

STRATEGIES FOR SUSTAINABLE WATER MANAGEMENT FOR ABANDONED MINES

Recovery from Low Metal Water

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Colorado School of Mines

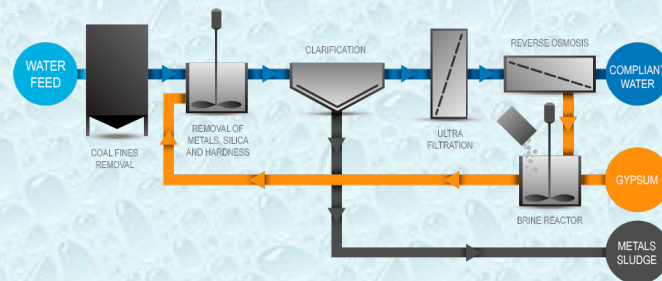
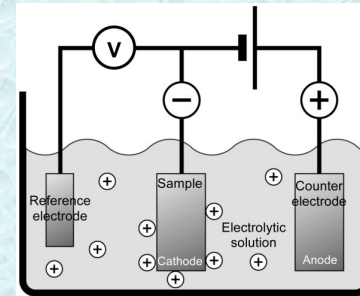
Opportunities with inactive and abandoned
hard-rock mine lands

April 10, 2017



CONTENT

- Opportunity
- Options
- Applications
- Future



CLARIFICATIONS

Orphaned or abandoned mines are those mines for which the owner cannot be found or for which the owner is financially unable to carry out clean-up.

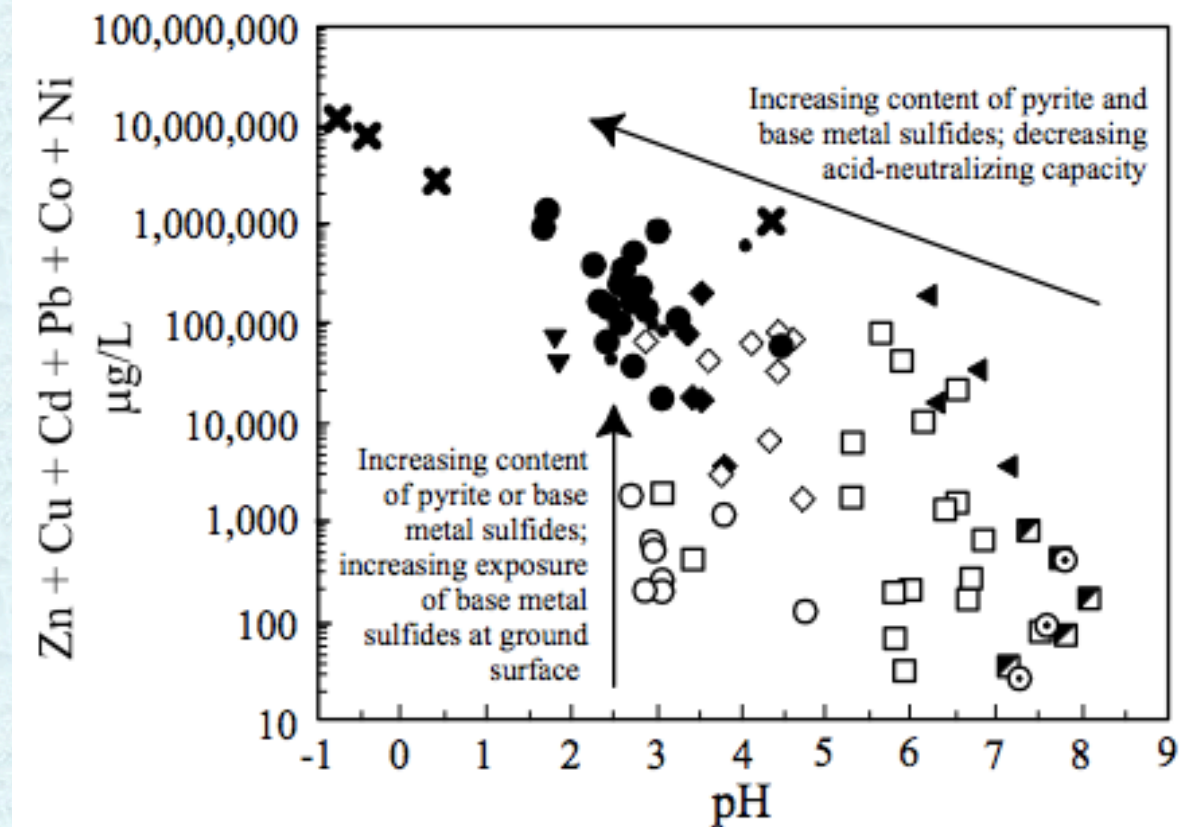
Inactive mines may be currently not operational but still have financially capable owners

Orphaned or abandoned mines should be the drivers for the path forward

MIW CONTAINS METAL VALUE

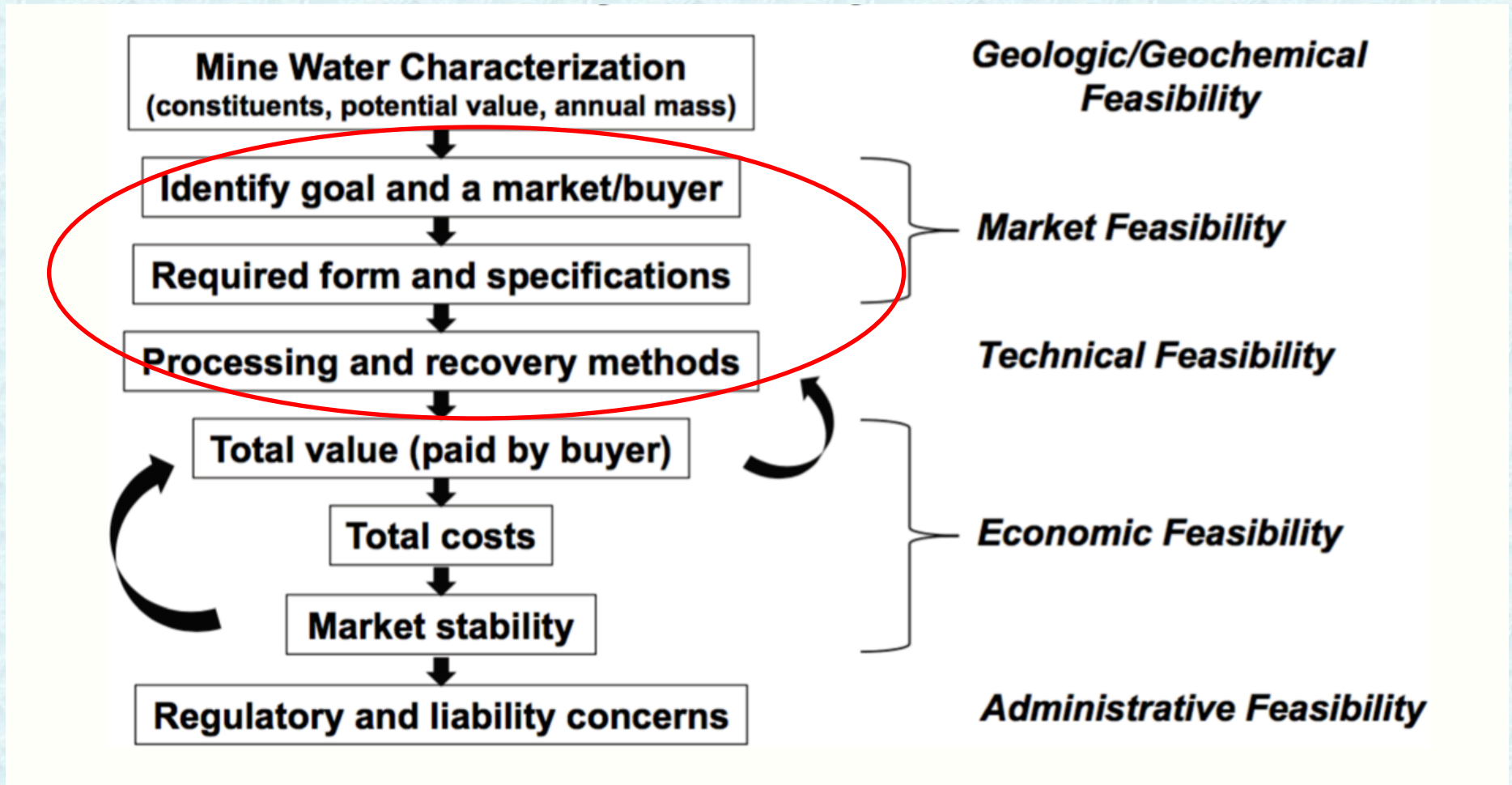


MIW = Mining Influenced Water



Seal and Foley 2002

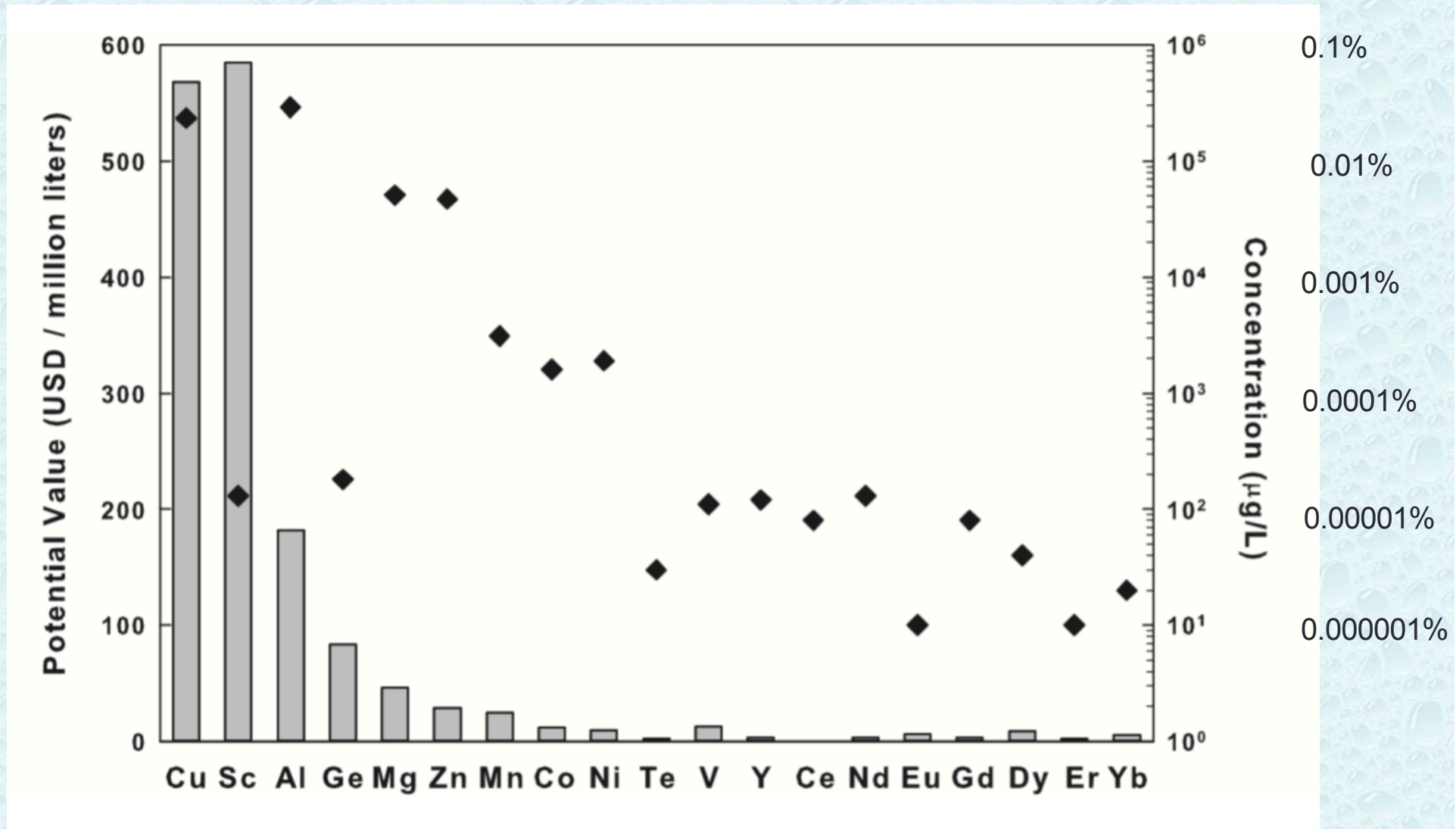
METAL RECOVERY FEASIBILITY CONSIDERATIONS



SUMMITVILLE MINE AND VICINITY



POTENTIAL VALUE FROM REYNOLDS ADIT



From Smith et al. 2013

million liters=ML

ARGO TUNNEL

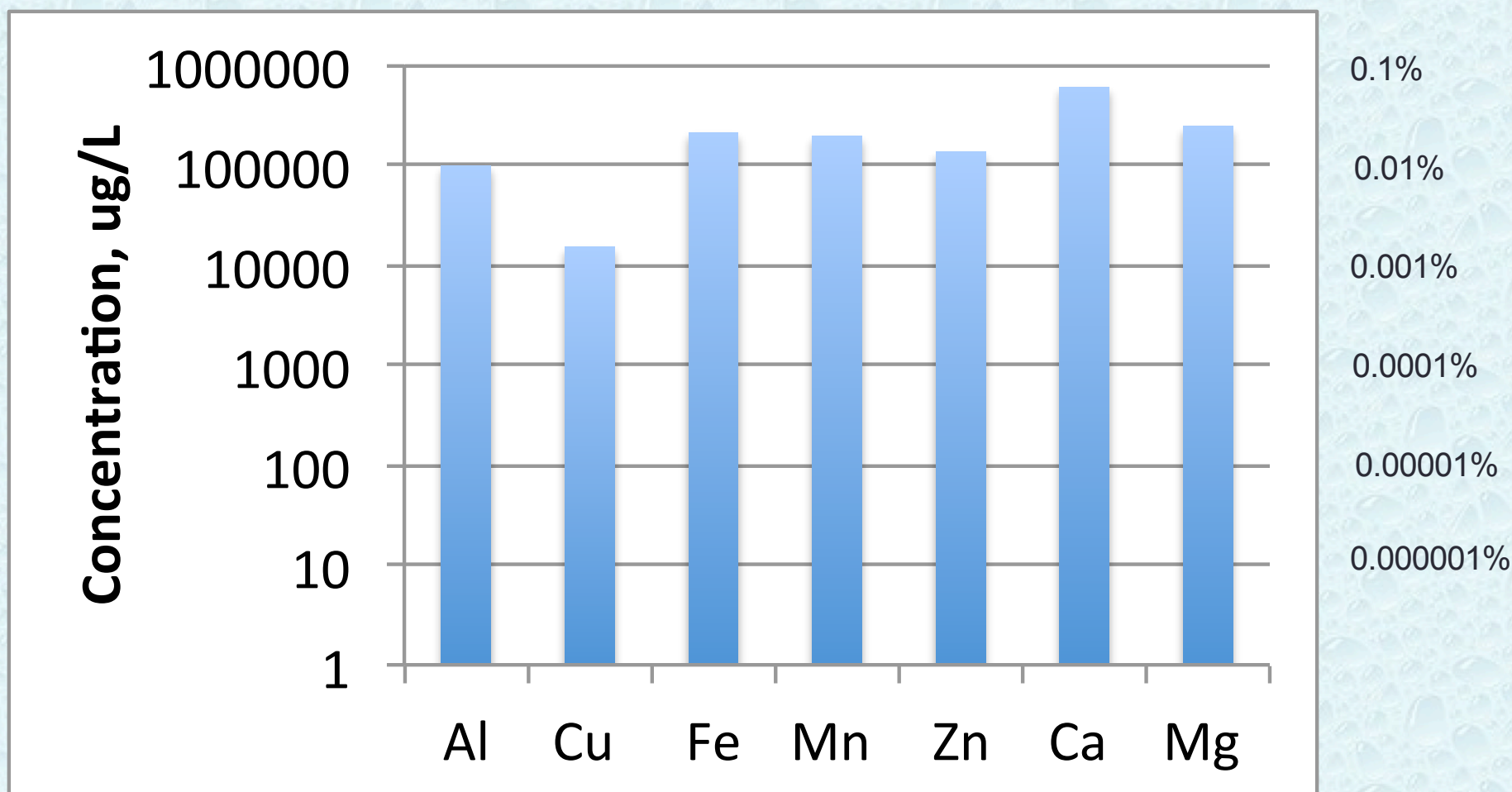


Conventional Treatment Example

ARGO TUNNEL WATER TREATMENT PLANT

250 gpm (1.4 ML/d) average flow in 2009

Major constituents in the Argo Tunnel MIW



ARGO TUNNEL SELECTED LIMITS

- Discharge limitations

Parameter	30 Day Average
Cadmium	3 µg/L
Copper	17 µg/L
Iron	15.8 mg/L
Zinc	225 µg/L
TSS	20 mg/L

Other regulated metals

Aluminum

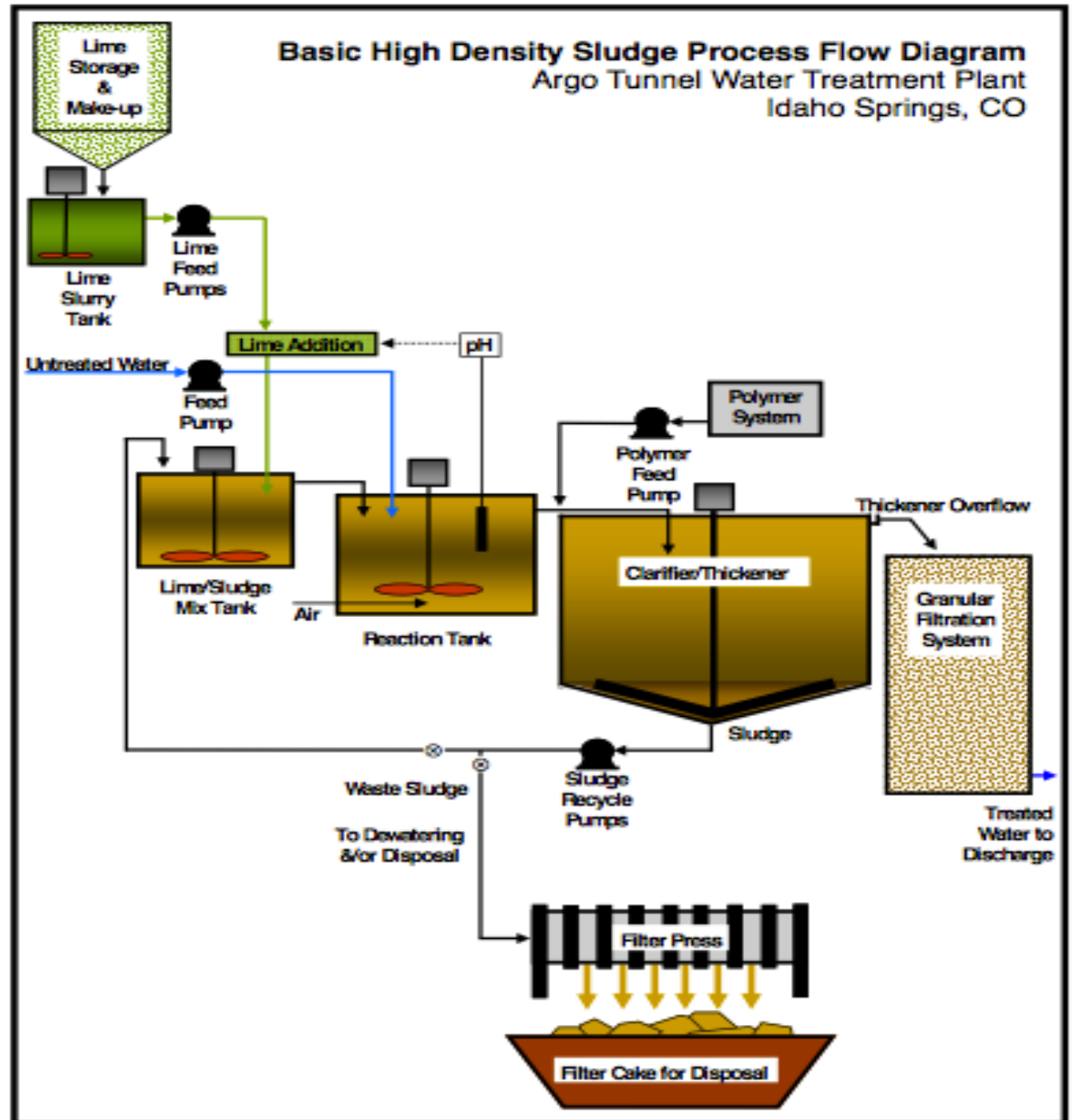
Arsenic

Lead

Manganese

Silver

ARGO TUNNEL WATER TREATMENT PLANT SCHEMATIC



ARGO TUNNEL WTP OPERATION COSTS

Year	2005-06	2006-07	2007-08	2008-09
Annual Cost	\$904,210	\$996,957	\$852,445	\$1,122,741
Change/Task Order	4%	2%	0%	10%
Chemicals	15%	10%	10%	10%
Lab/Admin/Clean	0%	1%	1%	0%
Maintenance/Repar	10%	10%	9%	10%
Monitoring	3%	2%	2%	2%
Routine Operation Labor	53%	57%	56%	51%
Sludge Disposal	14%	17%	22%	16%
Transition	0%	0%	0%	0%
Water Bill	1%	1%	0%	1%
Annual Disposal Cost	\$126,589	\$169,483	\$187,538	\$179,639

\$8.5/1000 gallons

NO METAL VALUE FROM LIME PRECIPITATION

Sludge Composition (approx.)

Metal	% of dry weight
Iron	50
Manganese	30
Aluminum	10
Zinc	10
Copper	1



Sludge contains 80% water!

METAL REMOVAL $\neq$ METAL RECOVERY

METAL RECOVERY OPTIONS FROM MIW

Selective Processes

Precipitation

Ion Exchange

Sorption

Electrochemical

WELLINGTON ORO METAL RECOVERY WTP



WELLINGTON ORO WTP

Flow rate 100 gpm in 2009

Target constituents in the Wellington Oro MIW

Element	ug/L	%
Zn	200,000	0.02
Cd	< 100	<0.00001
Al	NR	
Cu	NR	
Iron	NR	
Mn	NR	
Ca	NR	
Mg	NR	

NR = not reported

WELLINGTON ORO SELECTED LIMITS

- Discharge limitations

Parameter	30 Day Average
Cadmium	4 µg/L
Zinc	225 µg/L
TSS	20 mg/L

Unregulated metals

Aluminum

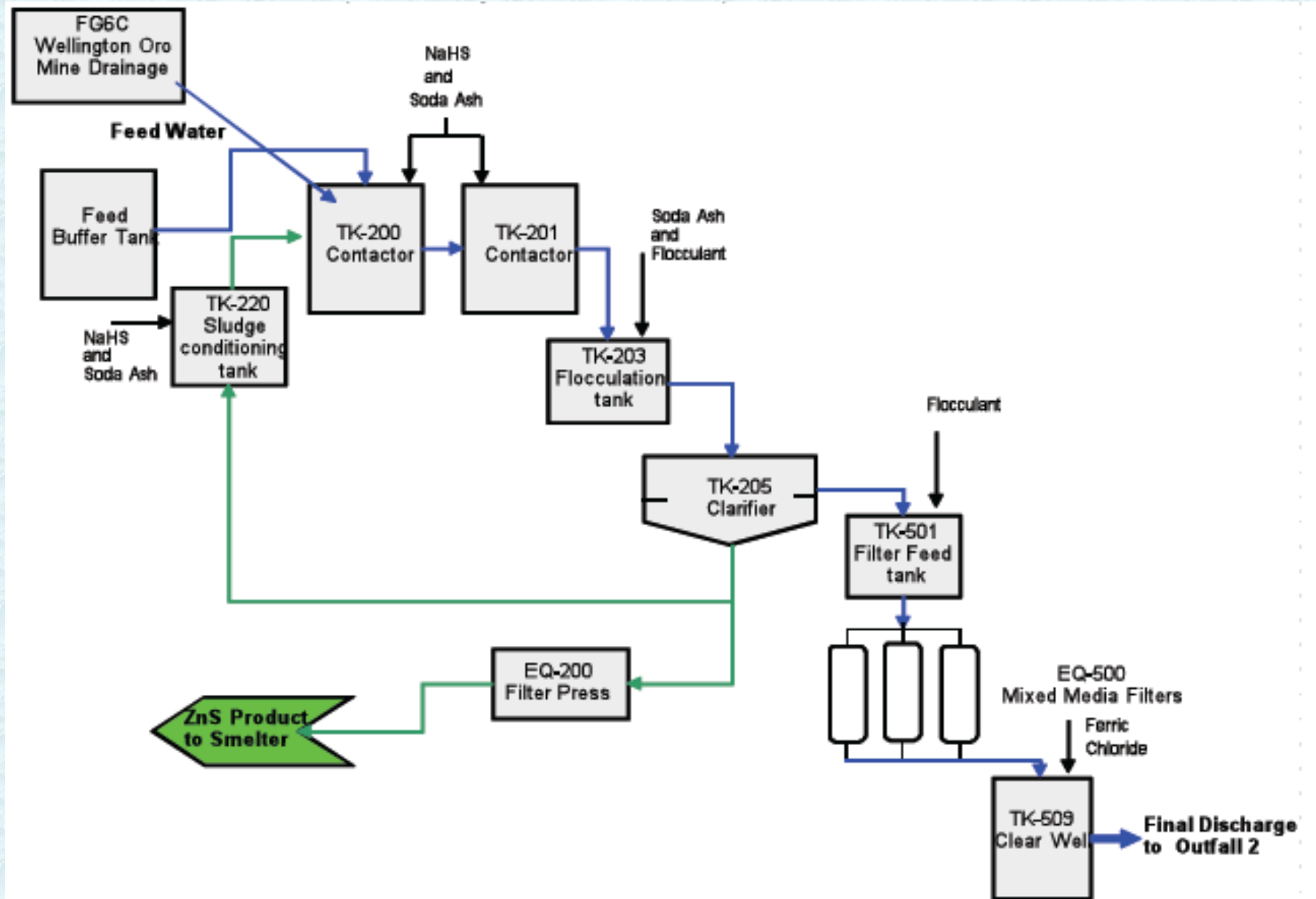
Copper

Iron

Lead

Manganese

WELLINGTON ORO PROCESS FLOW SCHEMATIC



WELLINGTON ORO SLUDGE

Smelter requirements

50% zinc minimum

Containing low levels or no:

Iron

Nickel

Thallium

Sludge Composition

Element	Percent
Water	18%
Zn	57%
S	38%
Trace	5%

Nyrstar Zinc Smelter – Clarksville, Tennessee

The only primary zinc smelter in the US currently has a working agreement with the Wellington Oro Operation

WELLINGTON ORO WTP OPERATION COSTS

Chemical Reagents (Soda Ash)	\$40000
Chemical Reagents (Sodium Hydrosulfide)	\$20000
Chemical (Other)	\$3000
Testing of effluent (outside agency)	\$15000
Shipping (to testing agency)	\$2400
Gas (heating)	\$9900
Electric (plant power)	\$15000
Sewer (office only)	\$1500
Phone / internet	\$1800
Plant Equipment Maintenance	\$19800
Supplies and operations materials	\$5000
BioteQ (consultant off-site monitoring)	\$30000
Zinc revenues (2009)	- \$18,900
Net expenses (2009)	\$144,500

\$4.0/1000 gallons

OTHER ZINC CHEMICAL FORMS

The MARKET dictates usable forms of zinc and chemical constraints.

Selected zinc fertilizer forms

<u>Zinc source</u>	<u>Water solubility</u>	<u>Soil type</u>
$\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$	high	all
$\text{ZnSO}_4 \cdot \text{H}_2\text{O}$	high	all
$x\text{ZnSO}_4 - x\text{ZnO}$	variable*	variable*
ZnO	low	acidic

* depends on relative proportion of ZnSO_4 and ZnO

POTENTIAL ZINC FORMS FROM PRECIPITATION

<u>Form</u>	<u>processing needed</u>
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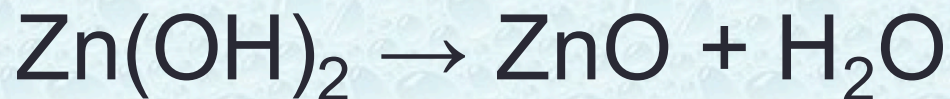
Zinc carbonate	
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drying

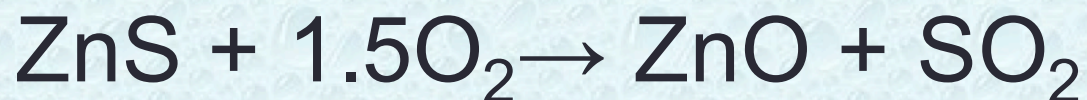
Zinc hydroxide	
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roast (100-250°C)



Zinc sulfide	
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roast (700-1000°C)



ZnCO_3 and ZnO are feedstock for ZnSO_4 manufacture

COMPARISON OF METAL RECOVERY OPPORTUNITY

ARGO TUNNEL

Constituent mg/L

Calcium	600
Magnesium	240
Aluminum	100
Copper	15
Iron	210
Manganese	190
Zinc	130
Cadmium	0.13
Lead	0.03

NELSON TUNNEL

Constituent mg/L

Calcium	250
Magnesium	30
Aluminum	1.5
Copper	0.2
Iron	0.2
Manganese	15
Zinc	80
Cadmium	0.5
Lead	1.0



Lower co-contaminant potential desirable

CONTAMINANTS RELATED TO ZINC MASS

Nelson Tunnel MIW

<u>Constituent</u>	<u>Metal/Zn precipitate*</u>	<u>Metal/Zn limit</u>
Cadmium	6.25 mg Cd/g Zn	≤ 0.14 mg Cd/g Zn
Lead	12.5 mg Pb/g Zn	≤ 0.28 mg Pb/g Zn

•

*assumed Cd and Pb 100% remove with Zn

Cd and Pb exceed fertilizer limits and reduce value of zinc product

MULTI-MICRONUTRIENT FERTILIZER OPTION

Multi-micronutrient slow release fertilizer of Fe, Mn, Cu and Zn

Micronutrient utilization examples in mg metal/g Zn

Crop	Fe/Zn	Mn/Zn	Cu/Zn
Rice	3500	2000	100
Potato	4500	400	400

Metal update rates g/hectare

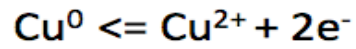
Crop	Zn	Fe	Mn	Cu
Rice	70	250	140	20
Potato	430	1970	150	160

ELECTRODEPOSITION

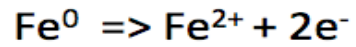


Cementation

Cathodic site



Anodic site

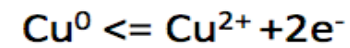


Solid metal surface

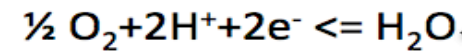
Applied potential

Electrowinning

(-)



(+)



Cathode

Anode



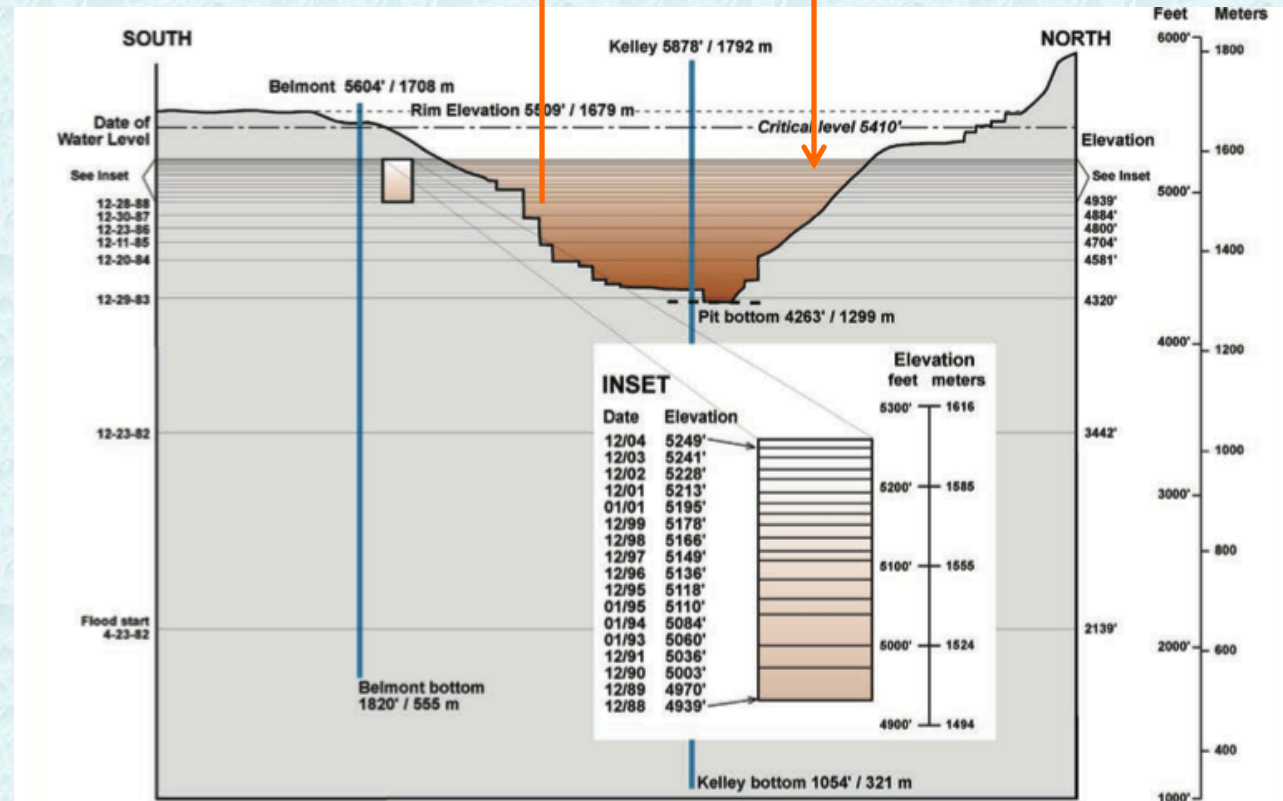
MIW ELECTRODEPOSITION SUCCESS

- Only one full-scale site identified world-wide
Berkeley Pit, Montana, USA



Cementation

70-80% copper
to processing



TECHNICAL APPLICATION CHALLENGES

- Low value metal concentration
- High concentrations of interfering metals
 - Argo Tunnel MIW

Metal	mg/L
Iron	120
Manganese	90
Aluminum	20
Zinc	40
Copper	4

- Residual metal exceeds regulatory limits
 - Berkeley pit cementation

$$\text{Cu}_{\text{in}} \approx 200 \text{ mg/L} \Rightarrow \text{Cu}_{\text{out}} \approx 20 \text{ mg/L}$$

TECHNICAL STRATEGIES

Problem: Low value metal concentration

Solution: Concentrate MIW

Problem: High concentrations of interfering metals

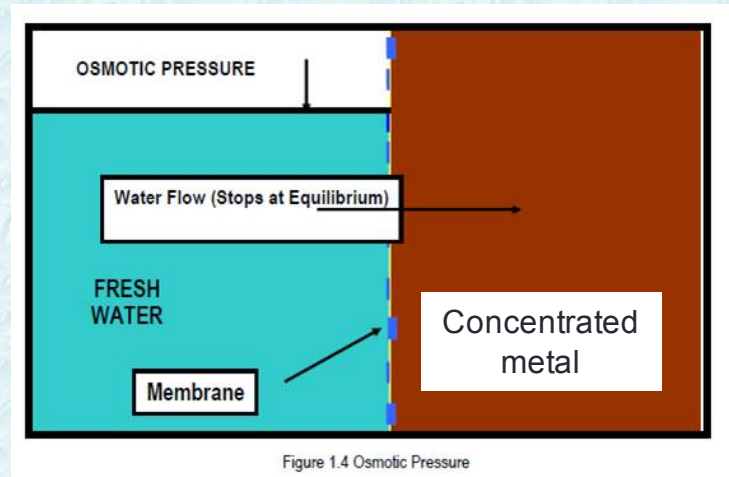
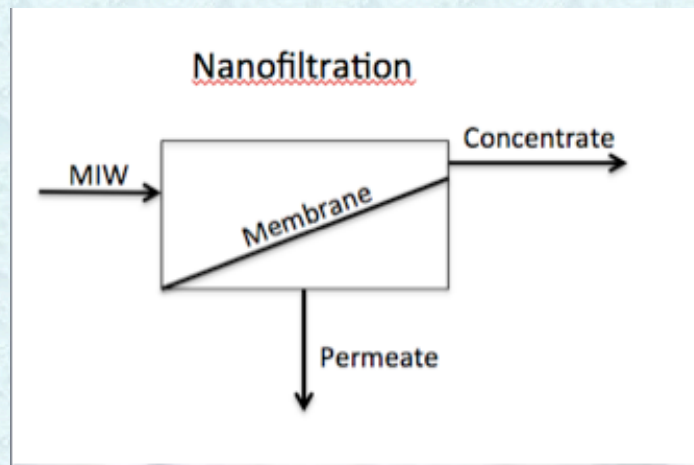
Solution: Pre-treatment to remove interference

Problem: Residual metal exceeds regulatory limits

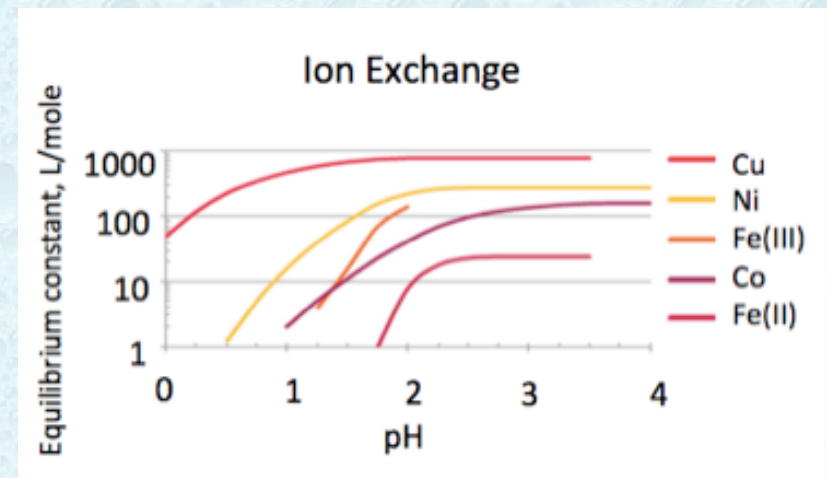
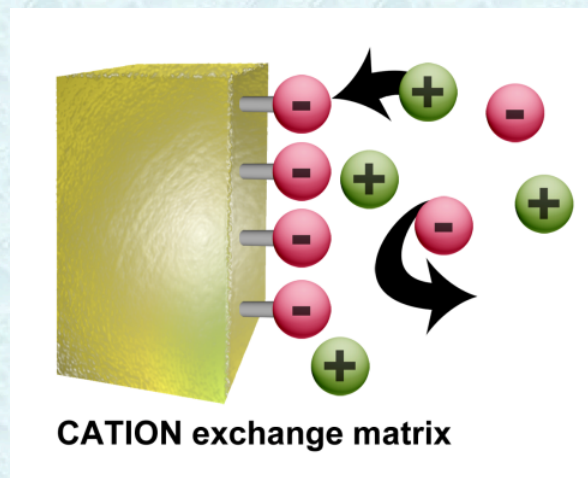
Solution: Post-treatment to removal residual

ENABLING PROCESSES

Membrane
option

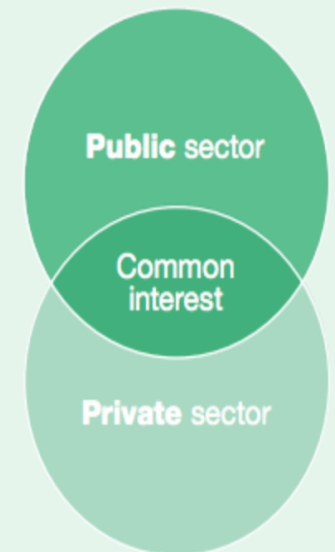


Selective
recovery
option



FUTURE

- MIW is a potential source of metal resources
- New treatment methods and strategies are needed to recover metal value
- New policies are needed to incentivize purchase of feedstock materials produced
- New policies are needed to facilitate partnerships



THANK YOU FOR YOUR ATTENTION



$\Rightarrow$

