Choosing Management and Remediation Systems

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Mine drainage framework

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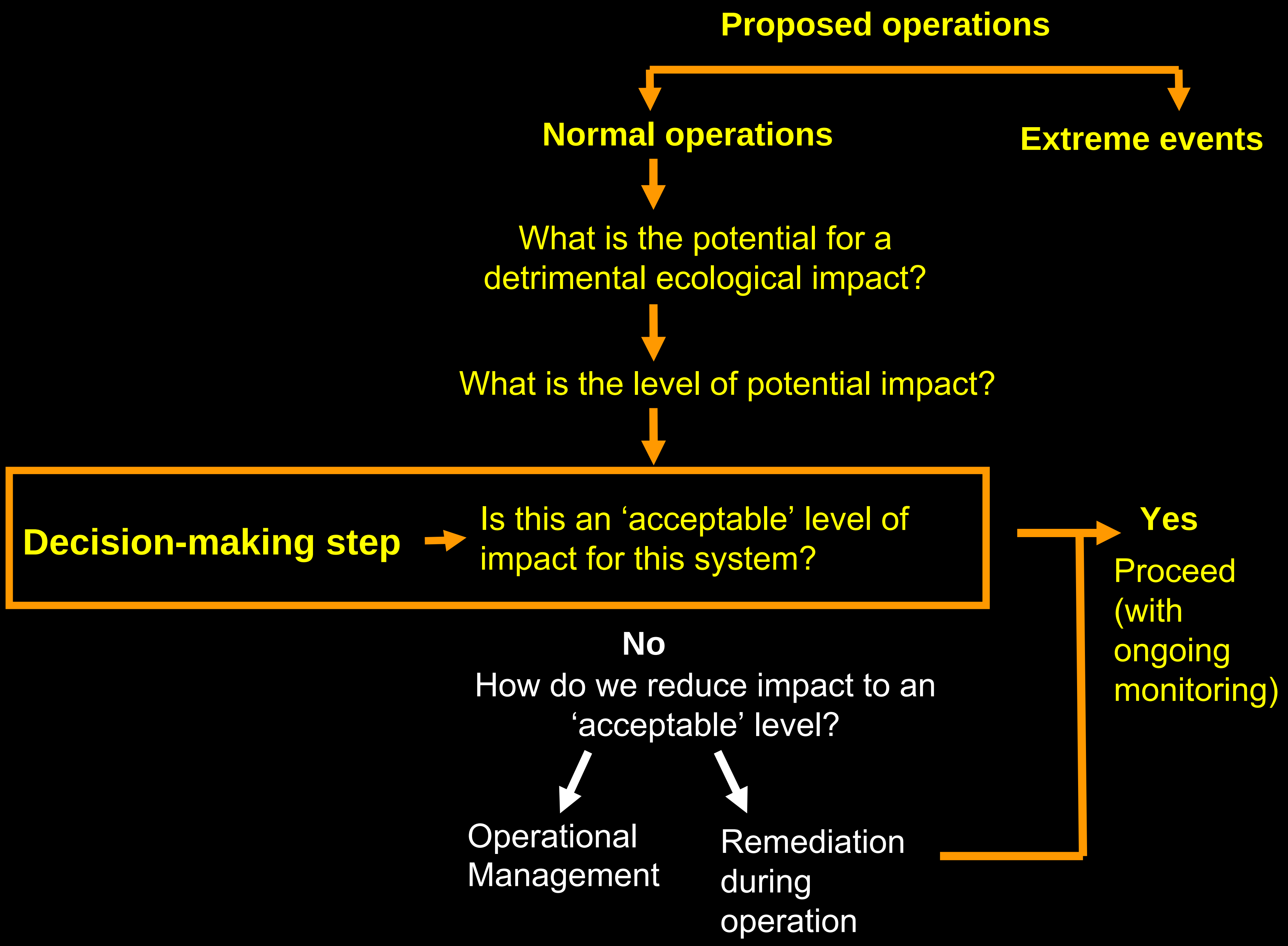
- Management and remediation in the Framework — Dave Trumm
- Mine waste management techniques — Rowan Buxton
- Water treatment for AMD — Dave Trumm
- Arsenic Treatment — Rachel Rait


Proposed operations
Normal operations
Extreme events
What is the potential for a detrimental ecological impact?
What is the level of potential impact?
Decision-making step
Is this an ‘acceptable’ level of impact for this system?
Yes
Proceed (with ongoing monitoring)
No
How do we reduce impact to an ‘acceptable’ level?
Operational Management
Remediation during operation

Ecological impacts deemed unacceptable and water quality targets are identified

- It is up to mine operators to decide *how* to meet targets

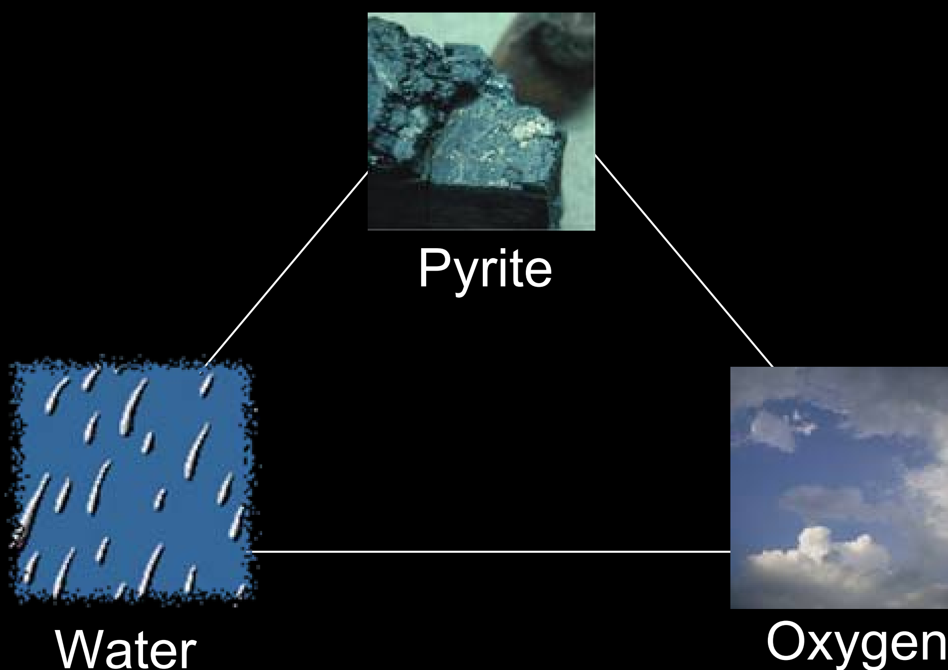
Framework provides - Toolbox

- Options for mine operators to meet targets
- Method to select options
- Confidence to stakeholders that mine operators have ability to meet targets

Overall Goal

Reduce impacts to acceptable levels

Mine waste management techniques can prevent or minimise unacceptable mine drainage



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Water treatment systems can remediate impacted water

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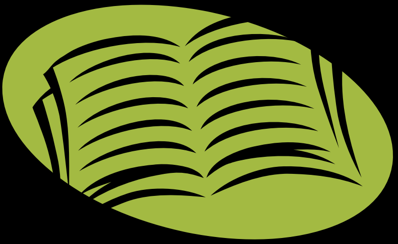


Framework provides methodology to select most appropriate option


Mine Waste Management
Minimising water quality impacts

Goals

- Prevent or reduce the amount of water entering the mine area
- Prevent or reduce the contact of water or oxygen with acid-forming materials
- Neutralise or reduce the concentration of contaminants present in mine drainage

Factors influencing mine drainage

- Landform & climate
- Mine type & history
- Arrangement & composition of strata
- Waste volume & proportions
- Grain size, porosity & flow paths
- Flow volume & rate

↓

Mine planning & management options

Pre-mining analysis

Rock geochemistry and water quality

- Non Acid Forming (NAF)
  - Turbidity
  - Trace metals

- Potentially Acid Forming (PAF)
  - AMD

Water Management (NAF)

Water Management (NAF)

- Surface water diversion
- Sediment collection

- Regrading
- Surface roughening
- Rapid revegetation


Potentially Acid Forming

Mine Waste Management

- Avoidance

  Total or partial reduction in excavation or exposure of problematic materials can limit or prevent sulphide oxidation and metal release

- Neutralisation

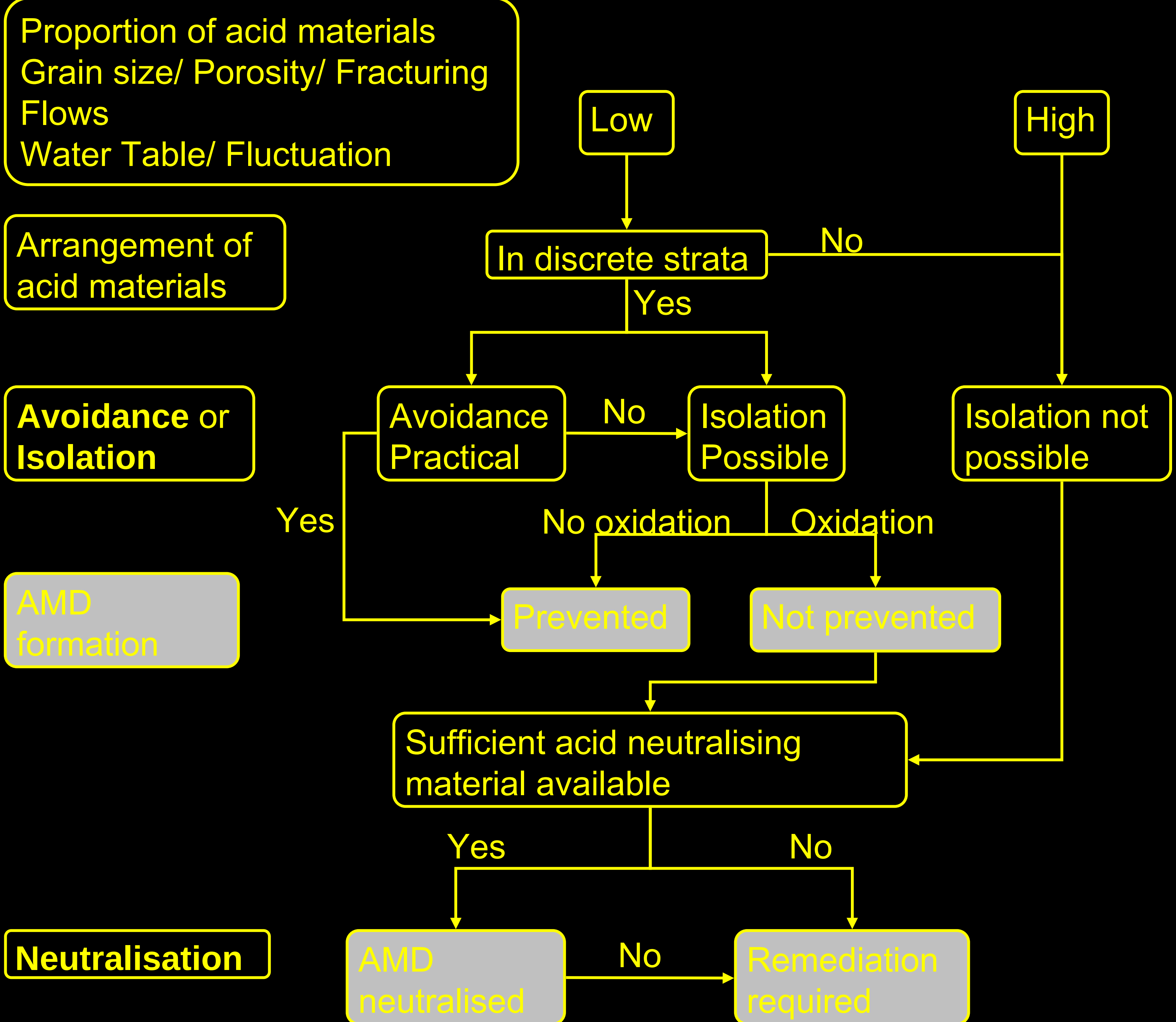
  Addition of alkaline material to offset acidity;

  inhibition of iron-oxidizing bacteria that catalyse acid generation

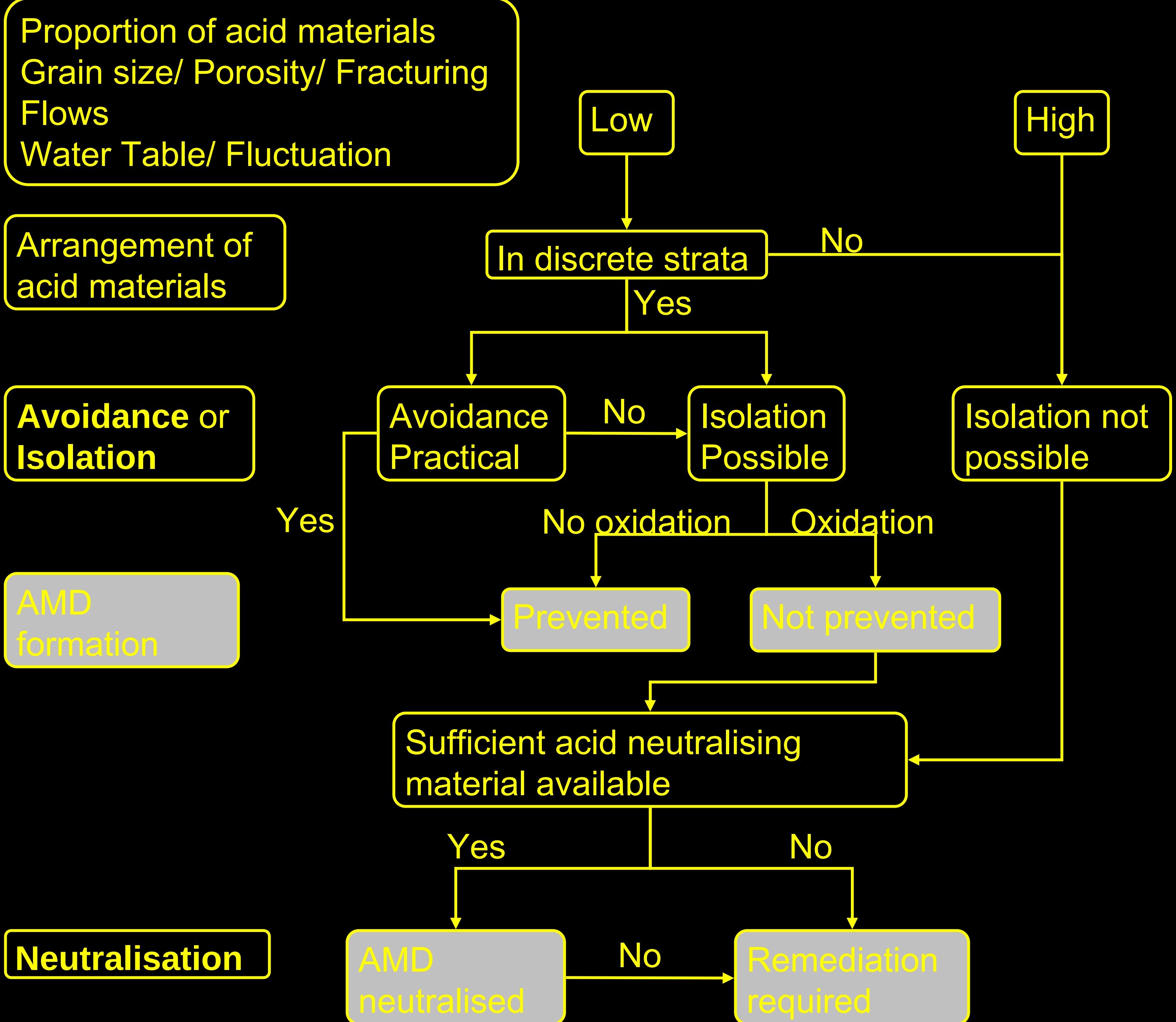
Mine Waste Management

- Isolation

Techniques to separate problem materials from oxygen & water - the vectors of acid formation/ transportation



Proportion of acid materials
Grain size/ Porosity/ Fracturing
Flows
Water Table/ Fluctuation
Low
High
Arrangement of acid materials
In discrete strata
No
Yes
Avoidance or Isolation
Avoidance Practical
No
Isolation Possible
Isolation not possible
Yes
No oxidation
Oxidation
AMD formation
Prevented
Not prevented
Sufficient acid neutralising material available
Yes
No
Neutralisation
AMD neutralised
No
Remediation required



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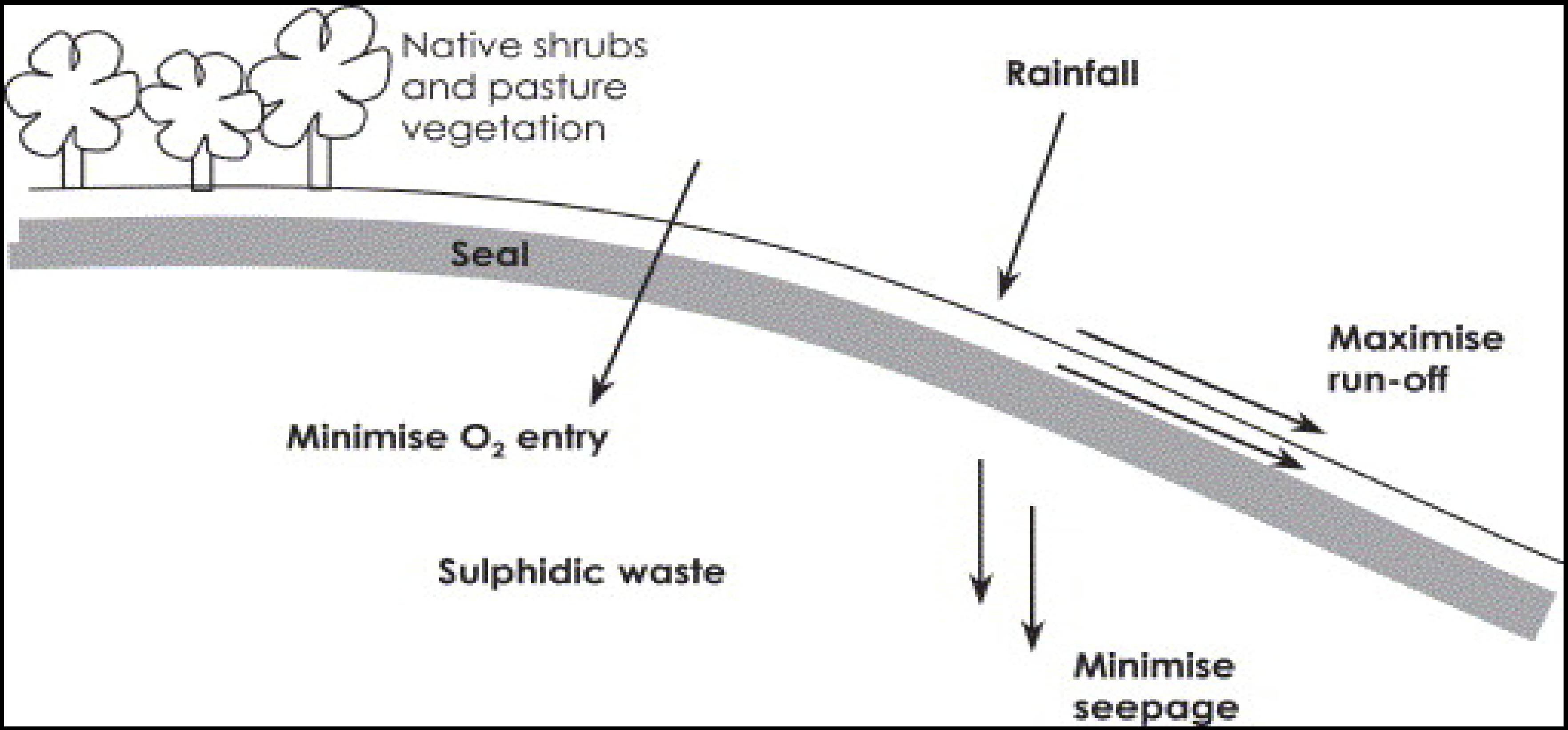
Isolation Strategies



Dewatering
Cover design
Inundation
Seals

Special handling
Cover materials
Barriers

Neutralisation Strategies

- Alkaline addition
- Blending
  - Mixing
  - Layering
- Bactericides
- Anionic surfactants

AMD Treatment

Low pH

High metal concentrations

Treatment = add neutralising agent to raise pH

Due to low solubility at high pH, metals precipitate

Active Treatment

- Continuous dosing with base (lime, caustic soda, soda ash)
- Regular operation and maintenance
- Reliable and effective but costly

Generally more common at operational mine sites

- Limited space for remediation
- Drainage chemistry & flow rate changes
- Power and people





DANGER
ANHYDROUS
AMMONIA
AMMONIA
DANGER

Limestone Dosing to Mangatini

(SE Environmental Team)

Temporary until 100 year plant constructed

50 tonne capacity (1-2 days supply)

Air cannons to fluidise limestone

Lime slurry discharge

Passive Treatment

- No continuous dosing with chemicals
- Takes advantage of naturally occurring chemical and biological processes
- Not “walk away” solution
- Less costly in the long term

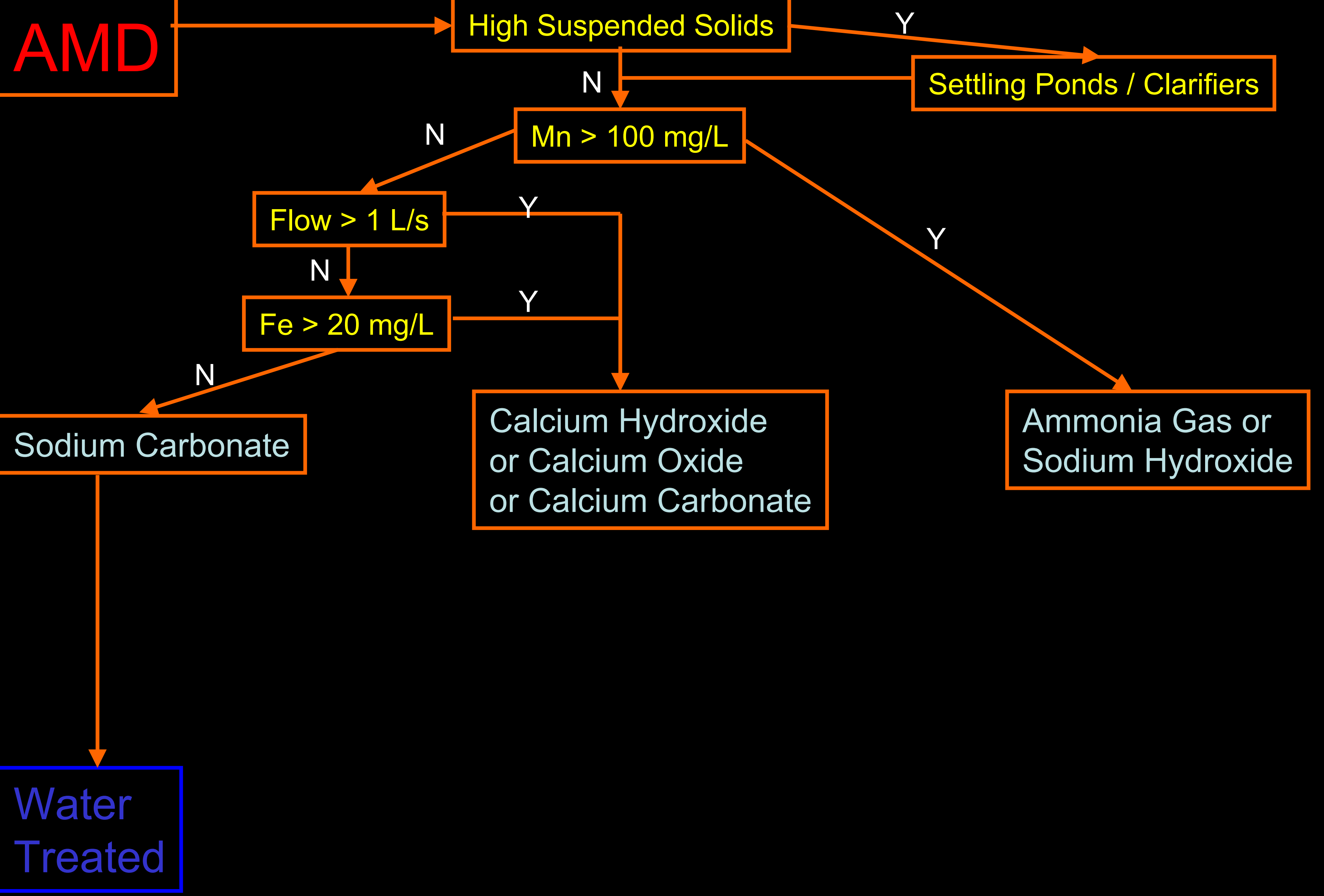
Generally more common at abandoned mine sites

- More space for remediation
- Stable drainage chemistry & flow rate
- No power or people


50 60 70 80 90 2600 10 20 30 40 50 60 70 80 90 270

Treatment Selection in the Framework

- Collect data
  - pH, acidity, Fe, Al, Mn, TSS, DO, flow rate
  - Active mine site?, power?, available land area
- Use flow charts to identify potential solutions
  - Active vs Passive Treatment
  - Active Treatment Options
  - Passive Treatment Options
- Review supporting information in tables, graphs


AMD
High Suspended Solids
Y
Settling Ponds / Clarifiers
N
Mn > 100 mg/L
N
Y
Flow > 1 L/s
Y
N
Fe > 20 mg/L
Y
N
Sodium Carbonate
Calcium Hydroxide
or Calcium Oxide
or Calcium Carbonate
Ammonia Gas or
Sodium Hydroxide
Water
Treated

AMD

High Suspended Solids

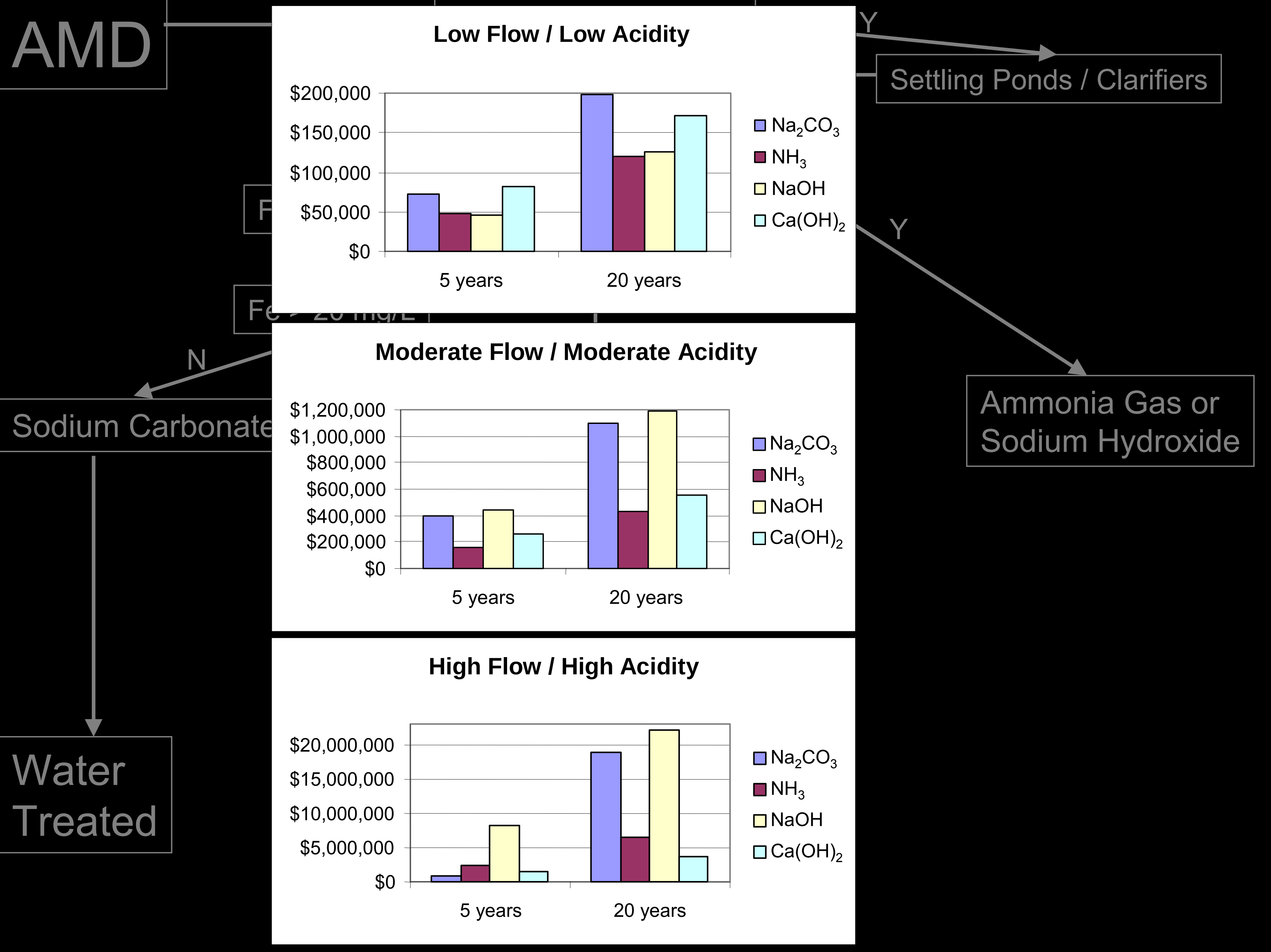
Y

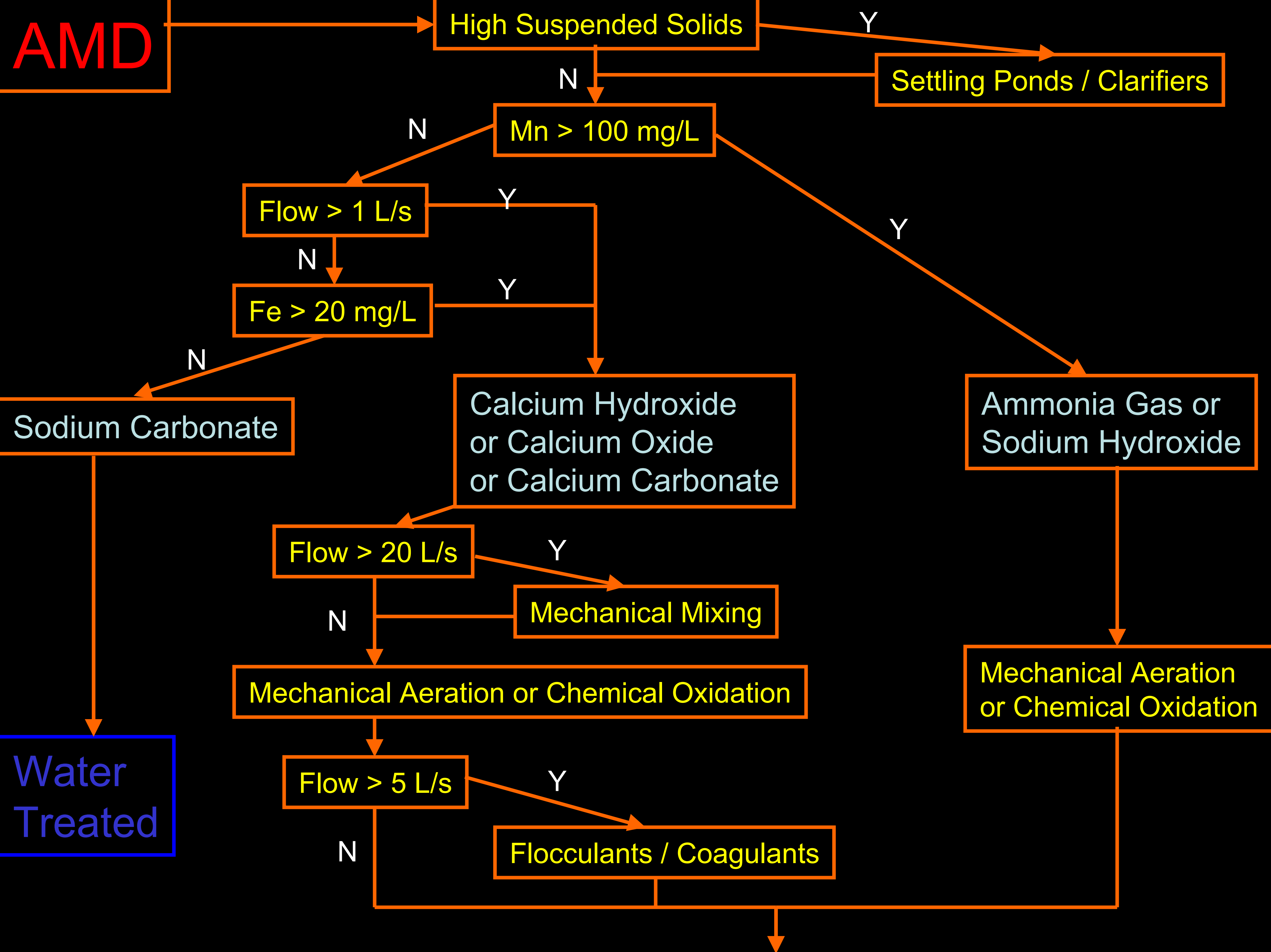
Settling Ponds / Clarifiers

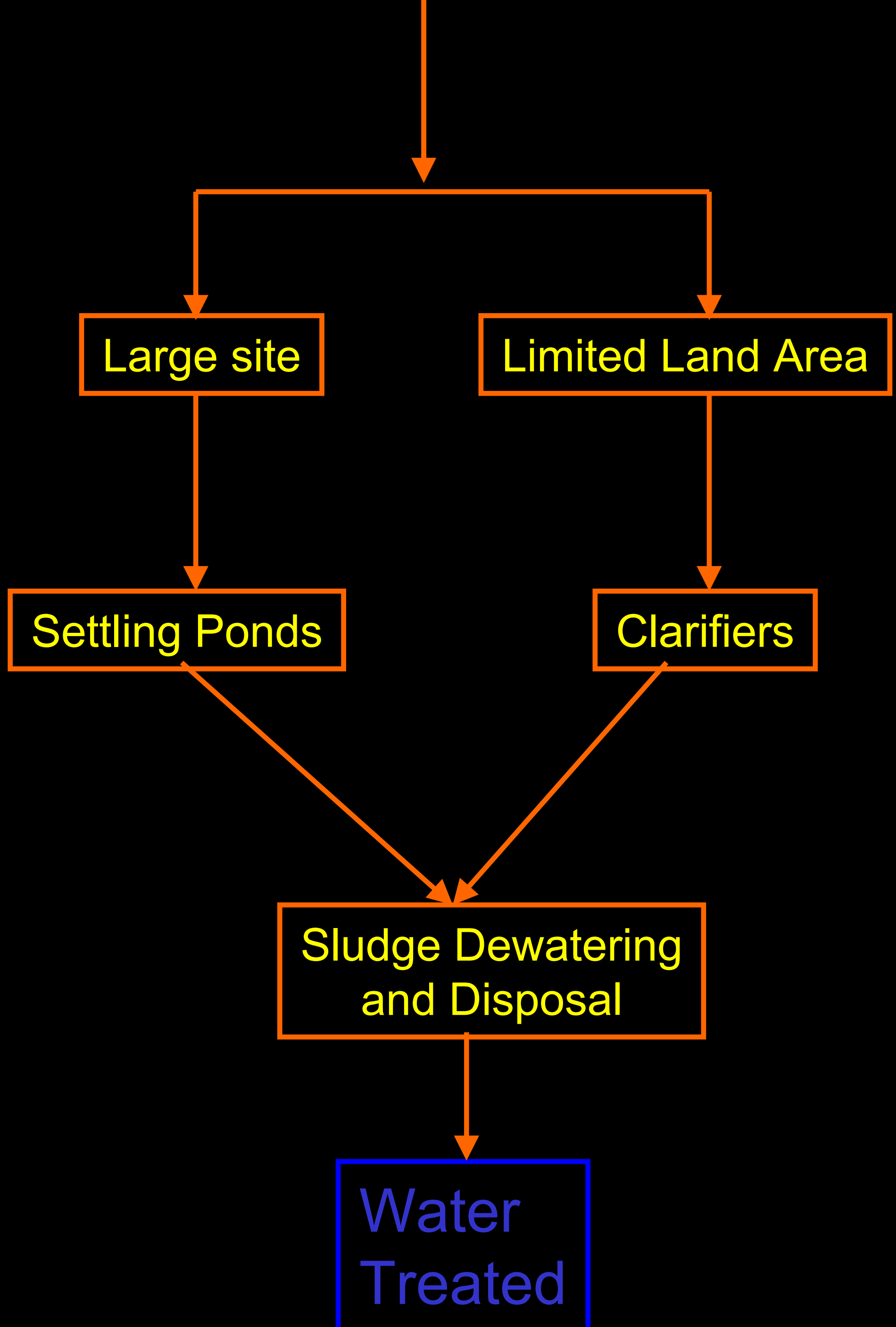
N

	Max pH	Effic	Vol	$	Dispenser Mechanism	Key Benefits	Key Limitations	Risk of Failure
Soda ash or sodium carbonate (Na_2CO_3)	11.6	95 - 100 (powder) 60 (briquettes)	1.06	0.56	Briquettes placed in wooden box or 55 gallon drum in AMD stream	powder form, most metals precipitate, low sludge volumes	issues, poor sludge settling rates, potential sodium toxicity.	briquettes if acidity loading rates increase significantly (best as an interim treatment or only for low flow/low acidity AMD)
Calcium Hydroxide		90 - 95	0.74	0.17	Silo or hopper with mechanical feed screw to dispense powder. Batching tank to mix powder with water. Can use aqueous slurry. Mixing suggested.	High efficiency, most metals precipitate, low cost, widely available	Health and safety issues, reagent saturation can lower efficiency	If acidity loading rates increase beyond system capacity to neutralise and settle hydroxides, treatment effectiveness will drop. Poor maintenance can result in plugged dispensing mechanism and complete failure.
(CaO)		90	0.56	0.11	Silo or hopper with mechanical feed screw to dispense powder or water wheel feeder with 1 ton storage bin (no power). Batching tank to mix powder with water. Mixing suggested.	High efficiency, most metals precipitate, very low cost, widely available	Health and safety issues, reagent saturation can lower efficiency, possible armouring of pebbles	If acidity loading rates increase beyond system capacity to neutralise and settle hydroxides, treatment effectiveness will drop. Poor maintenance can result in plugged dispensing mechanism and complete failure. Must be watertight or will hydrate and form calcium hydroxide and plug dispensing mechanism.
Calcium Oxide		100	0.34	0.60	Compressed and stored as liquid in tank, gas injected near bottom of pond or water inlet. No mixing required.	Very high efficiency, most metals precipitate, low sludge volumes	Health and safety issues, poor sludge settling rates, can be toxic to aquatic life, high cost	If acidity loading rates increase beyond system capacity to neutralise and settle hydroxides, treatment effectiveness will drop.
		100	0.80 (solid)	1	Stored as a liquid in tank, dispense through metering pump or valve and feeder hose near top of pond or water inlet. No mixing required.	Very high efficiency, most metals precipitate, low sludge volumes	Health and safety issues, poor sludge settling rates, potential sodium toxicity, highest cost of all chemicals, low freezing point	If acidity loading rates increase beyond system capacity to neutralise and settle hydroxides, treatment effectiveness will drop. If insufficient antifreeze added, can freeze in winter resulting in complete failure.
Calcium Carbonate		0 - 95	0.40 or 0.58	0.22	Silo or hopper with mechanical feed screw to dispense powder. Batching tank to mix powder with water. Mixing suggested.	Very high efficiency, most metals precipitate, low sludge volumes, low cost	Some health and safety issues, not widely available, lower reaction rate than calcium hydroxide	If acidity loading rates increase beyond system capacity to neutralise and settle hydroxides, treatment effectiveness will drop.
		0 - 90	1	0.04	Silo or hopper with mechanical feed screw to dispense powder. Batching tank to mix powder with water. Mixing suggested.	Safe to use, lowest cost of all chemicals, readily available, cannot overtreat	Low efficiency, not all metals removed (ineffective for Mn), armouring	If acidity loading rates increase beyond system capacity to neutralise and settle hydroxides, treatment effectiveness will drop.

Treated


AMD
Y
Settling Ponds / Clarifiers
Y
Ammonia Gas or Sodium Hydroxide
N
Sodium Carbonate
Water Treated
Low Flow / Low Acidity
$200,000
$150,000
$100,000
$50,000
$0
5 years
20 years
Na2CO3
NH3
NaOH
Ca(OH)2
Moderate Flow / Moderate Acidity
$1,200,000
$1,000,000
$800,000
$600,000
$400,000
$200,000
$0
5 years
20 years
Na2CO3
NH3
NaOH
Ca(OH)2
High Flow / High Acidity
$20,000,000
$15,000,000
$10,000,000
$5,000,000
$0
5 years
20 years
Na2CO3
NH3
NaOH
Ca(OH)2


AMD
High Suspended Solids
Y
Settling Ponds / Clarifiers
N
Mn > 100 mg/L
N
Flow > 1 L/s
Y
N
Fe > 20 mg/L
Y
Y
N
Sodium Carbonate
Calcium Hydroxide or Calcium Oxide or Calcium Carbonate
Ammonia Gas or Sodium Hydroxide
Flow > 20 L/s
Y
Mechanical Mixing
N
Mechanical Aeration or Chemical Oxidation
Mechanical Aeration or Chemical Oxidation
Water Treated
Flow > 5 L/s
Y
Flocculants / Coagulants
N


Large site
Limited Land Area
Settling Ponds
Clarifiers
Sludge Dewatering and Disposal
Water Treated

Sites with Existing AMD

- Chemistry and flow rate data real
- Use same selection flow charts
- Conduct laboratory experiments / small-scale field trials

Arsenic Treatment

- Waste rock management
  - Similar techniques are used as coal PAF
  - Selection based on cost and site characteristics

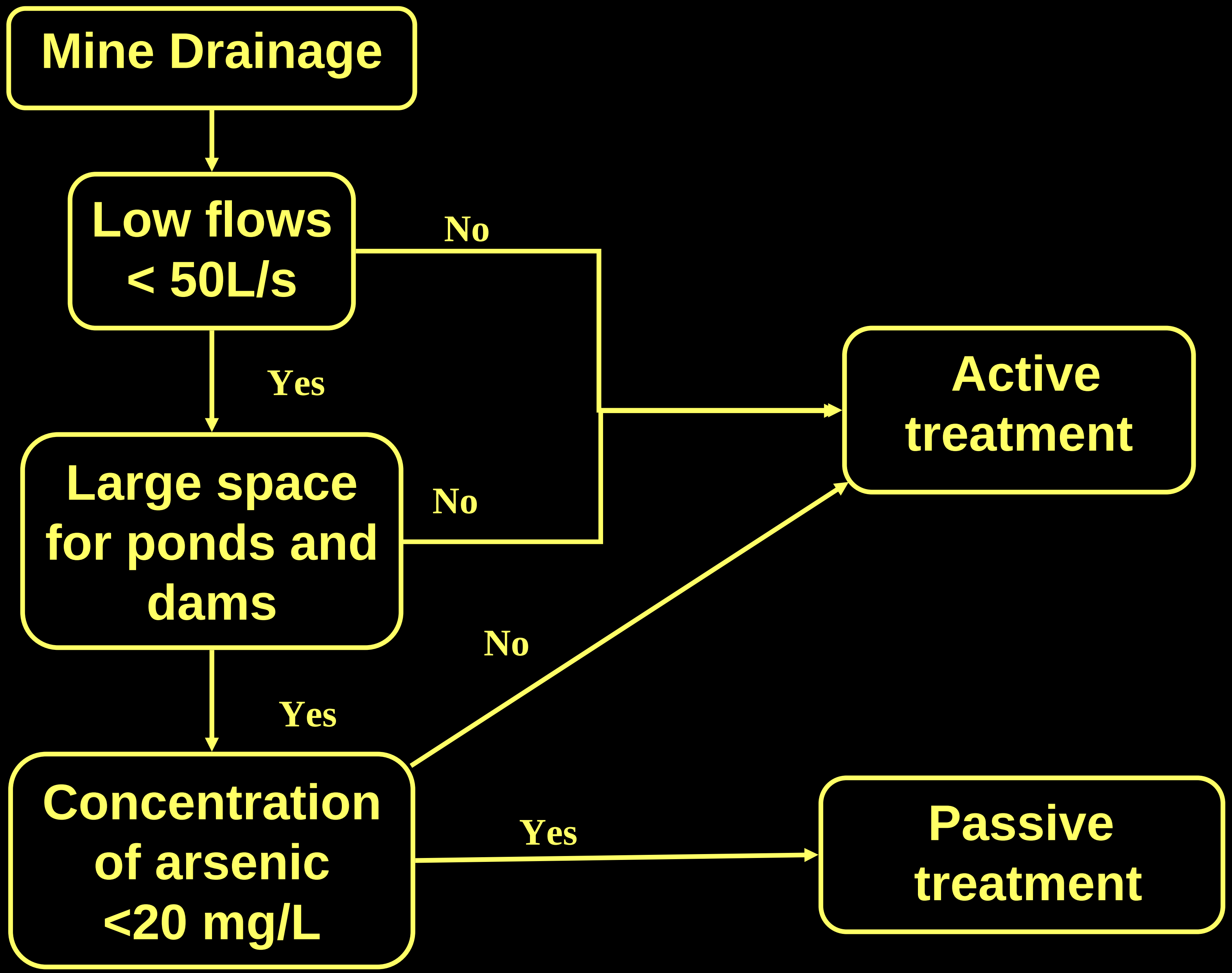
- Removal of arsenic through
  - Oxidation
  - Coagulation/filtration
  - Adsorption
  - Ion exchange
  - Membrane/reverse osmosis
  - Biological

Oxidation

Often pre-treatment

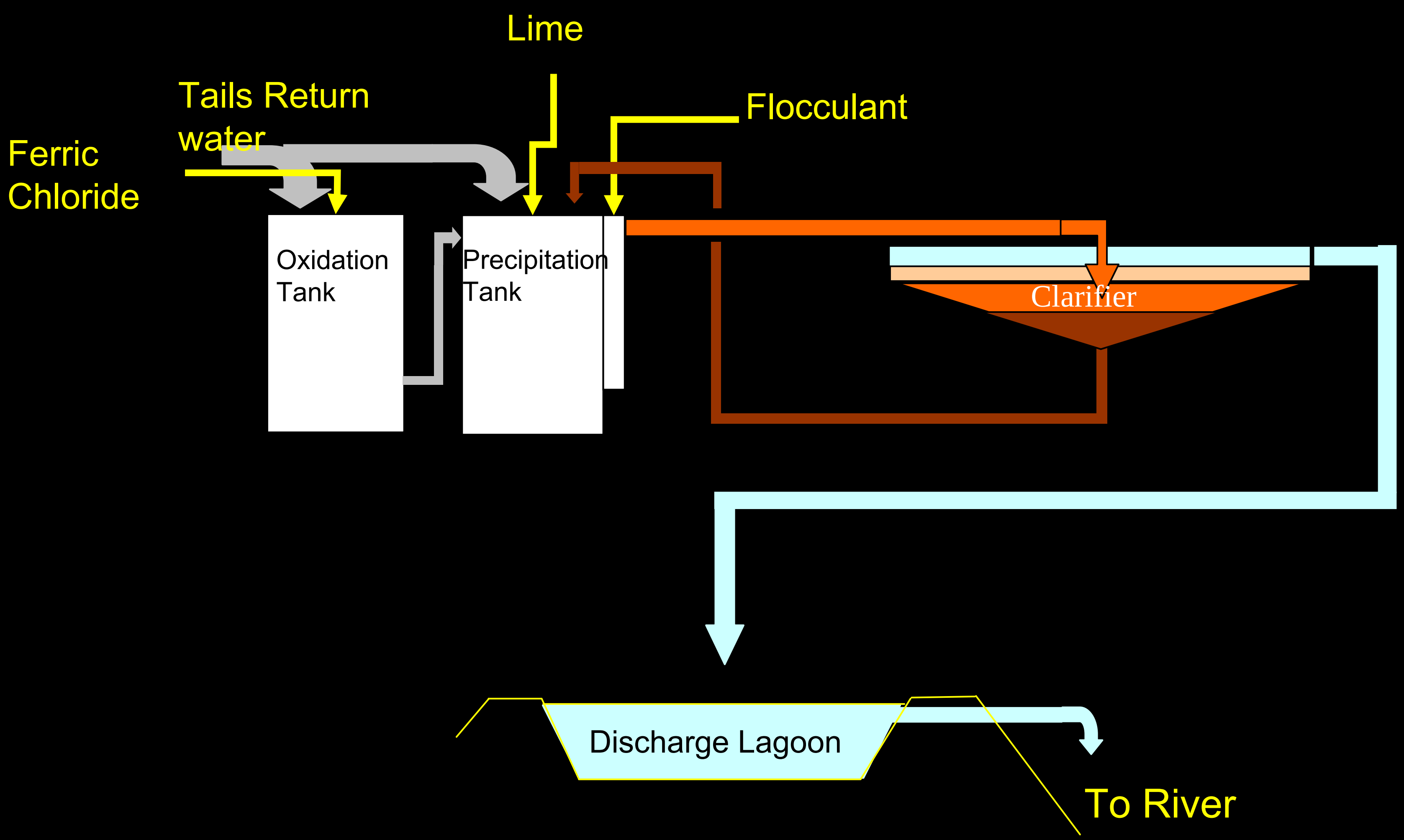
As(III) to As(V)

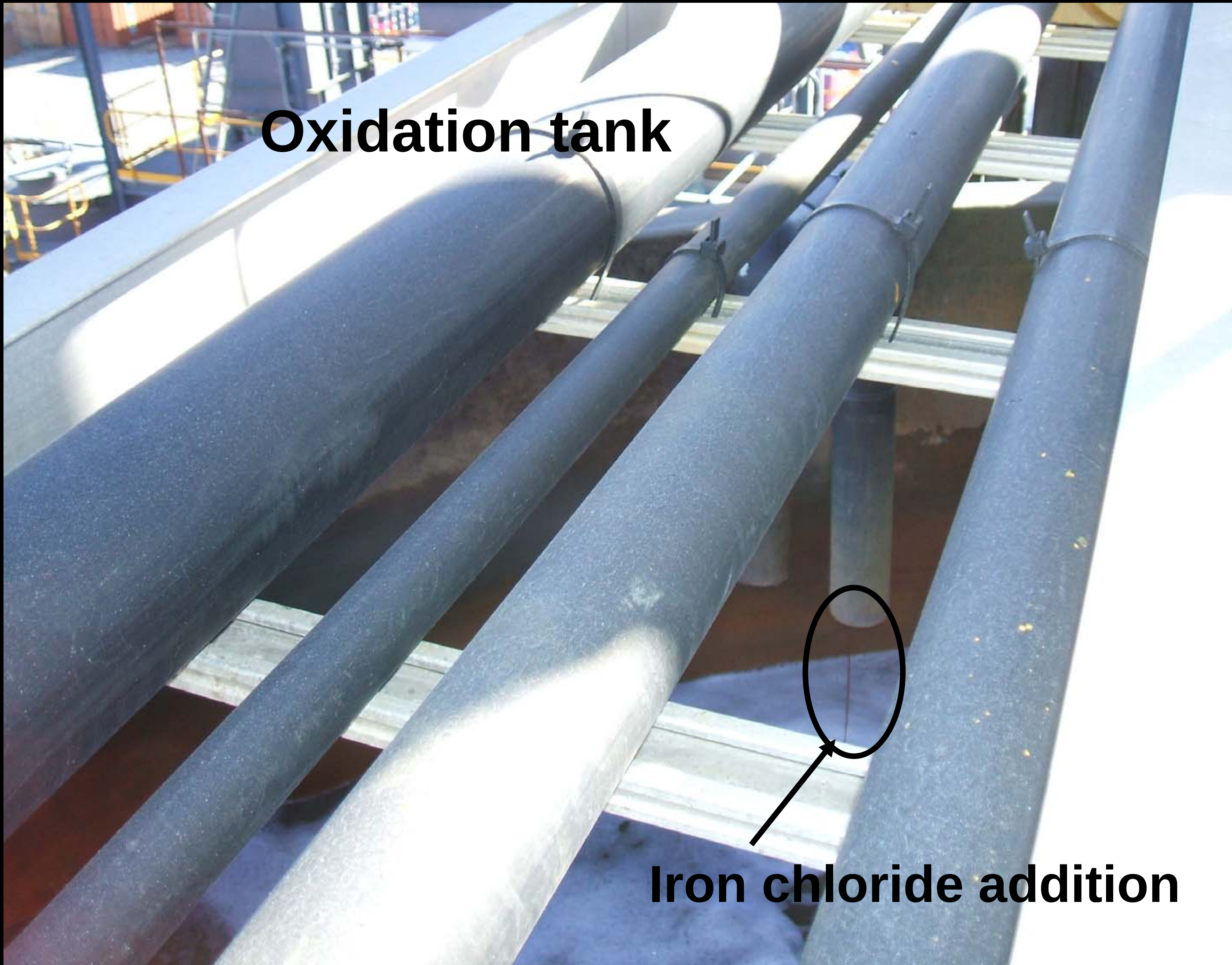
- Air oxidation
  - By stirring
  - Cascade
  - Air injection
- Chemical oxidation
  - Ozone, bleach, Mn Oxide, hydrogen peroxide, permanganate


Mine Drainage
Low flows < 50L/s
No
Yes
Large space for ponds and dams
No
Yes
Active treatment
No
Concentration of arsenic <20 mg/L
Yes
Passive treatment

Technique	Media	Relative cost	Factors to consider
Adsorption	iron-rich AMD sludge coated aggregate	low	Availability of AMD sludge Chemistry of AMD sludge Cost of preparing aggregate Sludge disposal requirements
Adsorption	iron grit and sand	low	Cost and availability of iron grit
Adsorption	Fe sulphate and calcite	High	Cost of chemicals
Coagulation precipitation	Iron oxide/hydroxide	High	Cost of chemicals Sludge disposal requirements

Example of operating active system Globe Progress Mine




Oxidation tank
Iron chloride addition

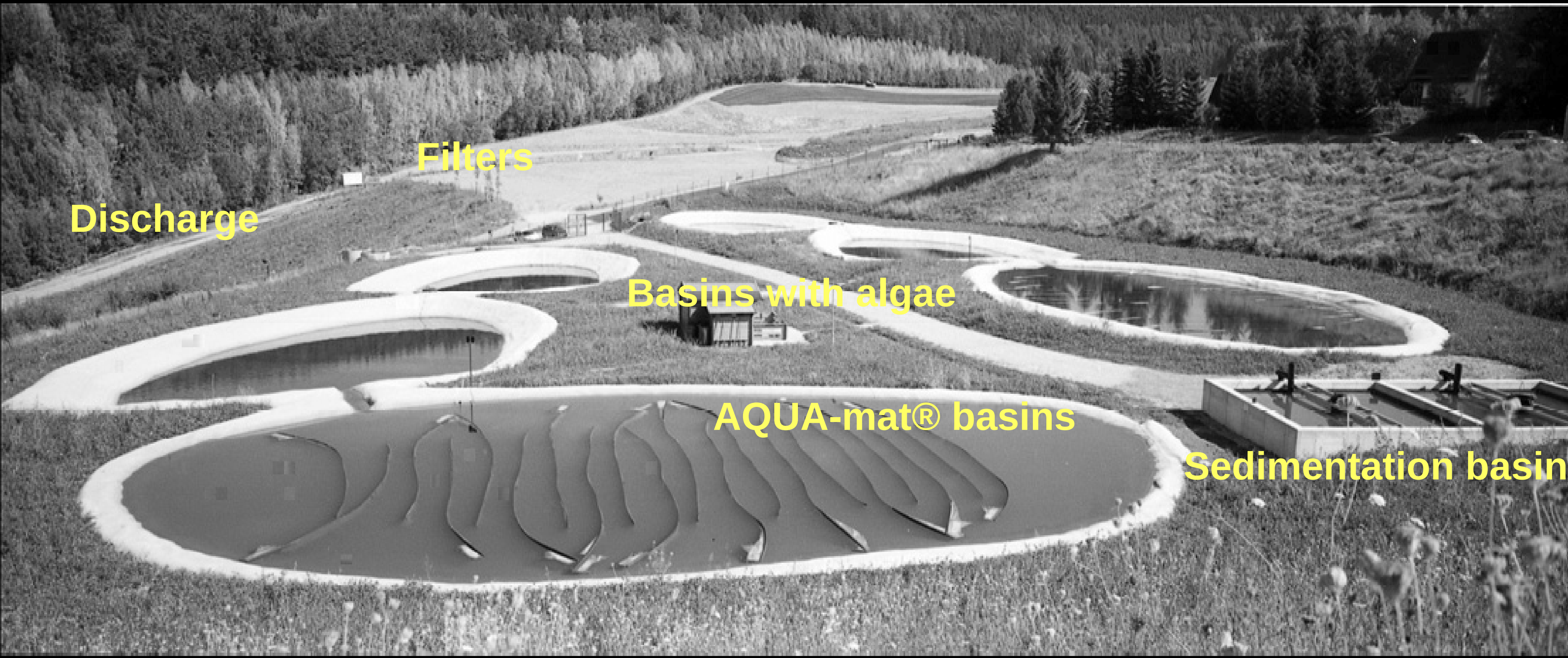
Oxidation Tank

Precipitation Tank

Passive systems

- System include:
  - Ponds
  - Wetlands
  - Dams
  - media-manganese oxide coated sand, zero valent iron, iron oxide coated sand…


Constructed wetland



Conclusion

- Waste rock management and remediation options have been presented together with selection criteria
- Provides a first cut for selection. Site specific characteristics will determine refinement of technologies
- Small scale tests may be required to optimize system for the site.