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Kuwait Environmental Remediation Program (KERP): South East Kuwait oil field FEED works and Remediation Program

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*** Kuwait Oil Company – Soil Remediation Group**



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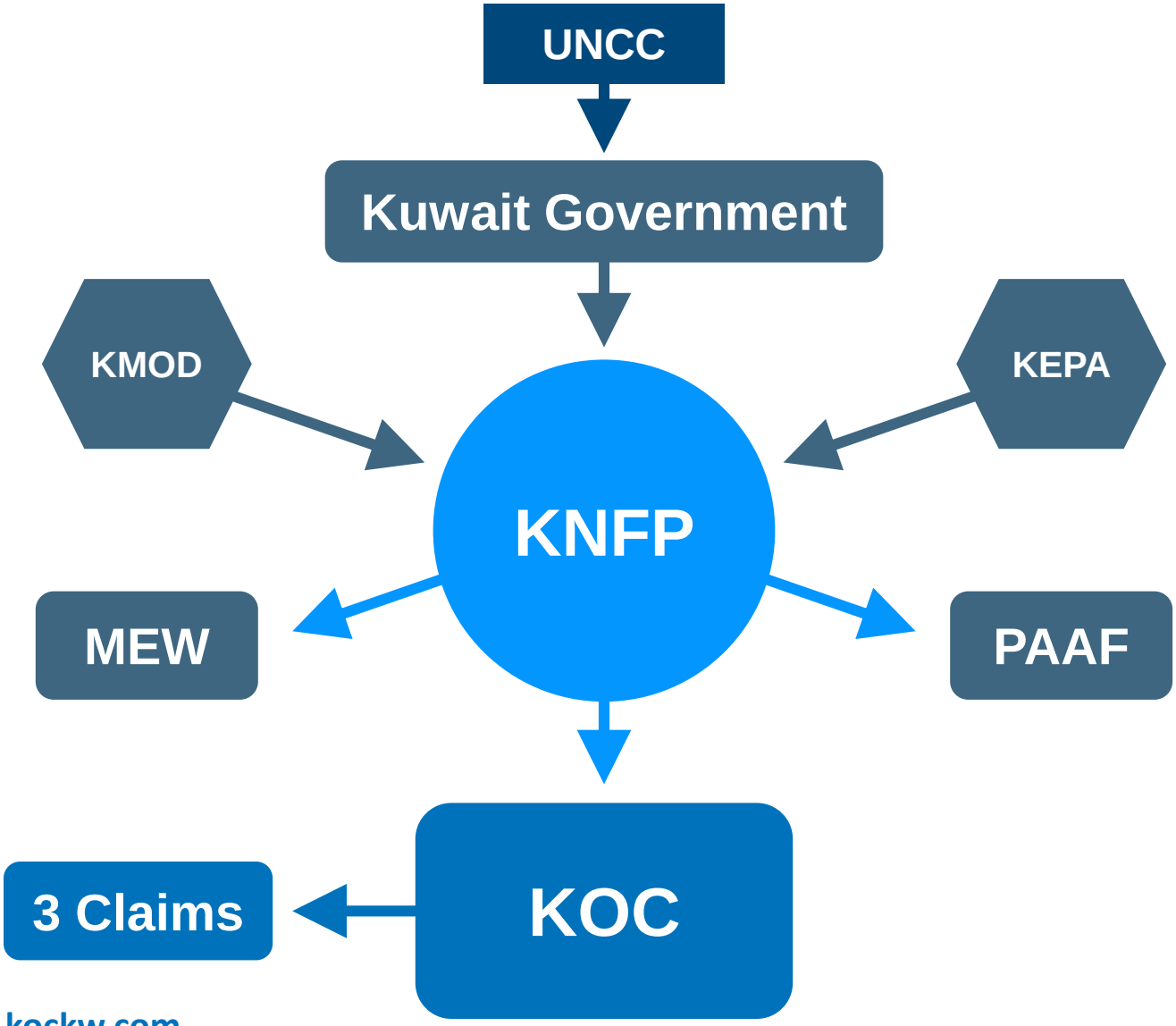
FEED Objectives

- **FEED (Front End Engineering Design).**

  - ***Bringing the picture into focus.***
  - ***Treatable contaminated soil vs. Landfill volumes within the time frame.***
  - ***Remediation contractors technical and financial assessment of most suitable technology to treat contamination.***
  - ***Provide sufficient data for tender pricing.***
  - ***Minimizing risk pricing by contractors.***
  - ***Assignment of treatment / landfill areas and reservation.***

KERP - Background

KERP Stakeholders Organization



KERP - KOC Claim Elements Awarded

The following Environmental Claim elements were awarded to KOC by United Nations Compensation Commission under Decision 258.

Claim No. 5000259

(Coastal & Marine Resources)

Claim No.5000450

(Remediation of areas in and around wellhead pits and Tarcrete)

Claim No. 5000454

(Remediation of areas damaged by oil lakes, oil-contaminated piles, oil trenches & oil spills)

Contaminated Features

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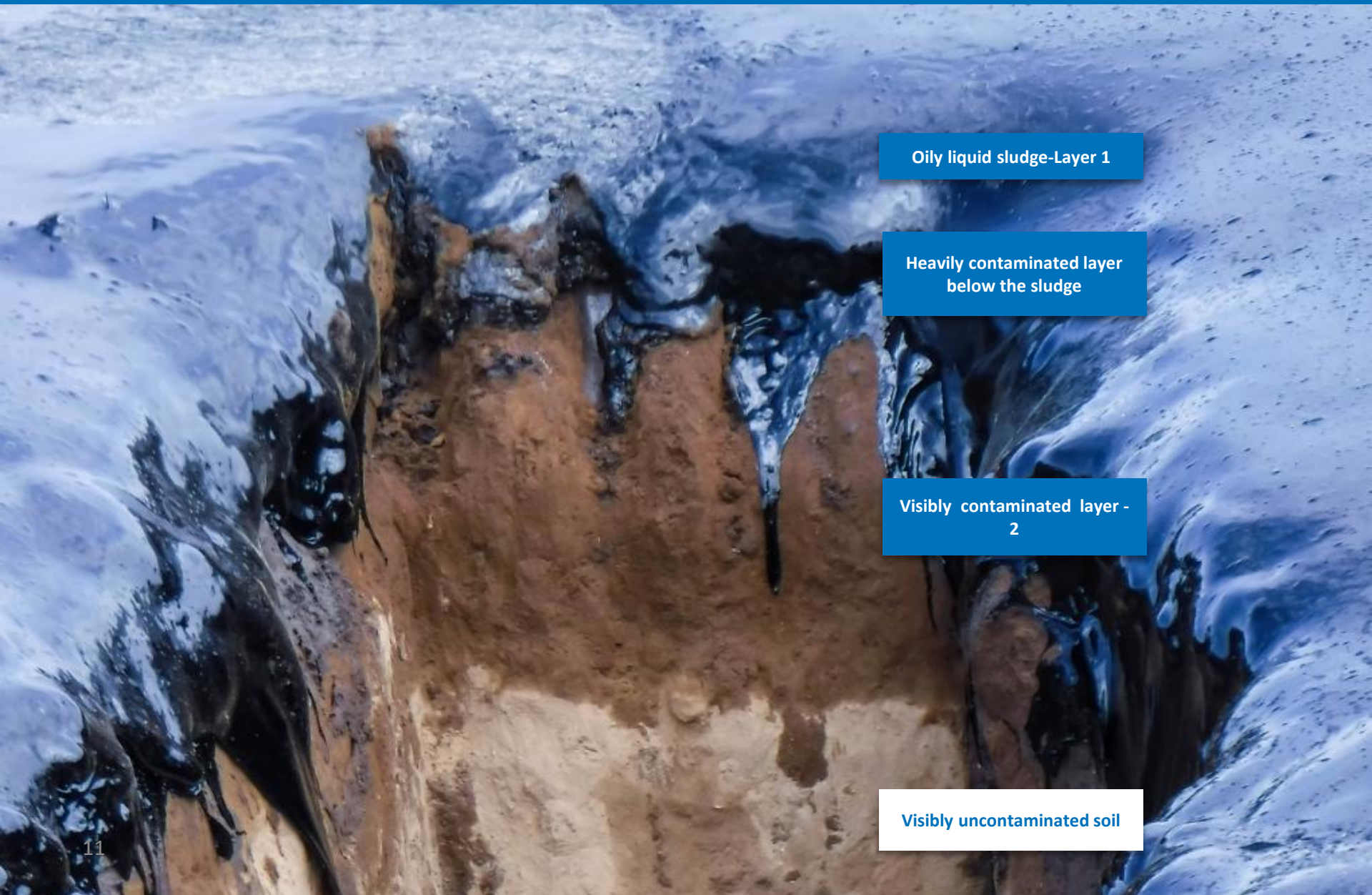
Contaminated Features

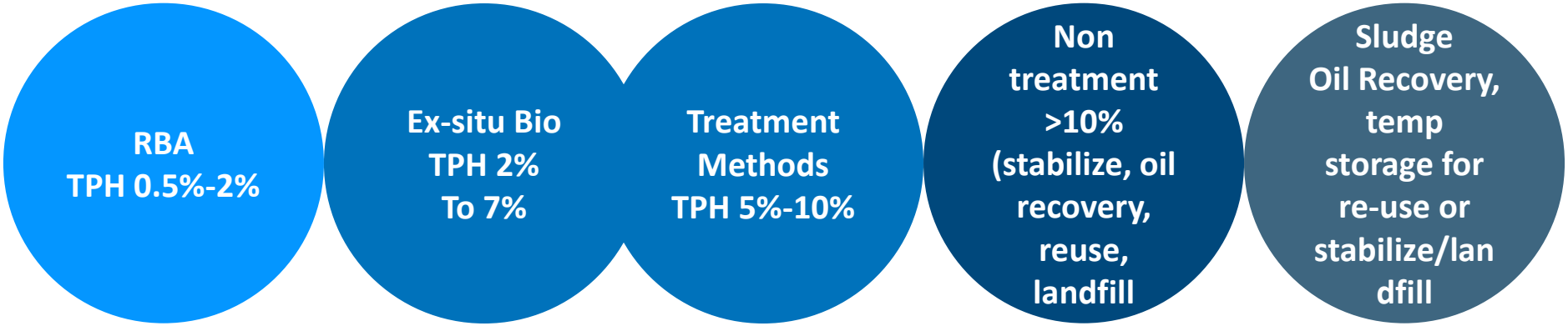
Oil Contaminated Piles

Dry Oil Contaminated Soil

Wet Oil Contaminated Soil



KERP Strategy - Total Remediation Solution



KERP Projects

Projects Name	Phase
Engineered Landfill (South East Kuwait)	Completed
Engineered Landfill (North Kuwait)	Completed
Excavation &Transportation (North Kuwait)	Completed
Excavation &Transportation (South East Kuwait)	Completed
UXO Phase-1	On going
Mega Remediation NK (4 Mm3)	*Under Committee Approval*
Mega Remediation SEK-I (9 Mm3)	*Under Preparation*

FEED Characterization

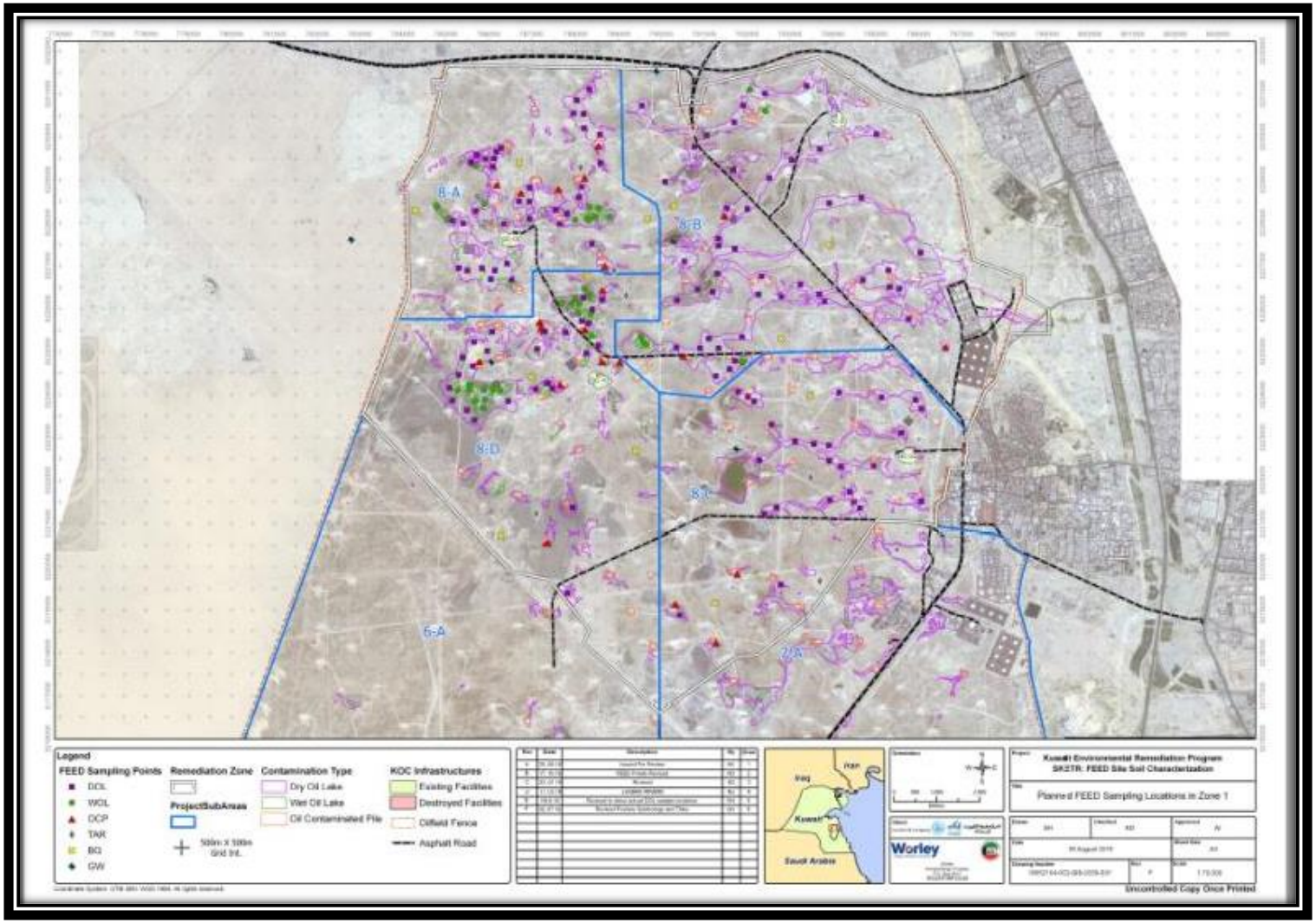
- KOC conducted a limited soil characterization study in south East Kuwait areas in 2014 and 2017.

FEED Characterization

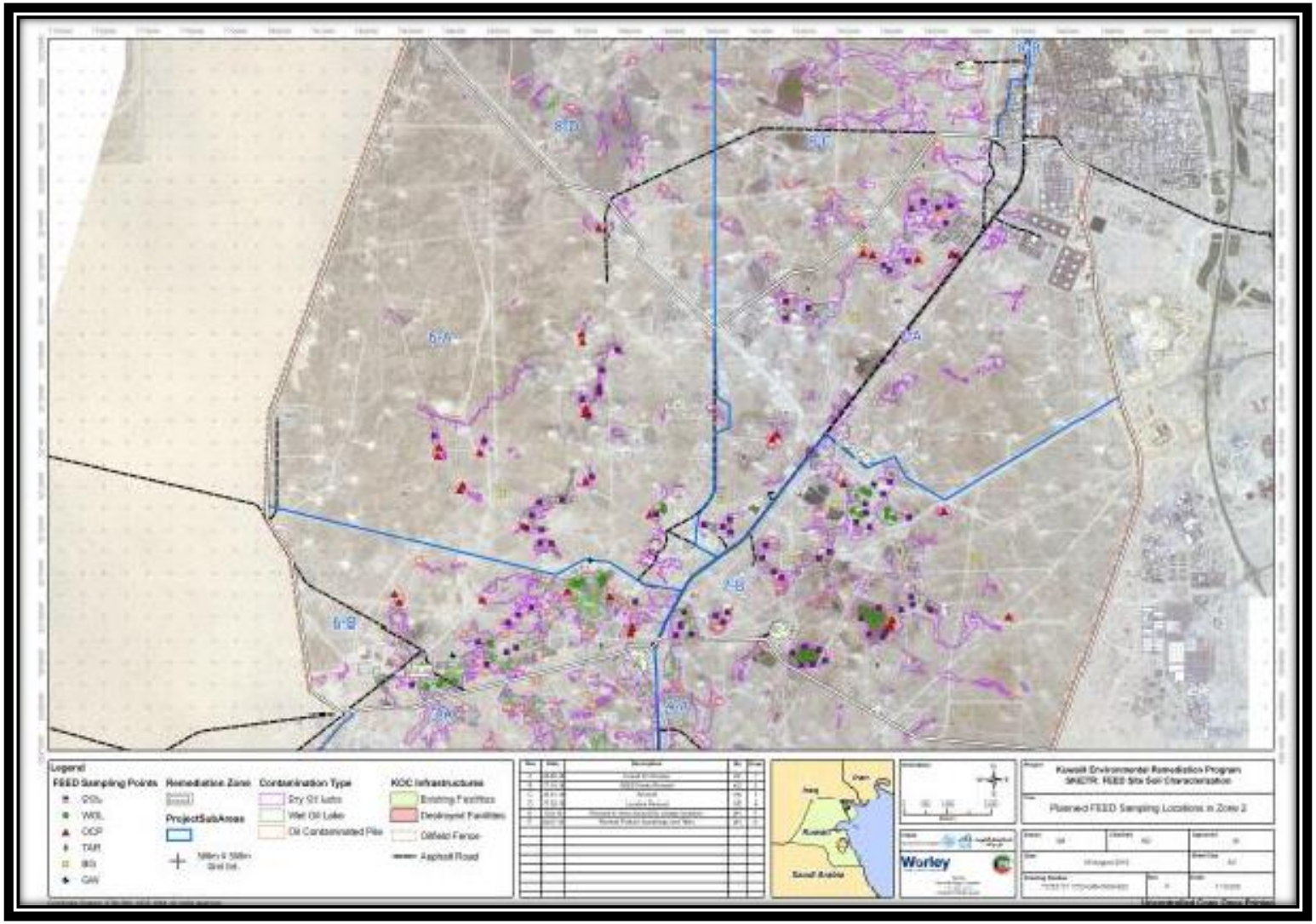
- KOC/Worley conducted a more detailed soil characterization study in south East Kuwait areas in 2019.

- 2000 locations across a contaminated area of approx. 70 km2 .

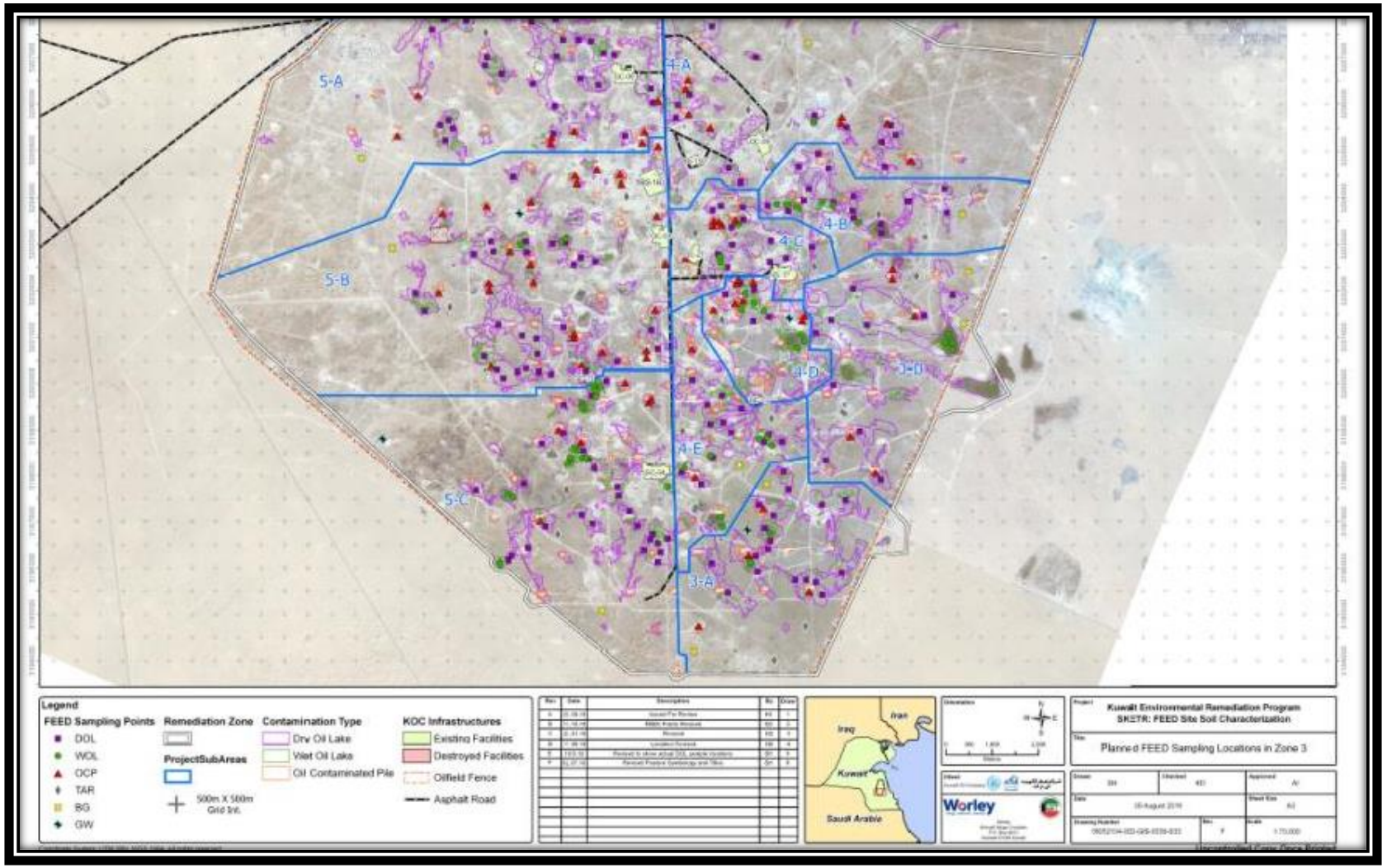
FEED Characterization



FEED Characterization



FEED Characterization



Data Maps via EQUIS software

FEED Characterization

FEED Characterisation Works (2019)

Feature Type	Land Coverage (km^2)	Material Type	# Samples	Mean TPH Concentration	Potential Remediation Approach	Comment
DOL	64.17	Layer 1 – hardened crust	103	**6.40%**	Treatment Technologies or landfill	
		Layer 2 - Oil contaminated soil	322	**2.20%**	Enhanced bioremediation	Depth profiling suggests potentially shallower contamination
WOL	5.59	Layer 1 - Oily Sludge	20	**18%**	Recovery/re-use or landfill	Sludge thickness varies but may be shallower
		Layer 2 - Oil contaminated soil	45	**2.90%**	Enhanced bioremediation	Depth profiling suggests potentially shallower contamination
OCP	5.19	Oil contaminated soil and free product (oil)	123	**7.20%**	Treatment Technologies (i.e. Soil washing)	Correlation between outward colour and contamination profile.

The FEED characterization work has provided essential data to support the development of remediation packages in line with the UN approved TRS.

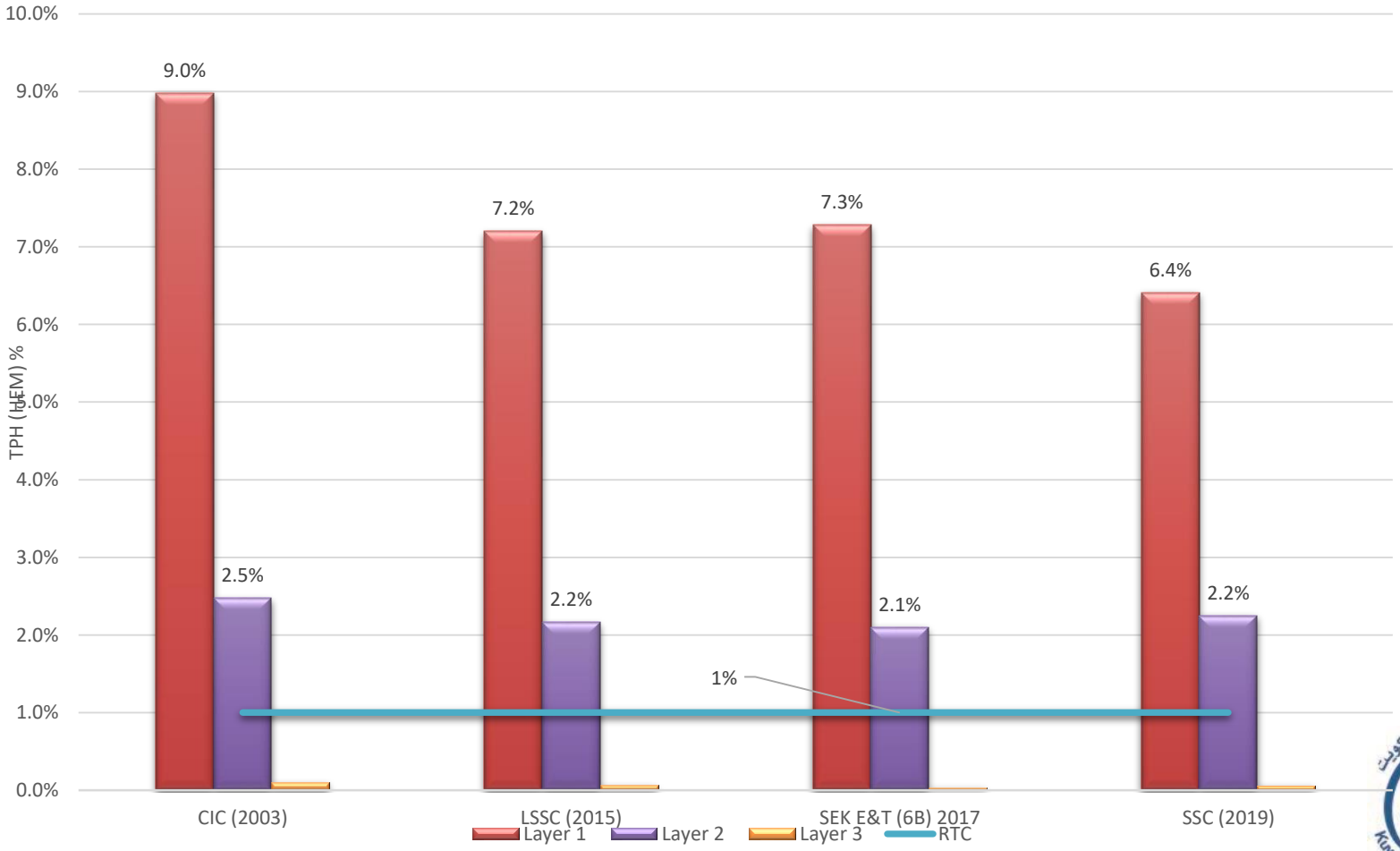
Data Informing Strategy

Original Data	All 26 M m³ heavily contaminated soils designated for landfill
Updated data	Sustainable remediation achievable on much higher percentage

Data Assessment – Bringing Into Focus

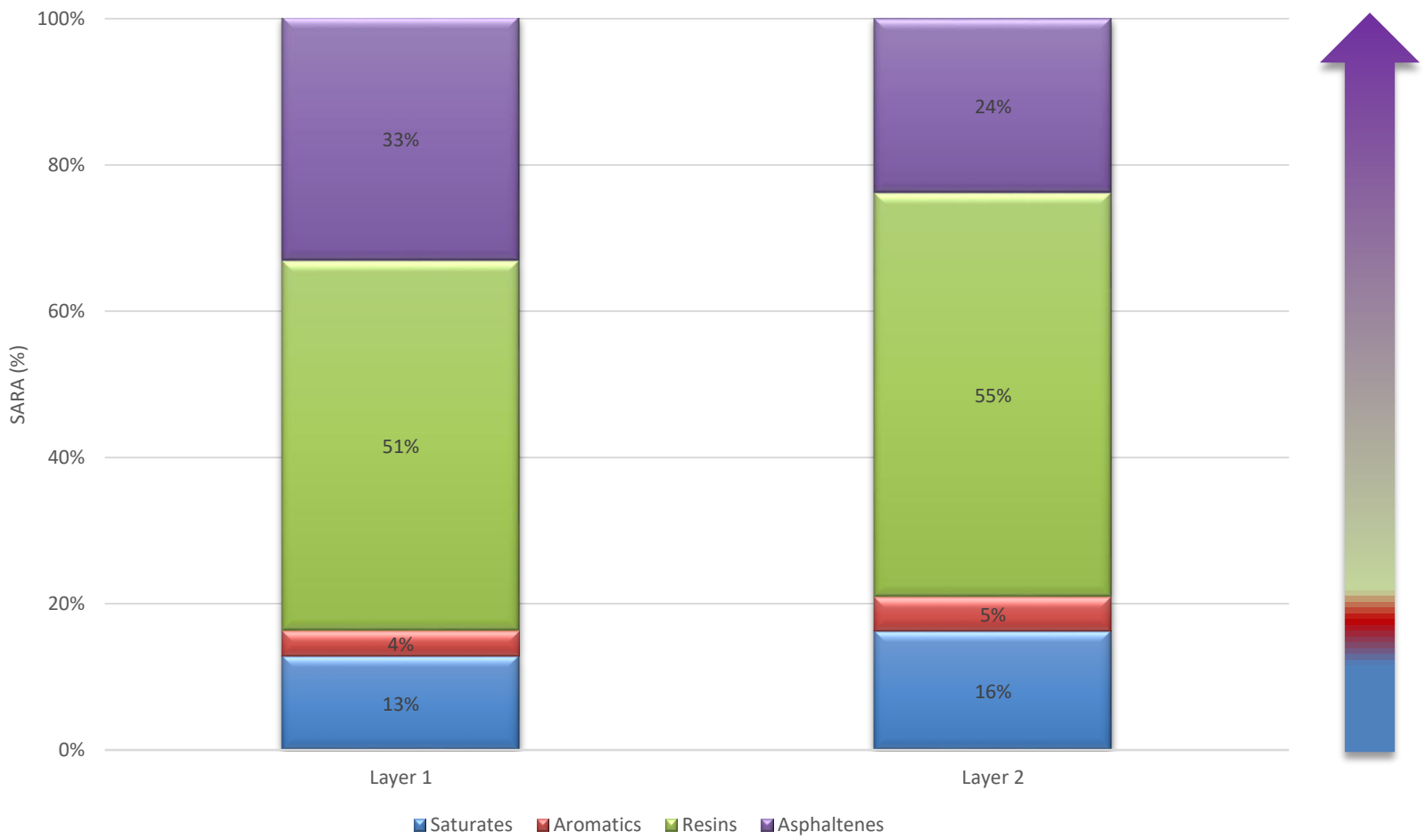
Example of findings from various characterization campaigns

- Surficial DOL Layer 1 (oil dominated material) general trend in concentration reduction, likely from weathering.
- Underlying DOL Layer 2 remains reasonably consistent across various sampling campaigns



Data Assessment – Bringing Into Focus

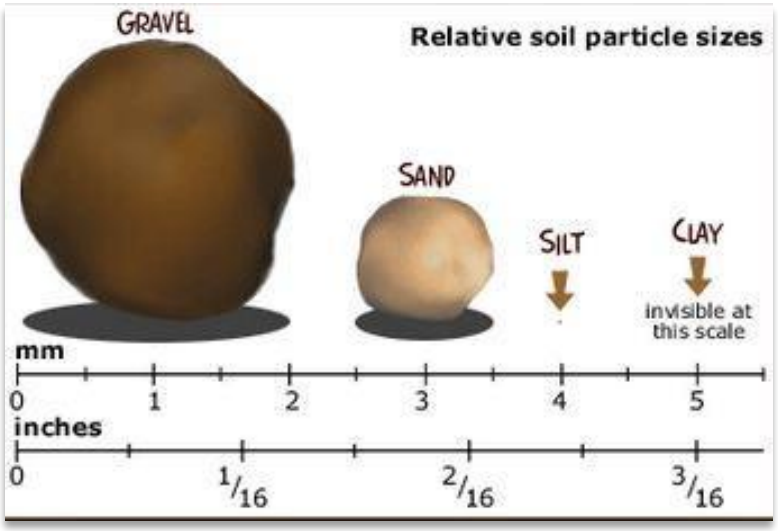
- Most recent TPH SARA analysis showing higher proportion of resins and asphaltenes



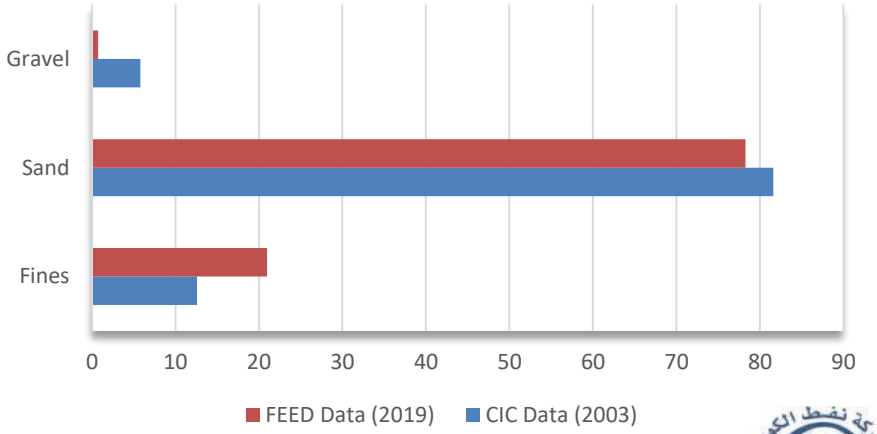
Data Assessment – Bringing Into Focus

Physical Parameters

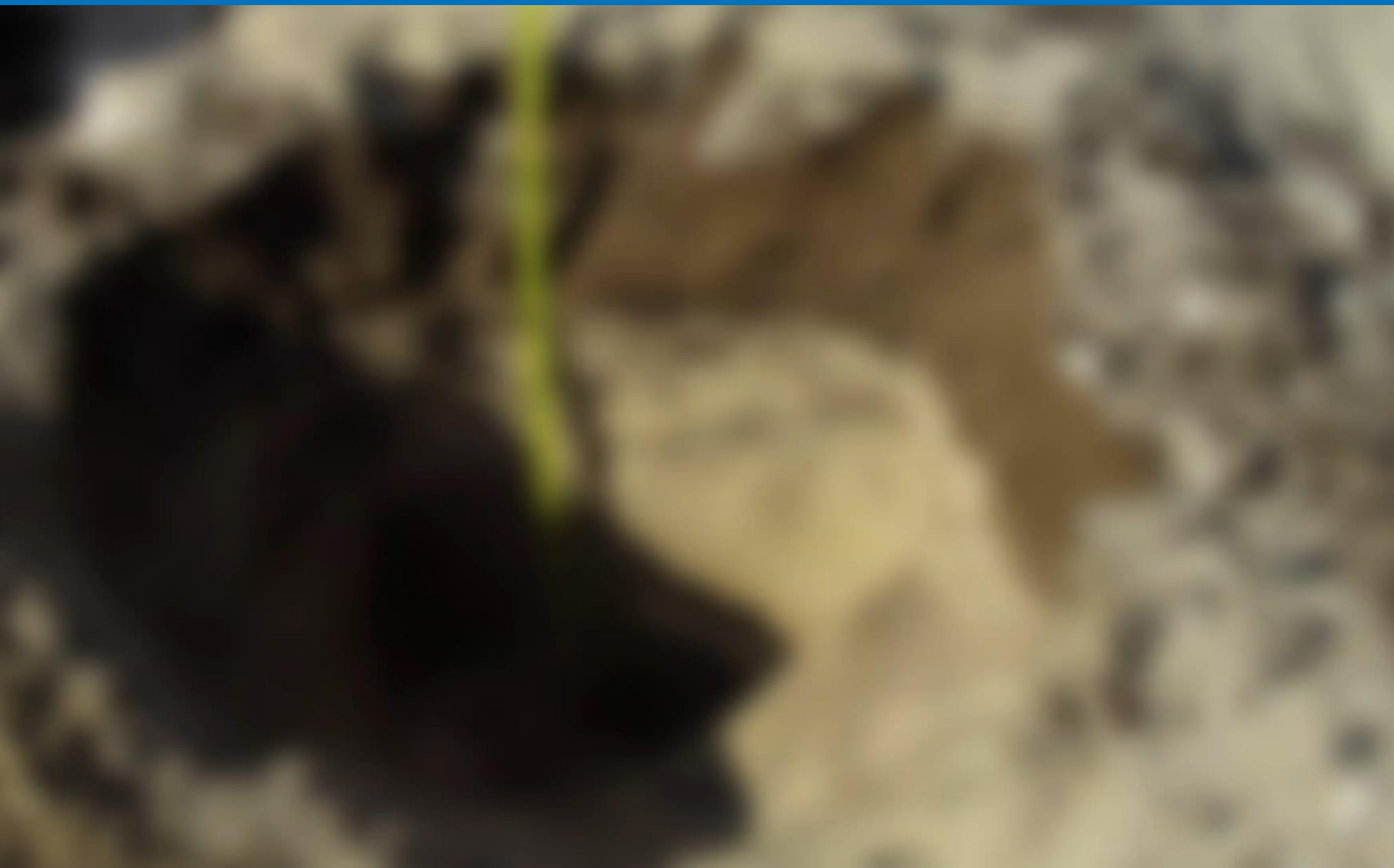
- The physical composition can impact choice of remediation technique
- FEED characterization undertook *wet* sieve assessment to try and simulate further this phenomenon, showing an increase in fines over earlier dry sieve data
- Lessons learned from other KOC remediation projects identified higher fines content (silt/clay) than expected
- Identified that sand can be weakly cemented silts that break apart under attrition (such as during soil washing).



Averaged Particle Size Analysis Comparison

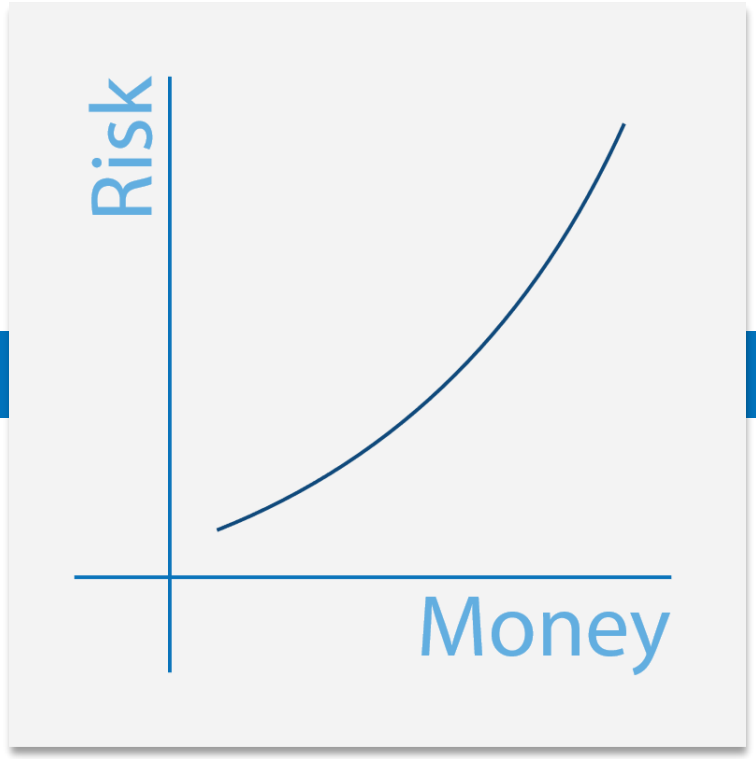


Coming into focus…



Risk Mitigation

- In summary, greater data wealth mitigates risk and consequently, reduces overall uncertainty and associated cost.



- KOC have invested in de-risking complex remediation programs.

KERP – Remediation SEK Project

TPH Range %	Indicative Total Volume Mm^3	Approximate Percentage SK (%)	Min. Treatment Requirement as Percentage of Total Volumes (%)
1.0 - 5.0	4.7	52%	90%
5.0 - 7.0	0.6	6%	80%
7.0 - 10	0.4	4%	70%
10 - 15	0.3	4%	N/A
15	3	34%	N/A
TOTAL	**9**		

Contractor Considerations

- Expected distances to be travelled to transport contamination 4-8 million km to complete works (100 to 200 times around the earth)
  - Dependent on Contractor Strategy (in-situ vs ex-situ)
- High pressure abrasive soil wash will result in an increase in waste production due to increasing fines
- Bioremediation TPH rebound to be considered in treatment period
- No HTTD allowed as per client directive

FEED / TRS Benefits

- Minimising Potential Claim against Company in the Future
- Avoid scenarios of remediation failures
- Competitive rates due to de-risking
- Achieve Kuwait Environmental Public Authority clean-up criteria.
- Less reliance on Landfill
- TRS provide more ecologically sustainable treatment solutions

Thank you

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A Subsidiary of Kuwait Petroleum Corporation

Data Analysis and Results

Limited Scope Investigation - Burgan - South East Kuwait (2014):

Table 1 : Minimum, Maximum & Mean for TPH level in Layers-1&2 of Wet and Dry Oil Lakes					
Material Type / Analysis	Minimum (mg/kg)	Maximum (mg/kg)	Geometric Mean (mg/kg)	Arithmetic Mean (mg/kg)	Standard Deviation (mg/kg)
Wet Oil Lake					
Layer 1	94,835	166,171	133,373	135,557	25,310
Layer 2	11,585	87,450	32,847	39,749	24,840
Dry Oil Lake					
Layer 1	718	126,811	17,576	27,847	10,271
Layer 2	9,923	35,126	23,660	28,507	4,847

Data Analysis and Results

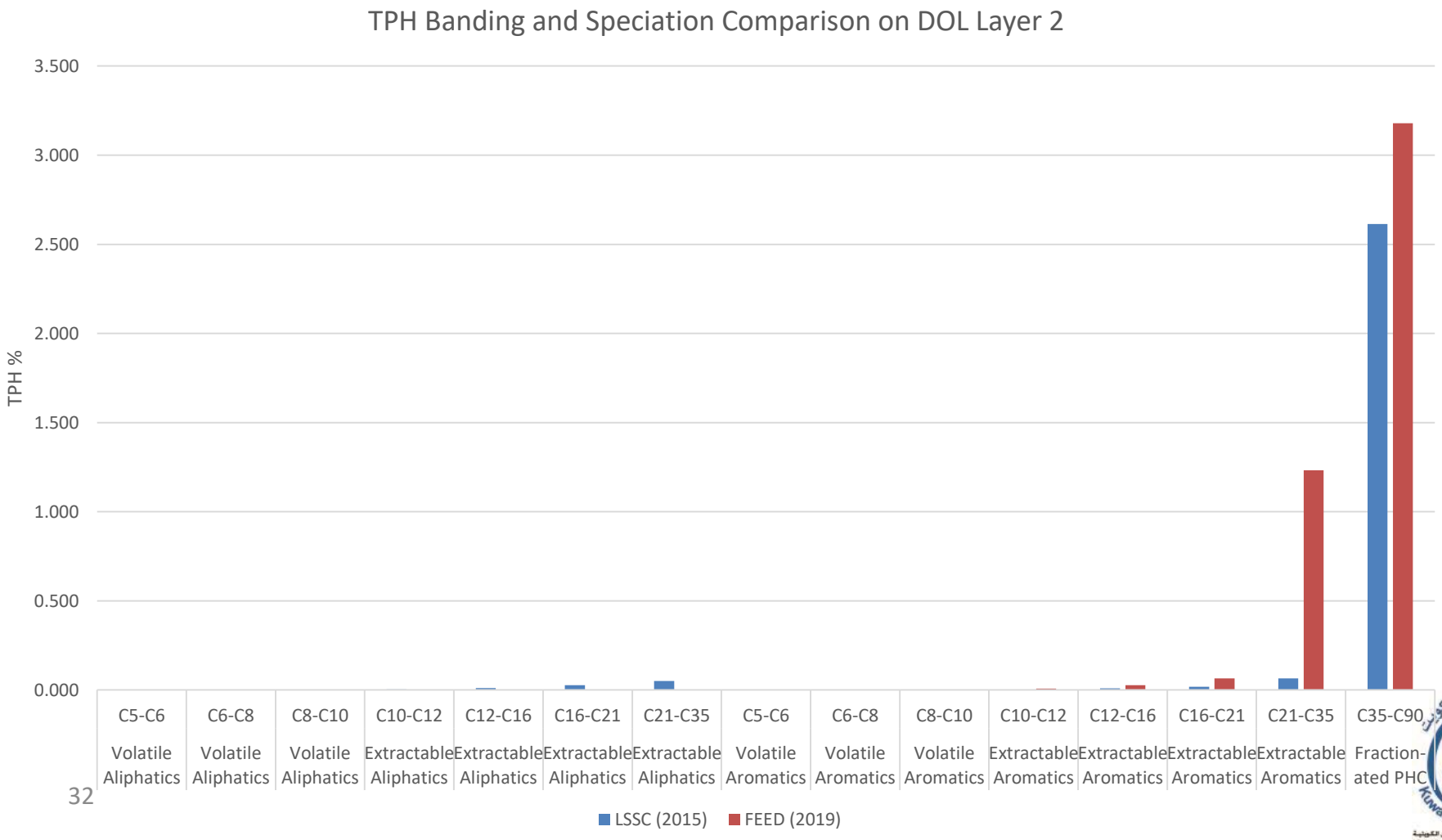
Petroleum Hydrocarbons Investigations in S&EK fields:

Table 2 : Minimum, Maximum & Mean for TPH level in Layers-1&2 of Wet and Dry Oil Lakes					
Material Type / Analysis	**Minimum (mg/kg)**	**Maximum (mg/kg)**	**Geometric Mean (mg/kg)**	**Arithmetic Mean (mg/kg)**	**Standard Deviation (mg/kg)**
Wet Oil Lake					
Layer 1	305,816	624,513	466,424	480,068	13,644
Layer 2	73,941	169,045	131,966	13,6521	4,555
Dry Oil Lake					
Layer 1	1,074	326,421	62,440	89,456	27,016
Layer 2	9,866	203,760	30,310	40,052	9,742

Data Assessment – Bringing Into Focus

Example of findings from various characterization campaigns

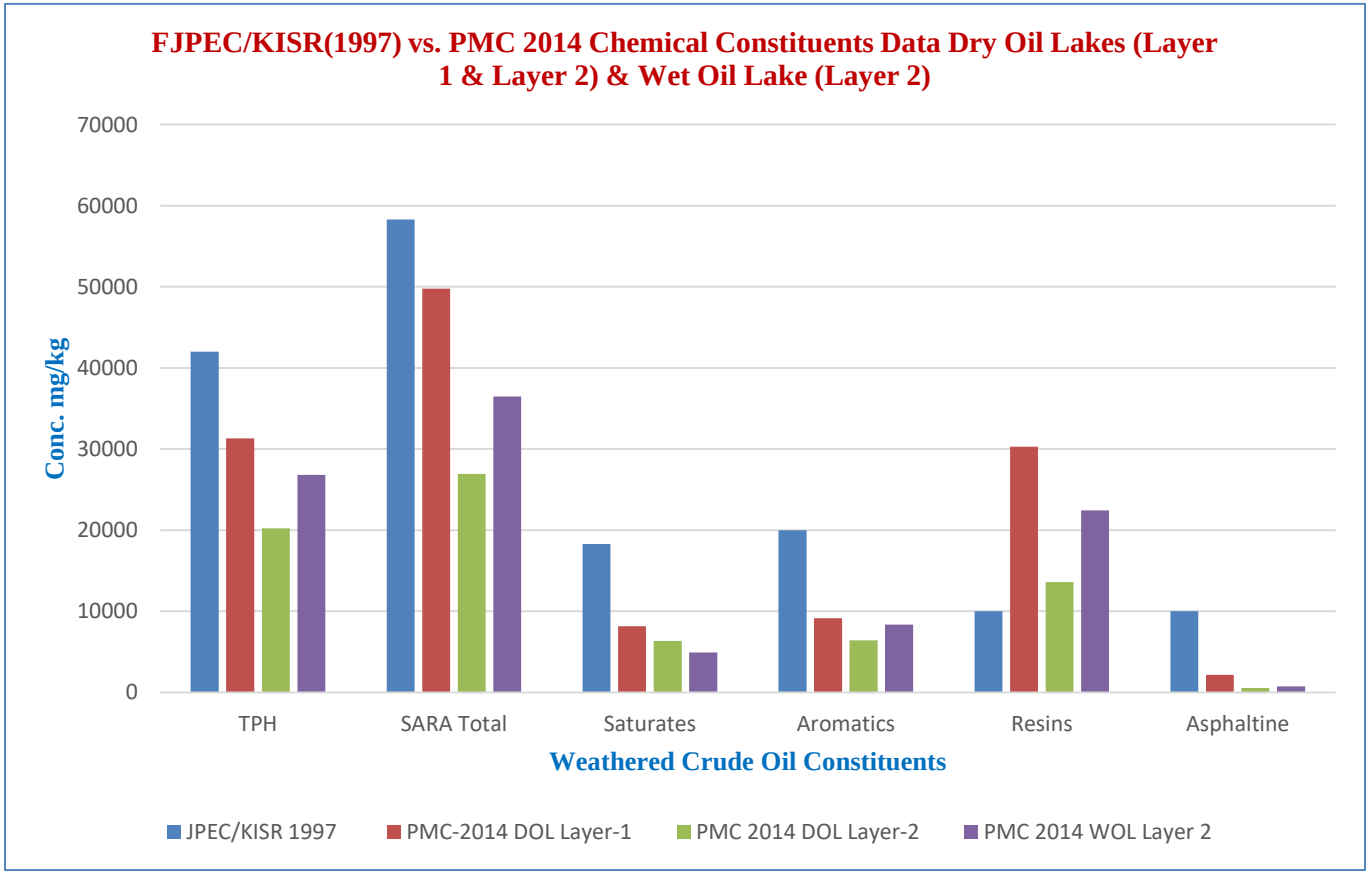
- TPH Criteria Working Group (CWG) banding and speciation comparison demonstrating larger chain length dominance (C35-C90) and absence of “light end” hydrocarbons.



Data Assessment – Bringing Into Focus

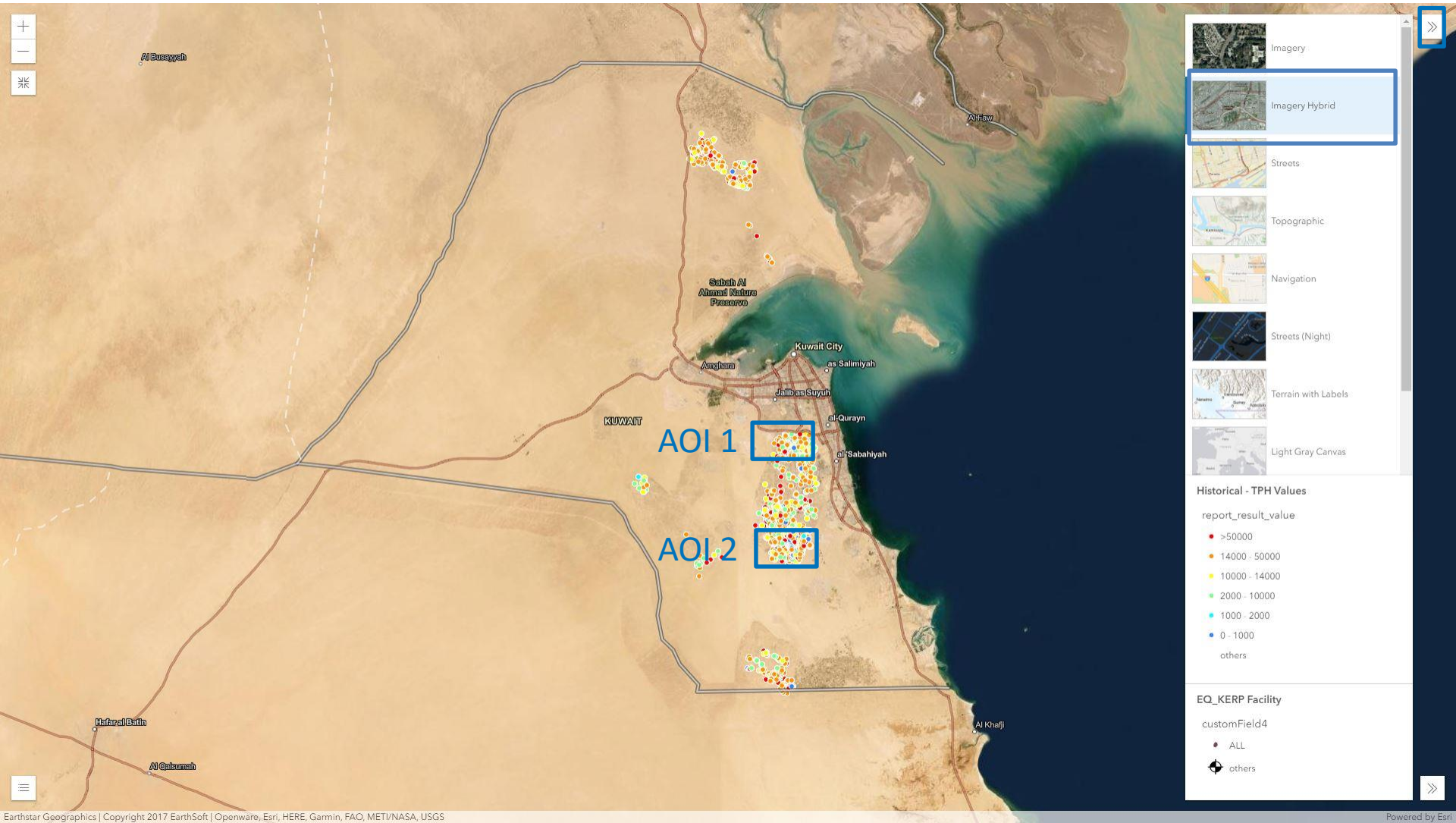
Utilizing detailed characterization for more predictive remediation approaches

- Utilizing TPH composition analysis when considering bioremediation or combination of bioremediation with other techniques

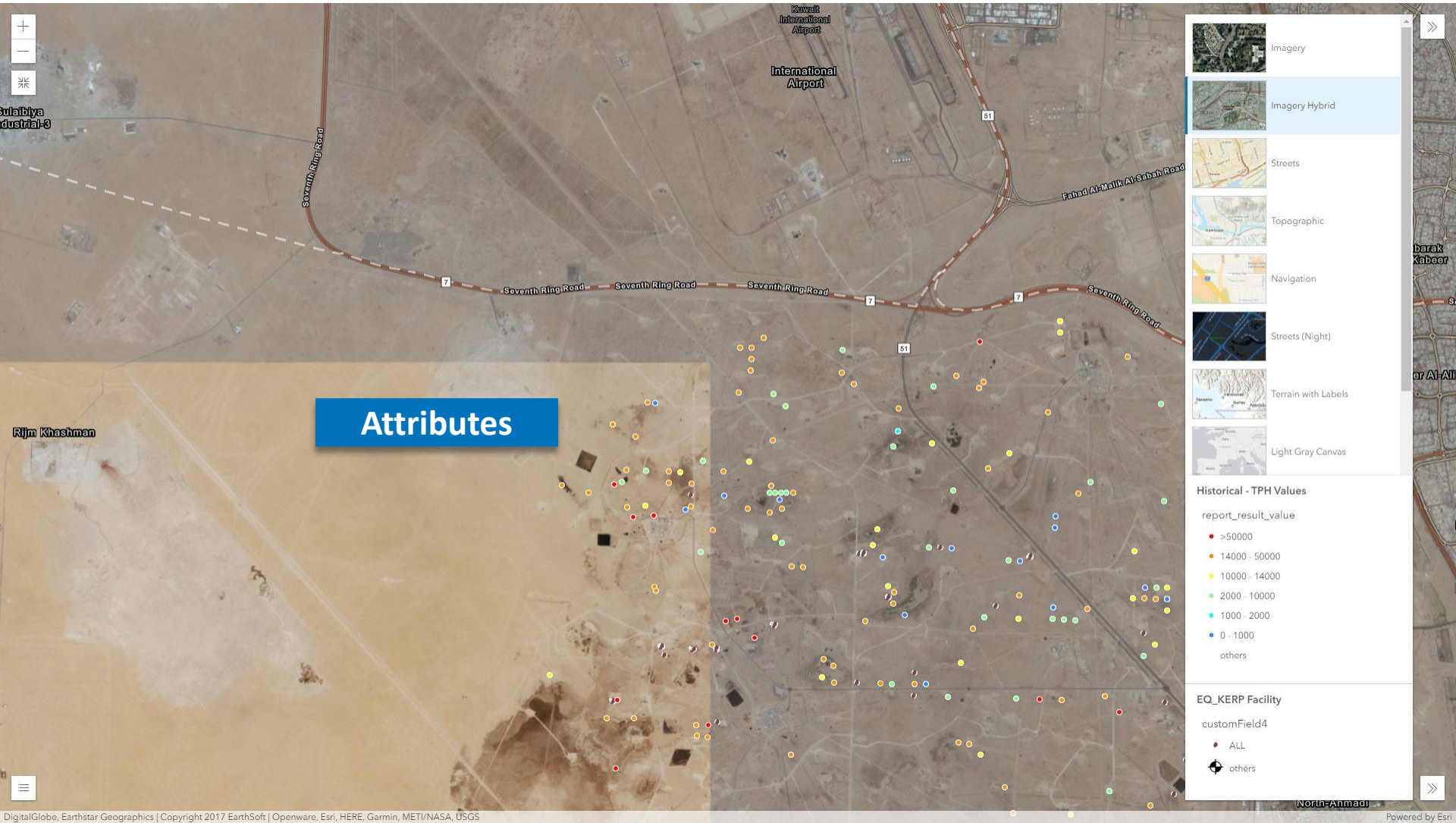


Increasingly challenging for bioremediation

Data Analysis and Results

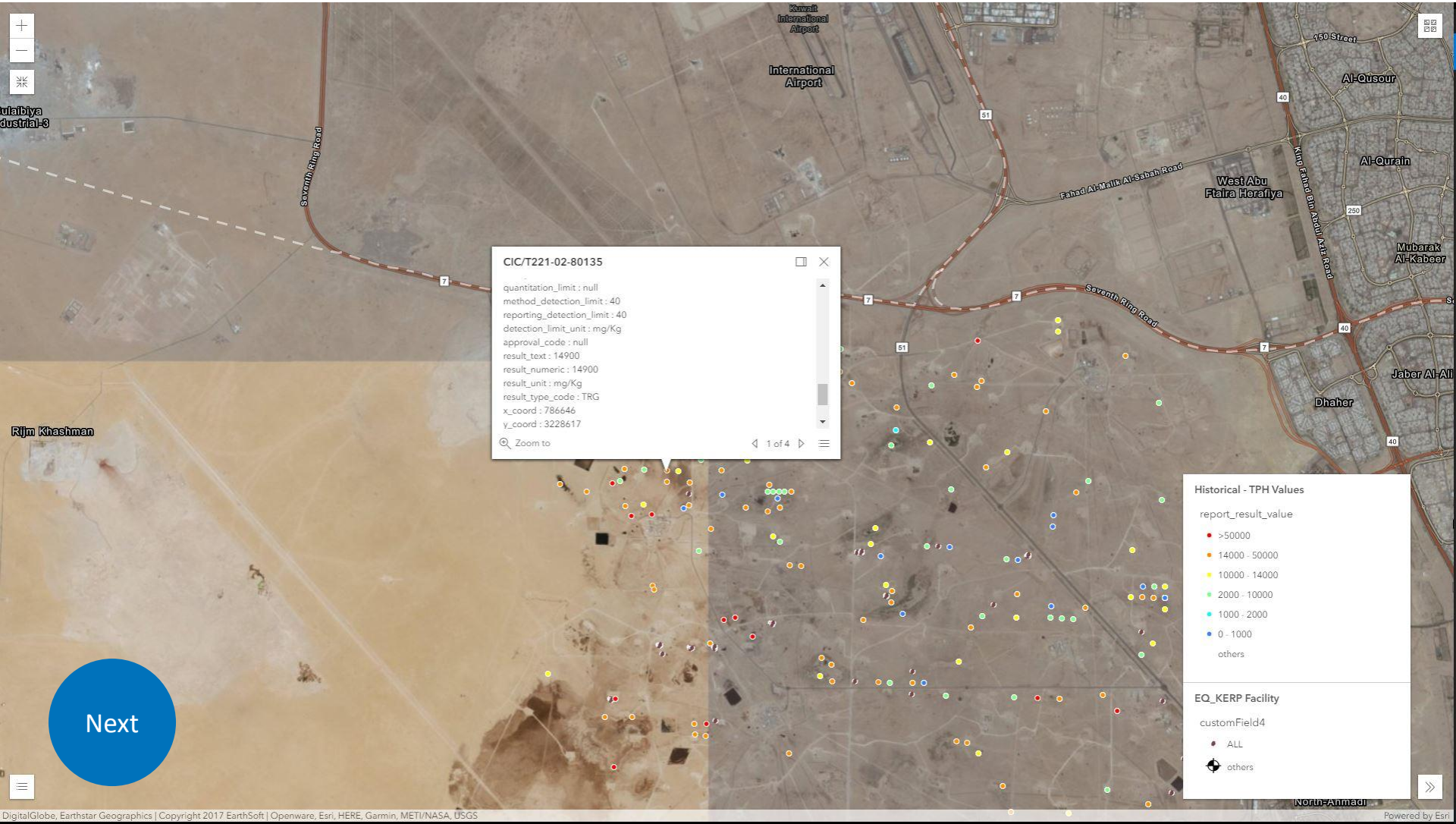


Data Analysis and Results



Data Analysis and Results

AOI 1



Next

Data Analysis and Results

AOI 2