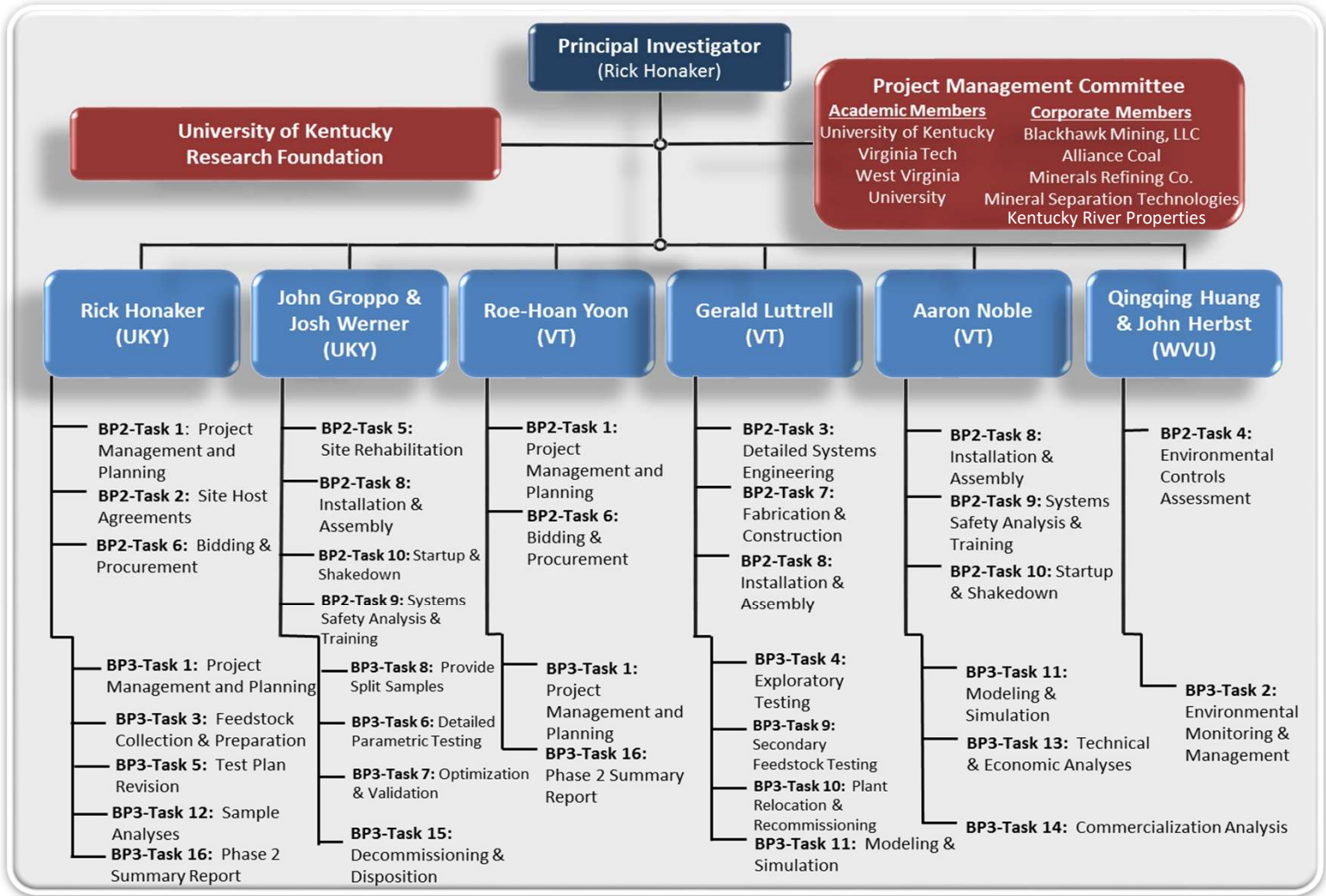


Pilot-Scale Testing of an Integrated Circuit for the Extraction of Rare Earth Minerals and Elements from Coal and Coal Byproducts Using Advanced Separation Technologies

PRINCIPAL INVESTIGATOR:
Dr. Rick Honaker
University of Kentucky

DOE Award Number: DE-FE0027035
Period of Performance: 3/1/2016 – 2/28/2020
NETL Program Manager: Charles Miller

2018 Project Review Meeting
Rare Earth Elements Research Portfolios
Tuesday, April 10, 2018



Project Objectives

- Develop, design and demonstrate a pilot-scale processing system for the efficient, low-cost and environmentally benign recovery of high-value rare earth elements (REEs) from coal and coal byproducts.
 - Integrate both physical and chemical separation processes;
 - Pilot-scale circuit will have a dry solids feed rate of ¼-ton/hr (0.23 tonne/hr) and will be capable of producing 5 - 7 pounds (2.3 – 3.2 kg) per hour of combined concentrates with purity levels of at least 2% total REEs by weight;
 - Technical and economic feasibility of the proposed system will be fully evaluated with respect to separation performance, throughput capacity, capital/operating costs, and environmental acceptability.
- The pilot-scale plant will be mobile and evaluated at two different locations and multiple feed stocks during the project period.

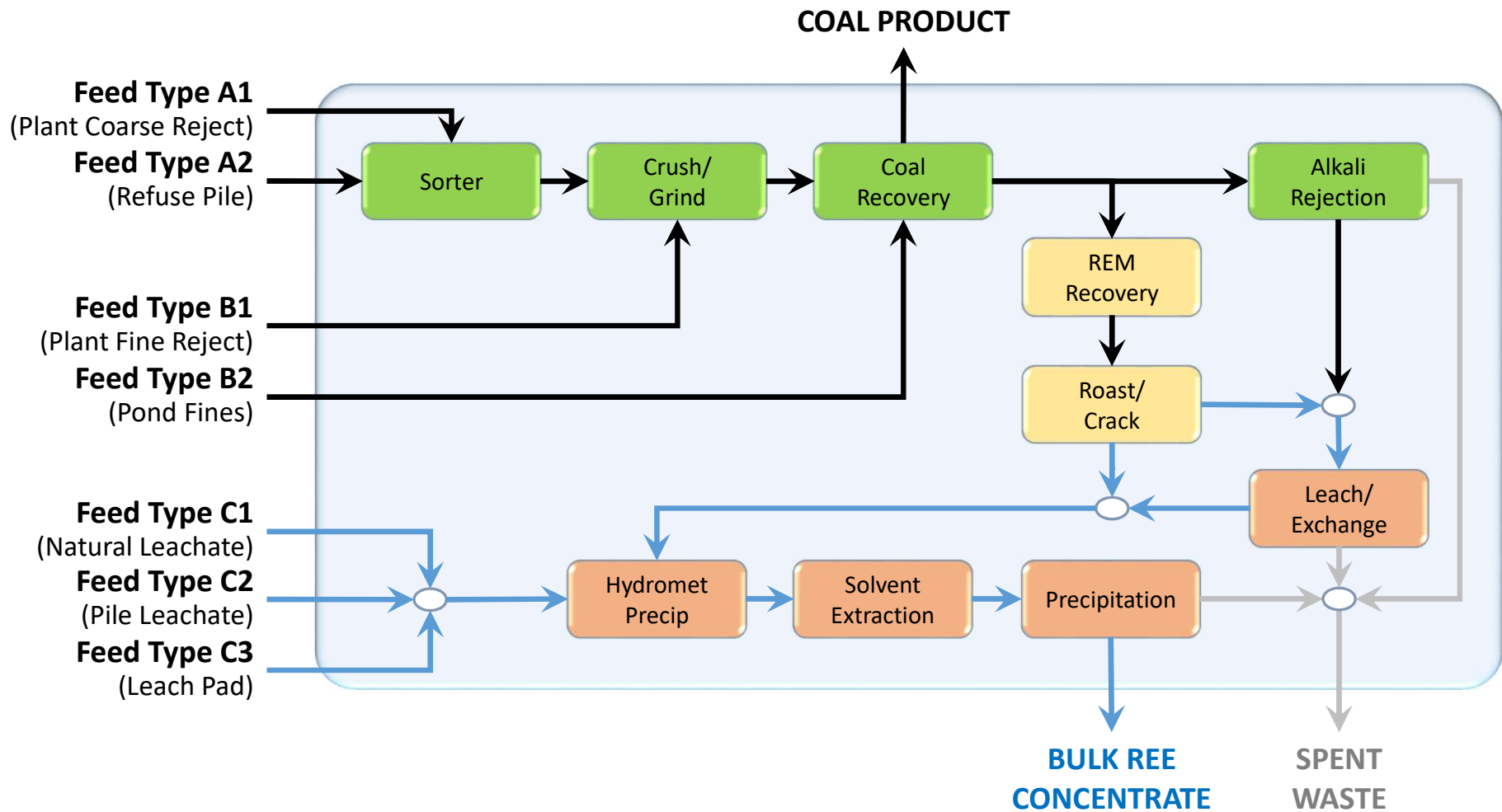
Phase 2 Budget Period 2 Schedule

		Q4			Q1			Q2		
		1	2	3	1	2	3	1	2	3
PHASE 2 BUDGET PERIOD 2 (Award to Shakedown/Commissioning)										
Task	Description	O	N	D	J	F	M	A	M	J
1.0	Project Management & Planning	■	■	■	■	■	■	■	■	■
2.0	Site Host Agreements		■							
3.0	Detailed Systems Engineering		■	■	■	■				
4.0	Environmental Controls Assessment		■	■	■	■	■	■	■	■
5.0	Site Rehabilitation				■	■	■	■	■	■
6.0	Bidding & Procurement				■	■	■	■	■	
7.0	Fabrication & Construction					■	■	■	■	
8.0	Installation & Assembly						■	■	■	
9.0	Systems Safety Analysis & Training								■	
10.0	Startup & Shakedown								■	■

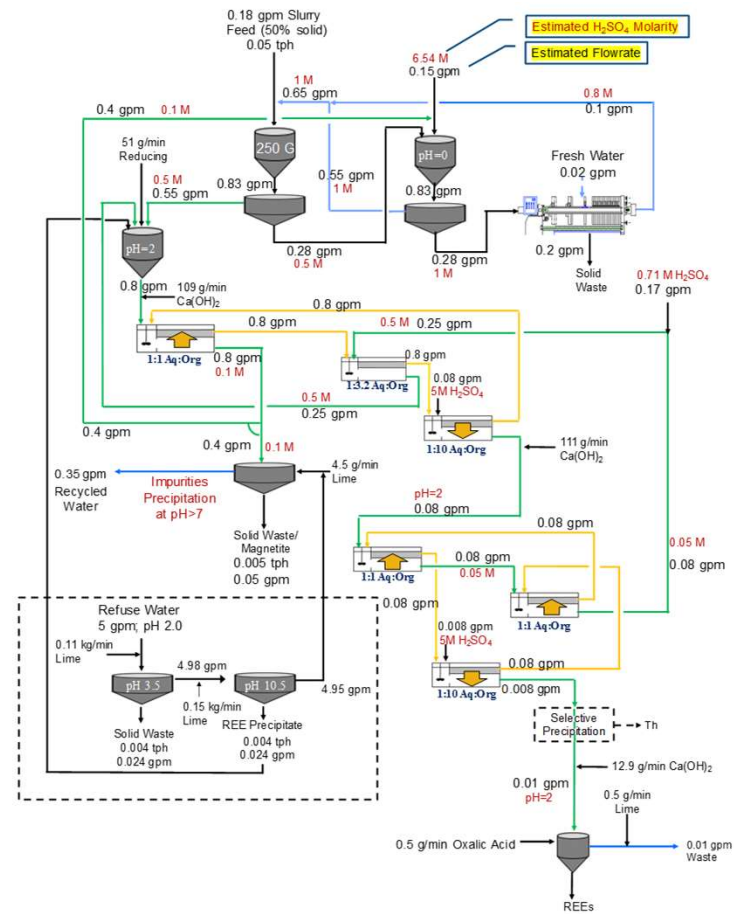
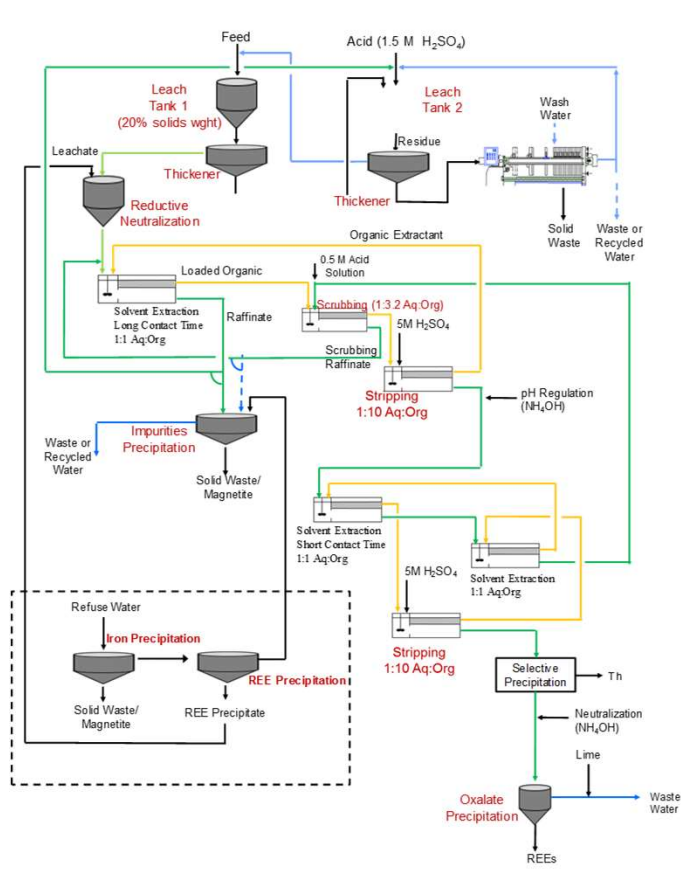
Phase 2 Budget Period 3 Schedule

PHASE 2 BUDGET PERIOD 3 (Initial Testing to Completion)		O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
1.0	Project Management & Planning																														
2.0	Environmental Monitoring & Management																														
3.0	Feedstock Collection & Preparation																														
4.0	Exploratory Testing																														
5.0	Test Plan Revision																														
6.0	Detailed Parametric Testing																														
7.0	Optimization & Validation																														
8.0	Provide Split Samples																														
9.0	Secondary Feedstock Testing																														
10.0	Plant Relocation & Recommissioning																														
11.0	Modeling & Simulation																														
12.0	Sample Analyses																														
13.0	Technical & Economic Analyses																														
14.0	Commercialization Analysis																														
15.0	Decommissioning & Disposition																														
16.0	Phase 2 Summary Report																														

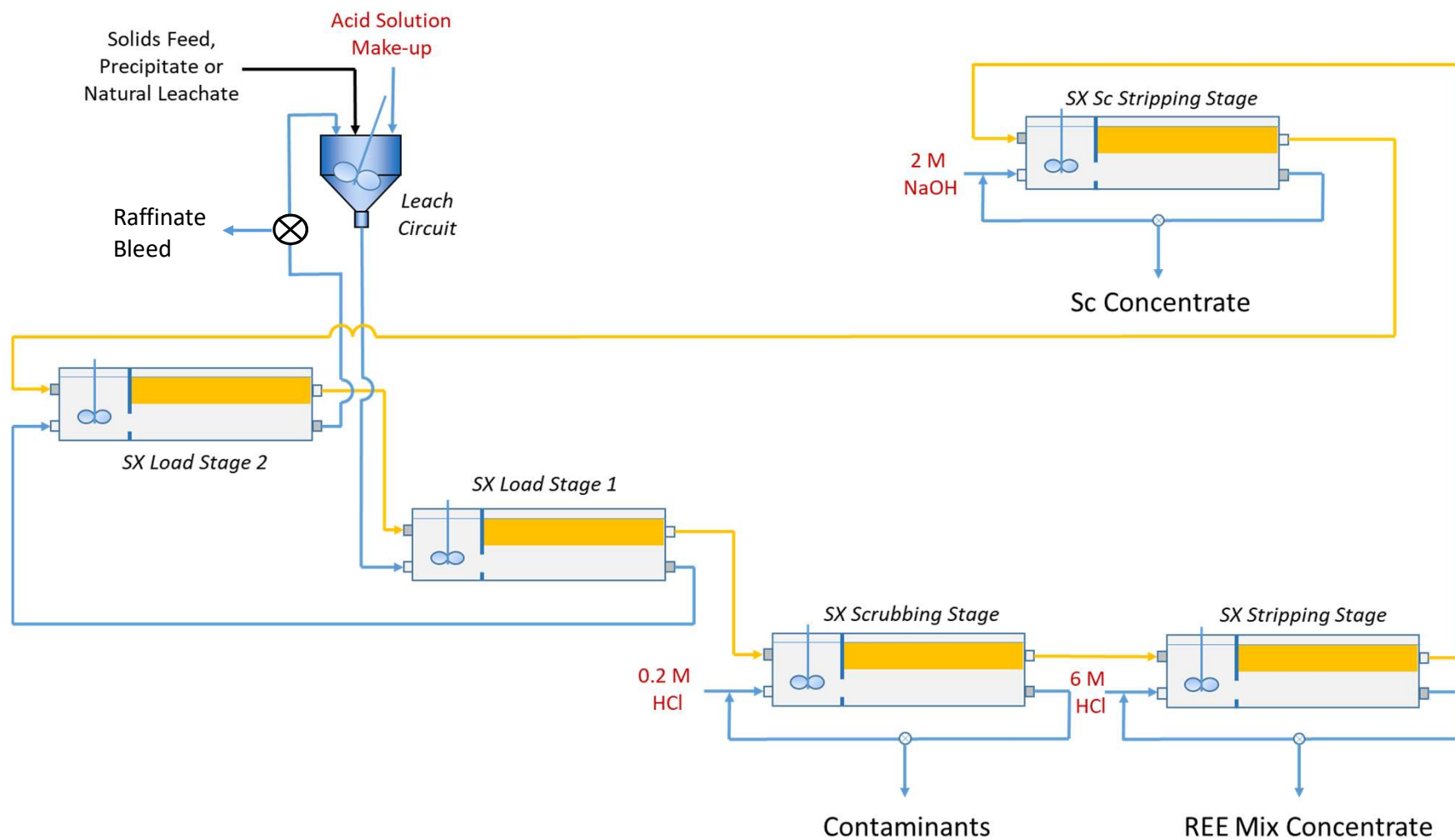
Flowsheet Concept



Hydrometallurgy Circuit



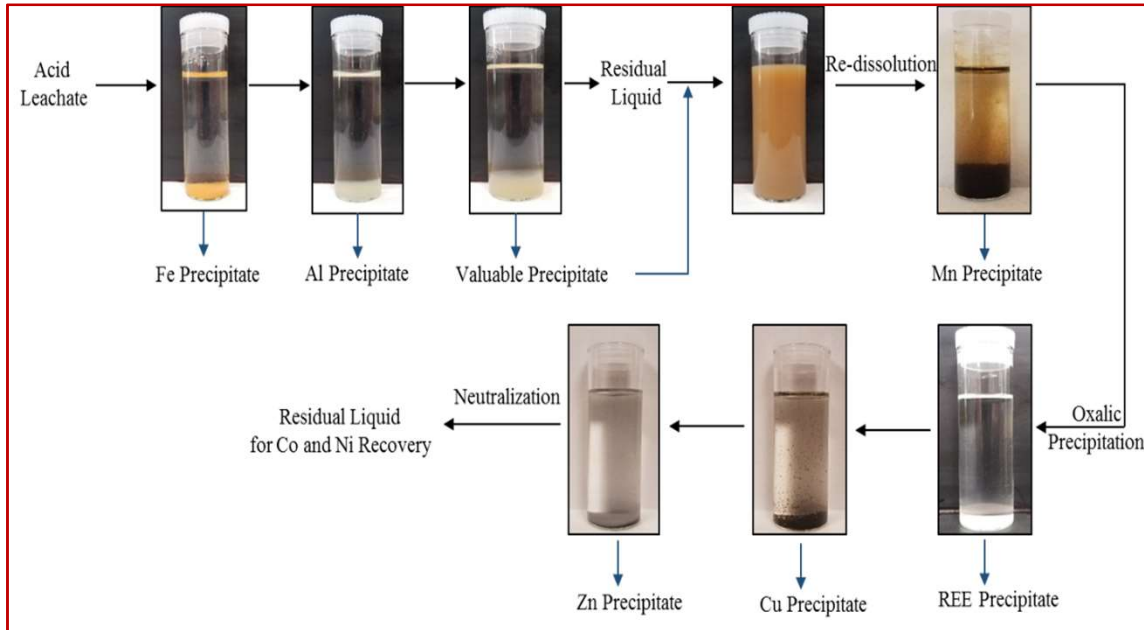
Solvent Extraction Circuit



Solvent Extraction REE Products

Rare Earth Element	REE Oxide (ppm)			
	Fire Clay		W. KY No. 13	
	Middlings	TUF	Middlings	TUF
Scandium	14	0	0	0
Yttrium	8,157	22,050	34,438	22,579
Lanthanum	82,149	28	757	128
Cerium	250,277	527	7,586	1,694
Praseodymium	24,421	150	1,142	465
Neodymium	98,745	545	6,021	3,441
Samarium	22,372	375	4,160	3,277
Europium	1,584	98	1,380	1,083
Gadolinium	13,921	950	9,152	8,280
Terbium	<DL	360	1,519	1,413
Dysprosium	6,472	4,475	11,883	11,295
Holmium	1,199	727	1,388	1,268
Erbium	700	2,392	3,149	2,306
Thulium	1,282	442	603	269
Ytterbium	<DL	1,228	1,558	329
Lutetium	391	123	171	23
Total	511,685	34,470	85,357	57,850

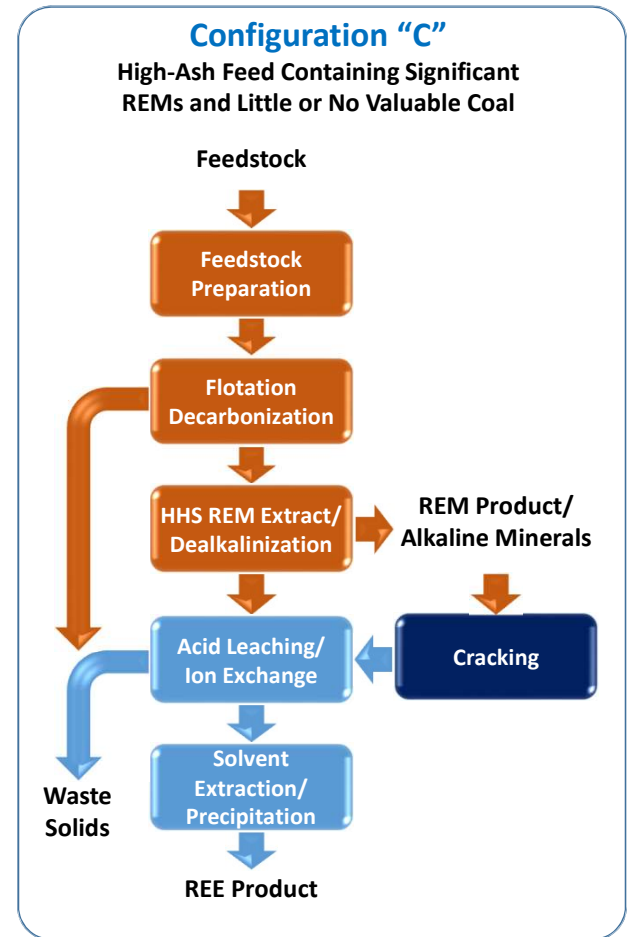
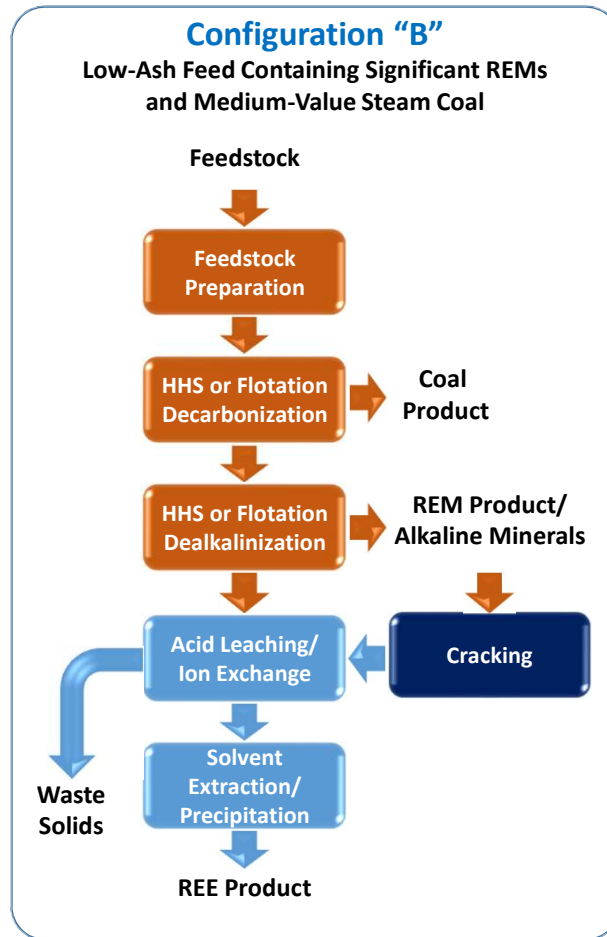
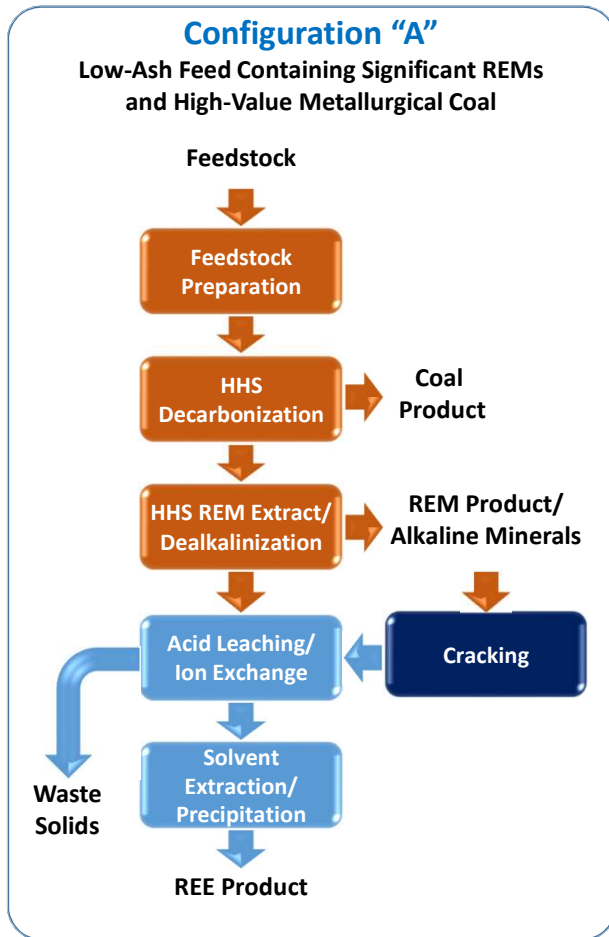
Selective Precipitation Option



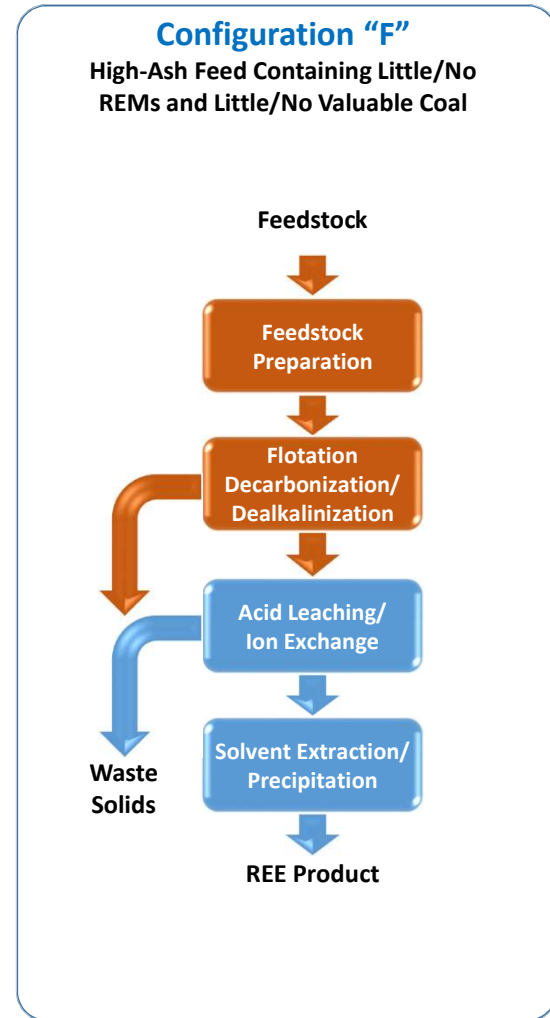
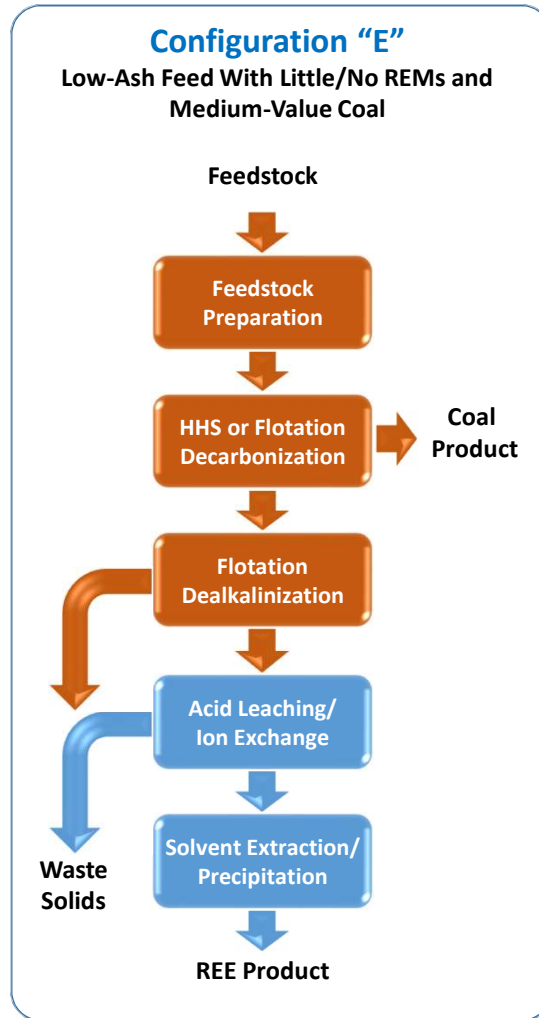
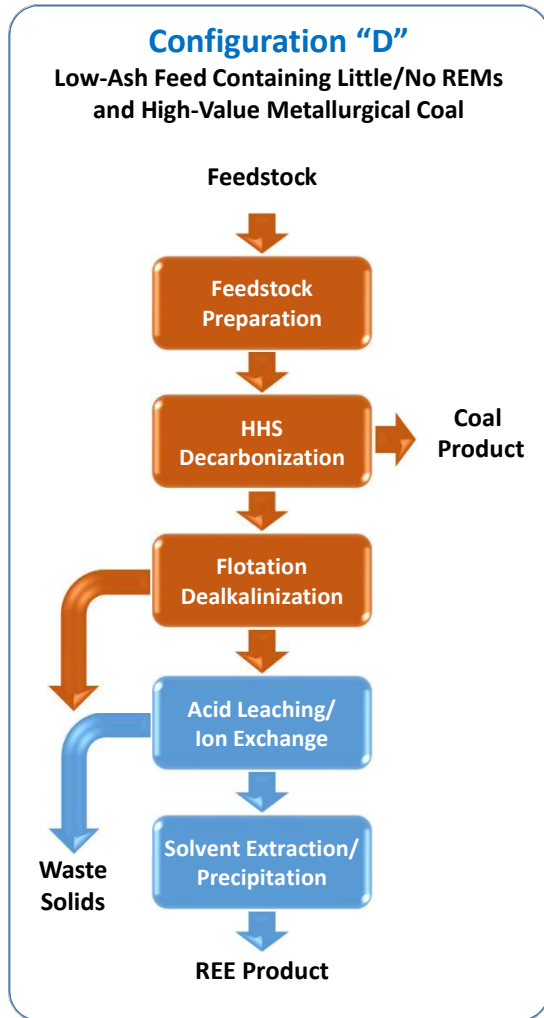
- 80% total REE recovery;
- 52% manganese oxide, 60% copper sulfide and 60% zinc sulfide;
- Achieved using a continuous process in a lab environment;
- Patent application submitted.

REEs	Content (%)
Sc ₂ O ₃	0.05
Y ₂ O ₃	21.05
La ₂ O ₃	9.11
CeO ₂	23.32
Pr ₆ O ₁₁	4.13
Nd ₂ O ₃	17.67
Sm ₂ O ₃	5.62
Eu ₂ O ₃	1.24
Gd ₂ O ₃	6.41
Tb ₂ O ₃	0.89
Dy ₂ O ₃	4.84
Ho ₂ O ₃	0.81
Er ₂ O ₃	1.55
Tm ₂ O ₃	0.19
Yb ₂ O ₃	0.92
Lu ₂ O ₃	0.17
Total	97.97

Configuration Options



Configuration Options



Process Train Layouts

- 1.00 – Preconcentration (Mine Site)
- 2.00 – Size Reduction/Liberation
- 3.00 – Physical Separation
- 4.00 – Acid Leaching
- 5.00 – Solvent Extraction & Precipitation
- 6.00 – Chemical Storage
- 7.00 – Rare Earth Mineral Concentration

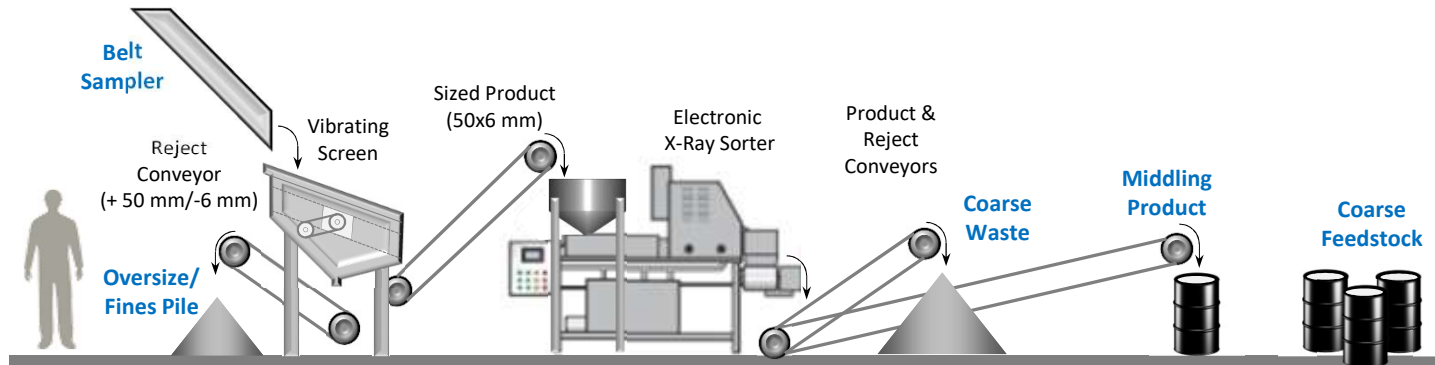


Construction work in progress...

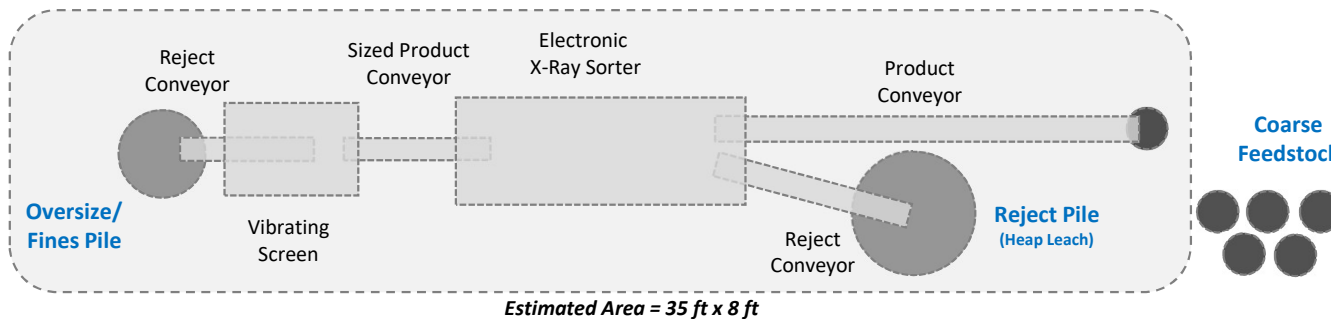


1.00 - Preconcentration

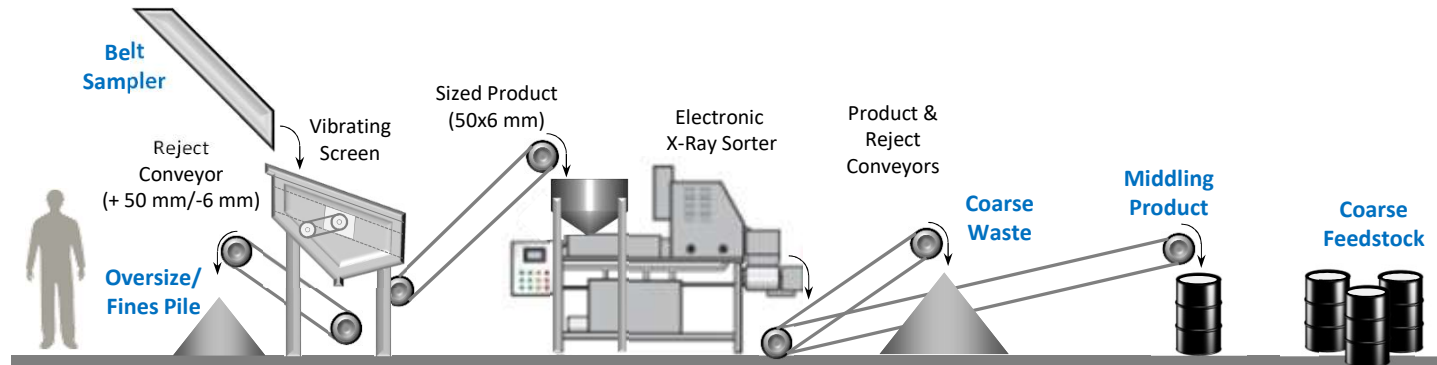
(Elevation View)



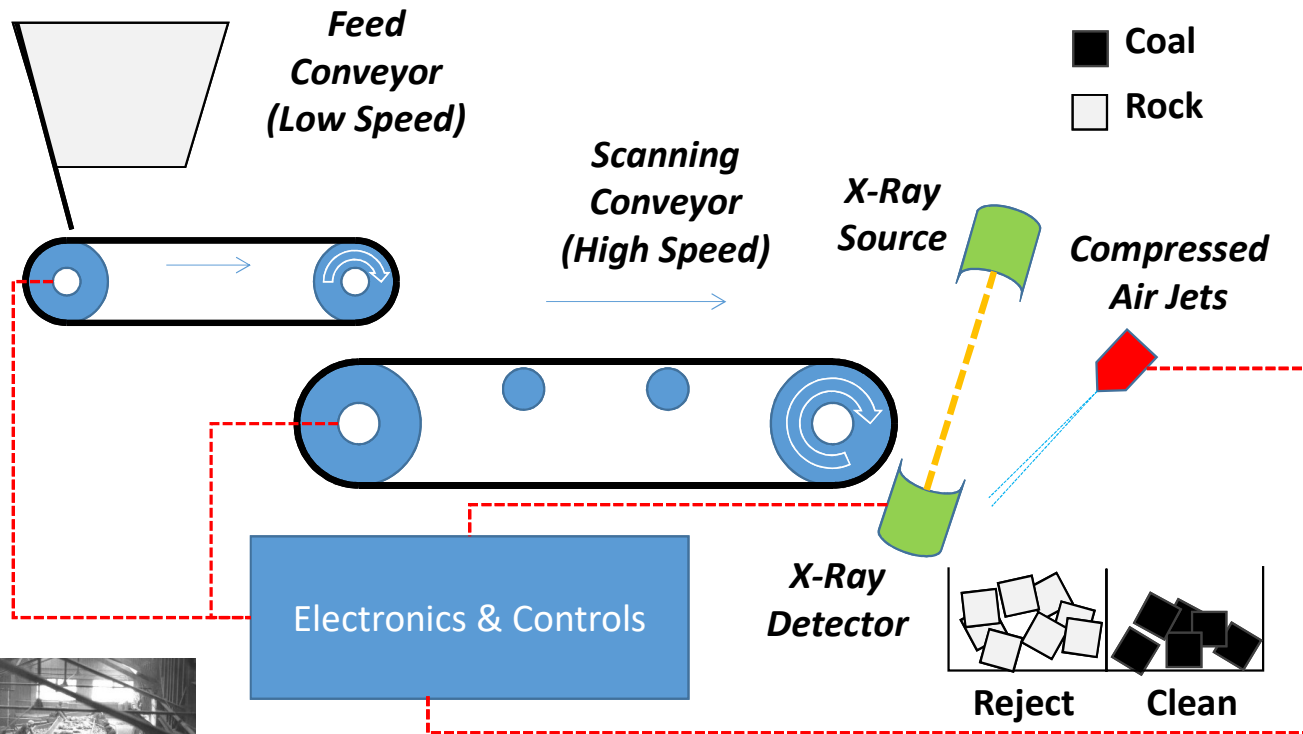
(Simplified Plan View)



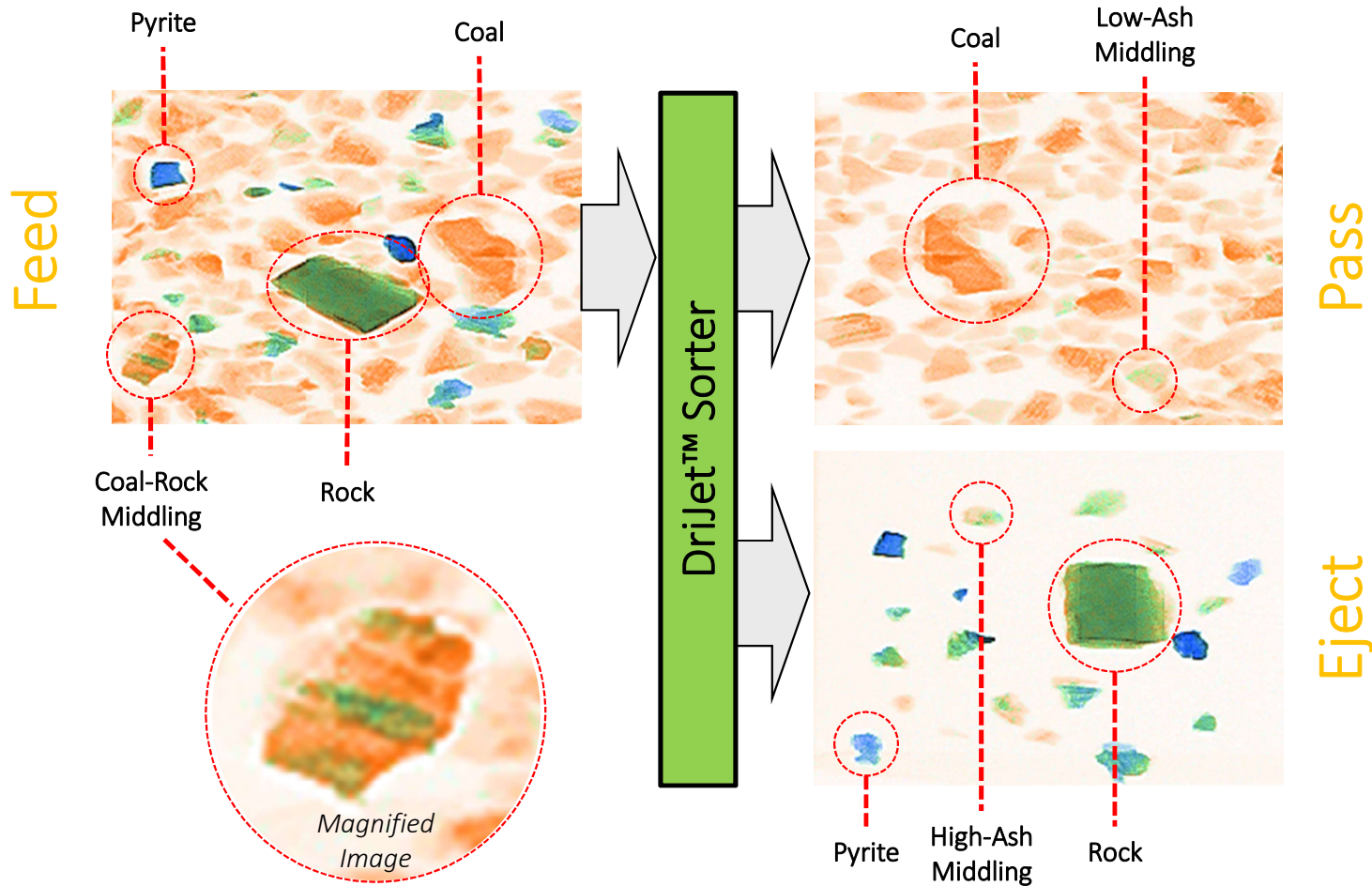
1.00 - Preconcentration



1.00 - Preconcentration



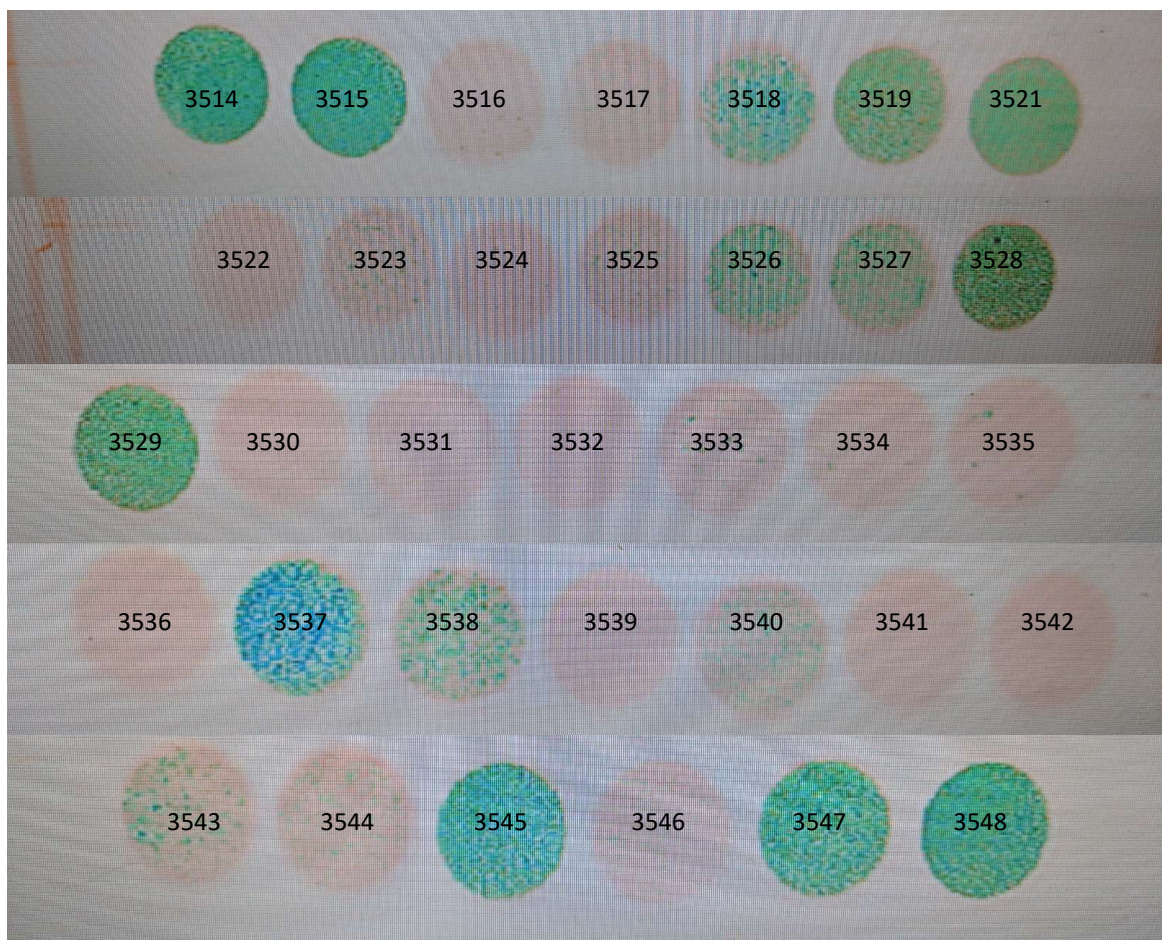
1.00 - Preconcentration



1.00 - Preconcentration



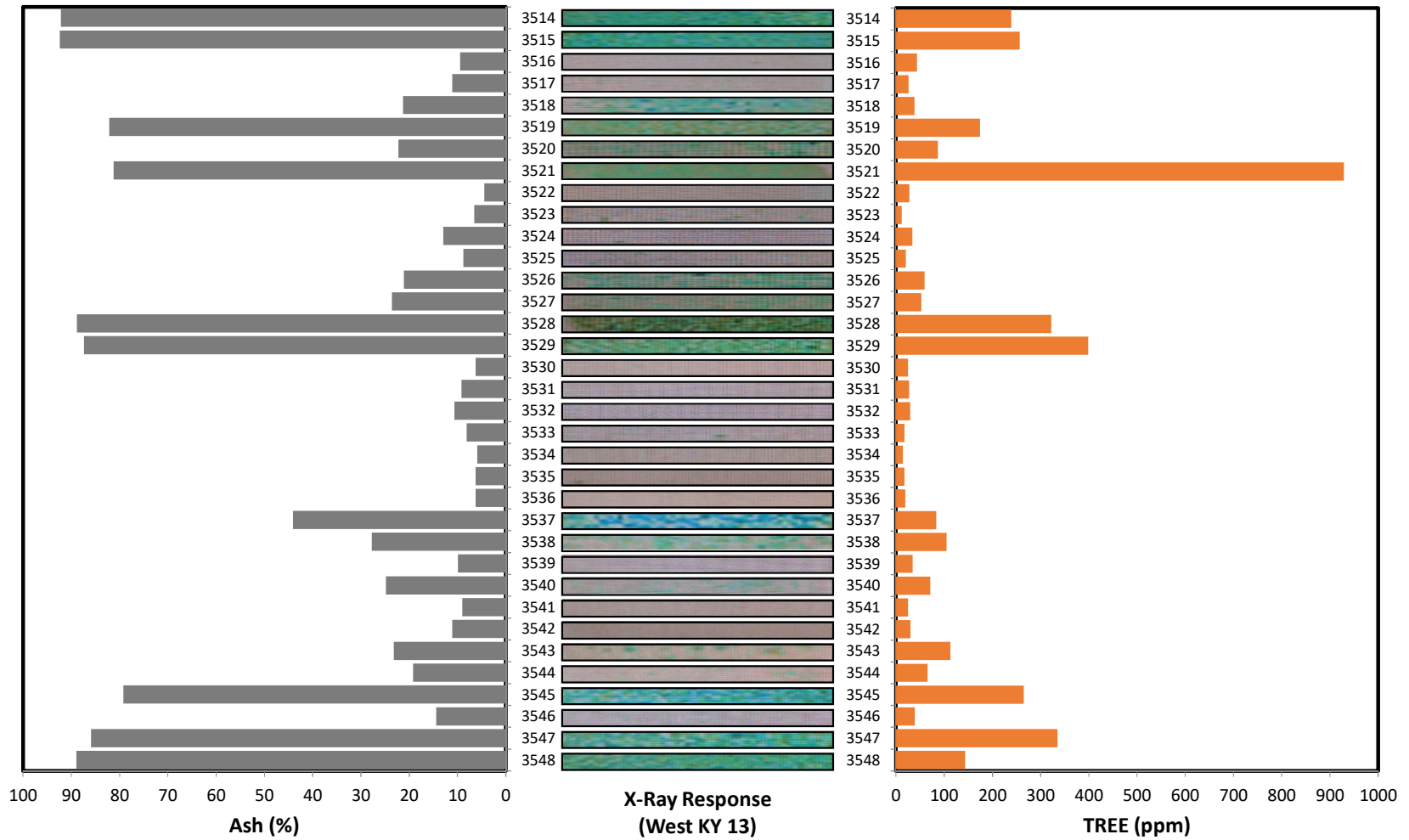
1.00 - Preconcentration



West Kentucky No. 13 – Bed Strata X-Ray Analysis



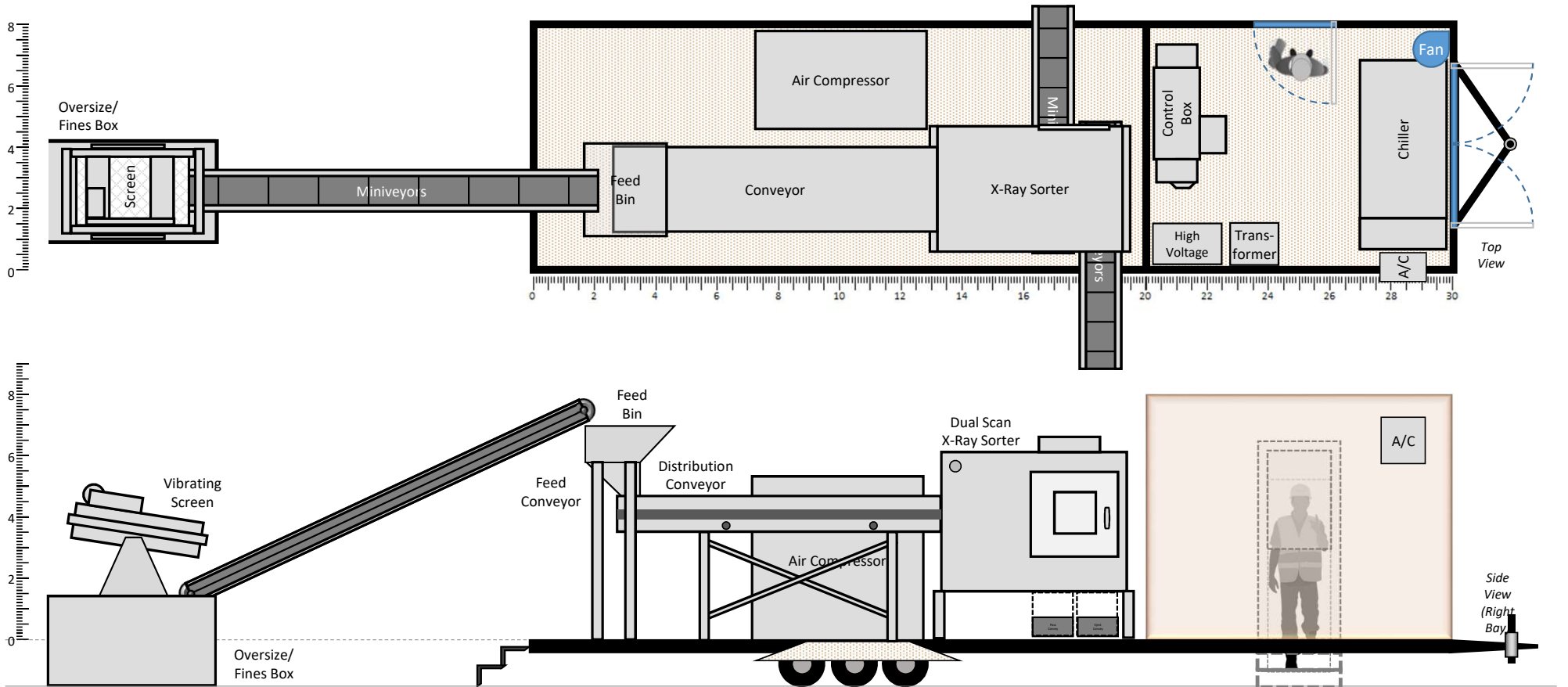
1.00 - Preconcentration



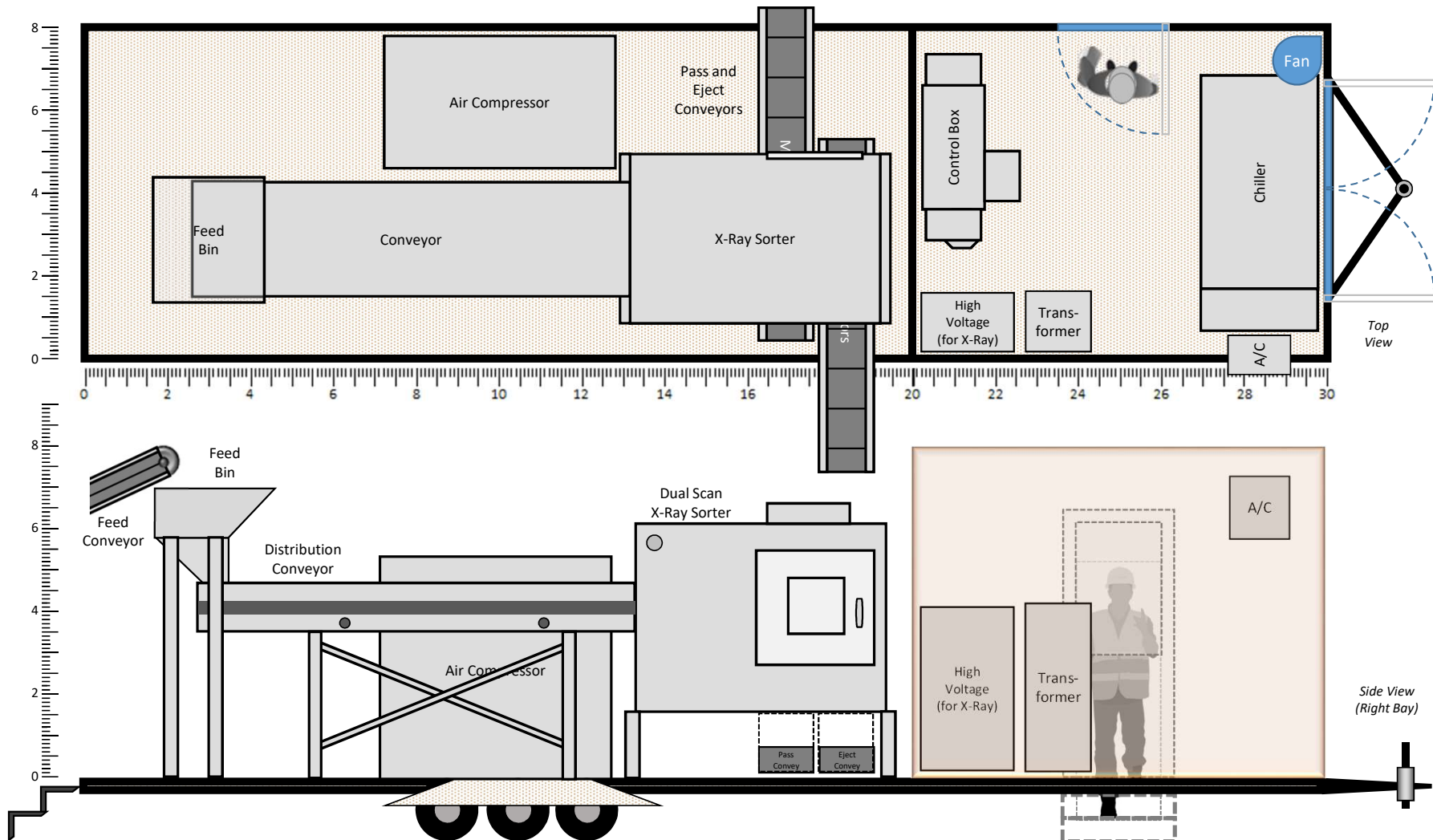
1.00 - Preconcentration



1.00 - Preconcentration

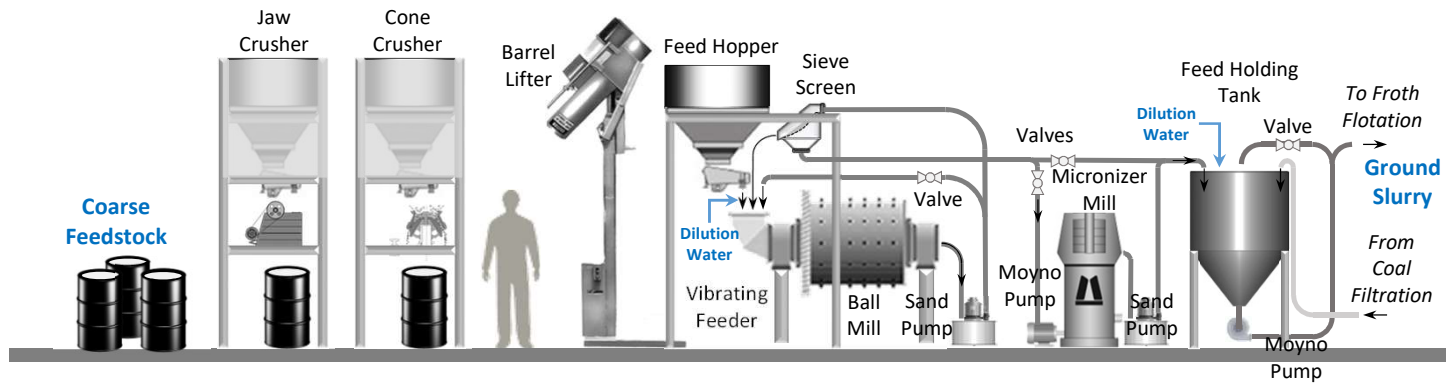


1.00 - Preconcentration

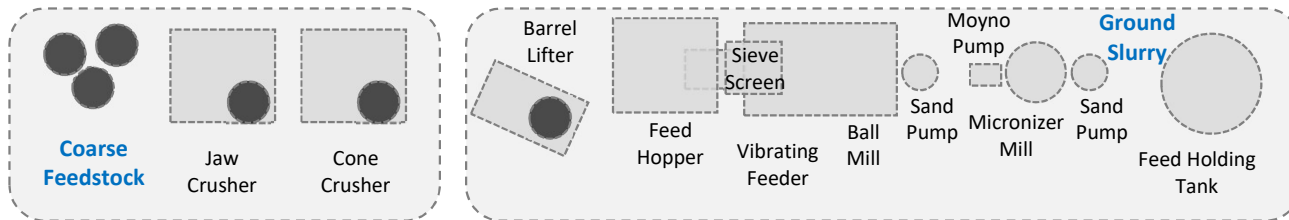


2.00 – Size Reduction/Liberation

(Elevation View)



(Simplified Plan View)

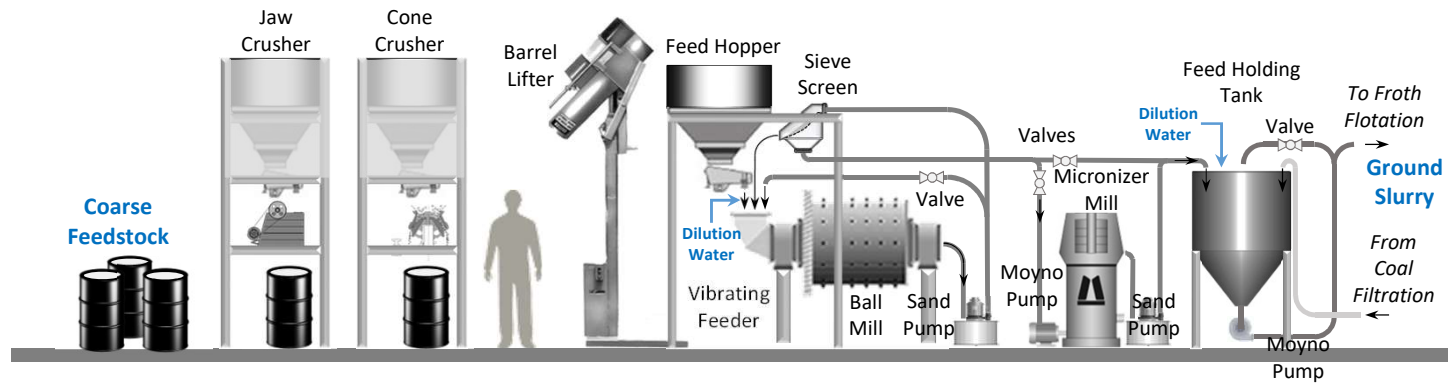


Estimated Area = 15 ft x 6 ft

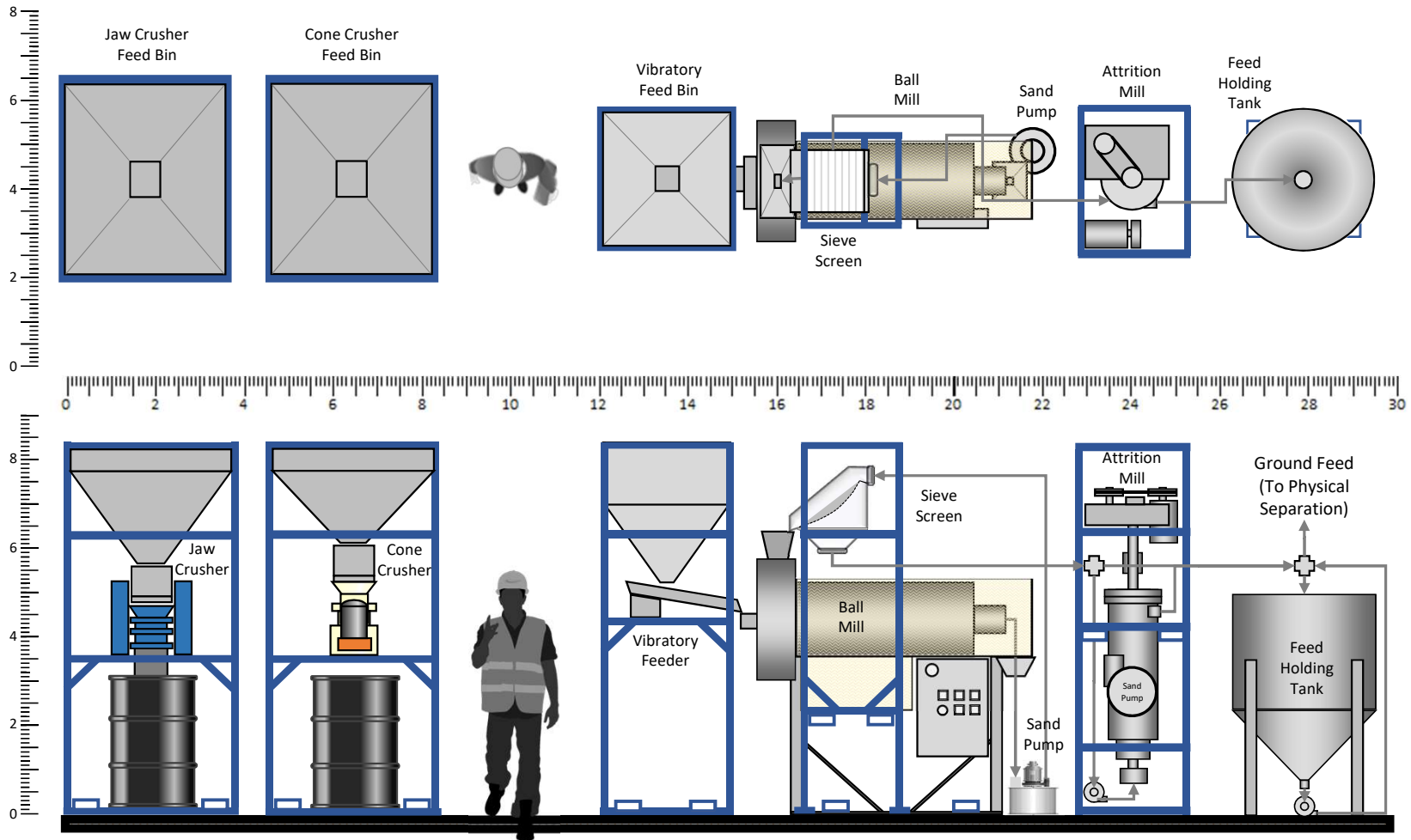
Estimated Area = 28 ft x 6 ft

2.00 – Size Reduction/Liberation

(Elevation View)

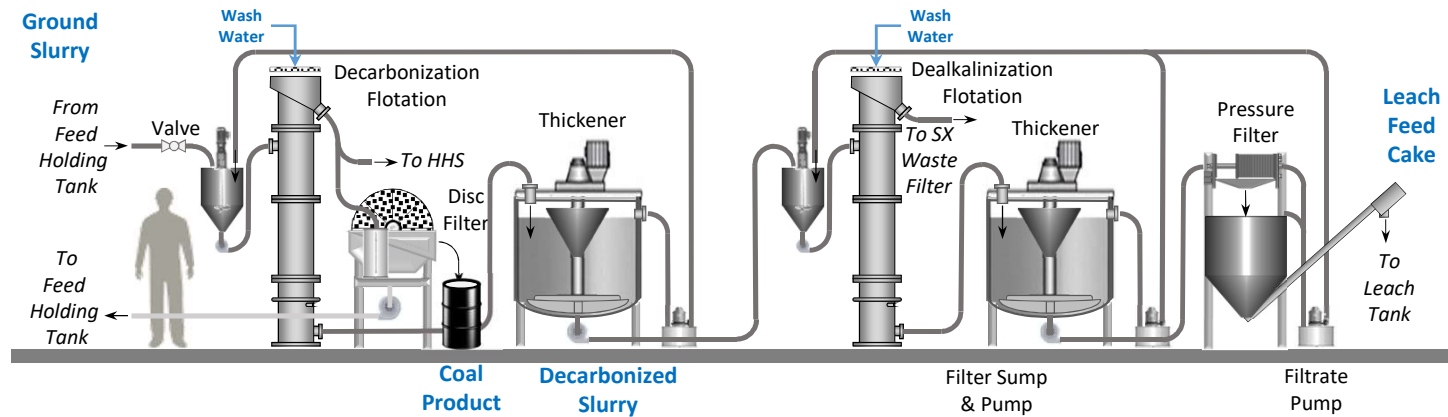


2.00 – Size Reduction/Liberation

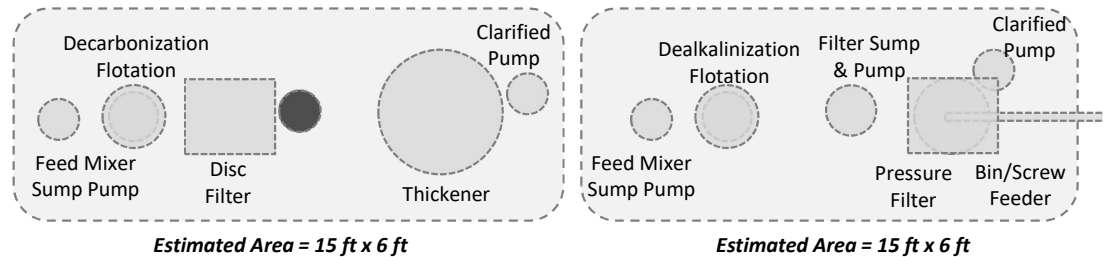


3.00 – Physical Separation

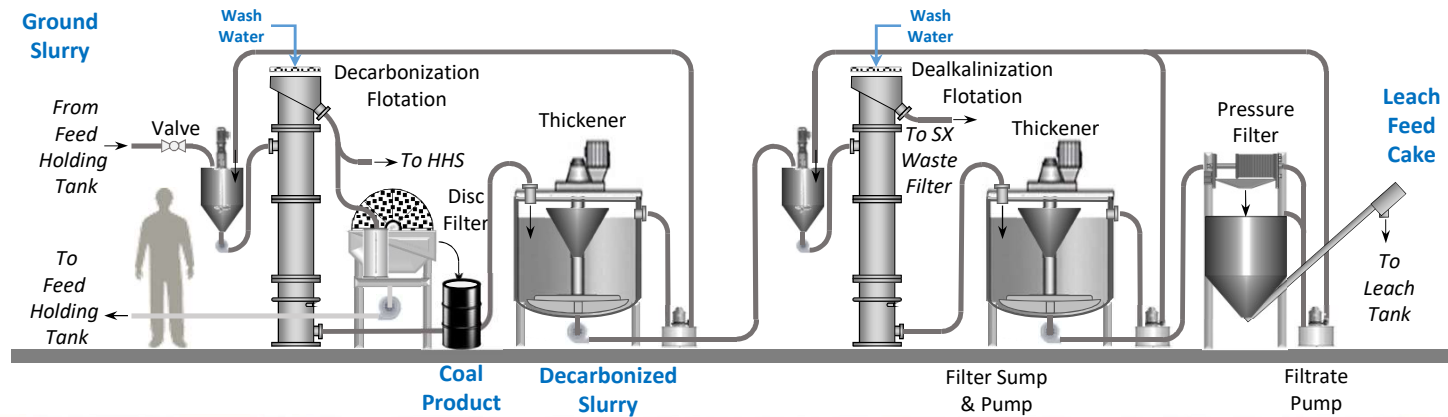
(Elevation View)



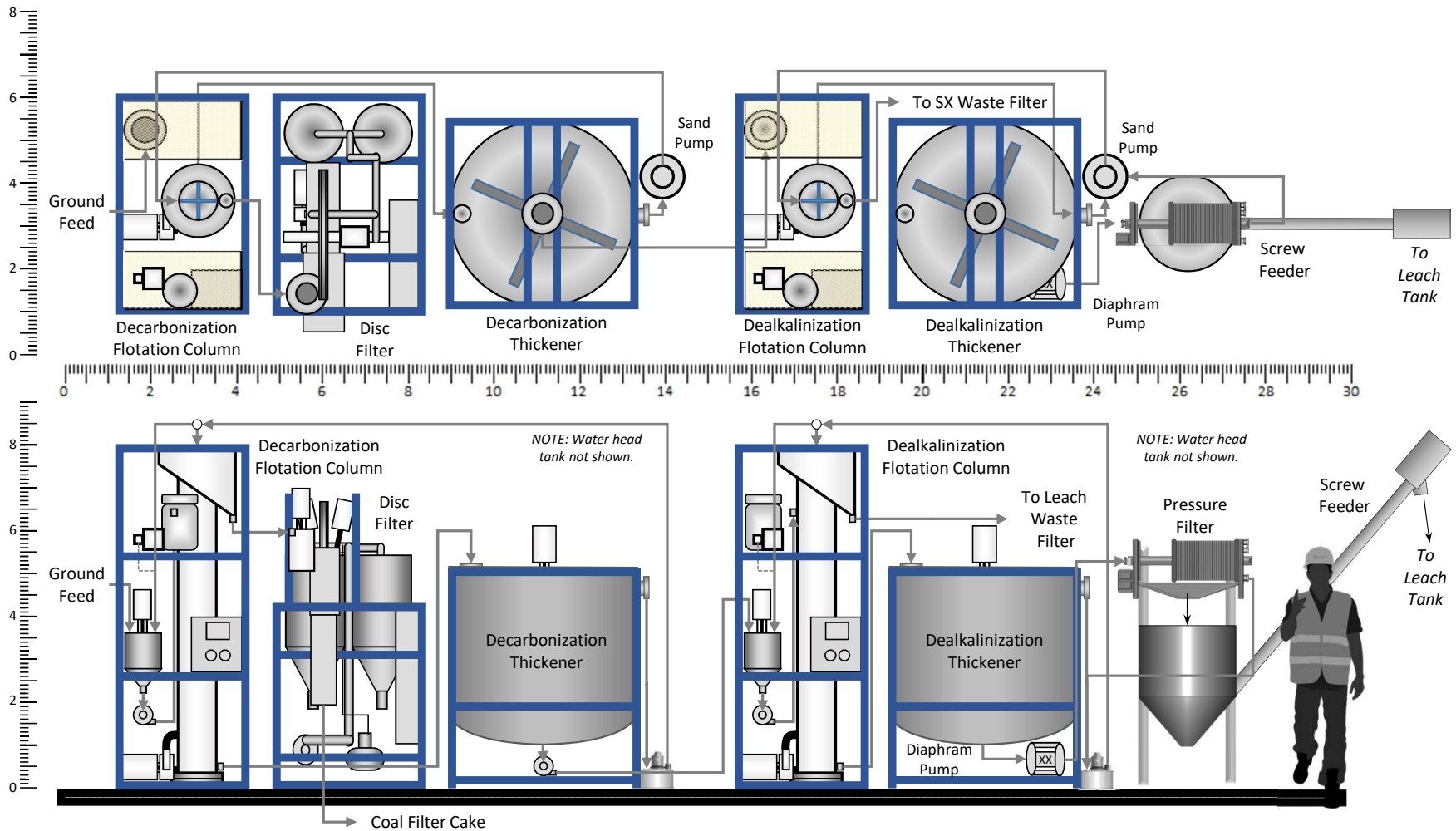
(Simplified Plan View)



3.00 – Physical Separation

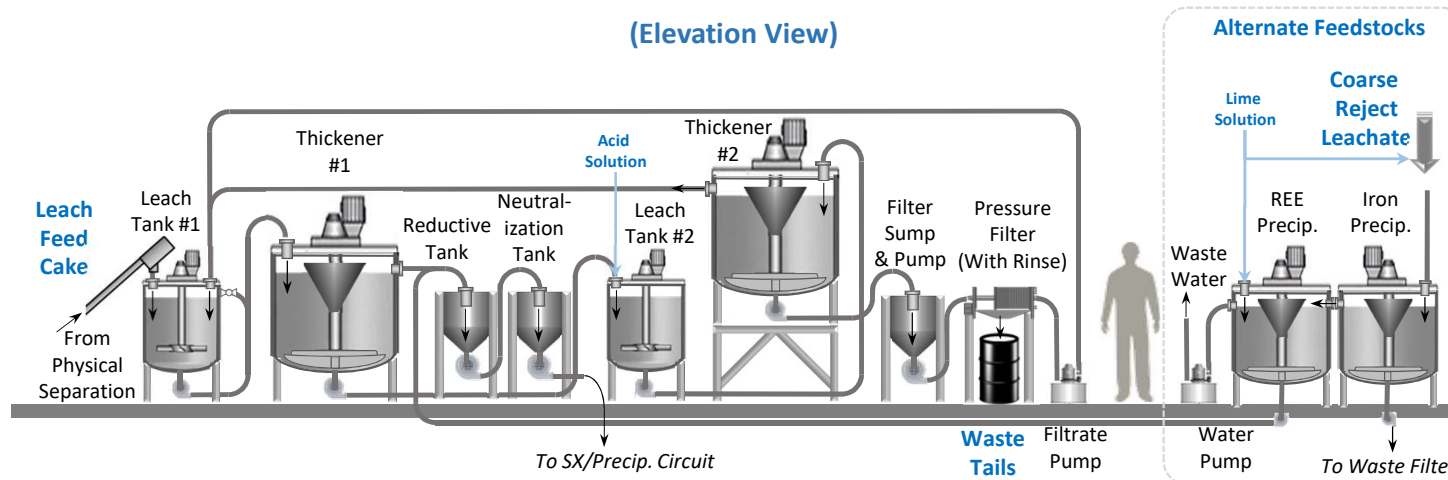


3.00 – Physical Separation

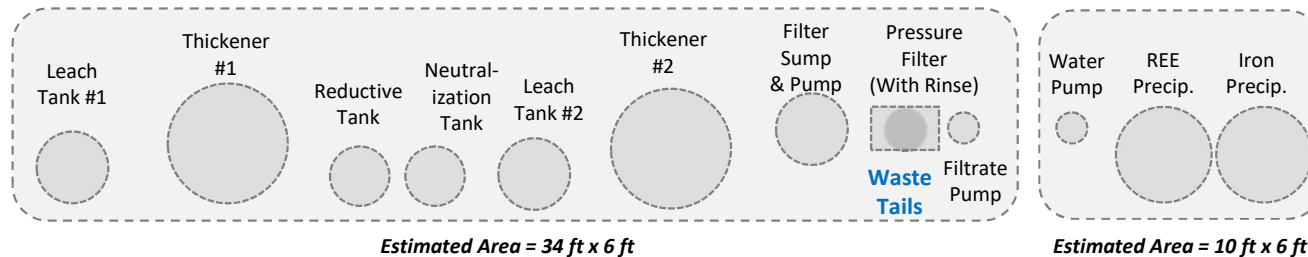


4.00 – Acid Leaching

(Elevation View)

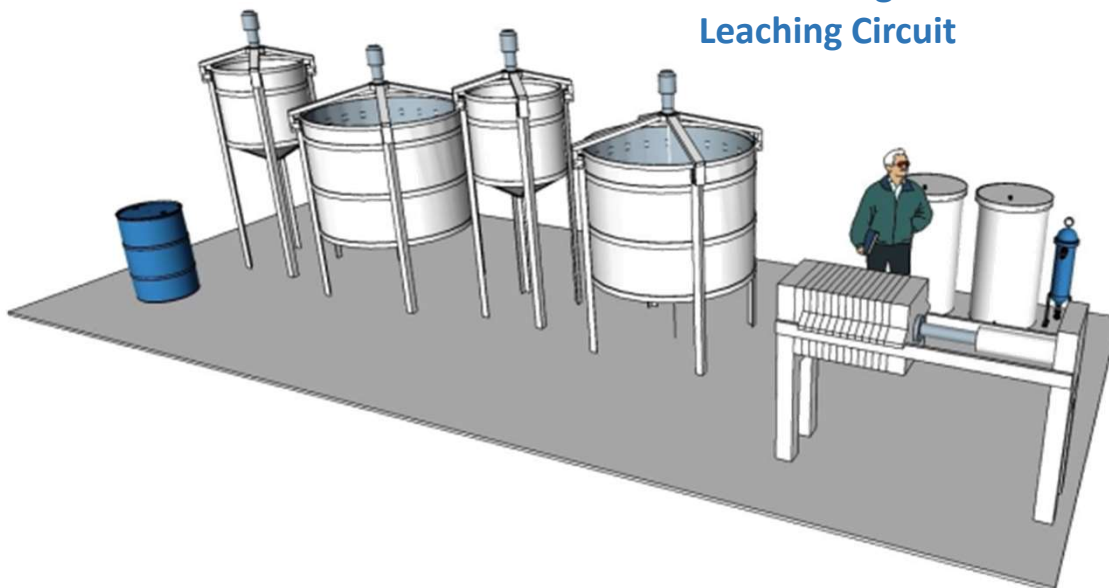


(Simplified Plan View)

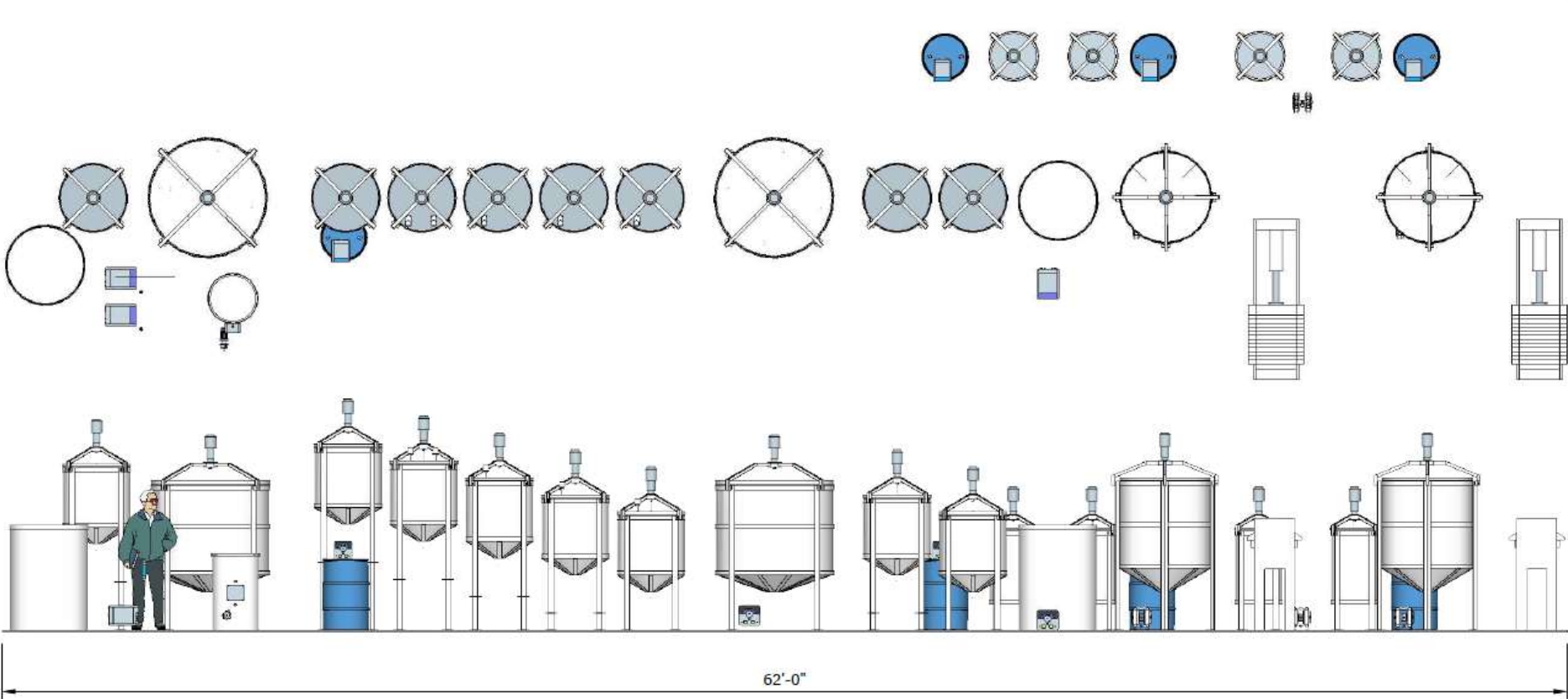


4.00 – Acid Leaching

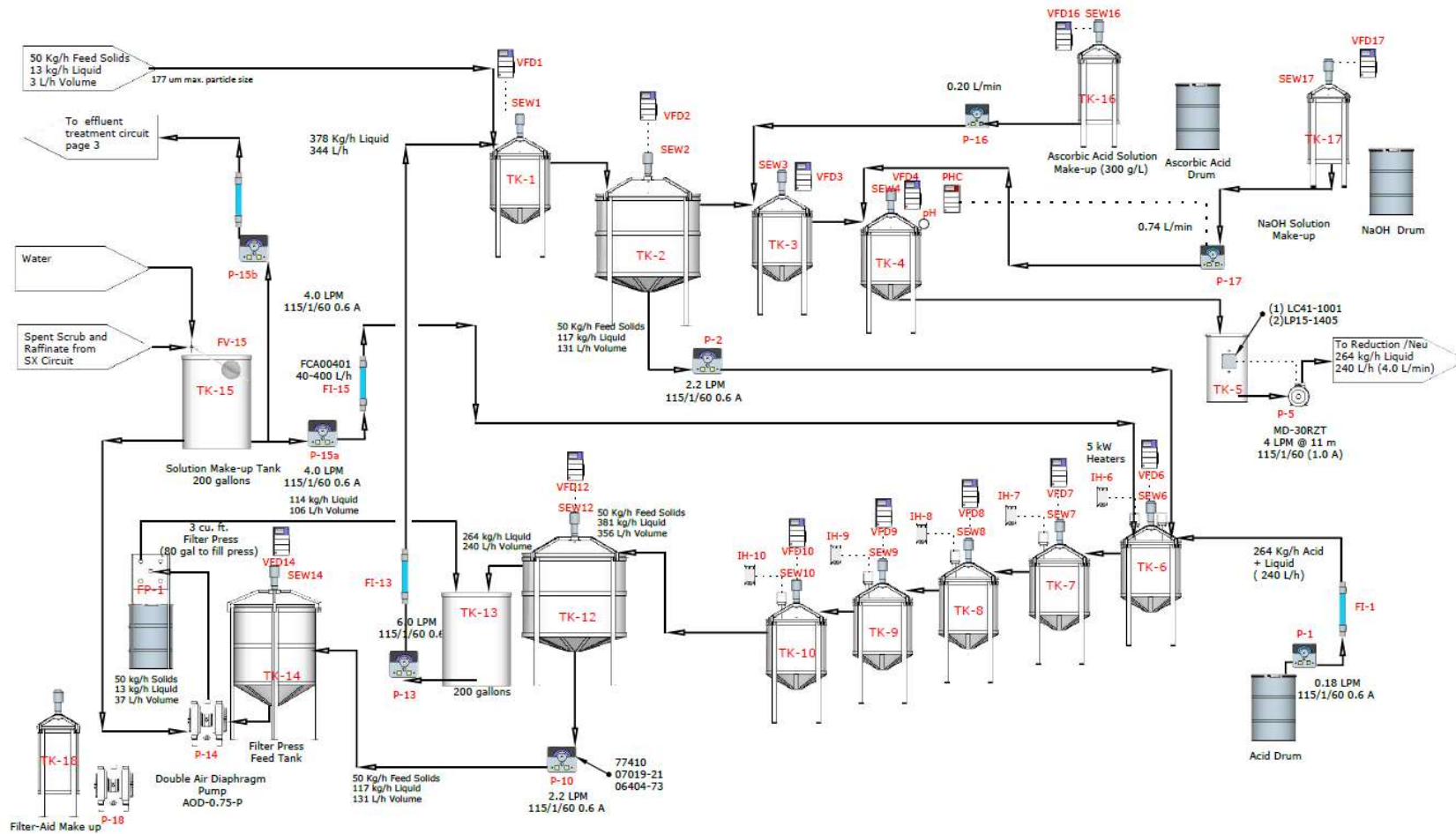
Two-Stage Leaching Circuit



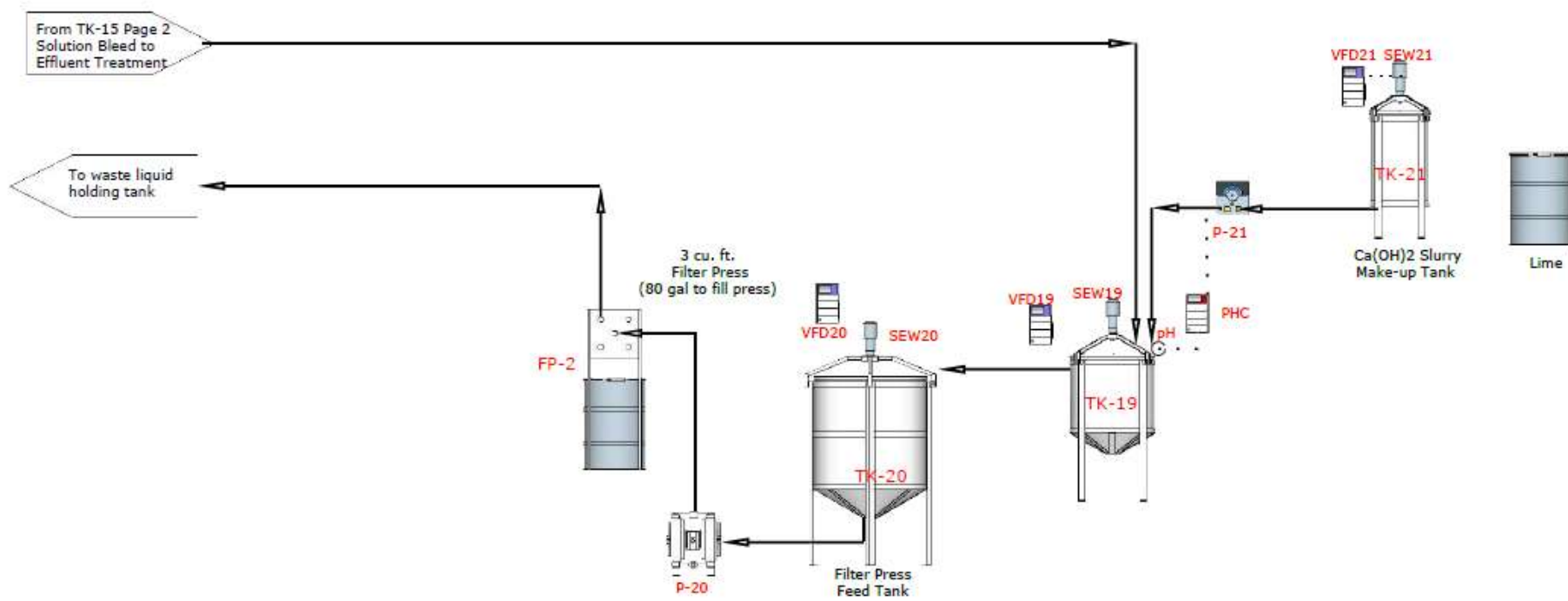
4.00 – Acid Leaching



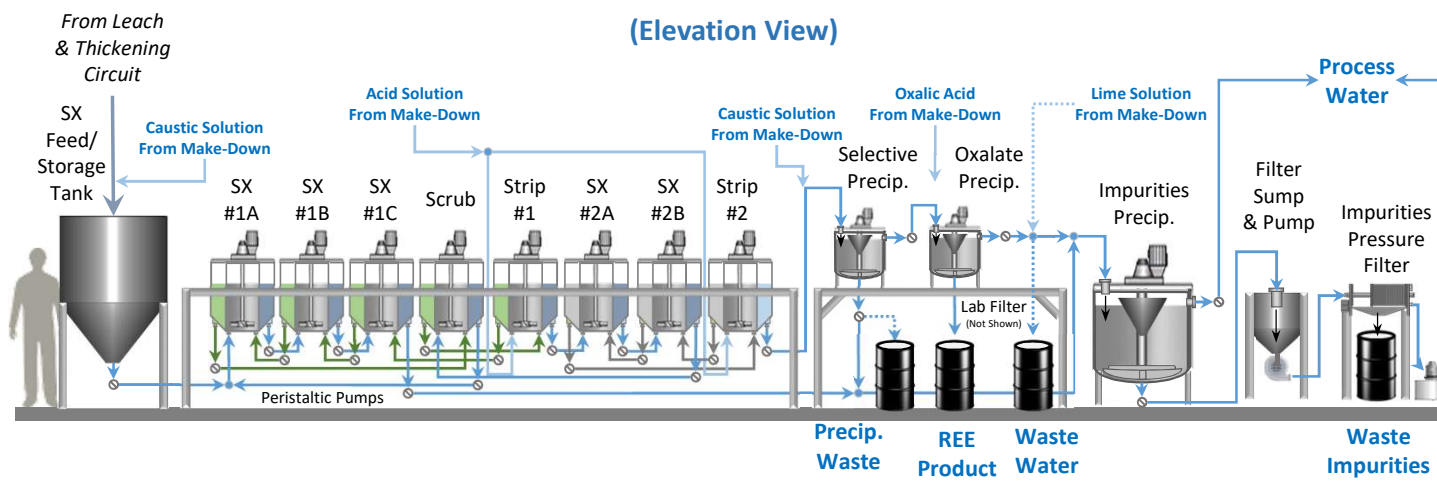
4.00 – Acid Leaching



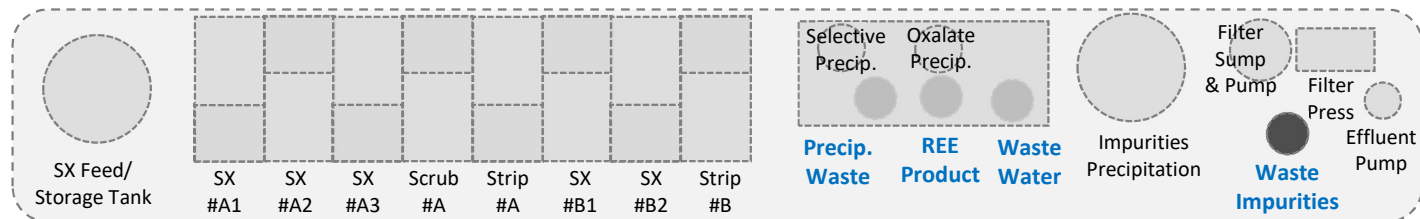
4.00 – Acid Leaching (Contaminant Bleed)



5.00 – Solvent Extraction/Precipitation

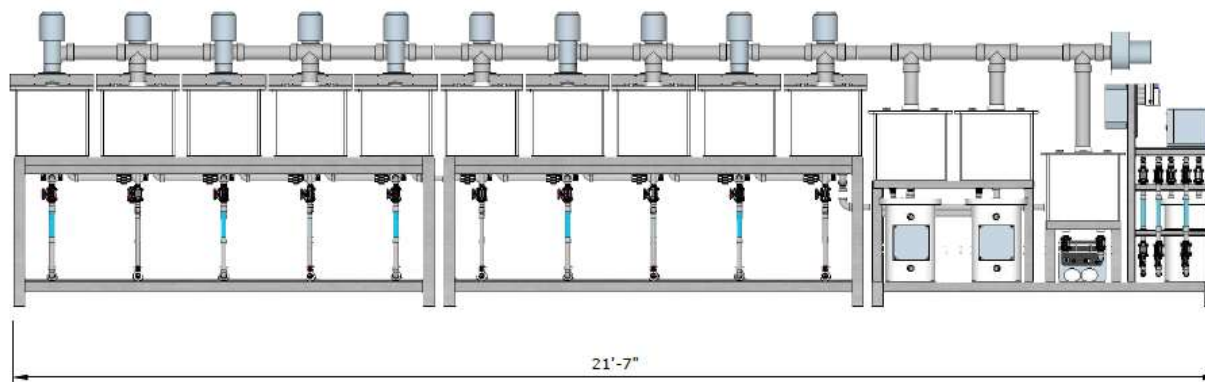
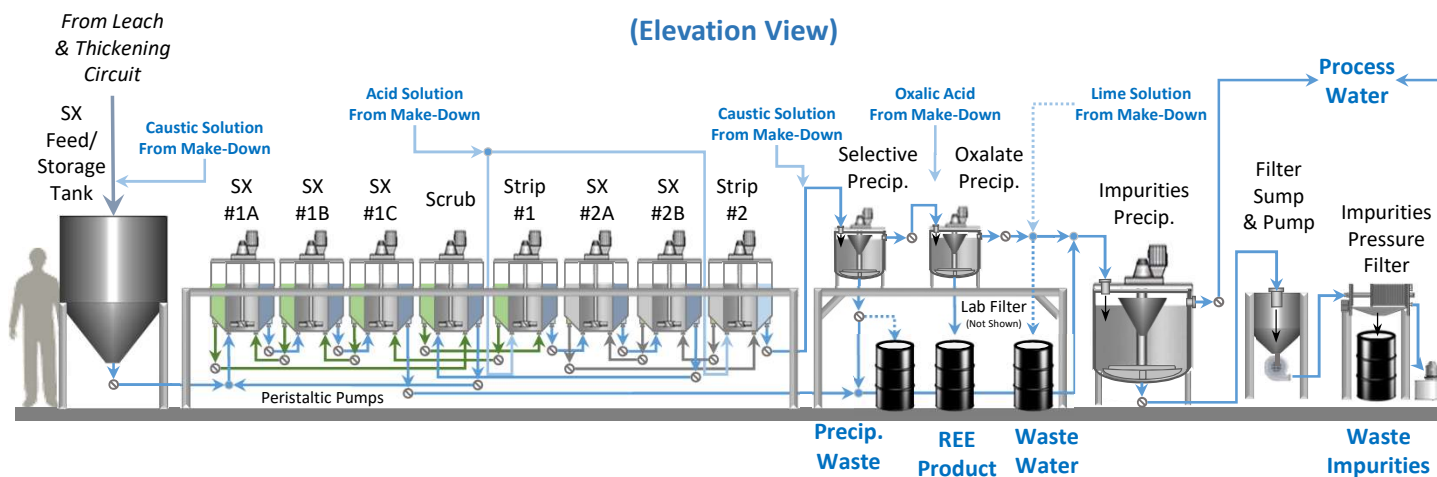


(Simplified Plan View)

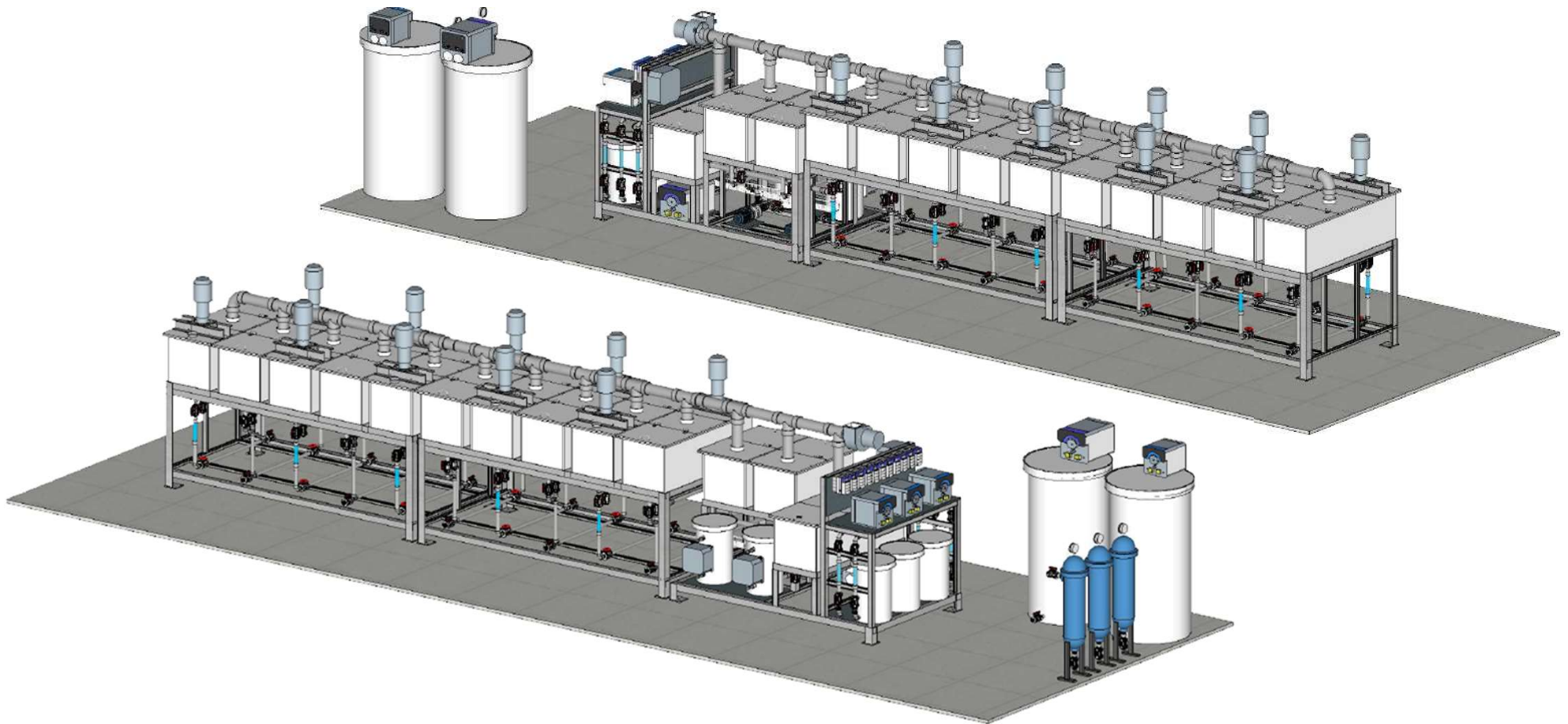


Estimated Area = 45 ft x 6 ft

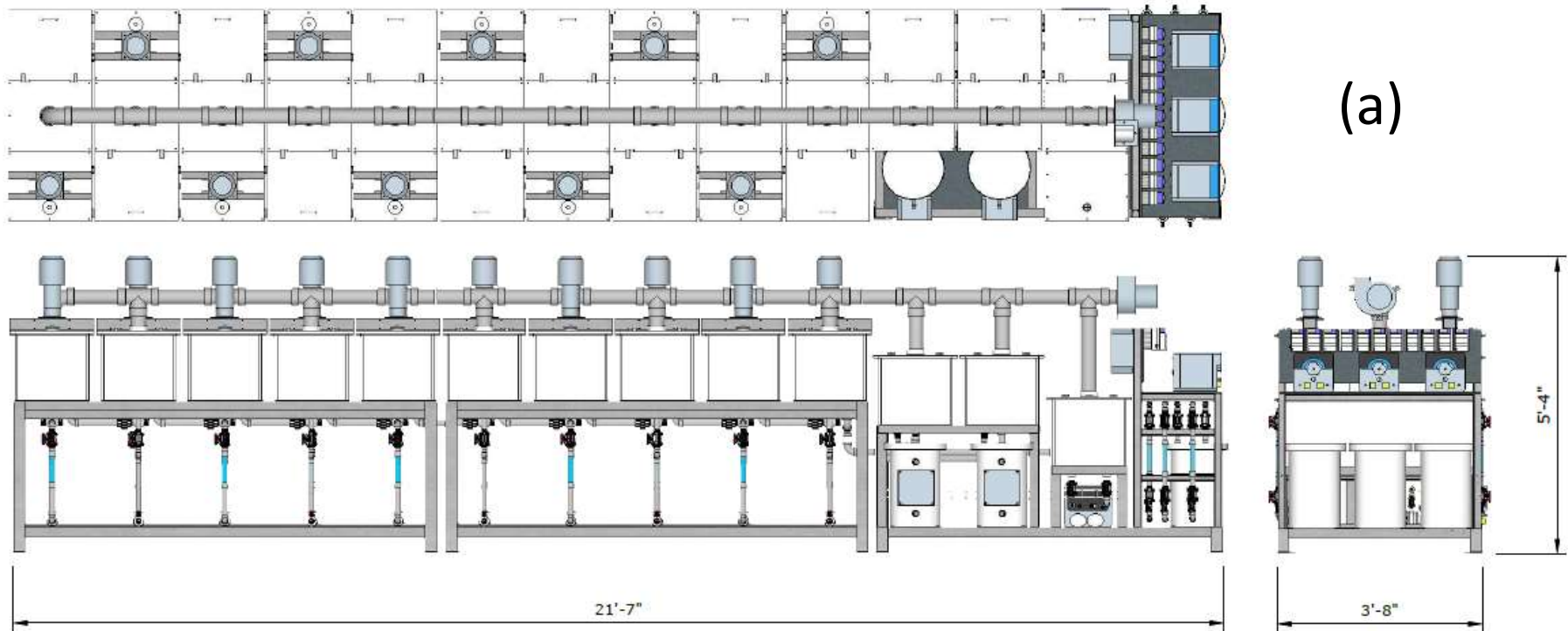
5.00 – Solvent Extraction/Precipitation



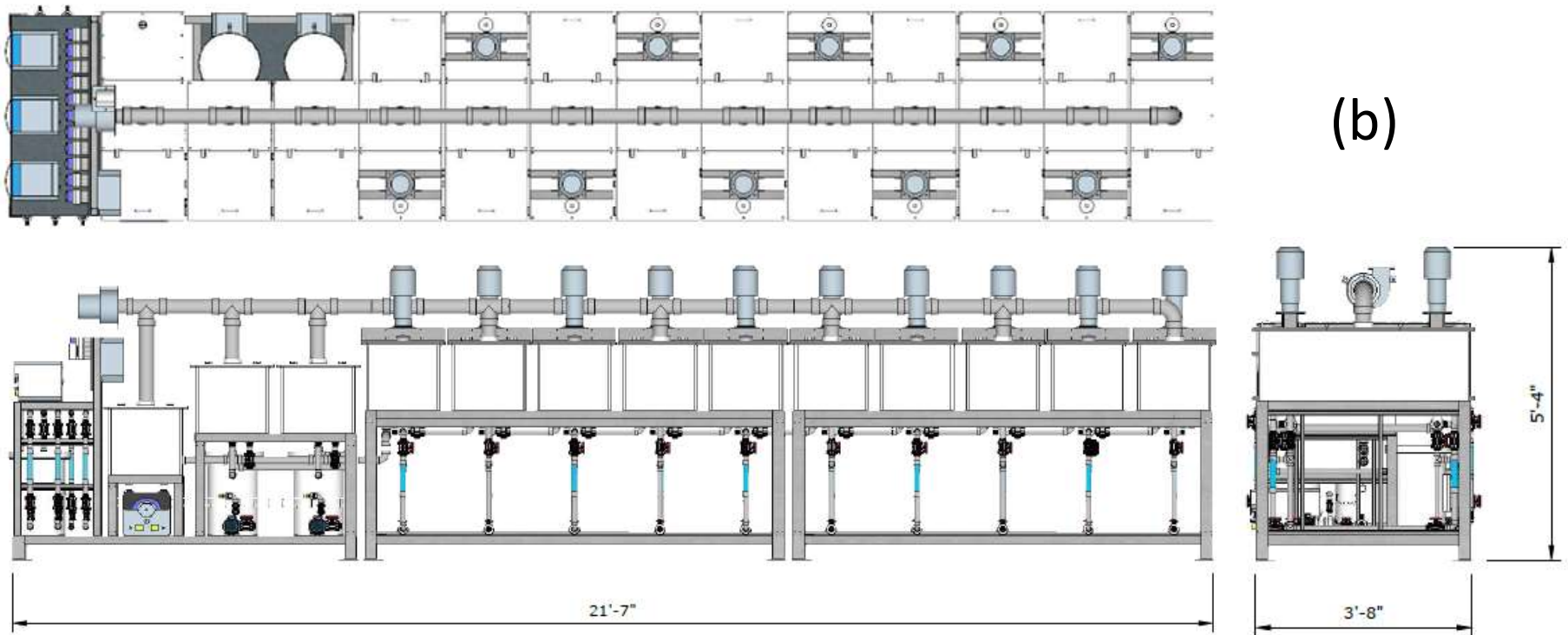
5.00 – Solvent Extraction/Precipitation



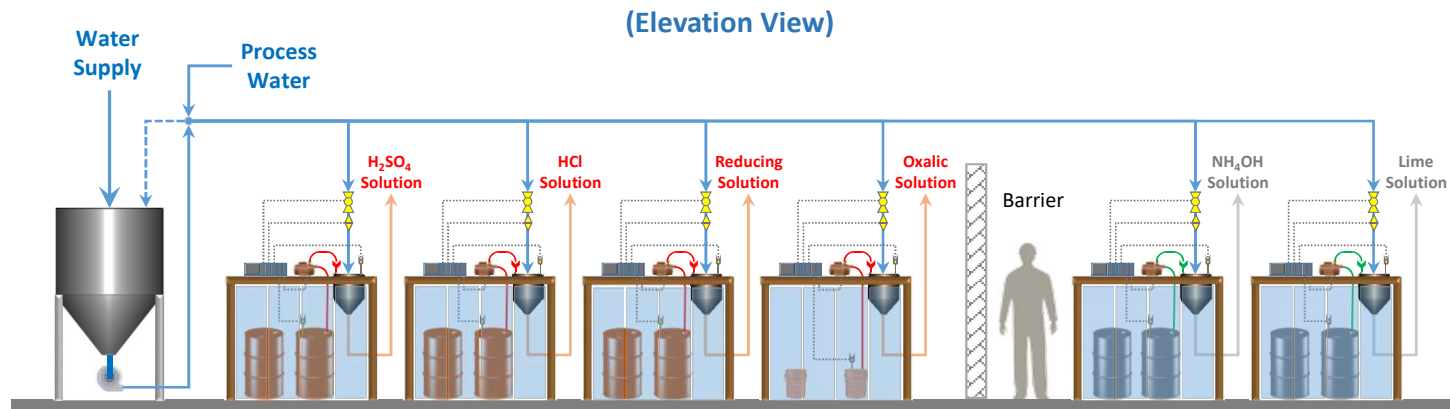
5.00 – Solvent Extraction/Precipitation



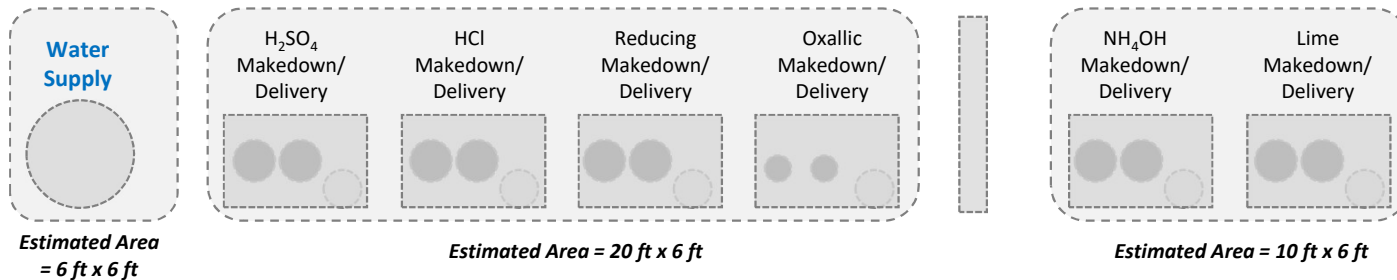
5.00 – Solvent Extraction/Precipitation



6.00 – Chemical Storage

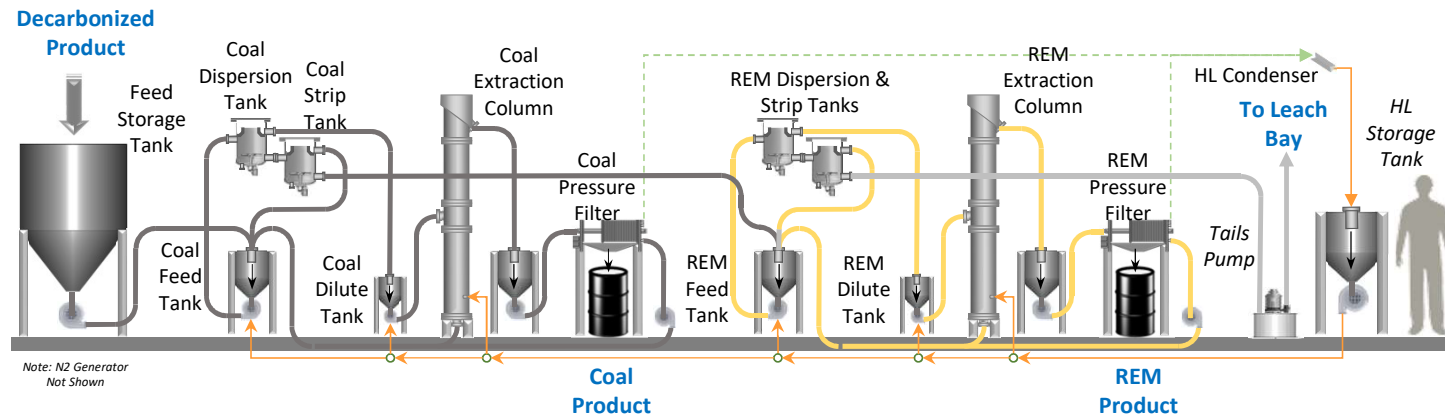


(Simplified Plan View)

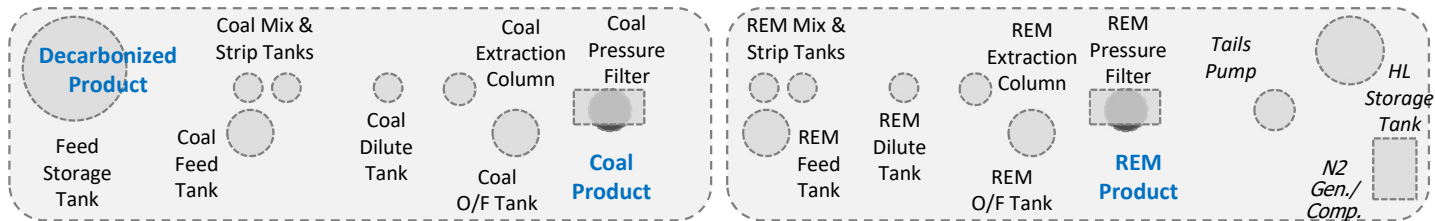


7.00 – REM Concentration

(Elevation View)



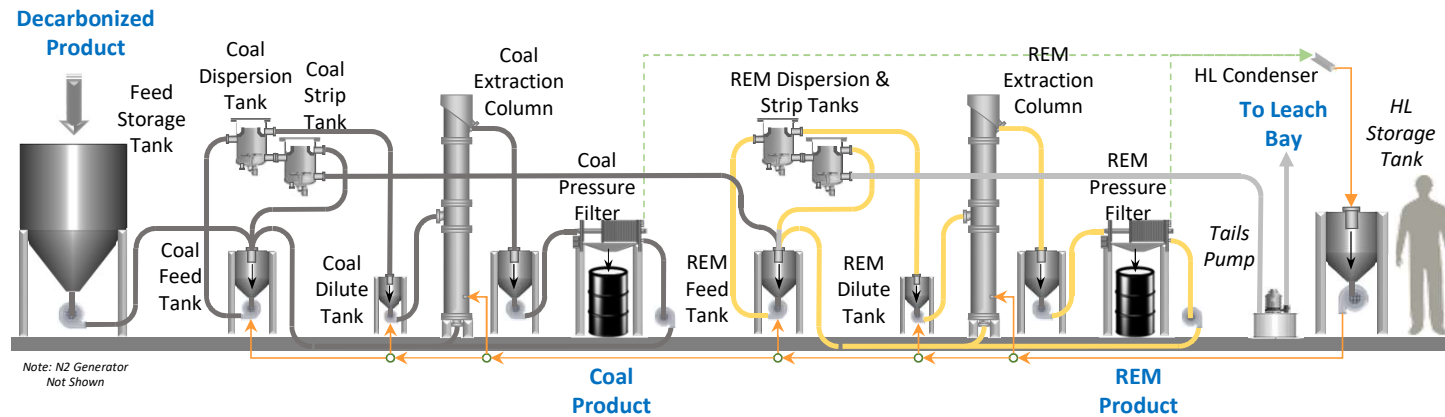
(Simplified Plan View – Alternative Configuration)



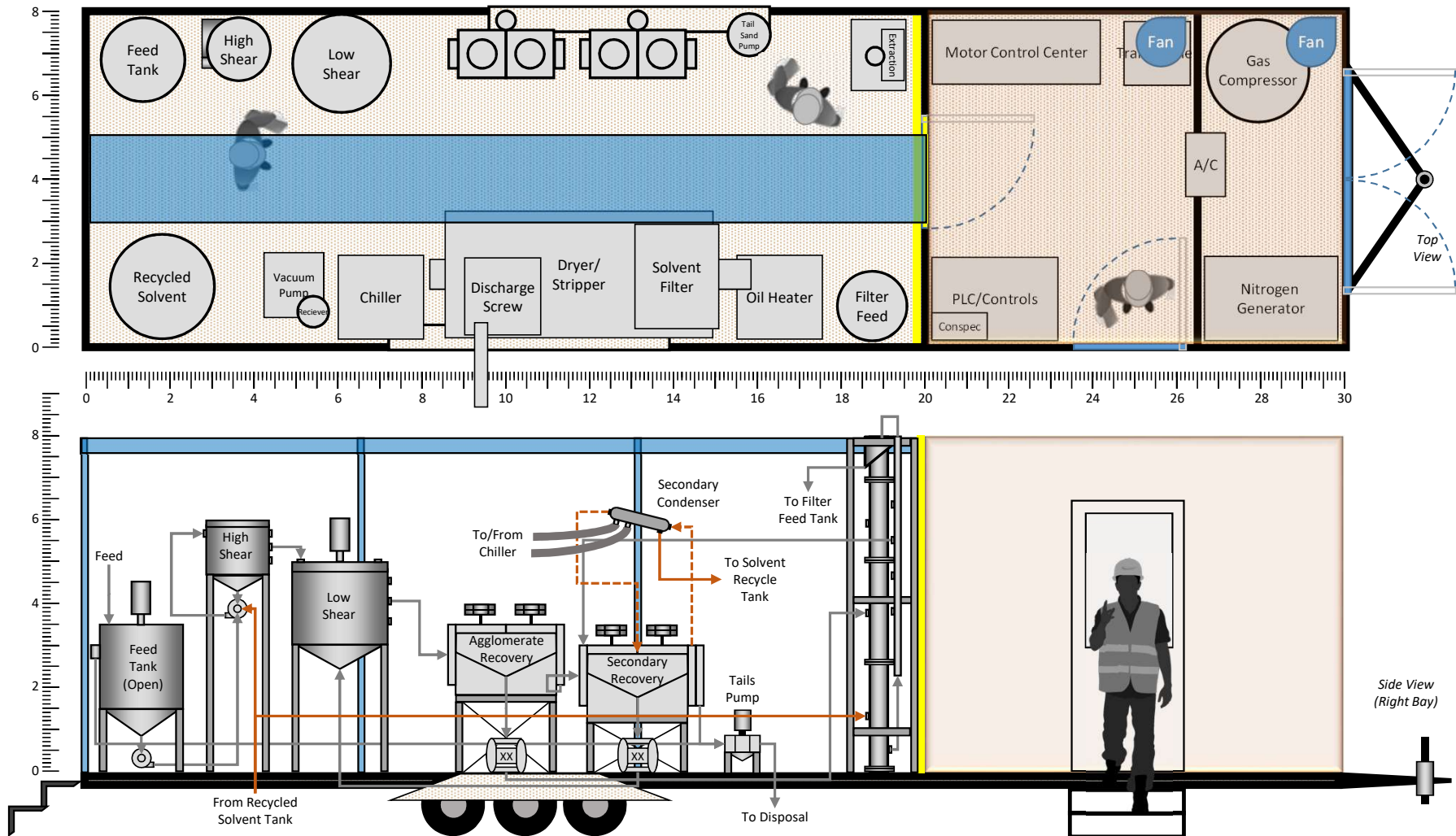
30 ft x 6 ft Bay (Mobile Towable Trailer)

7.00 – REM Concentration

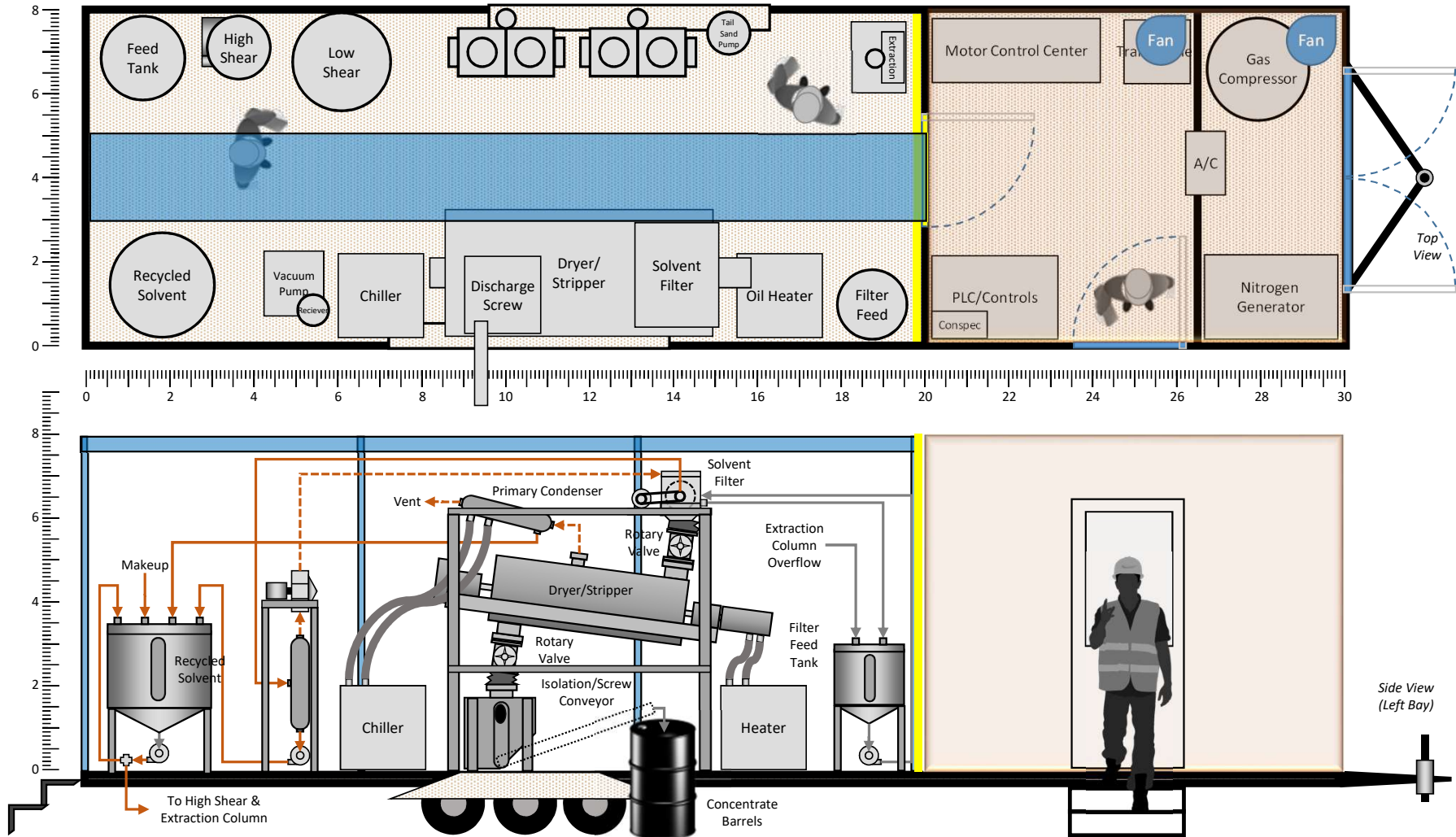
(Elevation View)



7.00 – REM Concentration



7.00 – REM Concentration



Site/Property Layouts

Dotiki Mine Site

Site Photographs

Process Train Layouts

Berms/Drains

Electrical Services

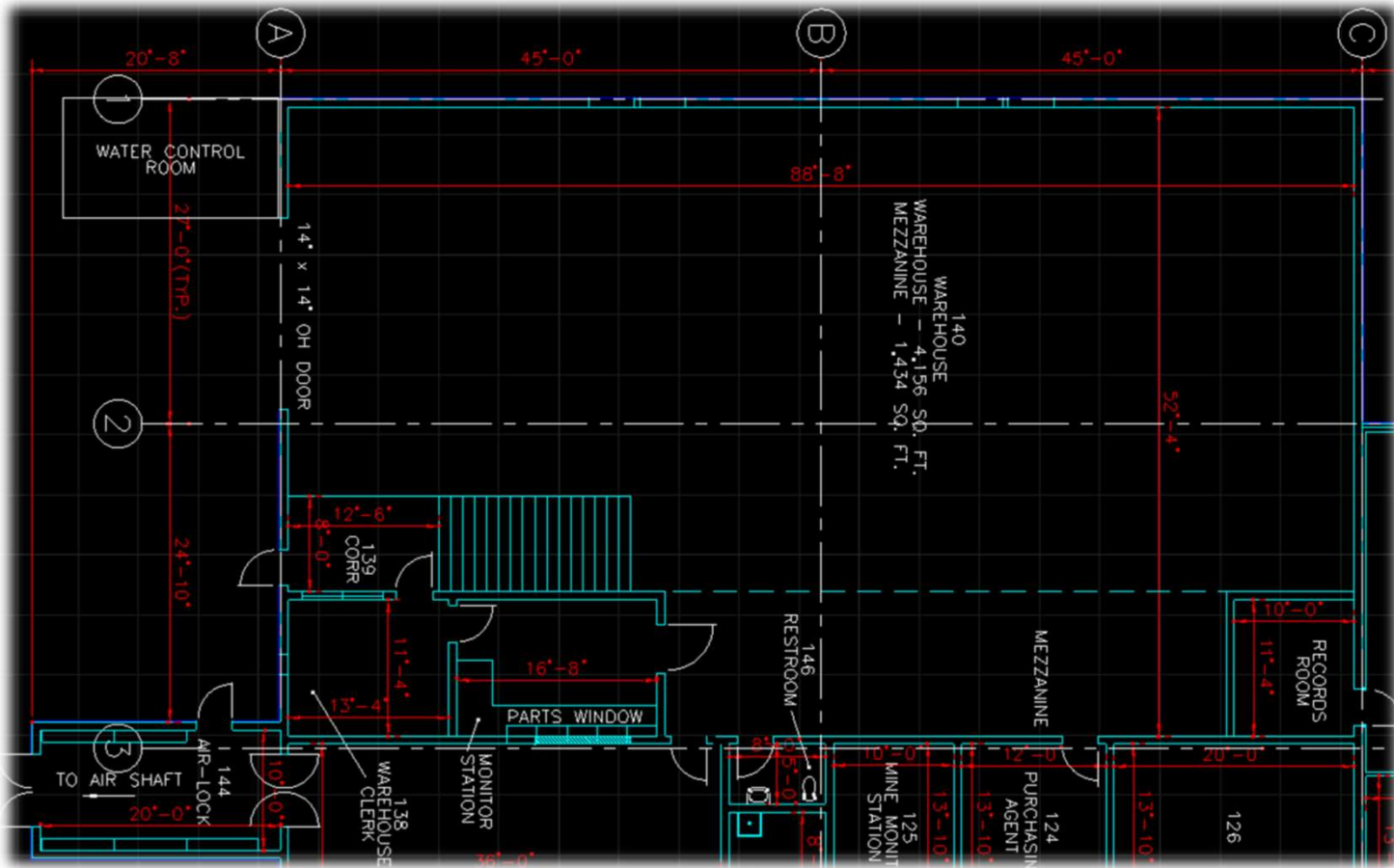
Miscellaneous



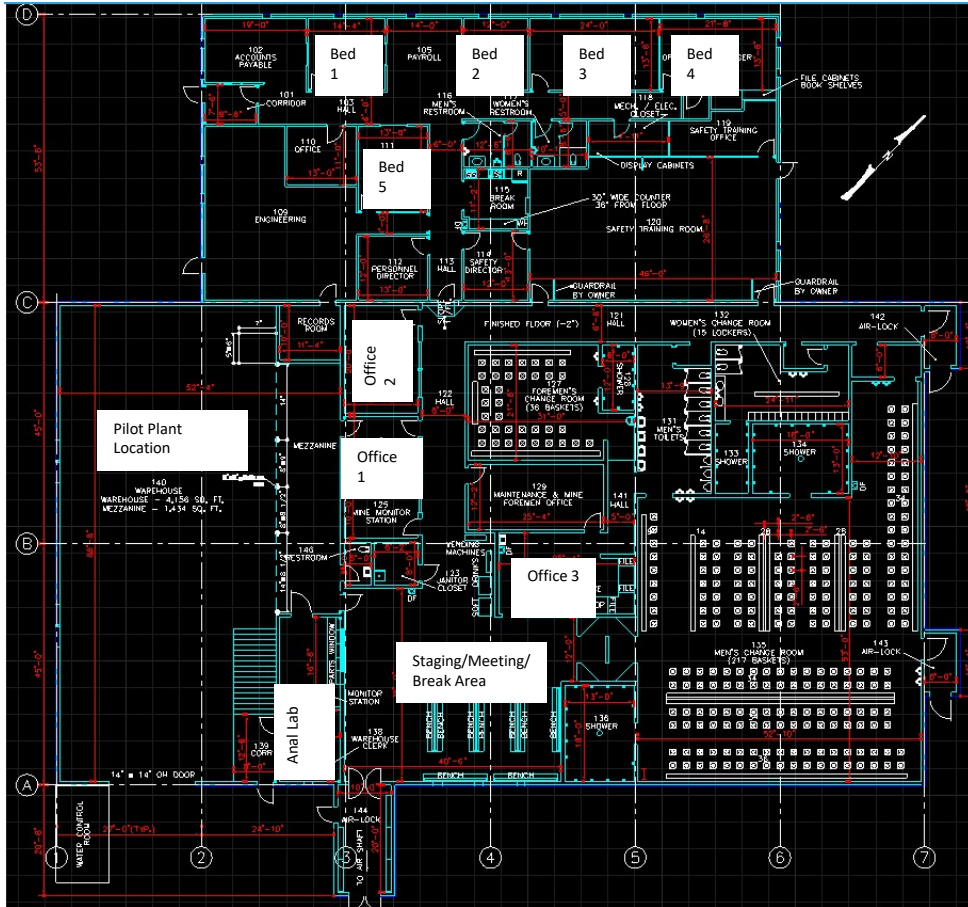
Dotiki – Building Structure



Dotiki – Building Floor Plan



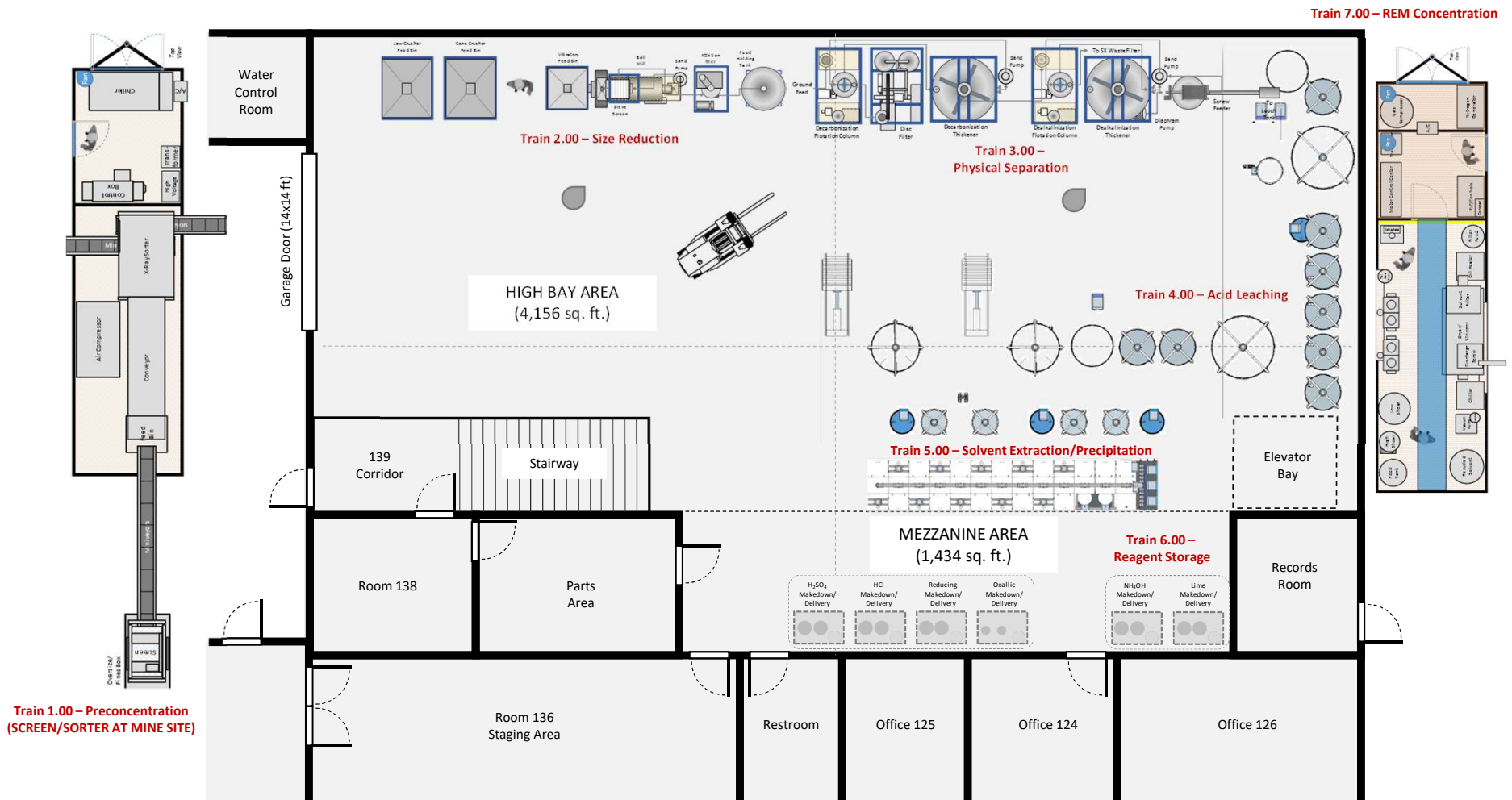
Dotiki – Accommodations



Dotiki – Working Area



Dotiki – Module Configuration



Summary

- Mobile ¼-tph REE pilot-plant will be operational by July 2018.
- System will be tested on multiple feed stocks at two locations.
- Plant consists of seven distinctly different process bays.
- Analyses capabilities will be available onsite to improve efficiency of test program.
- Aspen will be used for systems analyses and a techno-economic study.

