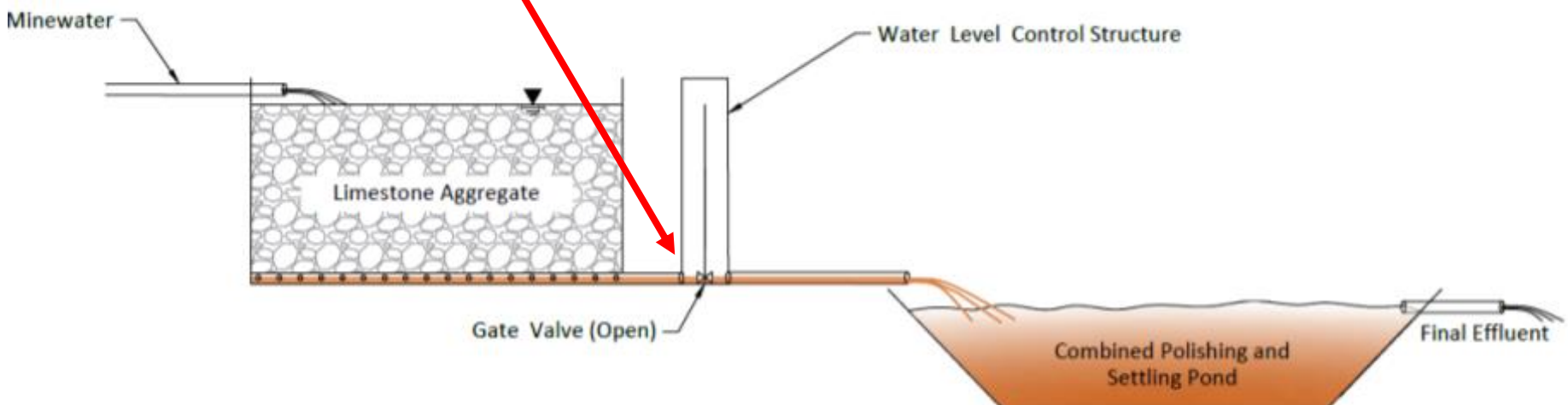

And they failed more often than we liked…

Alkaline Leach Beds

Drainable Limestone Bed



Standpipe at end controls water level in bed.
Take out plug at bottom and flush




Limestone Bed
Clogged with Fe oxides

Flushable Limestone Bed

Where metals might coat or clog.
Remove by flushing.

Steel Slag Ponds

- Steel slag = calcium alumino-silicate oxides
- Source is Mingo Junction, OH, steel mill

Sequence of Passive Systems Wales

Pennsylvania

Hybrid Systems?

However, we eventually learned that while the Sphagnum moss systems could handle relatively mild coal mine drainage, it was incapable of handling coal mine drainage with high metal loads unless there was large amounts of dilution available


The earliest constructed wetlands were for municipal wastewater treatment. These systems were also used to treat storm runoff, and capture sediment, oil, and grease.


AMD flowing through natural wetlands were often degraded due to the high flows and metal contents.
They became iron ponds!
Was treatment occurring?

Researchers documented:

- Minnesota Dept Nat. Res. – Eger et al. 1980
  Ni and Cu removal by peat (*Sphagnum*) bog.

- West Virginia Univ. – Wieder et al. 1982
  MIW treated in bog with sulfate reduction, pH 3 → 6.

- Colorado Dept Nat. Res. – Holm et al. 1983
  Fe removal in beaver ponds.


Sulfate reduction produces alkalinity and removes most metals from the mine water as sulfide minerals.