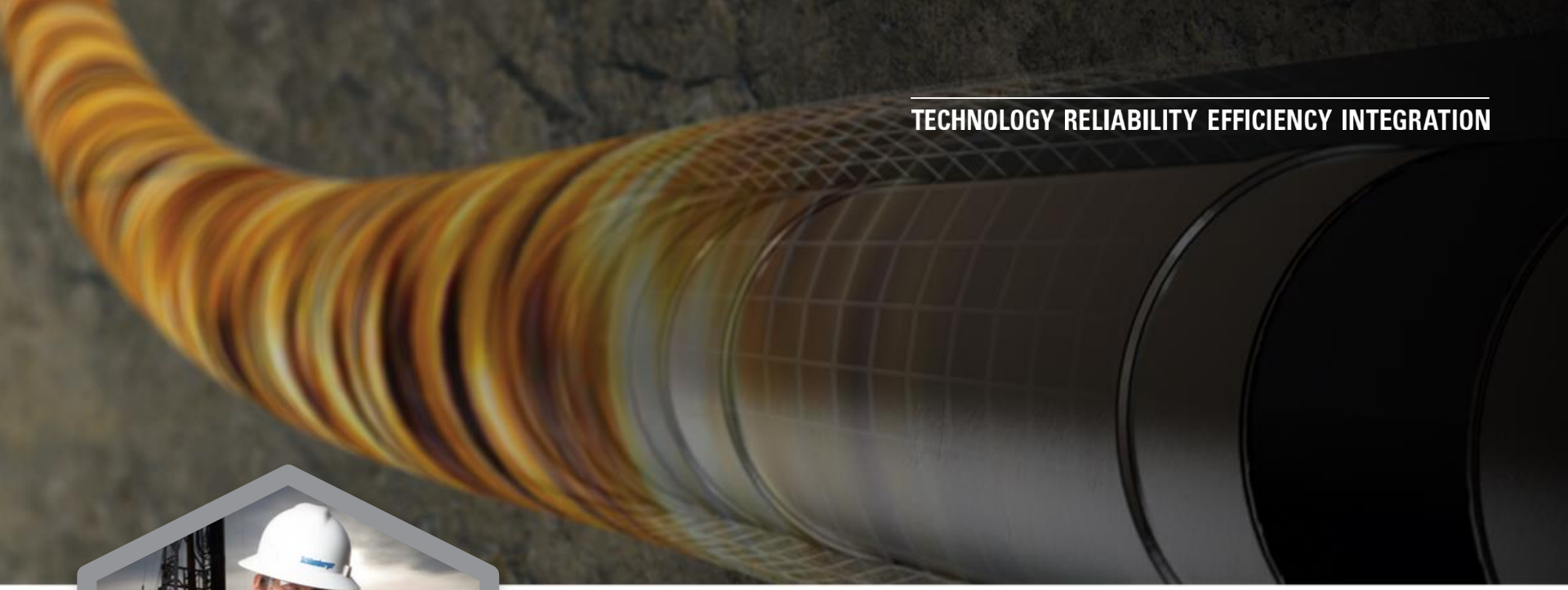

TECHNOLOGY RELIABILITY EFFICIENCY INTEGRATION

Beneficial Reuse of Oil Based Drill Cuttings – Opportunities and Challenges

Patrick Tyczynski, John Candler –
M-I SWACO, a Schlumberger company
AADE Fluids Study Group

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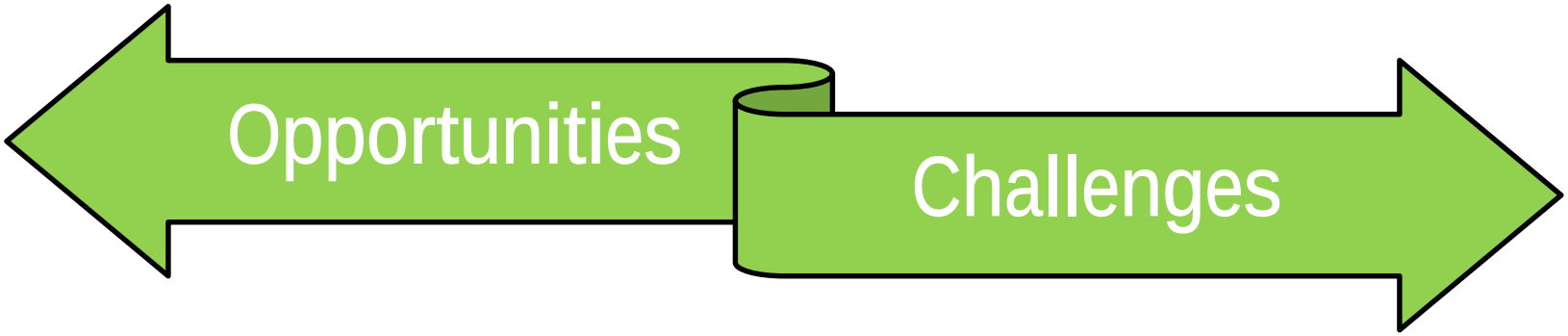
Beneficial Reuse



- Reduce the cost
- Reduce resource consumption
- Improve overall environmental performance
- Enhance community relationships

- Prevent environmental or human health impact
- Technical
- Regulatory
- Liability
- Sham recycling threats
- Finding a market for reuse

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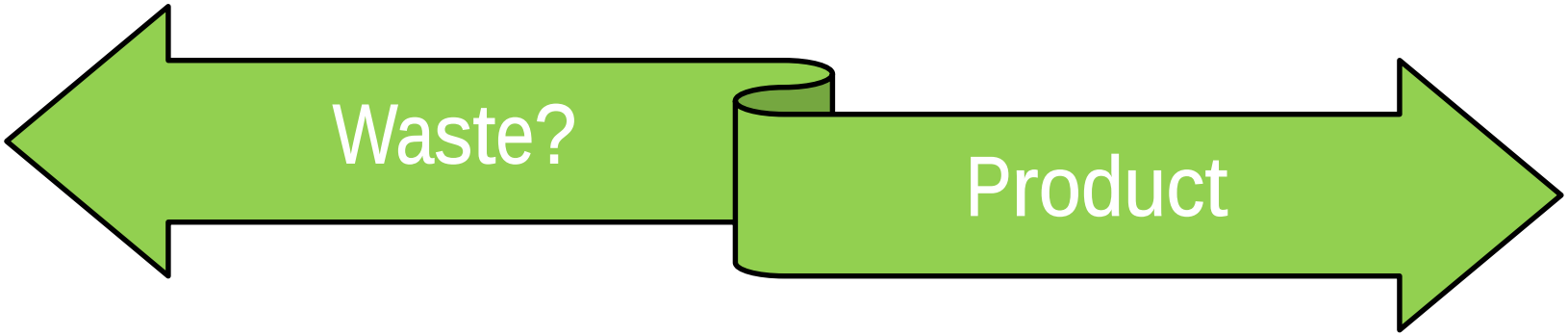
Management Options



- It may be harmful
- We have to test it
- We must dispose of waste properly
- We must be in compliance

- We must protect human health and the environment
- We must find a market for it
- We must test it to prove it meets requirements
- We must store and transport it safely
- We must be in compliance

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Oilfield Opportunities for Beneficial Reuse

Flow back /Produced Water

- Crop irrigation
- Reuse as makeup water for Hydraulic Fracturing
- Enhanced oil recovery

Drilling Fluid

- Reuse as a Drilling Fluid

Drill Cuttings

- Use of cuttings as construction aggregate
- Energy recovery
- Use of cuttings as a soil or soil enhancer
- Use of cuttings for wetland restoration

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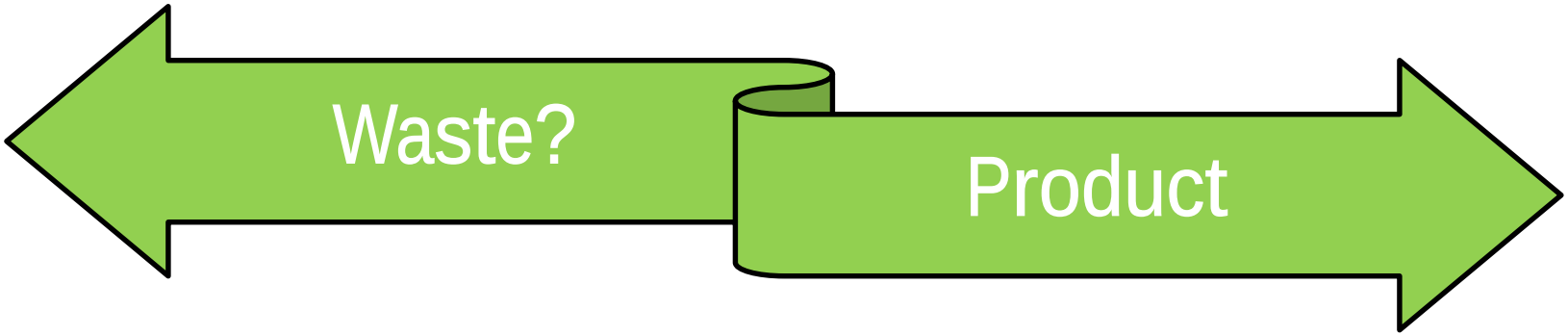
Drill Cuttings Reuse?



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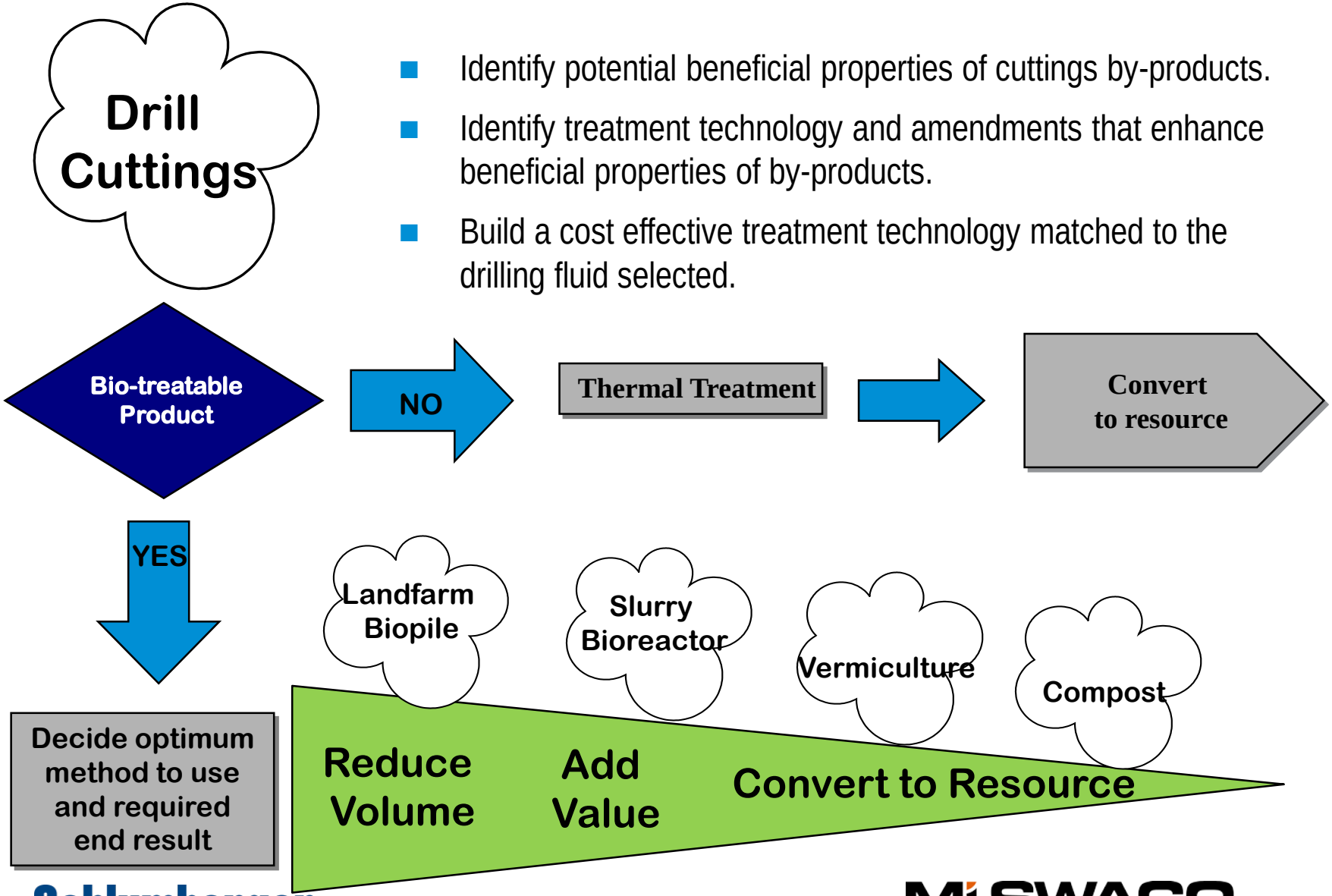
Treatment and Reuse Strategy



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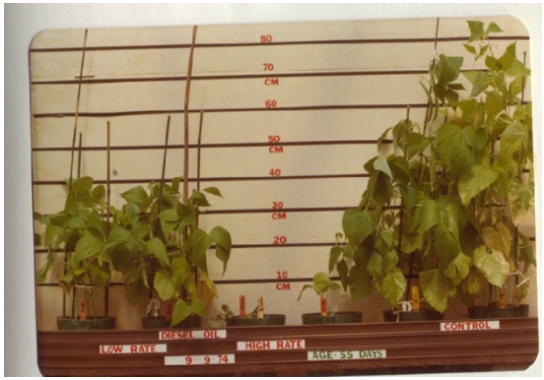
Product Selection Issues

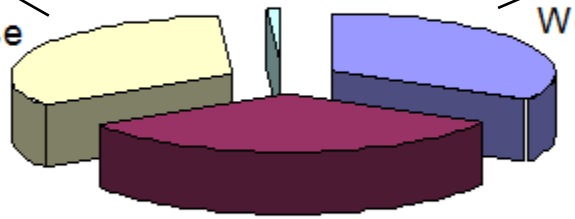


Diesel

Emulsifiers

External Phase

Weight Material



Internal Phase

Salt

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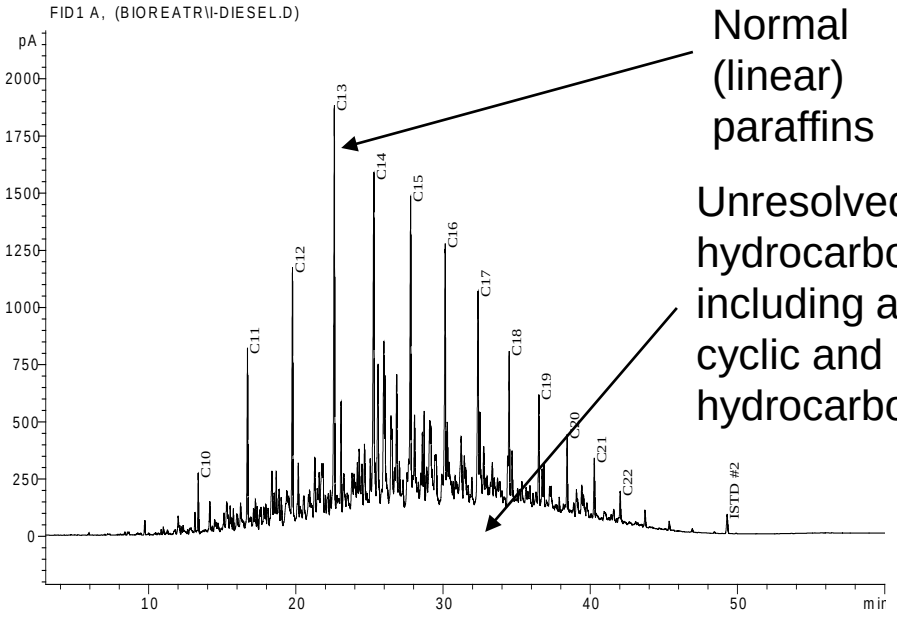
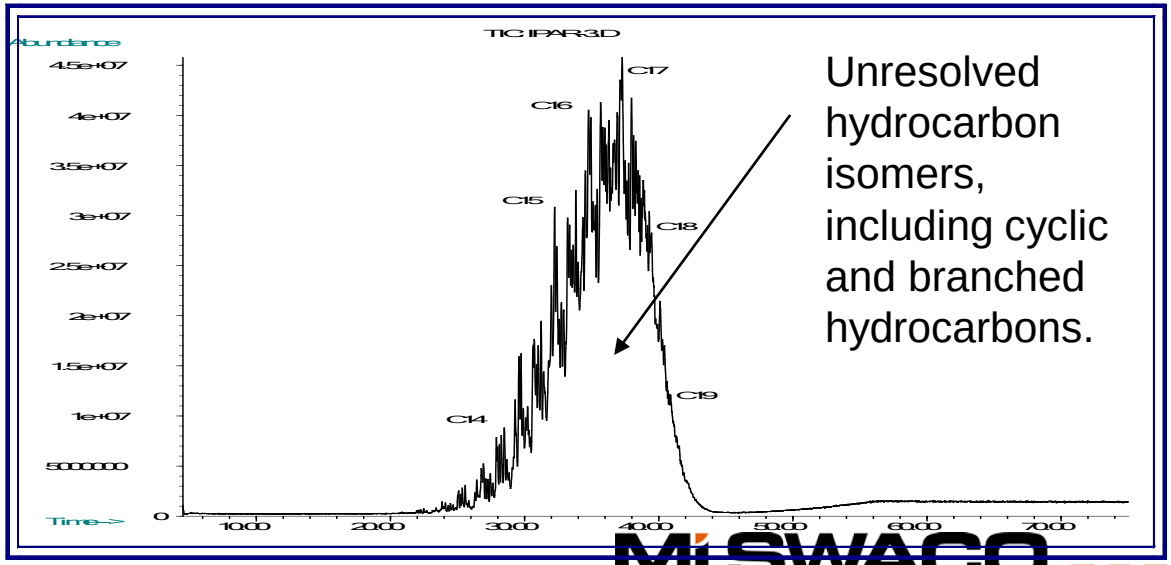
Root Causes of Problems with Base Fluids

- In diesel oil normal paraffins will biodegrade. However, aromatics and cyclic hydrocarbons are toxic and do not degrade quickly.
- In mineral oils and enhanced mineral oils, aromatics are removed and many normal paraffins are branched. While less toxic than diesel they biodegrade slower than diesel.





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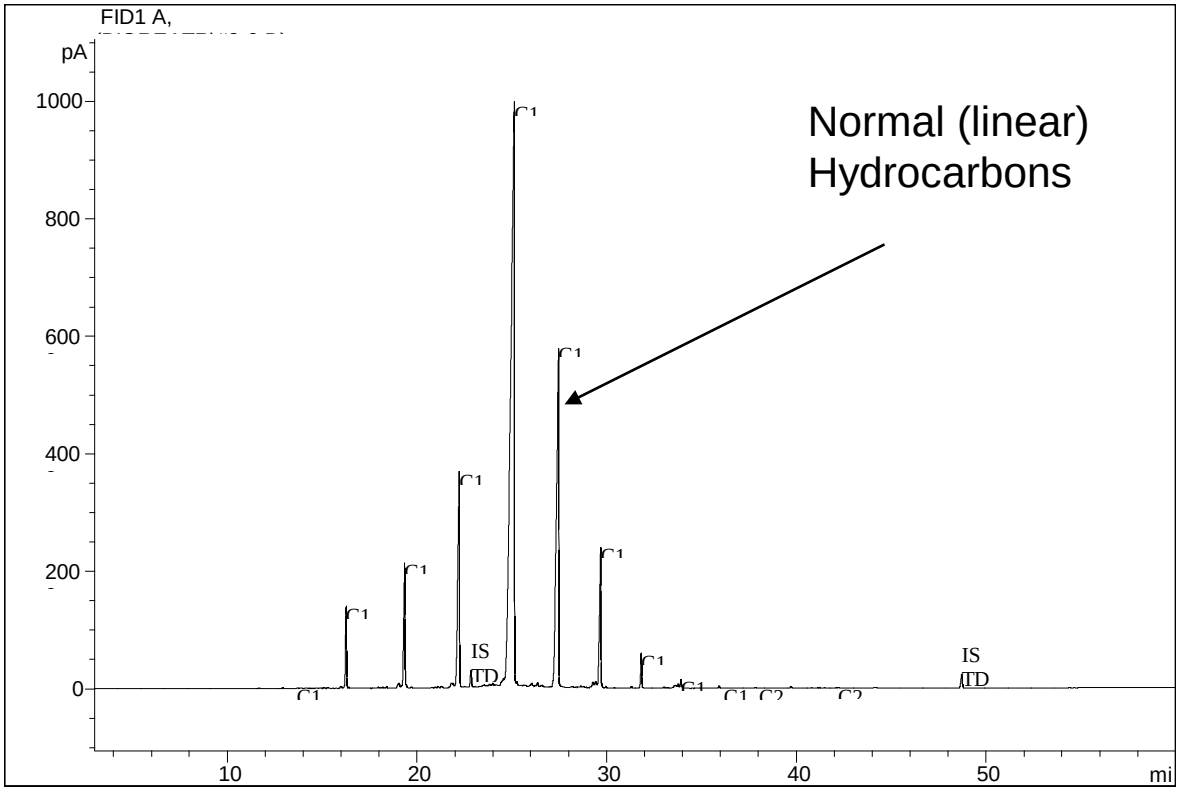
Chemistry Can Resolve Root Causes of Environmental Issues



- Linear hydrocarbon chemistry provides a base fluid that biodegrades rapidly under aerobic conditions because it is linear, and it is low molecular weight. Linear hydrocarbon chemistry also provides a base fluid with low toxicity because the structures are less toxic than aromatic and cyclic structures of the same molecular weight.

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Environmental Testing

Test Type	Name	Purpose
Biodegradation	Respirometry	Measure biodegradation
Biodegradation	Hydrocarbon removal	Measure biodegradation and evaporation
Phytotoxicity	Seed emergence	Plant growth and soil productivity
Phytotoxicity	Root elongation	Plant growth and soil productivity
Phytotoxicity	Root mass	Plant growth and soil productivity
Aquatic Toxicity	Microtox	Runoff water toxicity
Aquatic Toxicity	Springtail	Runoff water toxicity

Base Fluid Environmental Testing

Table 1 Biodegradability of Various Base Fluids		
Treatment	% Reduction of Hydrocarbons	Biodegradability Rank
C_{11-14} LP	97	1
C_{12-13} LP	94	2
Ester	91	3
Isomerized Tetradecene C_{14} (IO)	83	4
Diesel	61	5
Branched Paraffin	43	6

Table 2 Toxicity of Various Base Fluids*					
Treatment	Water Toxicity	Animal Toxicity	Alfalfa Phytotoxicity*		Toxicity Rank
	Microtox IC_{50}	% Earthworm Survival	% Seed Emergence	% Root Elongation	
Branched Paraffin	106	100	95	107	1
C_{11-14} LP	98.5	100	96	134	2
C_{12-13} LP	65.9	100	95	120	3
Isomerized Tetradecene C_{14} (IO)	61.7	100	101	144	4
Diesel	10.3	0	7	2	5
Ester	5.9	0	0	0	6

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Root Causes of Problems with Internal Phase

- Electrical Conductivity
- Lack of biodegradation
- Plant toxicity
- Water column toxicity

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New Chemistry May Address Root Causes of Environmental Issues

- Nitrate and acetate chemistry selected and blended to provide optimum environmental performance to maximize soil productivity and minimize water column toxicity.

Table 4
Biodegradability , Toxicity & Electrical Conductivity of Formulations and Treated Cuttings
6% w/w Loading on Topsoil from Southern Alberta Grassland

	Biodegrad-ability (65 days)	Animal Toxicity		Alfalfa Phytotoxicity*			Relative Electrical Conductivity (after 65 days)
System	% Loss of Extractable Hydro-carbons	% Springtail Survival	% Earthworm Survival	% Seed Emergence	% Root Elon-gation	% Shoot Mass	
Formulation A	98	80	100	100	149	97	1.0
Formulation N	98	87	93	4	11	47	4.0
Std. Diesel / $CaCl_2$ / Barite Formulation	68	0	0	3	8	25	4.9
Formulation A with Barite	99	90	100	100	108	105	0.8
Bioreactor-Treated Cut-tings, Form. NA	-	93	100	109	134	129	-
Bioreactor-Treated Cut-tings, Form. N	-	73	100	113	116	121	0.2

*Phytotoxicity test results are normalized to Control test values of 100.

- Reference: AADE 01-NC-HO-11, Can Synthetic-Based Muds Be Designed to Enhance Soil Quality?

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Chemistry Can Resolve Root Causes of Environmental Issues

- Hematite weighting material is anticipated to enhance soil quality more than Barite

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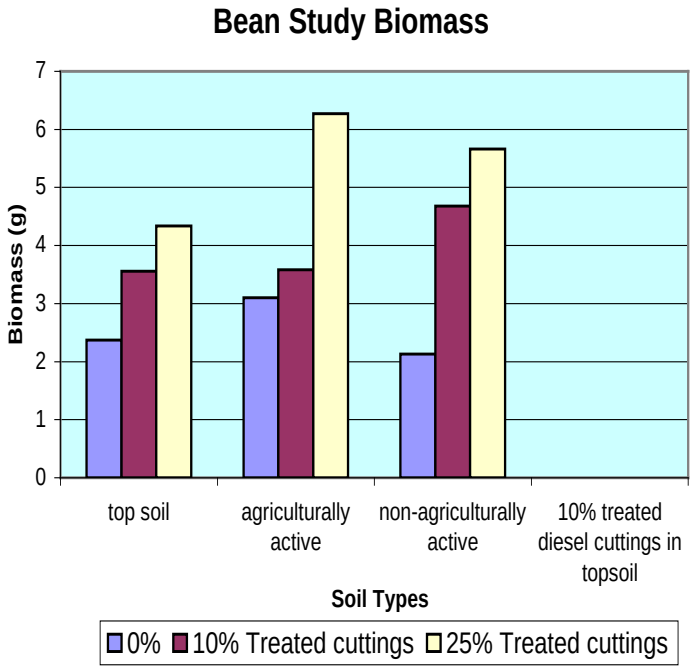
Results of Study

- Generates drilled cuttings that may promote biomass growth in amended soil



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Key Drilling Fluid Performance Requirements

- Standard mud properties -- especially rheology, electrical stability and filtration -- are quite as good as for a typical invert mud when heat-aged for 16 hr at 250 F; pushing this to 300 F does not alter the properties significantly.
- Resistance to contamination -- drilled solids, seawater, additional weighting material -- is excellent.
- Drillability is superior, as per reports from use in New Zealand, Colorado, Peru.

Meets Current Discharge Requirements

Contaminants of Concern	OGCC Allowable Concentration	BLM Allowable Concentration	Soil Analysis Results
TPH – Non-sensitive Area	10,000 mg/kg	10,000 mg/kg (F)	7000 mg/kg
TPH – Sensitive Area	1,000 mg/kg	1,000 mg/kg (F)	
Benzene	5 ug/l (B)	10 ppm (mg/kg)	(H); BTEX not expected using the system
Toluene	1,000 ug/l (B)	(G)	
Ethylbenzene	680 ug/l (B)	(G)	
Xylene	10,000 ug/l (B)	(G)	
Electrical Conductivity (EC)	<4 mmhos/cm or 2x background	<4 mmhos/cm	2.66
Sodium Adsorption Ratio (SAR)	<12	12	4.8
Exchangeable Sodium Percentage (SAR)	(A)	15	5.0
pH	6-9	6-9	7.94
Total Dissolved Solids	<1.25 x background (B)	(G)	92.8
Chlorides	<1.25 x background (B)	(G)	(H)
Sulfates	<1.25 x background (B)	(G)	(H)
Arsenic	41 mg/kg (C), (E)	<41 mg/kg	ND
Barium (LDNR True Total Barium)	180,000 mg/kg (C), (E)	<40,000 mg/kg	ND
Boron (Hot Water Soluble)	2 mg/l (C), (E)	(G)	(H)
Cadmium	26 mg/kg (C), (E)	<26 mg/kg	ND
Chromium	1.500 mg/kg (C), (E)	500 mg/kg	12.0 mg/kg
Copper	750 mg/kg (C), (E)	(G)	(H)
Lead	300 mg/kg (C), (E)	<300 mg/kg	12.1 mg/kg
Mercury	17 mg/kg (C), (E)	<17 mg/kg	ND
Molybdenum	(D), (E)	(G)	(H)
Nickel	210 mg/kg (C), (E)	(G)	(H)
Selenium	(D), (E)	<10 mg/kg	ND
Silver	100 mg/kg (C), (E)	(G)	ND
Zinc	1,400 mg/kg (C), (E)	<500 mg/kg	17.9 mg/kg

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Summary

- ONSHORE SBM possesses the excellent drilling properties of conventional invert muds and generates drilled cuttings that may be used to enhance the quality of soil.
- One version of ONSHORE SBM is expected to undergo relatively rapid natural biodegradation when mud-laden cuttings are land-treated directly.
- Another version of ONSHORE SBM can be used in conjunction with bioreactors or composting to generate cuttings that may be disposed of in areas where regulations severely limit electrical conductivity (salts) and TPH of initial discharges.

ONSHORE SBM Experience

- Bioreactor and Compost development 1999 - 2001 –
- Field use – New Zealand – 2001.
- Field use – Colorado – 2006.
- Field use Peru 2013.

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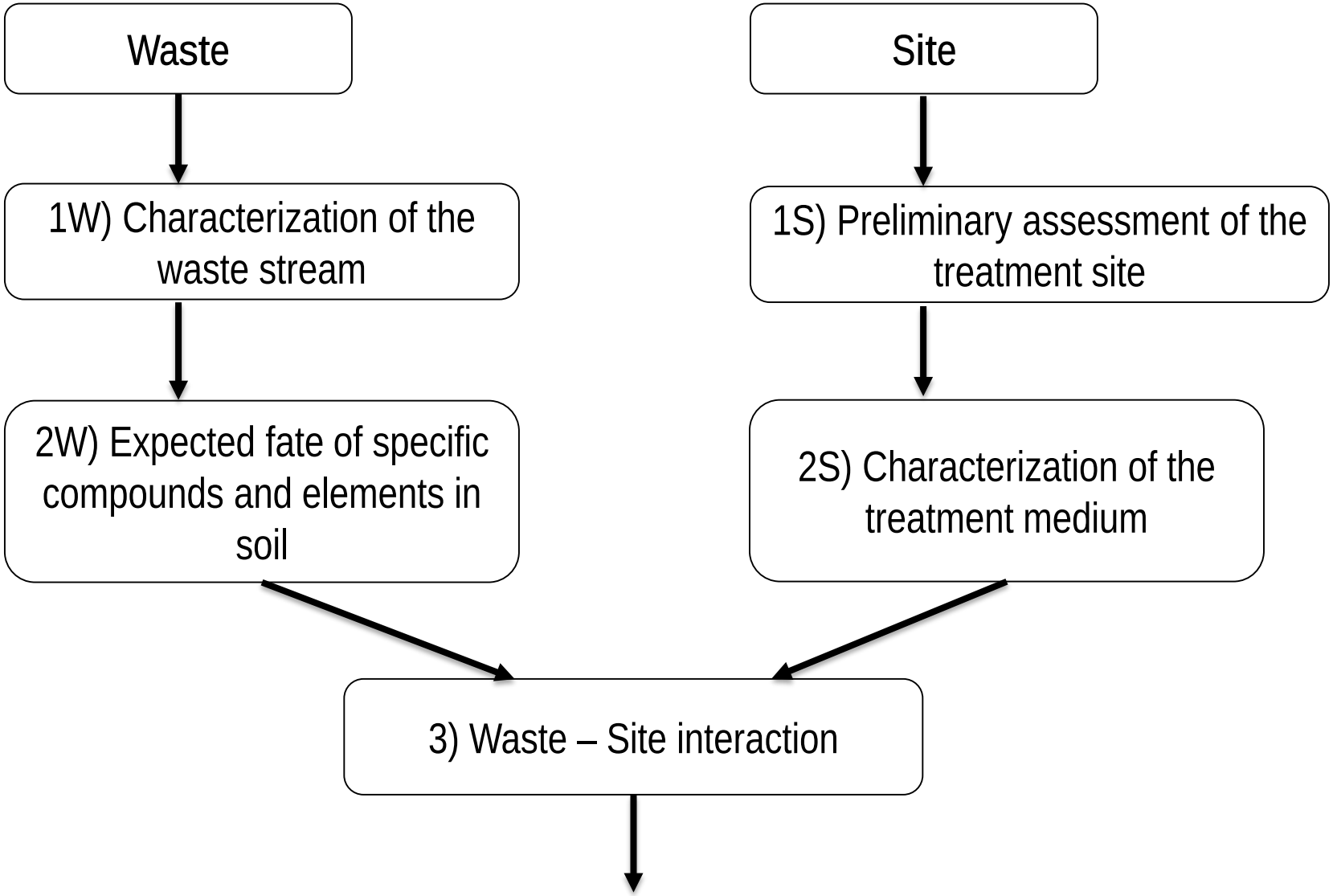
Limitations to Bioremediation

- Molecular structure
  - Branched/cyclic/aromatic hydrocarbons harder to degrade than linear hydrocarbons
- Oxygen concentration
  - Aerobic degradation is most efficient
  - Low oxygen concentrations will reduce rates of degradation
- Temperature
  - Rates of microbial activity related to temperature
- High salt concentrations
  - Impacts microbial activity and the disposal of the final waste

Project Design and Implementation Plan- Flow Chart



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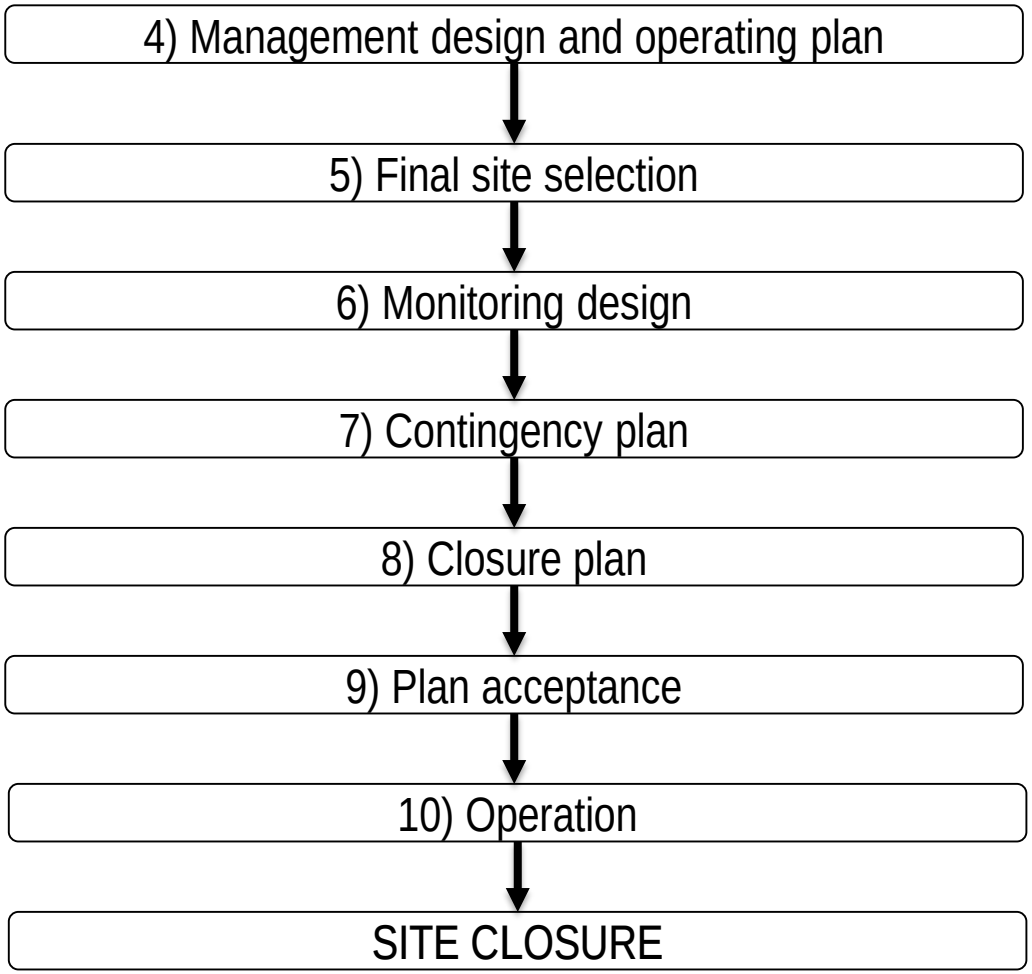

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Design and Operating Plan

- Water control and water protection will occur in two phases.
- During the pre-treatment storage phase
  - SBM drill cuttings with 10 – 20% retention by weight will be contained in a small area designed to prevent any water run-on or run-off
  - The groundwater will be protected by an impermeable barrier, i.e. liner.
- During the treatment phase,
  - percent base fluid on the amended cuttings will be lower
  - base fluid will be tightly incorporated into the treatment matrix
  - amended cuttings will be placed in a lined area
  - focus will be on designing the grade of the treatment area to prevent any storm water run-off from leaving the location.

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Composting Treatment

- Cuttings application - bioremediation
- Mechanical incorporation of the amendments and cuttings together using
  - traditional landfarming equipment
  - tractors, loaders and excavators
  - special versatile attachment: a unique solution for fast & effective processing

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Monitoring Plan & Testing

- Monitoring for the constituents of concern as defined by applicable regulation using appropriate analytical methods
- Topics to be considered for the monitoring program include:
  - treatment zone concept
  - analytical considerations
  - statistical considerations
  - type of monitoring

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Checklist Questions for Beneficial Reuse:

Question	Answer
Is the secondary material similar to an analogous raw material or product?	Yes, Composted cuttings have excellent performance and meet land spreading discharge requirements.
What degree of processing is required to produce a finished product?	Conversion of synthetic hydrocarbons to biomass and adjustment of soil structure.
What is the value of the secondary material?	Reduction in top soil consumption and reduction is disposal cost.
Is there a guaranteed market for the end product?	Yes, as long as more drilling jobs continue and there is a need for soil.
Is the secondary material handled in a manner consistent with the raw material/product it replaces?	Yes, once the cuttings are converted to biomass.

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Summary

- ONSHORE SBM possesses the excellent drilling properties of conventional invert muds and generates drilled cuttings that may be used to amend soil to promote biomass growth.

- Reuse it, don't dispose it!

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Questions?

- Questions and comments on the reuse of Drill Cuttings as a soil amendment?

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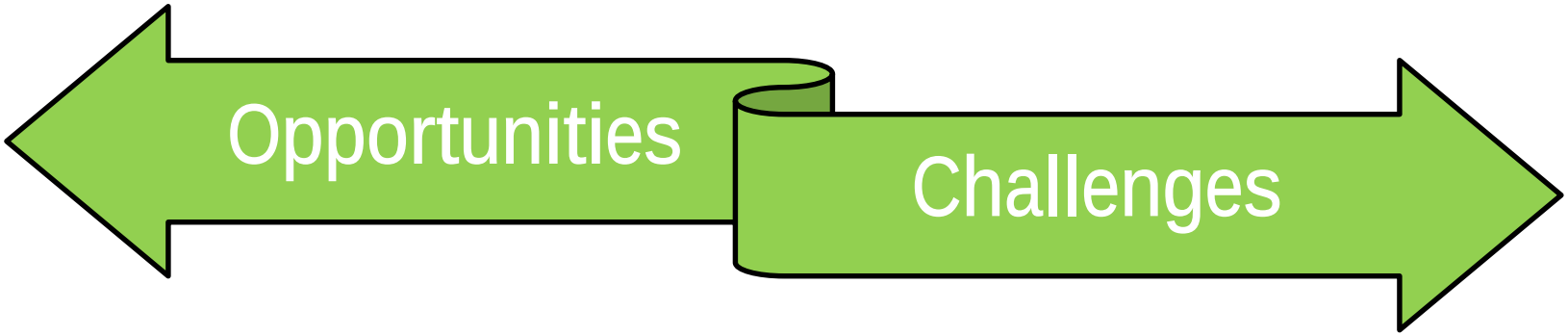
Beneficial Reuse is a Valuable and Important Tool



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