A Partnership of Inventure, TMRC, PSU & K-Tech

Recovery of Rare Earth Elements from Coal Mining Waste Materials

Presented by Rusty Sutterlin Ph.D (Chief Science Officer)

Inventure

LETTERS OF SUPPORT

Blue Line Corporation

TMR Texas Mineral Resources Corp.

Lockheed Martin

Jeddo Coal Company

Mercedes-Benz

NUCOR

Southern Company

Mitternight

ASME Code Shop · Petrochemical Process Equipment

Governor
Kay Ivey

Robert Aderholt
Member of
Congress

Terri Sewell
Member of
Congress

Mayor
Walt Maddox

Senator
Richard Shelby

The University of Alabama

Stillman

PennState

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The Search for REE’s

Refined the Methodology of Using Yttrium as an Indicator to Estimate Total Rare Earth Element Concentration

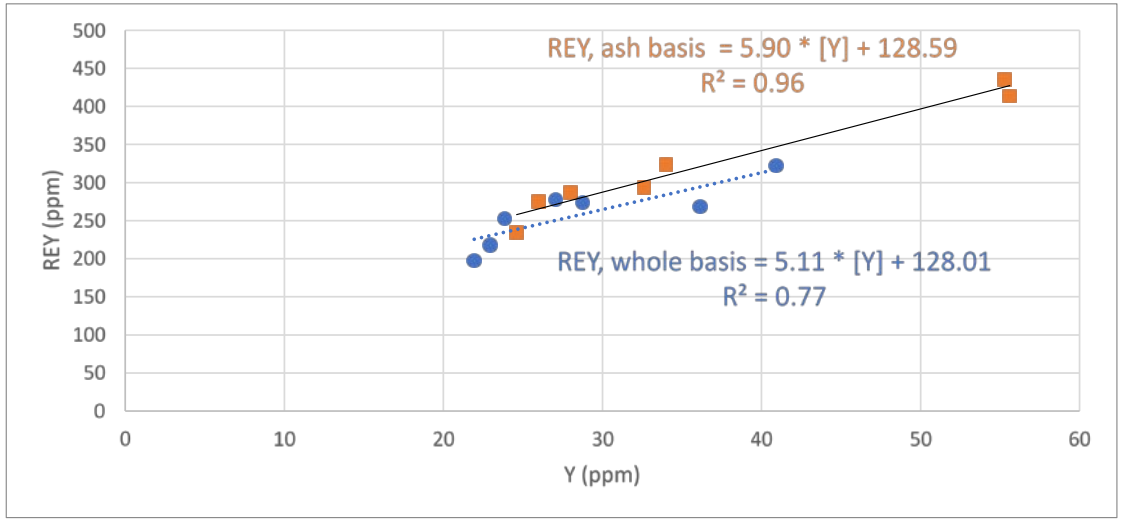
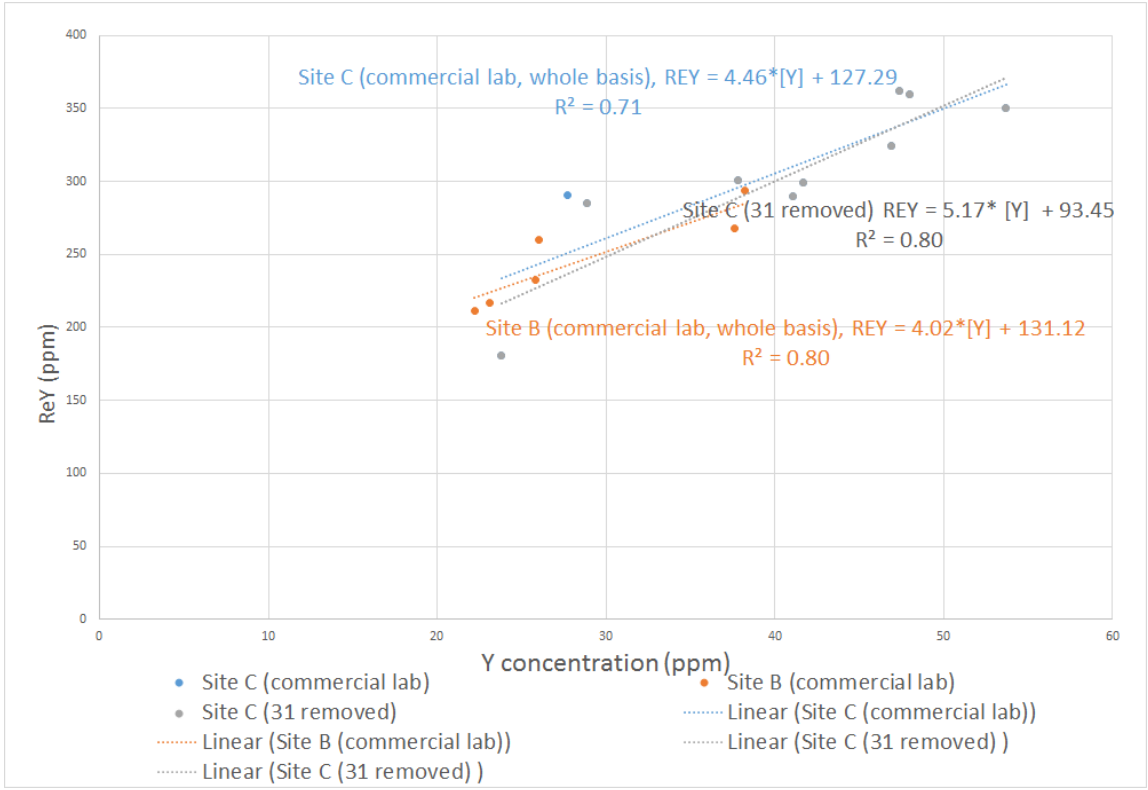


Figure 6. Linear fits of REY versus Y for samples B1-B7



Source: **Xiaojing Yang , Daniel Kozar , Daniel Gorski , Anthony Marchese, James Pagnotti, Rusty Sutterlin , Mohammad Rezaee, Mark S. Klima , Sarma V. Pisupati**, "*Using Yttrium as an Indicator to Estimate Total Rare Earth Element Concentration: A Case Study on the Rare Earth Element and Yttrium Distribution Patterns of Materials Associated with Pennsylvanian Coal*s", Manuscript to be submitted to **Journal of Rare Earth Elements**

North Eckley, Pa. Site

Pagnotti Enterprises, Inc

- Phase 1 Search Resulted in
  - Analyzed 74 coal overburden samples from 9 mine sites
  - 17 AMD sludges with more to go

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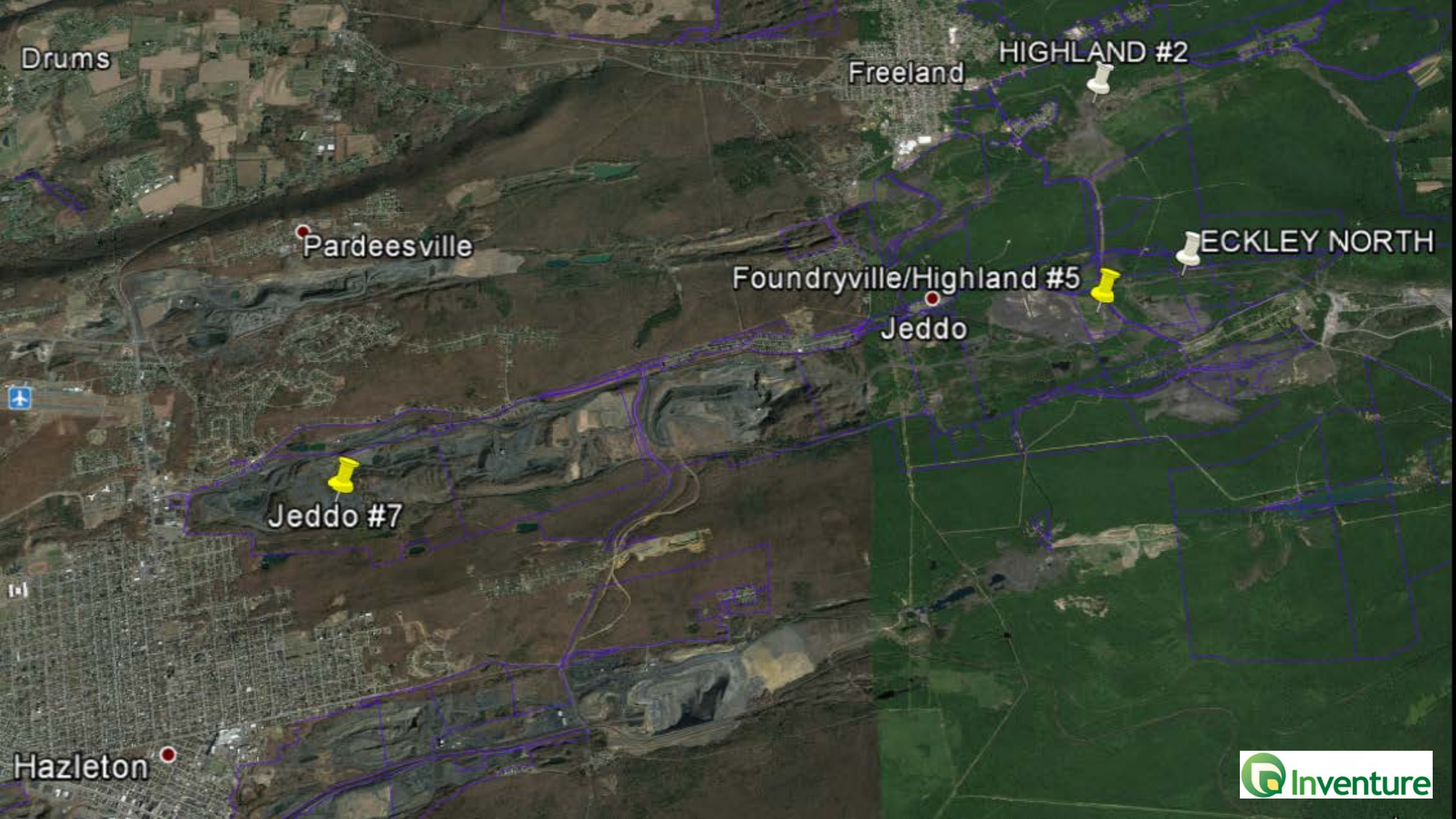
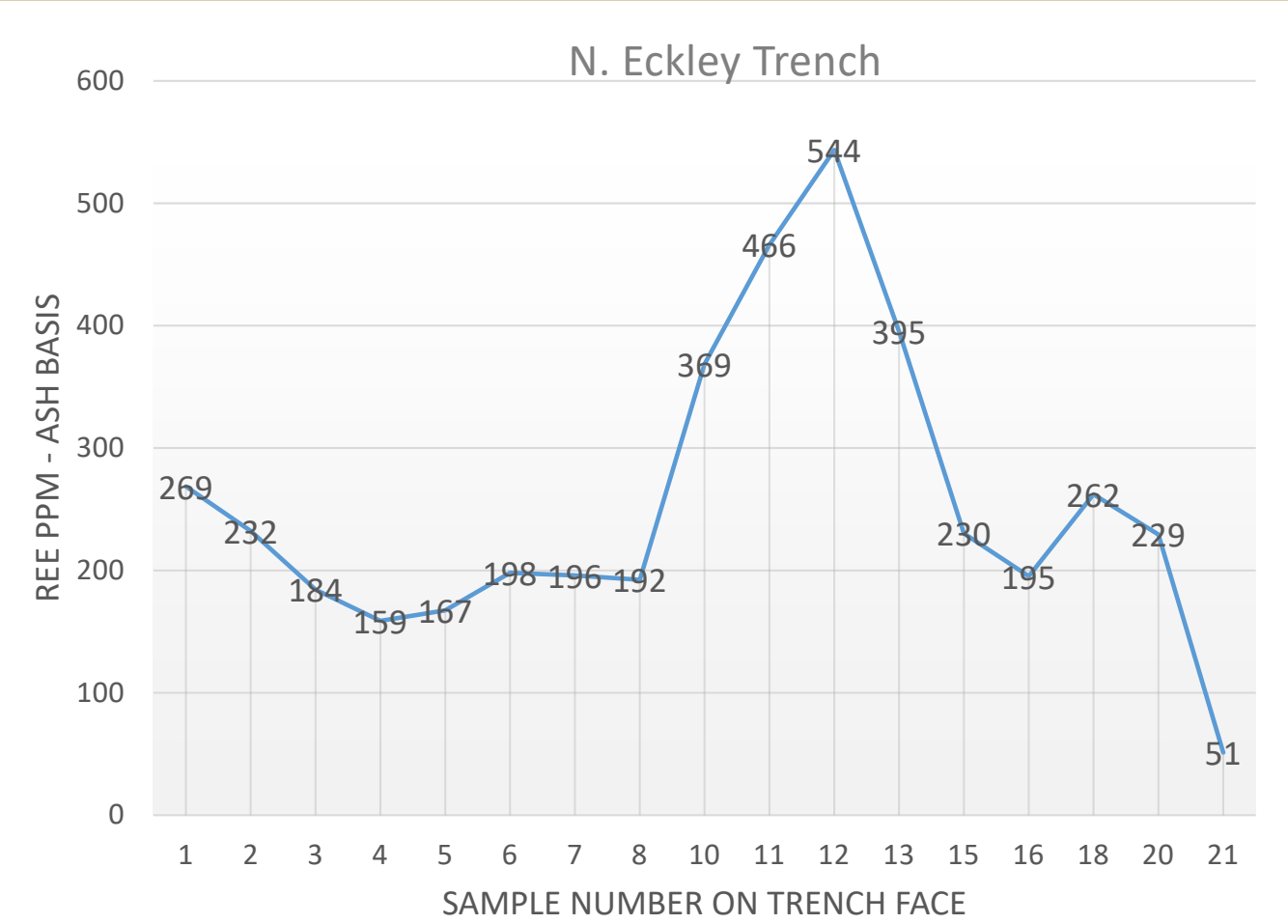

Drums
Freeland
HIGHLAND #2
Pardeesville
ECKLEY NORTH
Foundryville/Highland #5
Jeddo
Jeddo #7
Hazleton
Inventure

North Eckley, Pa. Site



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Acid Mine Drainage Sludge

Location	Description	Total REE ppm (Whole Dry Basis)
Central, PA	AMD 1	604
Central, PA	AMD 2	1716
Central, PA	AMD 3	734

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Extraction and Separation of REE’s and Valuable BiProducts

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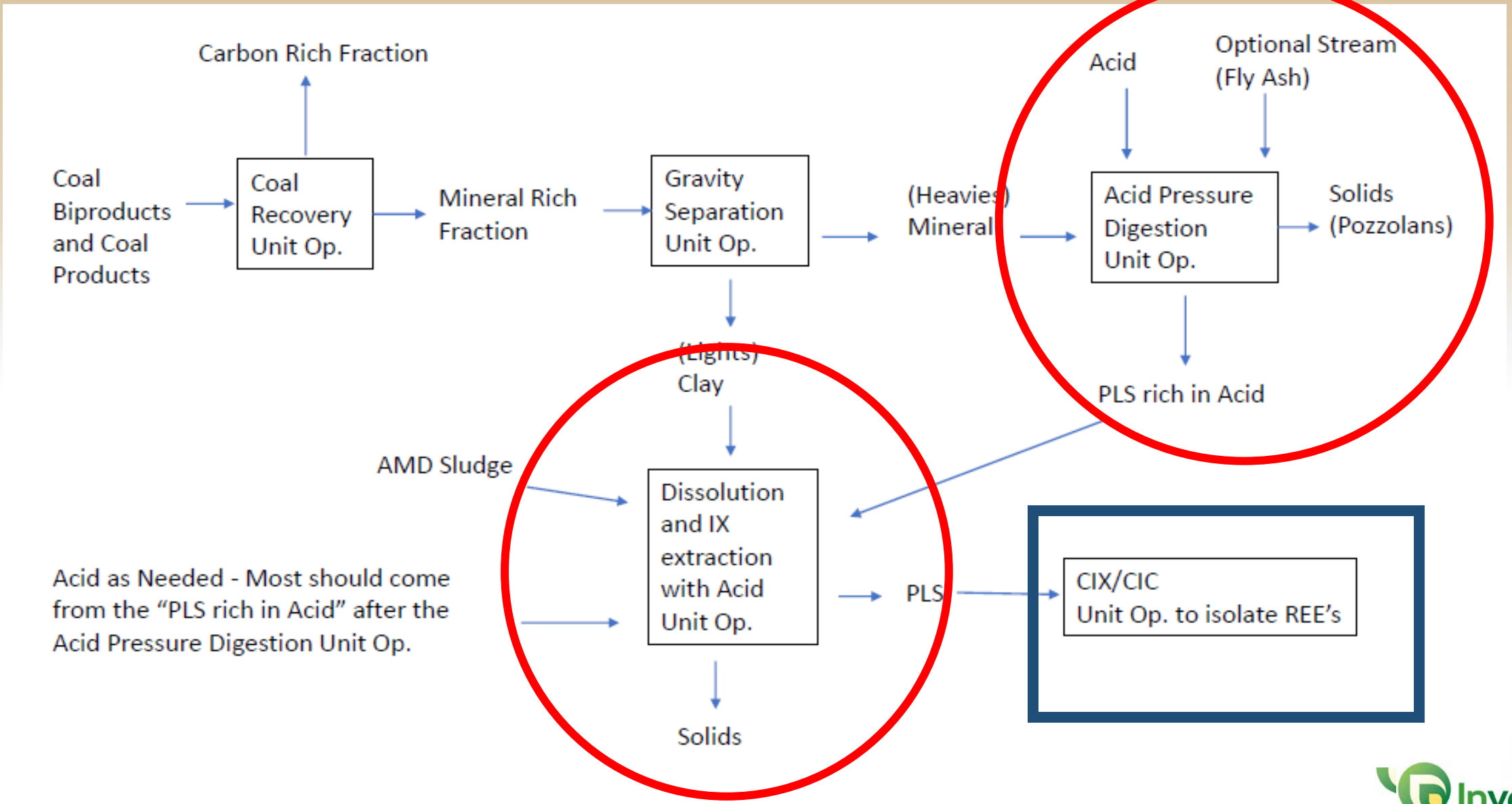
Multi-Feedstock Extraction Process to Generate a Pregnant Leach Solution (PLS)



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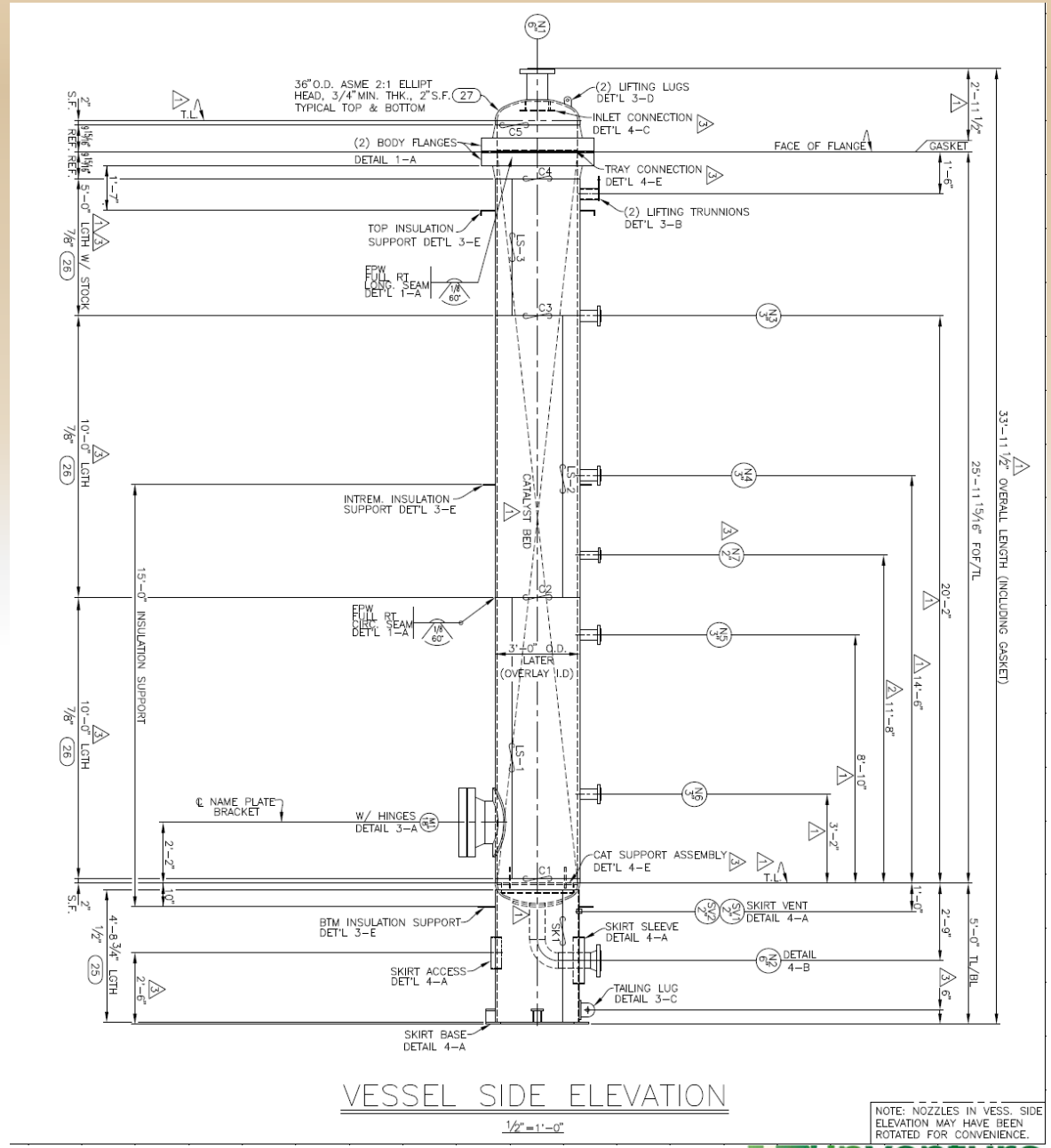
Method 1 to Generate a PLS

High Temperature (210°C) Pressure Leach



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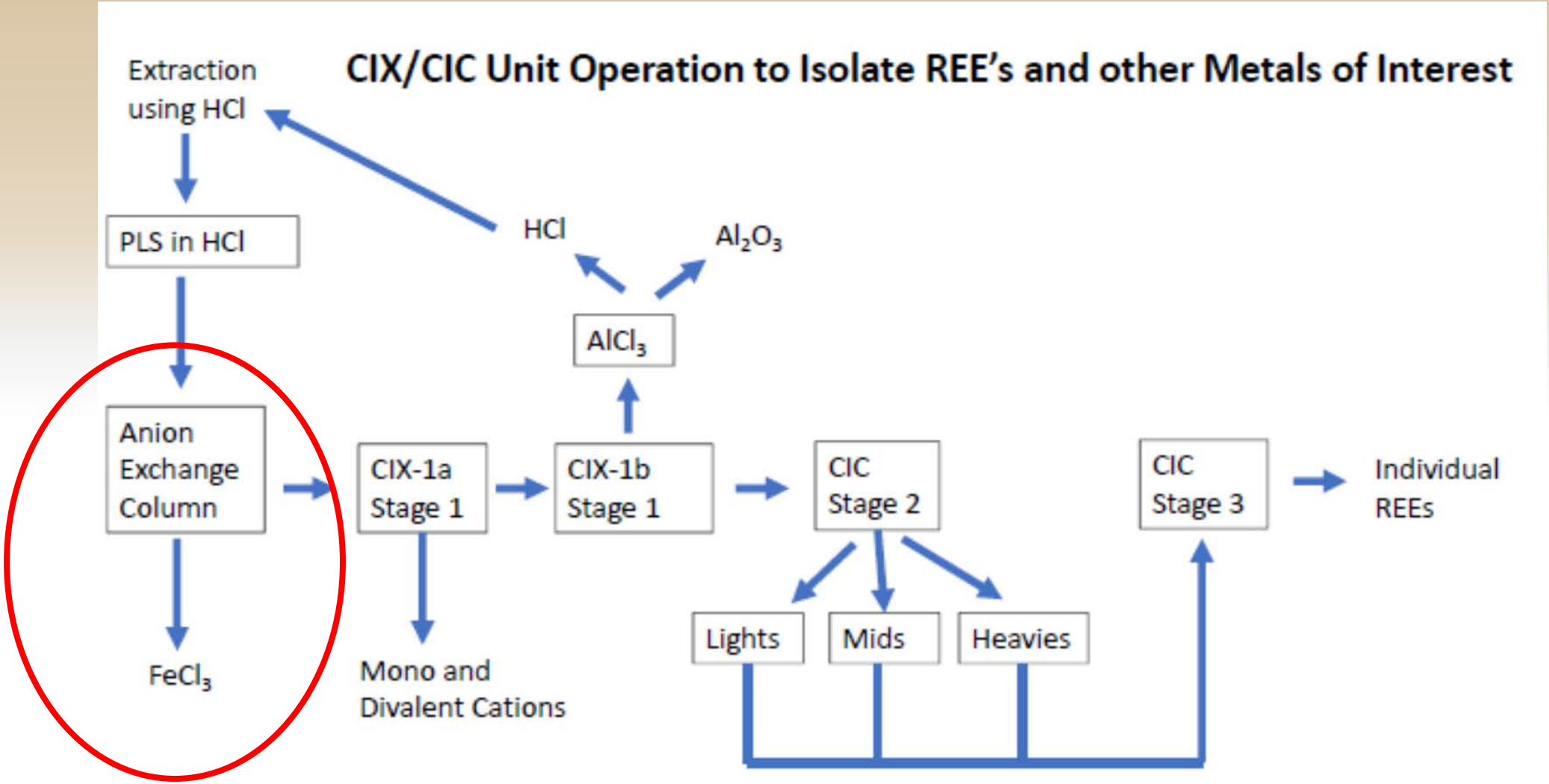
Method 2 to Generate a PLS

Ambient Acid Leaching

Separation Process - Anion Exchange



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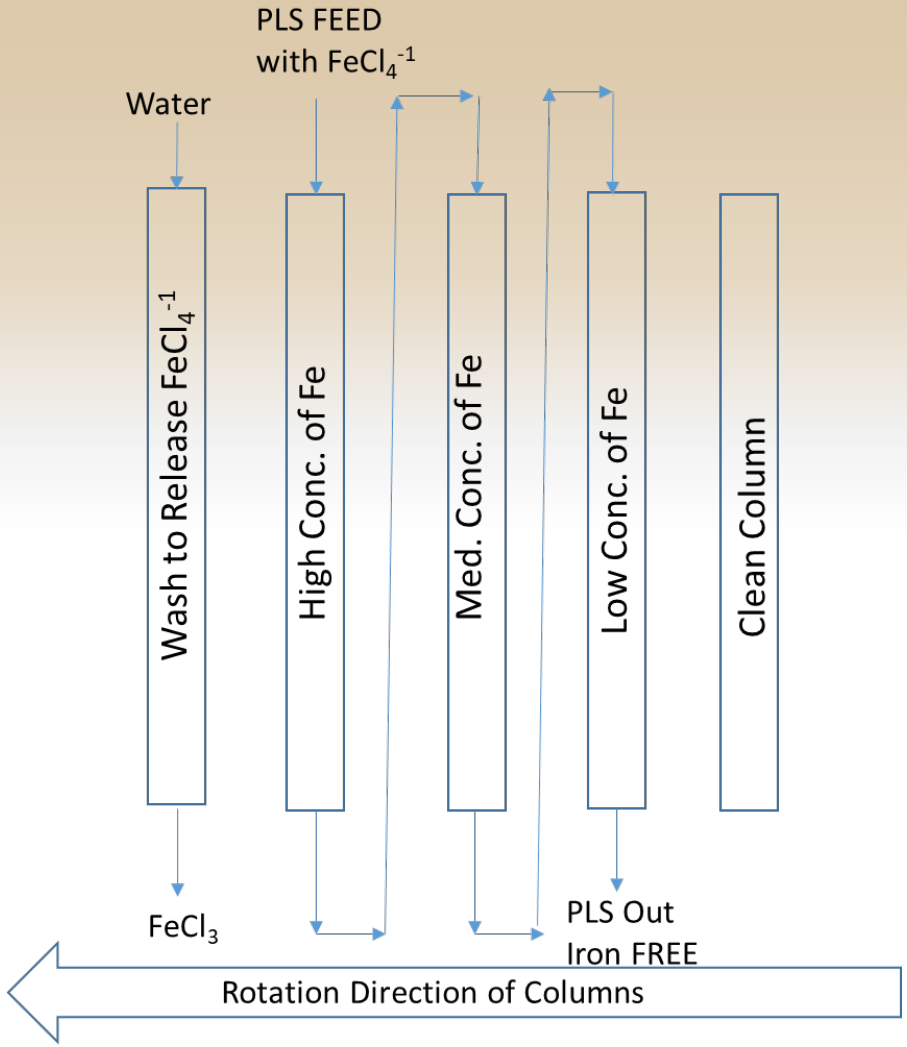
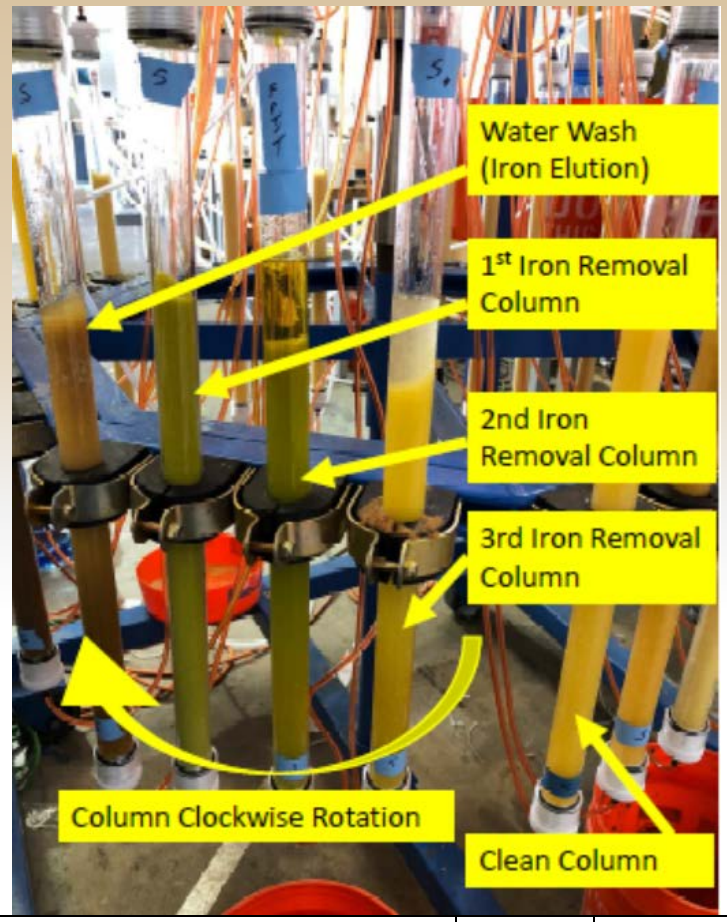
Separation Process - Anion Exchange

Iron Removal Step

$3HCl + Fe \rightarrow FeCl_3$
$4HCl\ (excess) + Fe \rightarrow FeCl_4^{-1}$
$FeCl_4^{-1} + H_2O\ (wash) \rightarrow FeCl_3$

The $FeCl_3$ solution is a popular water flocculating agent used all over the world for water purification.





Sample Name	Iron (ppm)	REE (ppm)
PLS CIX FEED	1566.7	150.3
PLS Solution exiting the Iron Removal Column	3.6	126.6
Iron Exiting the Iron Water Wash Column	2412.0	19.9

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Separation Process - Anion Exchange

Iron Removal Step

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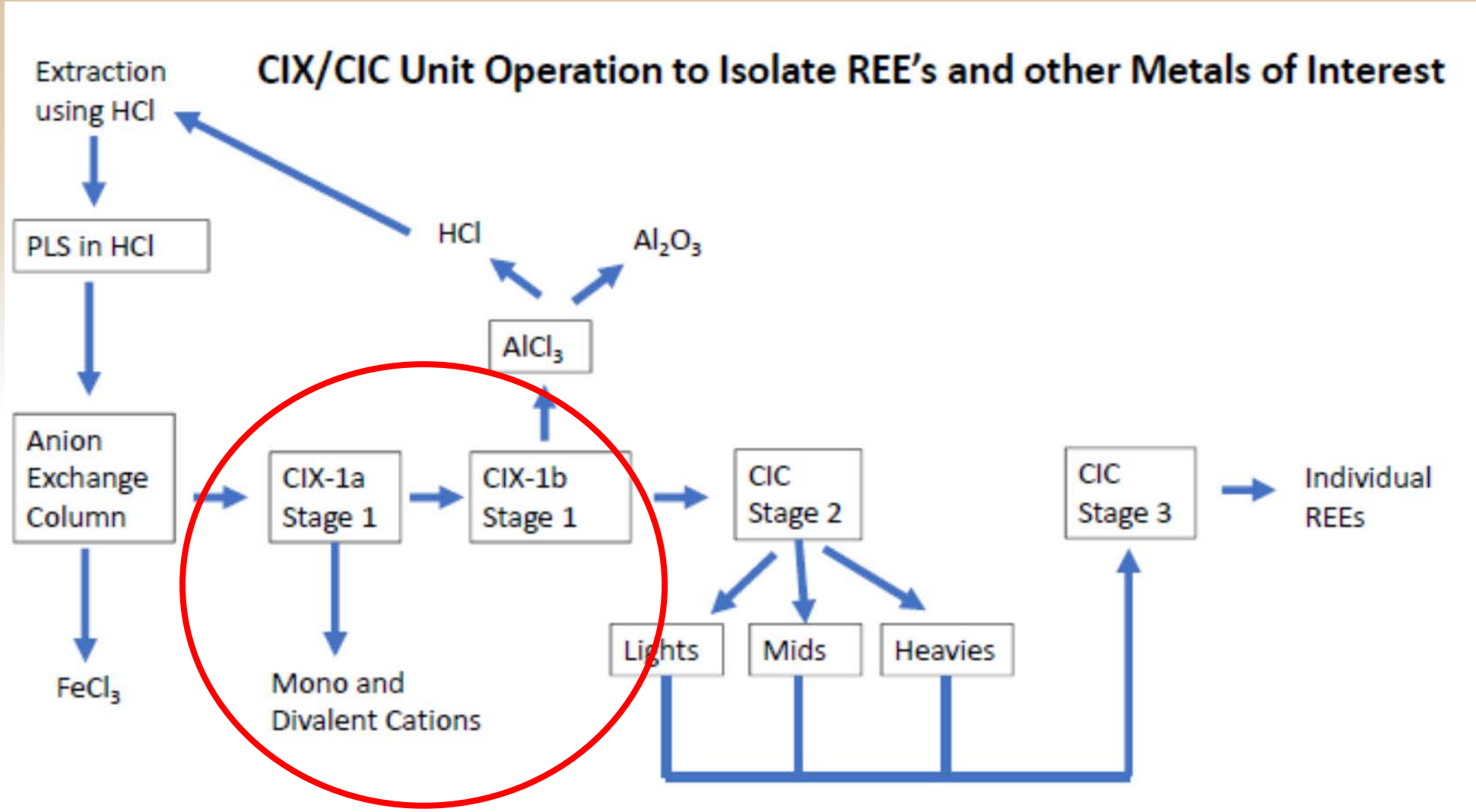
Separation Process – CIX Stage 1

Non- REE Removal



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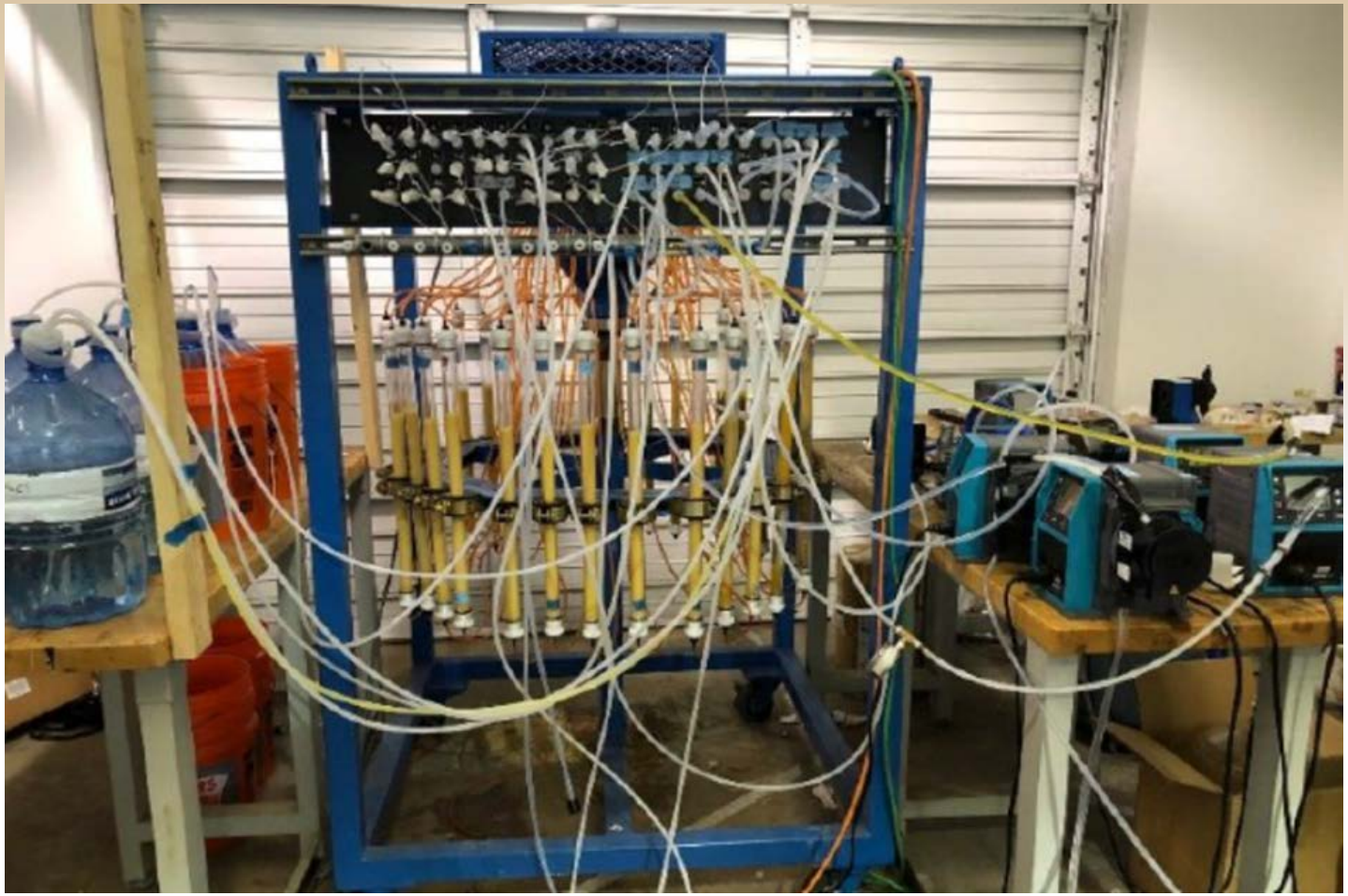
Separation Process – CIX Stage 1



REEs recovered after acid mine drainage sludge has passed through the CIX system.

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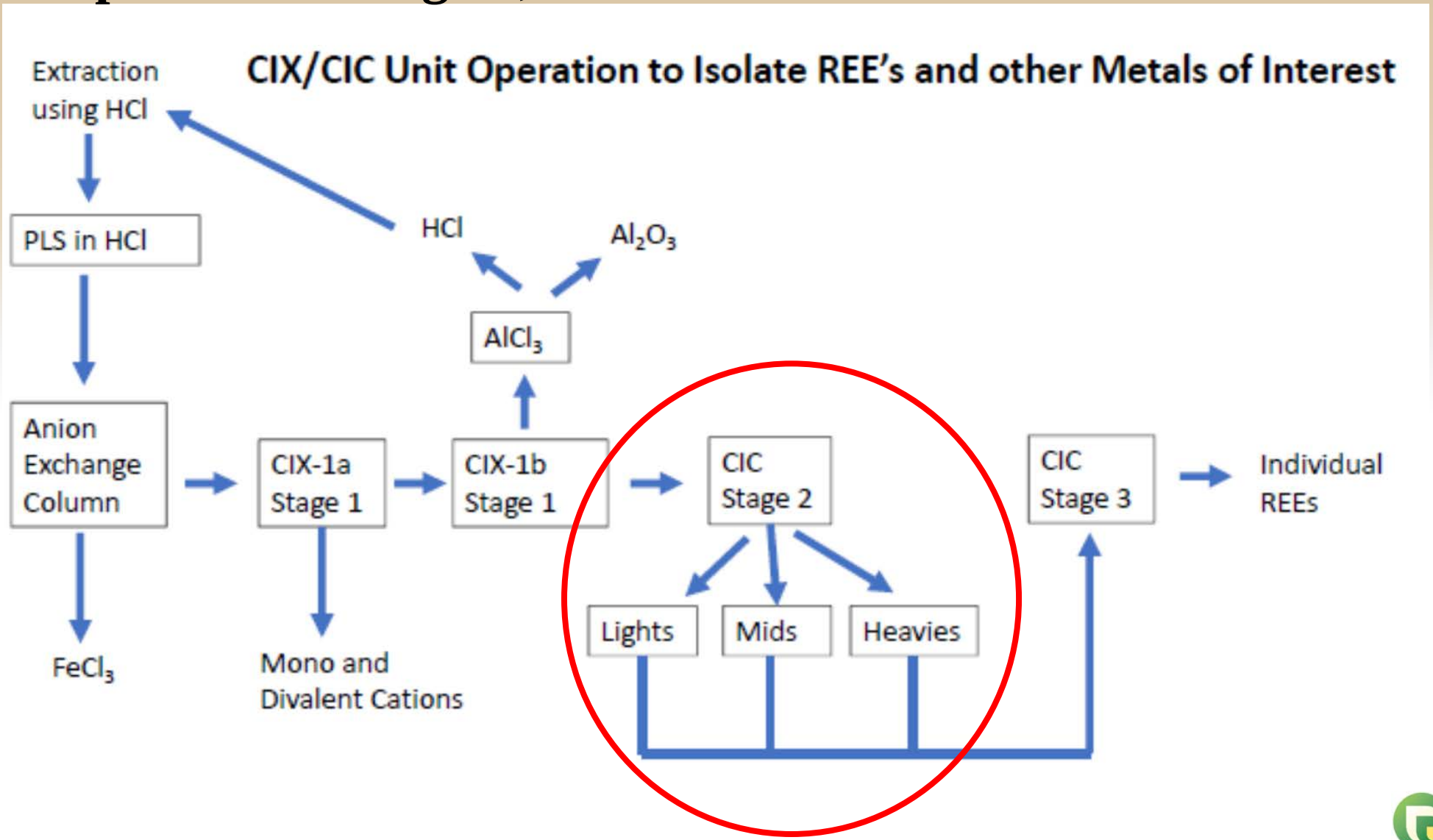
Separation Process – CIX Stage 2

Separation to Lights, Mids and Heavies.



Separation Process – Stage 2

Separation to Lights, Mids and Heavies.

Smaller chromatography system used for stage 2 that separates the REEs into their light, mid and heavy fractions.

Lights	Mids	Heavies
Individual REE, 314.88 ppm SC – 29.76 Y- 8.05 La - 62.92 Ce – 214.15	**Individual REE, 107.56 ppm** Pr – 9.63 Nd – 63.29 Sm – 13.66 Eu – 4.27 Gd -16.71	**Individual REE 33.06ppm** Tb – 1.95 Dy – 8.05 Ho – 10.24 Er – 5.85 Tm – 1.46 Yb – 4.51 Lu – 1.00
The results after Stage 2 that show the REE's divided up into three fractions.		

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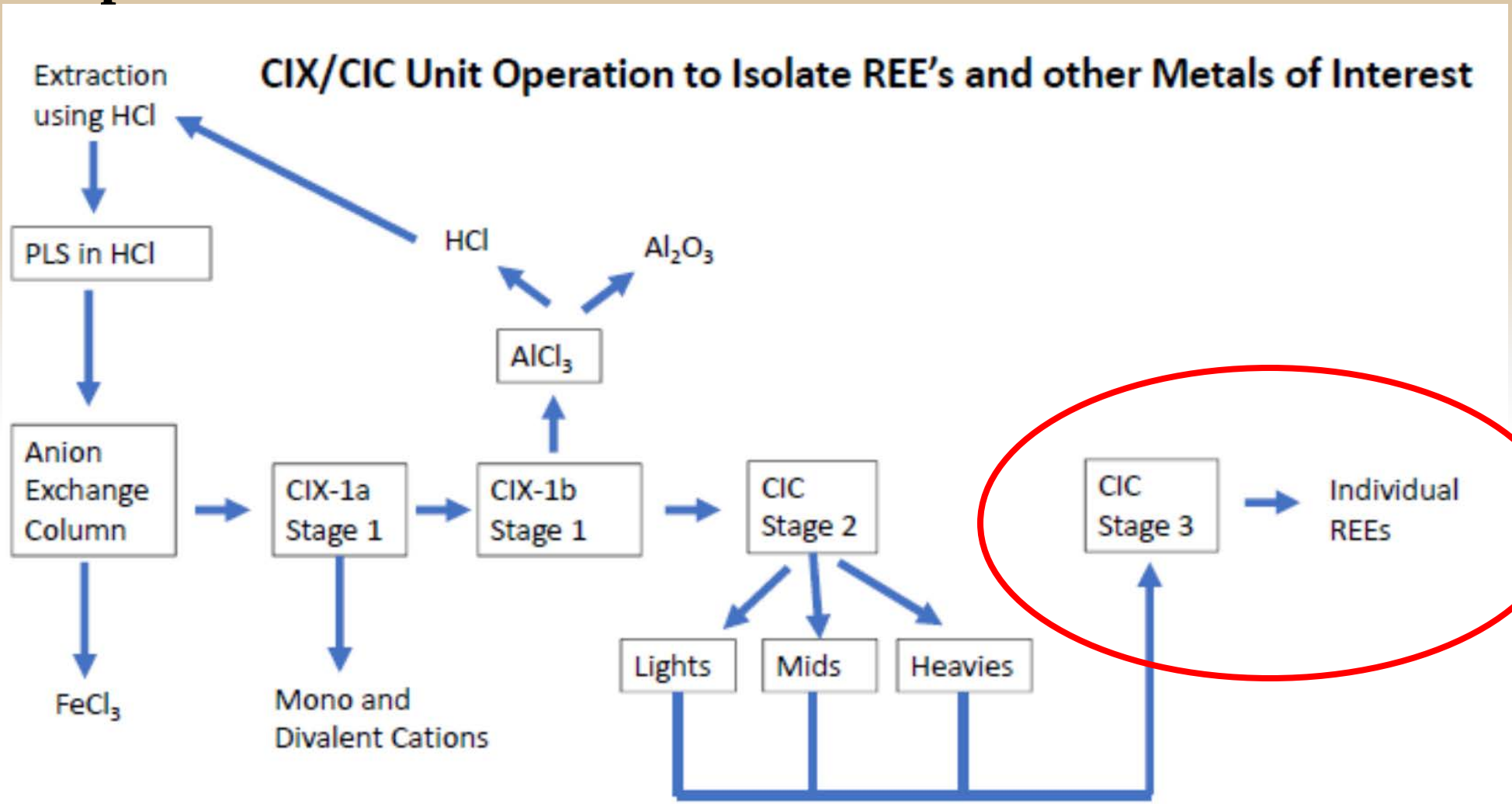
Separation Process – Stage 3

Separation to Individual REEs.



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Separation Process – Stage 3

Separation to Individual REEs.

REE Samples

Do REE’s Make Money?

Revenue Streams of Aluminum, Iron and REE's

Assuming 200 MTPD with our Elemental Composition and DOE REE Pricing

	MT/year	Recovery %	Sell Price ($/MT)	Gross Component Revenue ($/yr)
Aluminum	5544	0.75	2350	13,028,400
Iron	4950	0.75	52	257,400
REEs TOTAL	19	0.75	From Worksheet	4,753,730
Note: Iron Chloride is $400/Ton and is a 40% solution. (14% Ferric Ion)				

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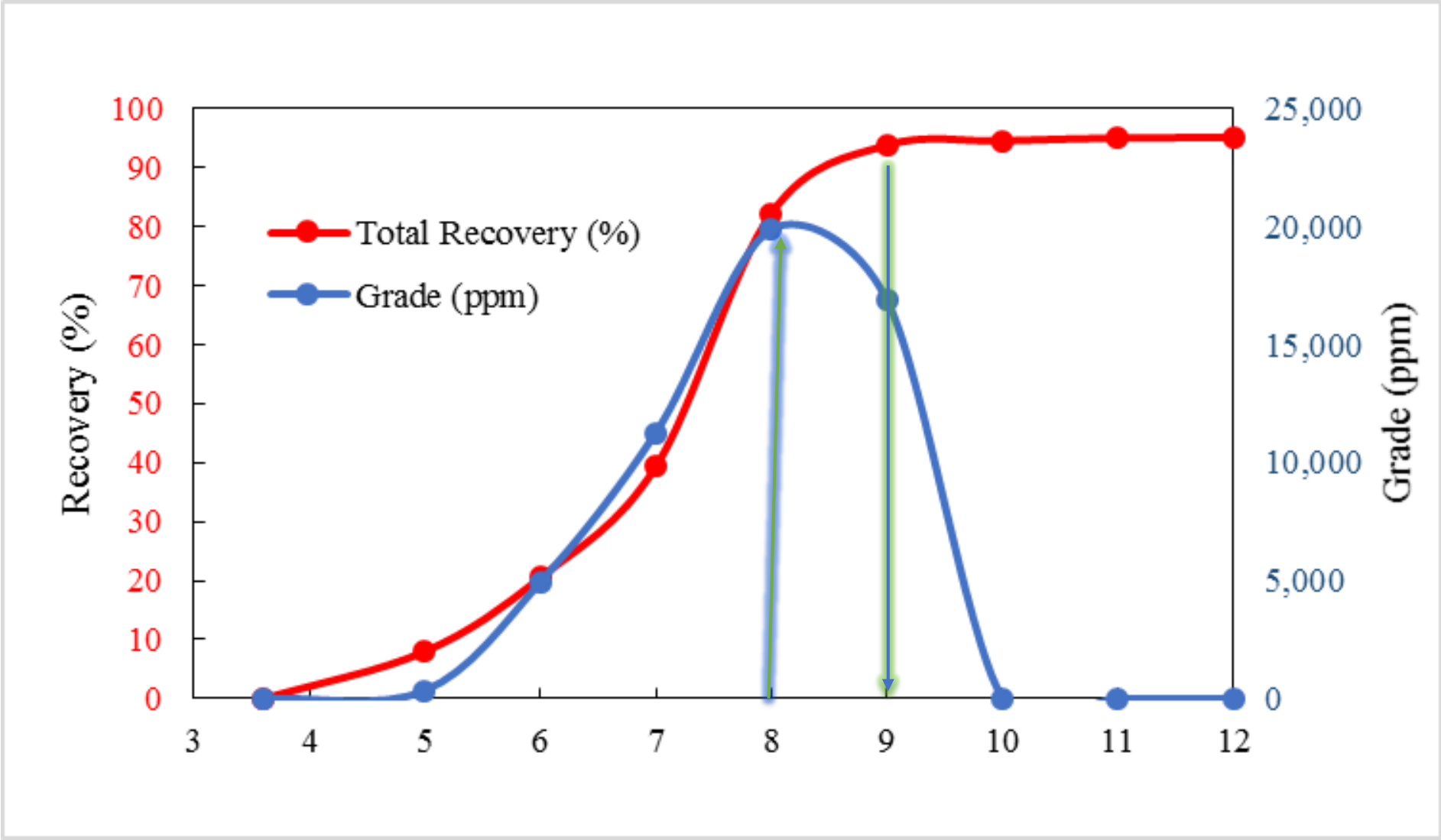
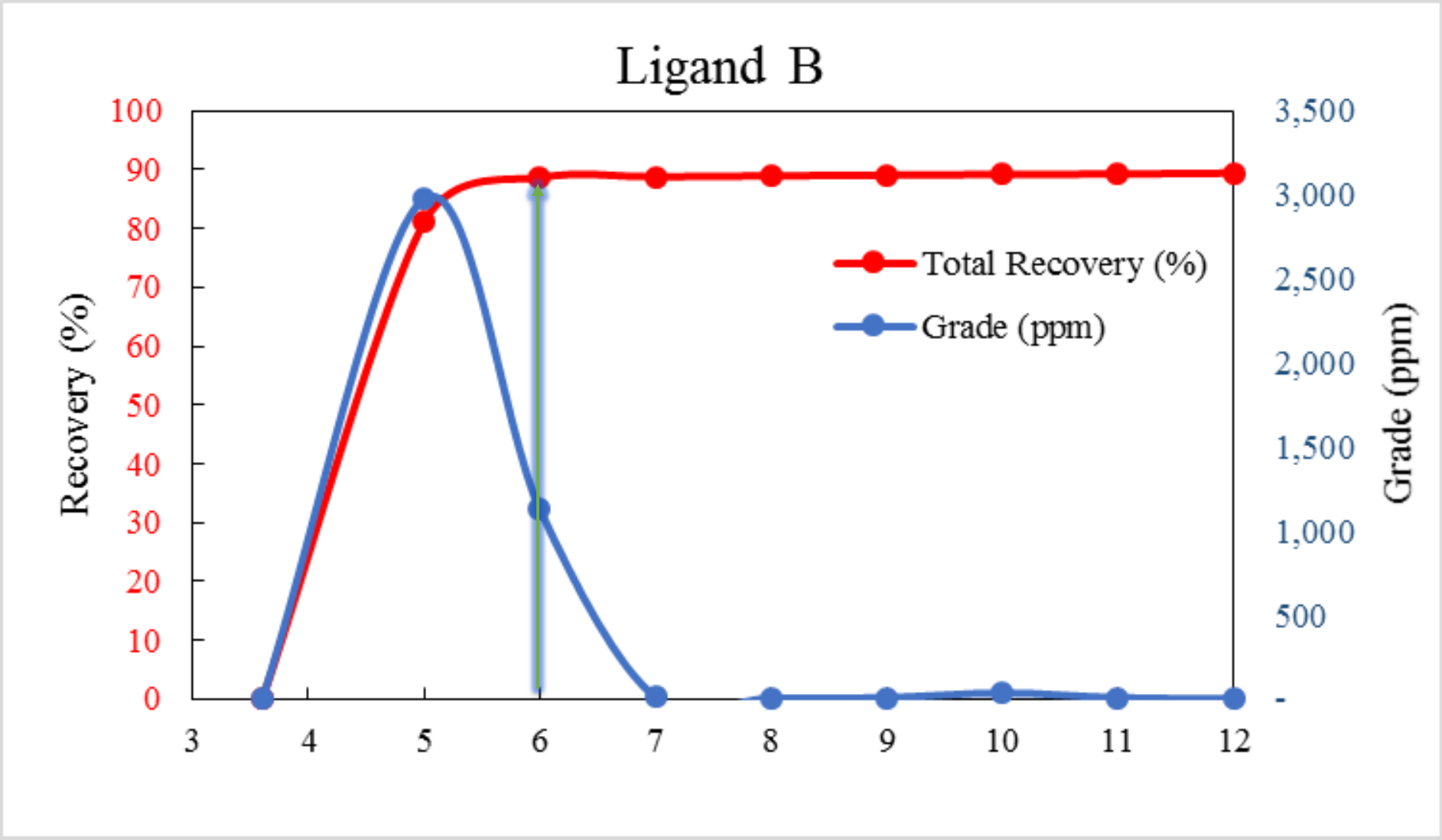
Other Extraction and Separation of REE’s

REEs were extracted and concentrated to 2% on a dry and whole sample basis with 95% recovery



Proprietary PSU ligand B was developed and thereby reduced extraction pH to 5 with high recovery (90%)



Inventure Recent Success

- Vitamin E Plant in China
- Final Engineering of Two Fatty Acid Acidulation Plant
- Detailed Engineering Phase of a Glycerin to Propylene Glycol Plant in Louisiana
- Partnership with Air Liquide/Lurgi to market oleochemical technologies.

Inventure is quickly becoming a provider of multiple new technologies and taking those technologies to commercial scale.

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