Development and testing of an integrated AMD/REE-CM Plant

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- West Virginia Dept. of Environmental Protection
- TenCate Corp.
- Rockwell Automation, Inc.
- Shonk Investments LLC

Federal Goals

Develop secure, domestic source of rare earth elements and critical minerals to support U.S. industry and defense establishment

e.g. advanced radars, miniaturized electronics, turbine blades, F-35s

Funding: USDOE/National Energy Technology Laboratory

Sources-Coal derived wastes:

Acid Mine Drainage-AMD:

- Applications to Hardrock AMD
- Coal Ash
- Coal Tailings-Refuse

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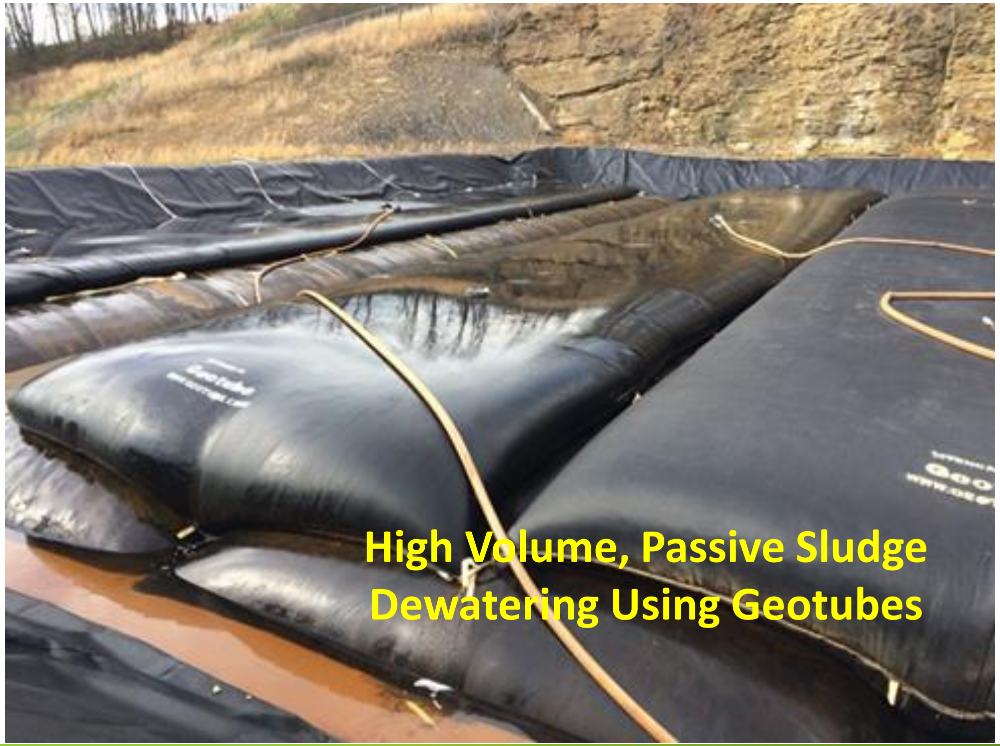
Project Objectives and Goals

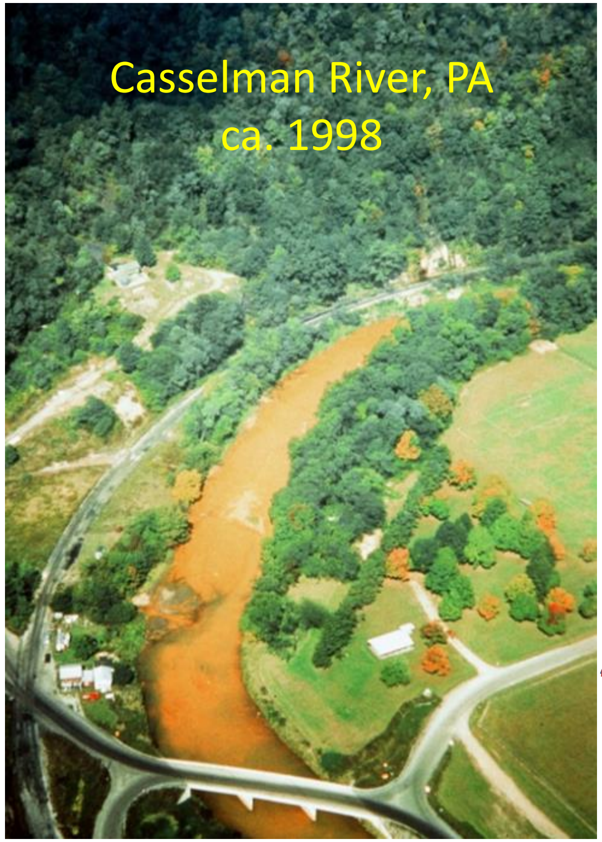
Develop and test a pilot-scale, continuous process for treating Acid Mine Drainage (AMD) while producing an enriched Rare Earth, Critical Mineral product

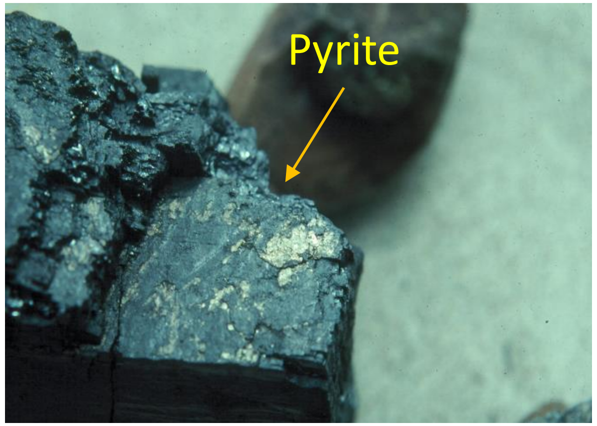
Goals:

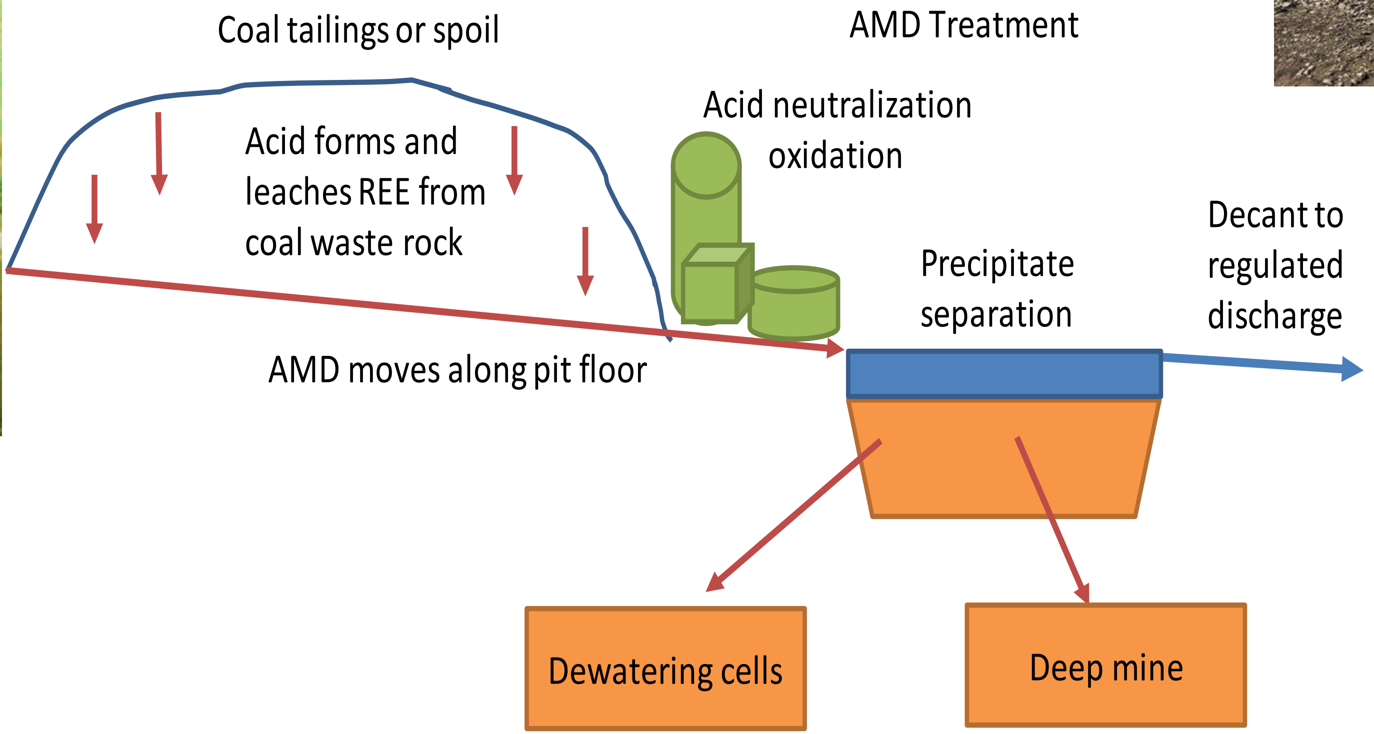
- Design, construct and operate a full-scale upstream concentrator and ALSX unit at an active AMD discharge treatment site.
- Pre-Concentrate grade: exceeding 0.5% REE/CM
- Final MREO grade exceeding 90% grade with > 50% HREE+CM/TREE
- Demonstrate production capacity of > 500 kg/yr
- commercially attractive efficiencies and processing costs.
- Net environmental benefit.



Acid mine drainage is a water quality problem and a resource opportunity







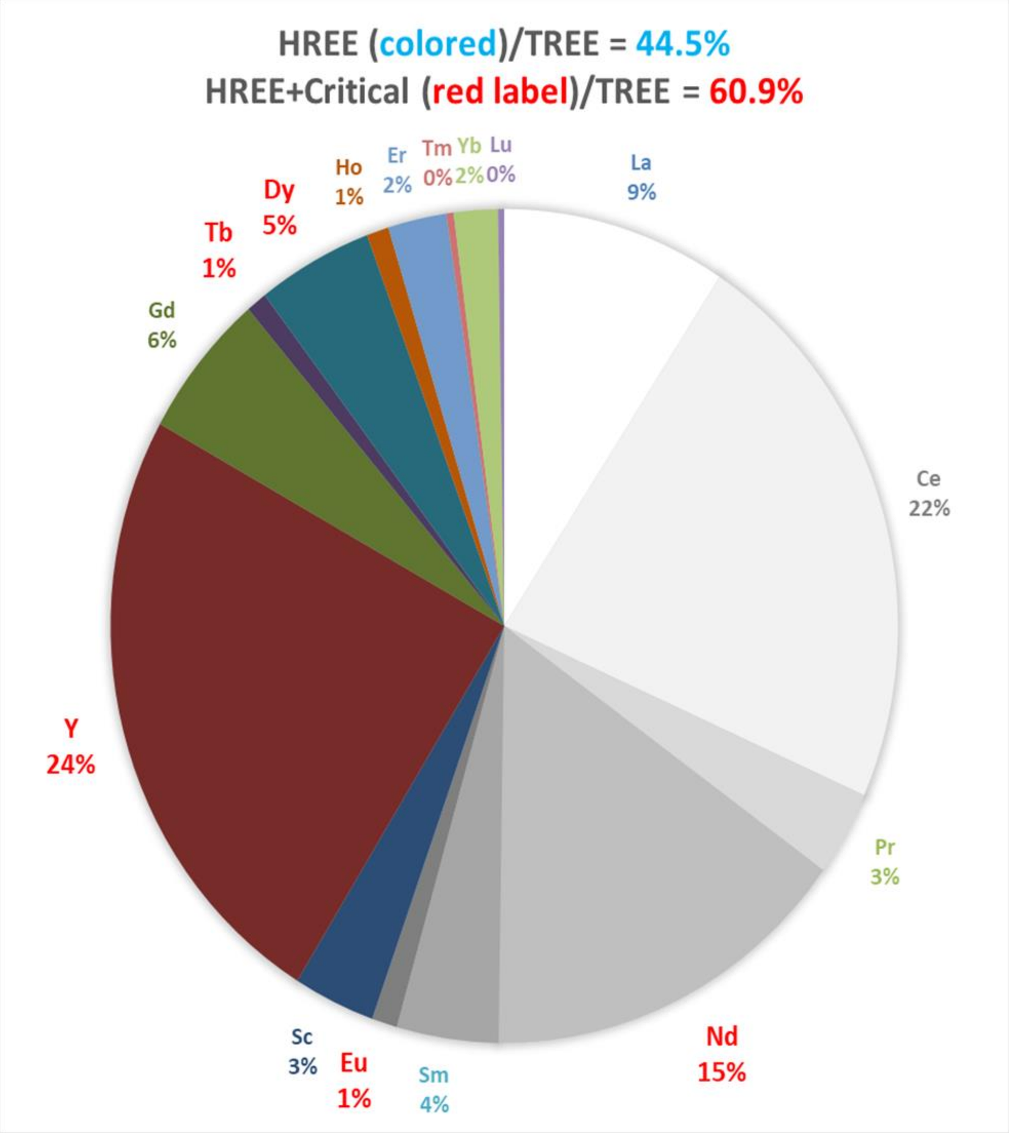
WVDEP's Muddy Creek AMD Project

Highly automated and efficient

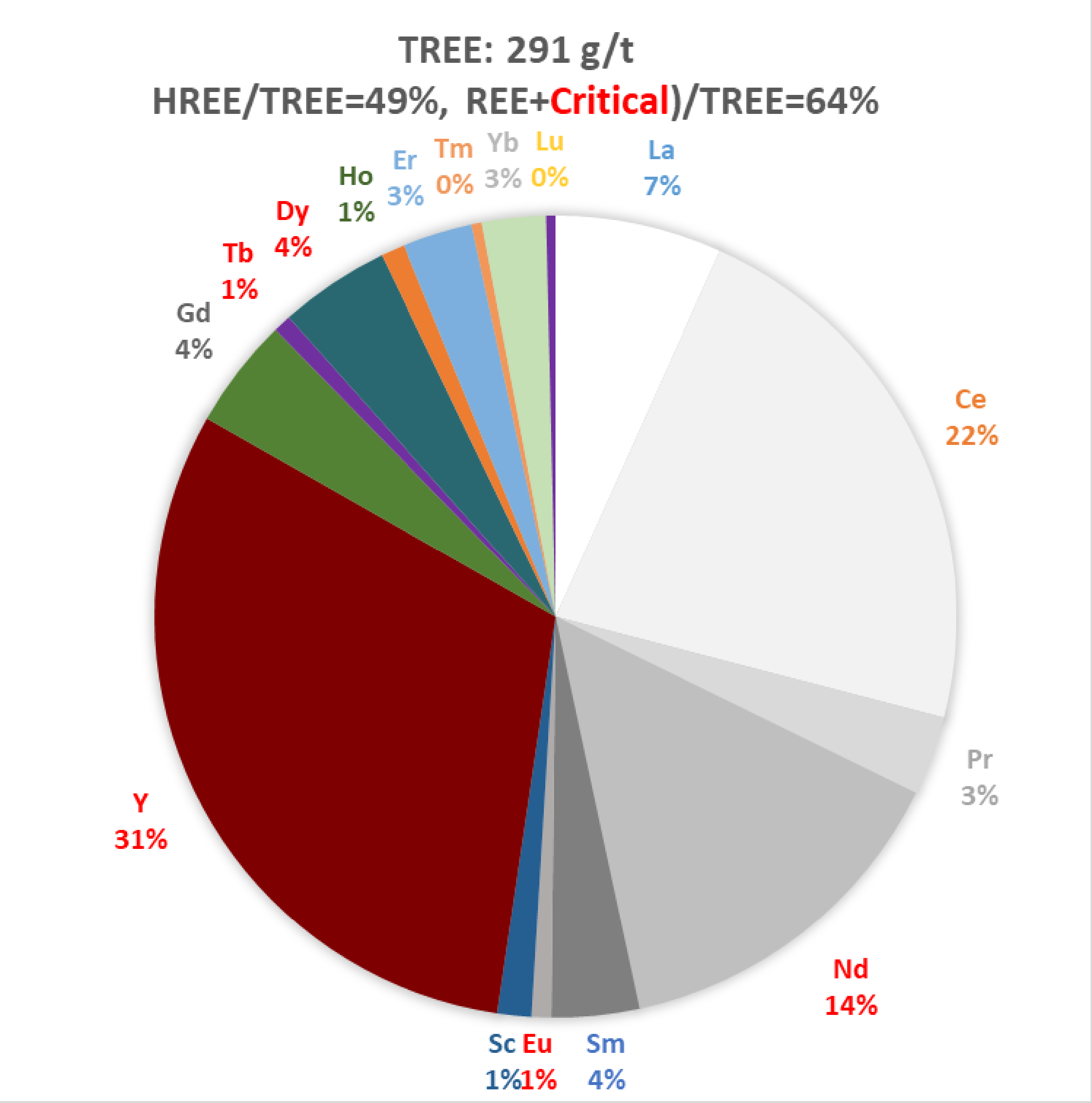
Interior of plant showing controls

REEs in Acid Mine Drainage

Average of 155 coal AMD sites

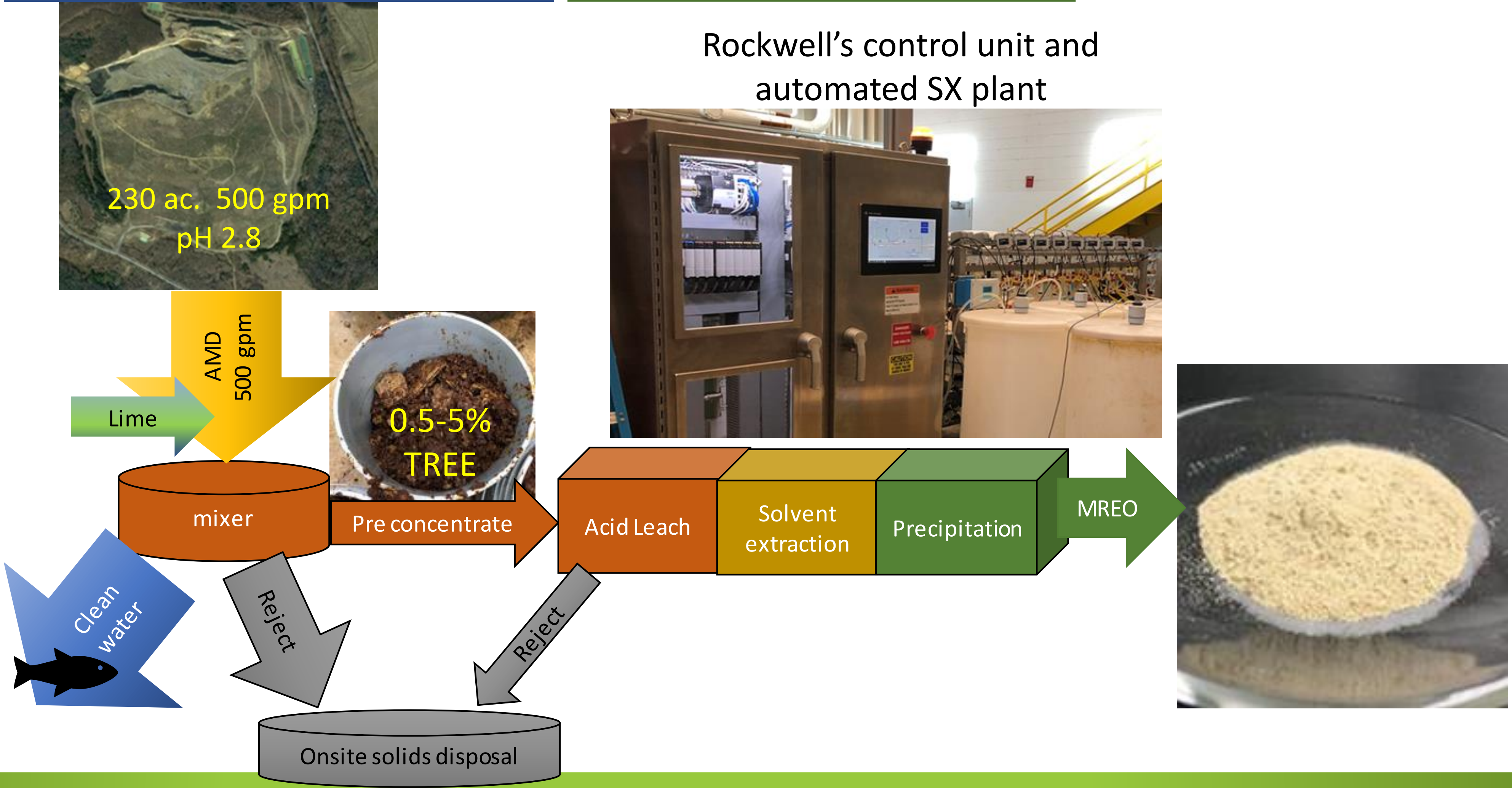


Berkeley Pit, Copper mine

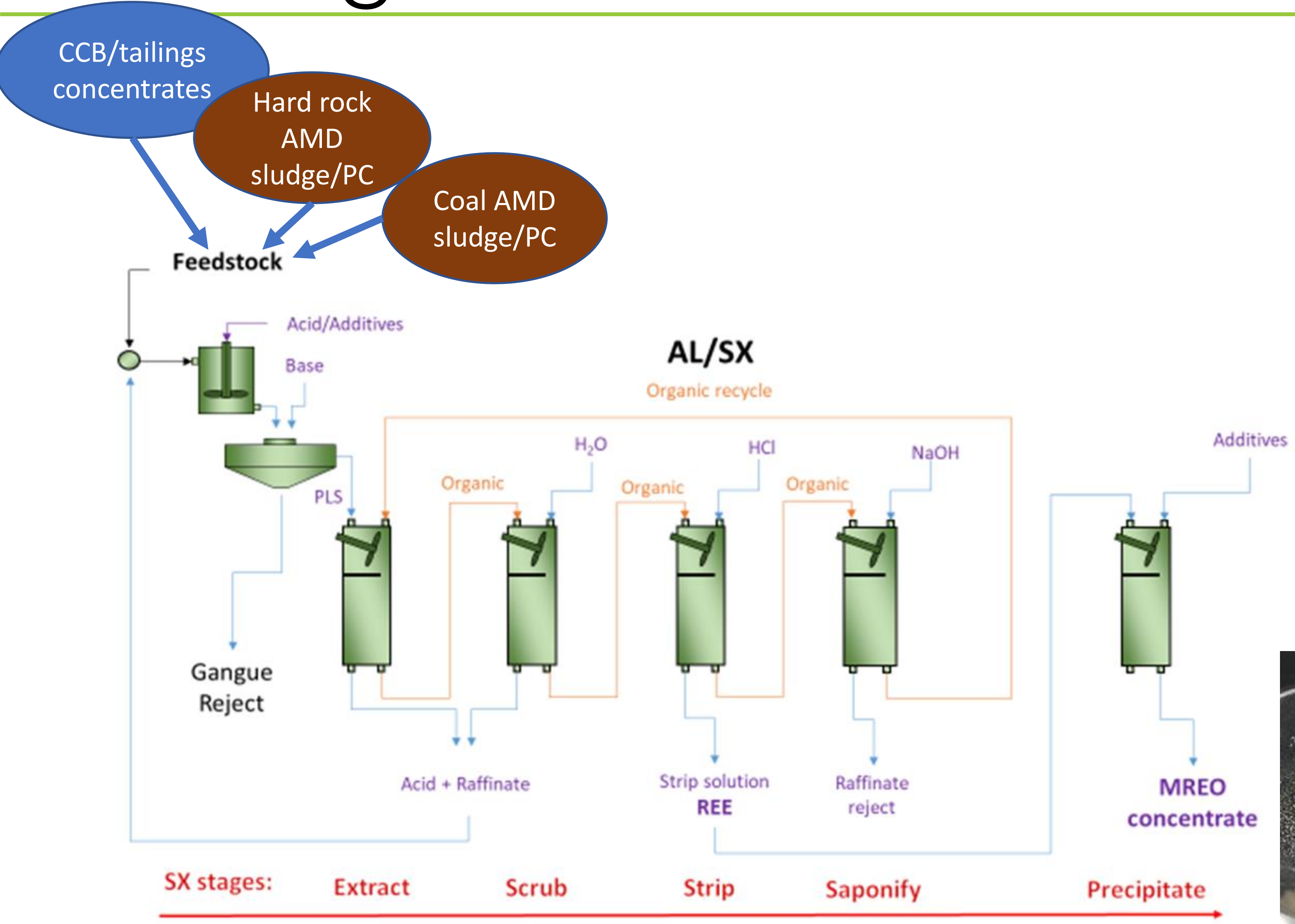


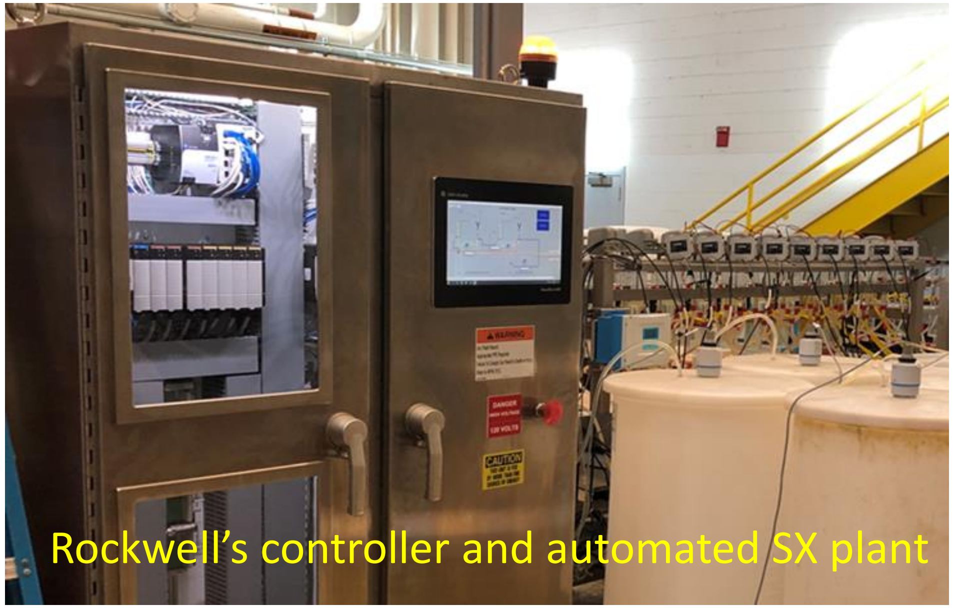
Project ETD67: Pilot Plant-WVDEP A34 Permit

AMD treatment, Upstream Concentrator	REE/CM Refinery



Refining REE/CM from feedstock





90-100% MREO

Patent pending refining technology

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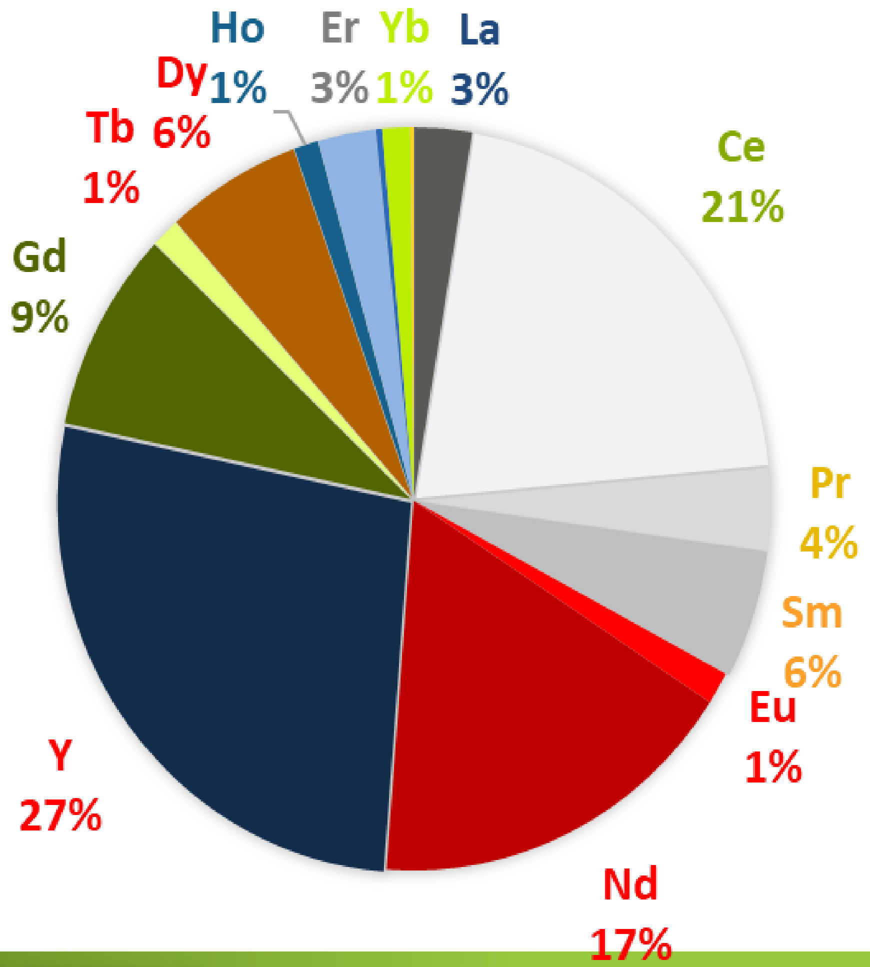
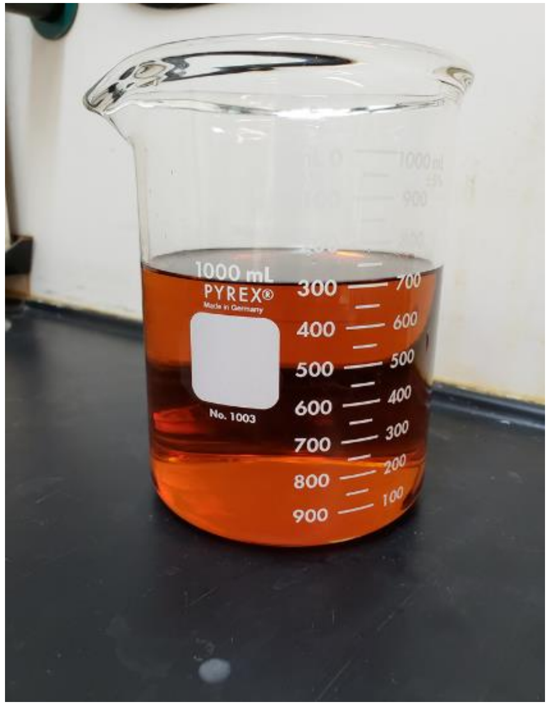
Recent AL/SX results-AMD sludge: Simple circuit optimized for HREE



Sample # 2880	Grade
TREE	100.0%
LREE	51.2%
HREE	48.8%
HREE+CM	67.2%

Improved Acid Leach Procedure:
PLS = 200-320 mg TREE/L



The Resource base: two strategies

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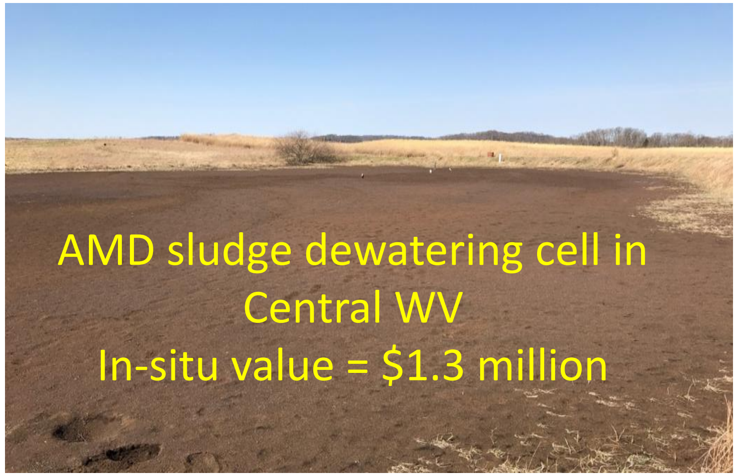
AMD Sludge Recovery>300 g/t (ppm)

AMD sludge cells sampled		76	
REE Basket price	$	237	$/kg
Sludge mass DWB		1,062,413	t
Average TREE grade		663	g/t
TREE mass		350	t
Estimated contained value	**$**	**79,633,629**	



Direct AMD Recovery

REE production from AMD: Northern + Central APP			
AMD production		1,503,371	gpm
Average TREE conc.		0.269	mg/L
TREE production		807	t/yr
Estimated contained value	**$**	**191,362,343**	

Copper Mine AMD, Butte MT

Berkeley Pit

900 ft deep

1 mile across

AMD precipitates:

140 MM m^3

Estimated REE:

12,000 t DW

Economic and Environmental Benefits

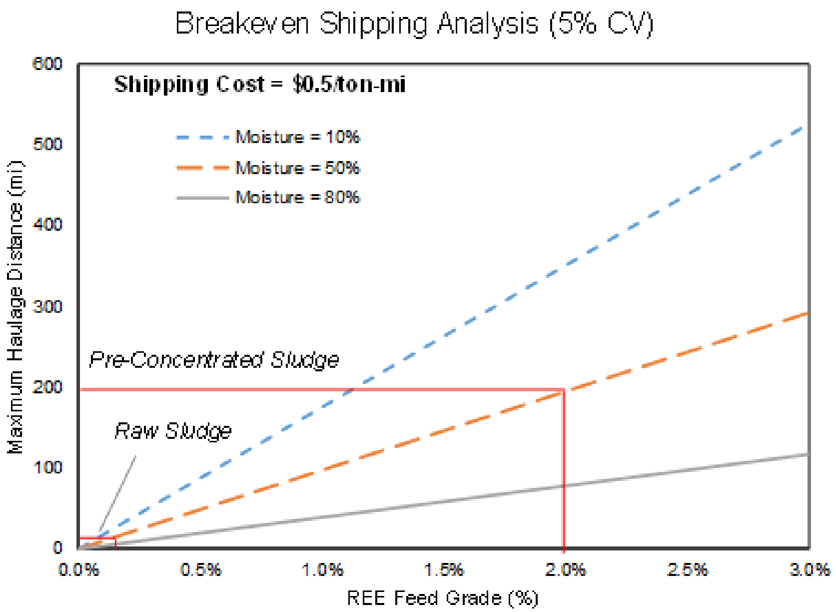
Streams restored while recovering REE/CM

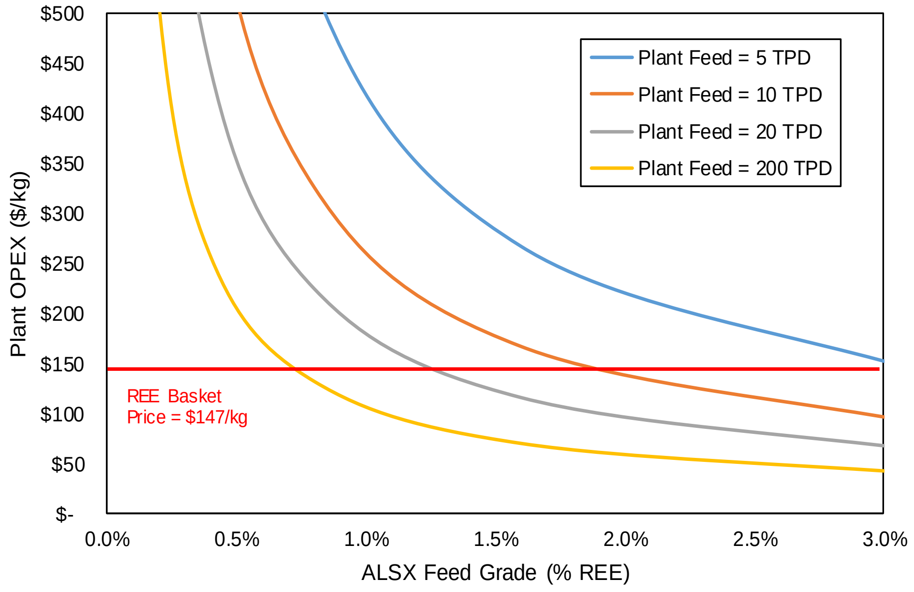
Anticipated 'profit' from A34 plant

Basket price	$	237	/kg MREO
Total processing cost	$	54	/kg MREO
Estimated profit	$	183	/kg MREO
AMD feed		500	gpm
AMD quality		0.8	mg TREE/L
Production		880	kg MREO/yr
		669	kg Cobalt/yr
Production		1,549	kg/yr
Estimated annual profit*	$	184,448	

Does not include: capital cost recovery
taxes
elemental losses
oxide separation costs

Economic Feasibility Analysis





Economic Parameter	Value
Plant Feed Rate/Grade	175 TPD @ 2% REE
Product Rate/Grade	2 TPD @ 90% MREO
Operating Period	20 years; 10% discount rate
REE Basket Price	$147 /kg
REE Recovery	59%
Plant CAPEX	$20 Million
Plant OPEX	$54 / kg
NPV	$80 Million
IRR	61%
Payback period	1.5 operating years

Technology Status: Market needs

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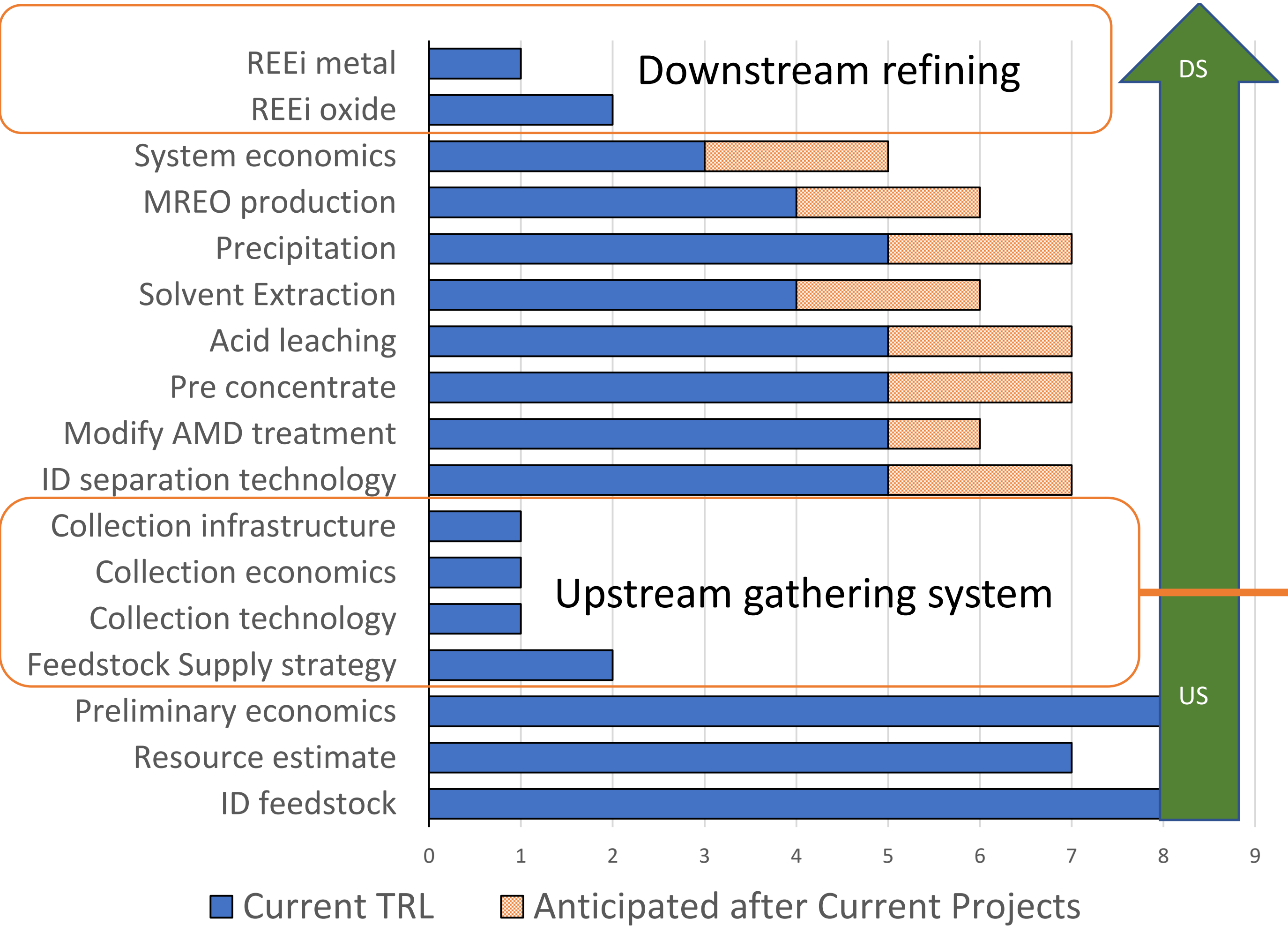


Distributed supply chains:

Forestry, Power gen, Agriculture

Hypothetical Hub and Spoke Arrangement for collecting AMD concentrates for regional processing facilities

Permitting: Net Environmental Benefit

Regulatory Environment:

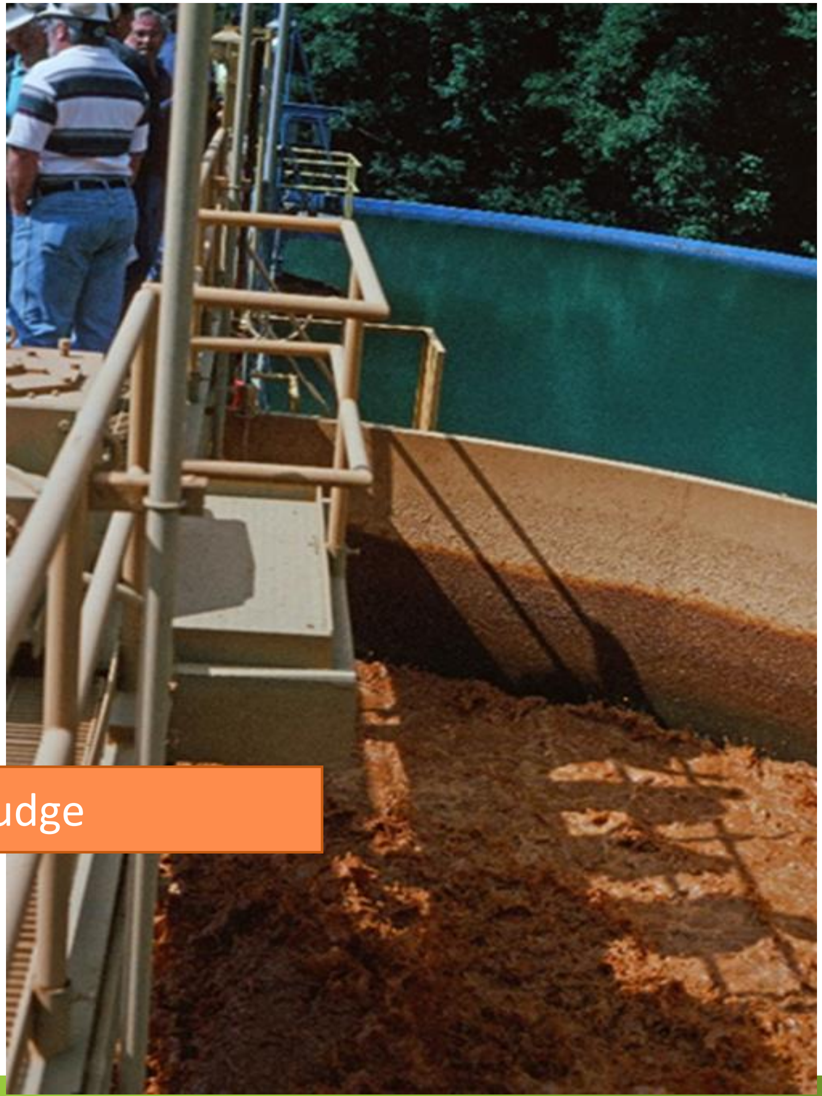
- Active permits: State primacy CWA sec 402
- Abandoned mines: CWA sec 404 (maybe)
- Federal OSHA
- No NORMS: Naturally occurring radioactive materials
- Compliance with NRC limits:
    - < 1 mSv/yr over background

Waste Handling

Nearly all waste remains at the AMD treatment plant

- Near Bismarck WV
- Designed to:
  - Treat AMD to meet CWA compliance levels
  - Recover high grade Rare Earth Oxide
- Waste is AMD sludge without the Rare Earths
  - Non-hazardous
  - Onsite disposal

Sludge



Key Points

Low upfront cost/risk

1. Leveraging: Our feedstock is a byproduct of AMD treatment-most capital costs are included in the AMD treatment plant
1. Environmentally Benign:
    1. Supports stream and river remediation efforts
    2. No Radioactivity in the tailings
2. High value product: 67% Heavy + Critical to Total REE
3. No to minor permitting issues
4. Short time to reach production: months
    - Minimum exploration costs
    - No mining cost
    - Pre development cost

- Future needs:
    - scale up to continuous production
    - develop upstream supply chain

Questions:

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