An IR-Based Rapid Field Analytical Method for TPH Measurement - Field Deployment and Performance Evaluation

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Project Background

Opportunity

Soil samples from hydrocarbon impacted soil in exploration and production operations need to be tested for Total Petroleum Hydrocarbon (TPH)

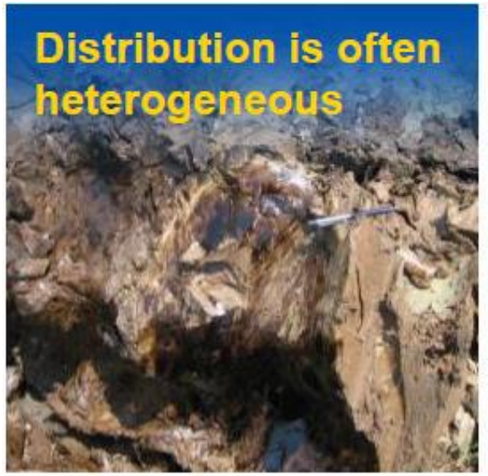
- **Delays in sample analyses** and **decision making** due to large # of soil samples per week needing analysis
- Lab analysis can take 2-4 weeks

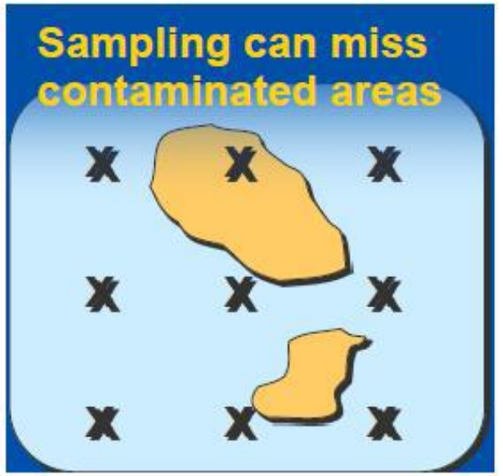
Approach

Development of rapid TPH analytical method to increase accuracy and efficiency

1) Real-time remediation process monitoring

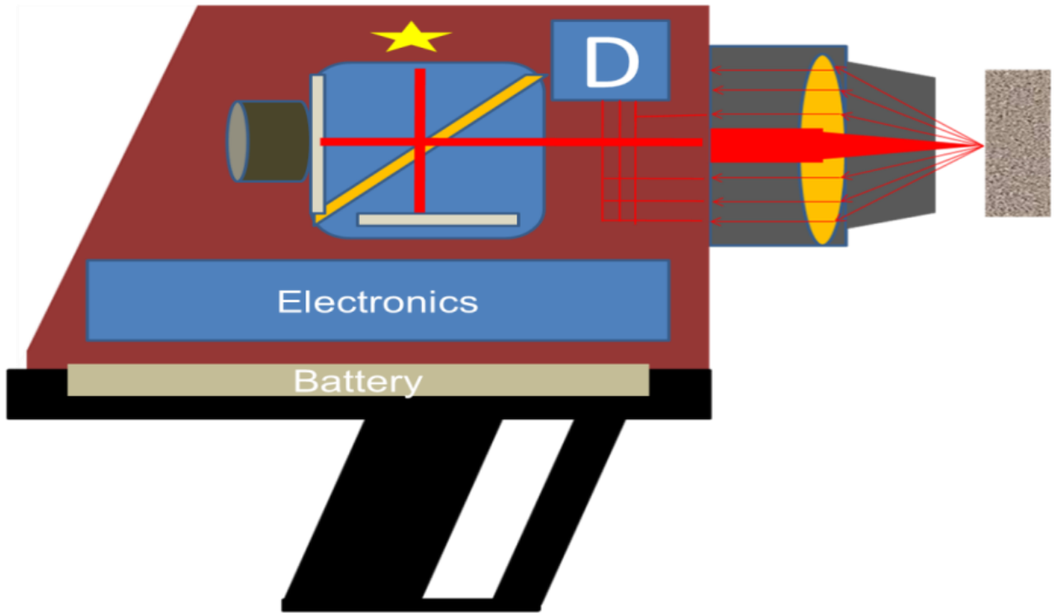
2) Reducing the number of samples going to lab





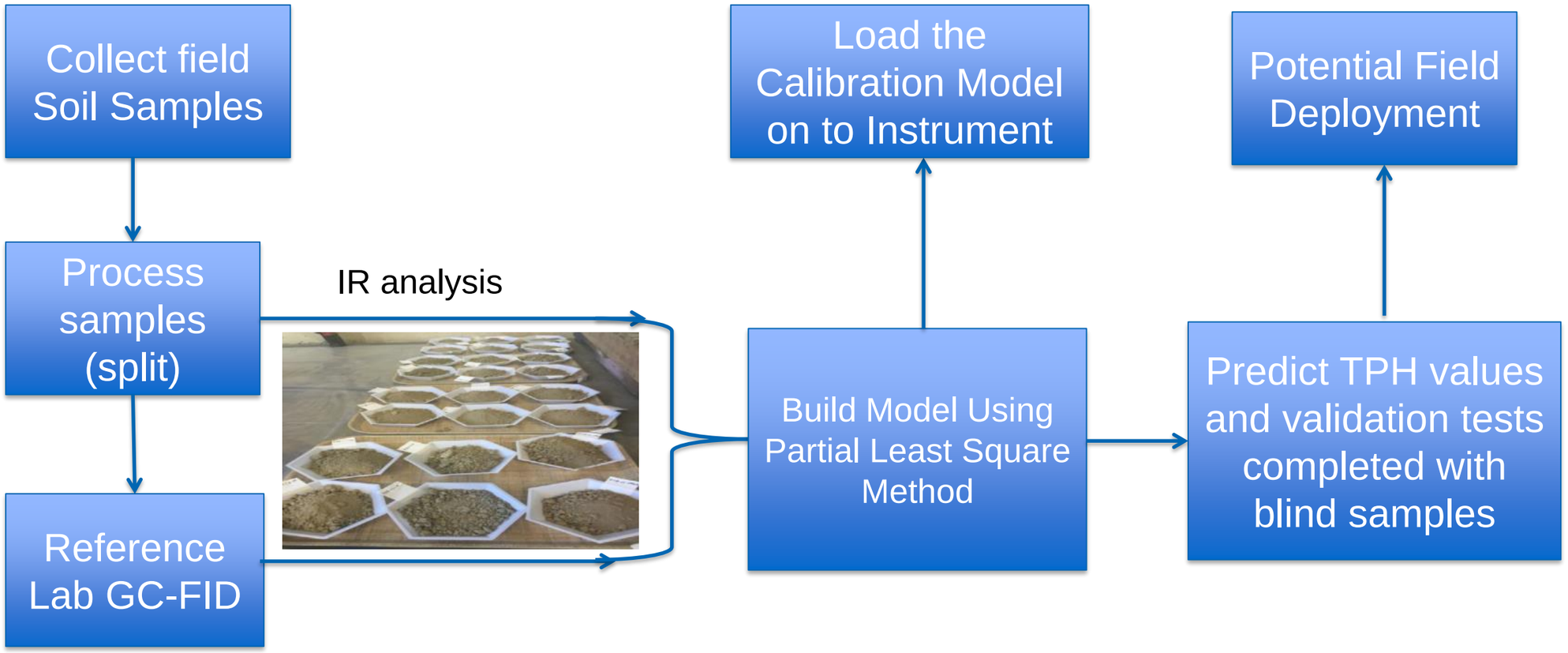
Handheld IR Instrument for Non-Destructive TPH Measurement

- Portable handheld IR instrument
- Diffuse reflectance of IR light reflected from the sample
- The world's first handheld instrument for the direct measurement of TPH in soil
- User simply pulls the trigger for a 15 second reading of TPH (C_{10}-C_{36}) in mg/kg



IR light is emitted
Interacts with the surface of the sample
Light is diffusely reflected back to detector
IR spectrum (readout) is produced

Field Pilot Approach



Pilot Studies Results Evaluation – Field A

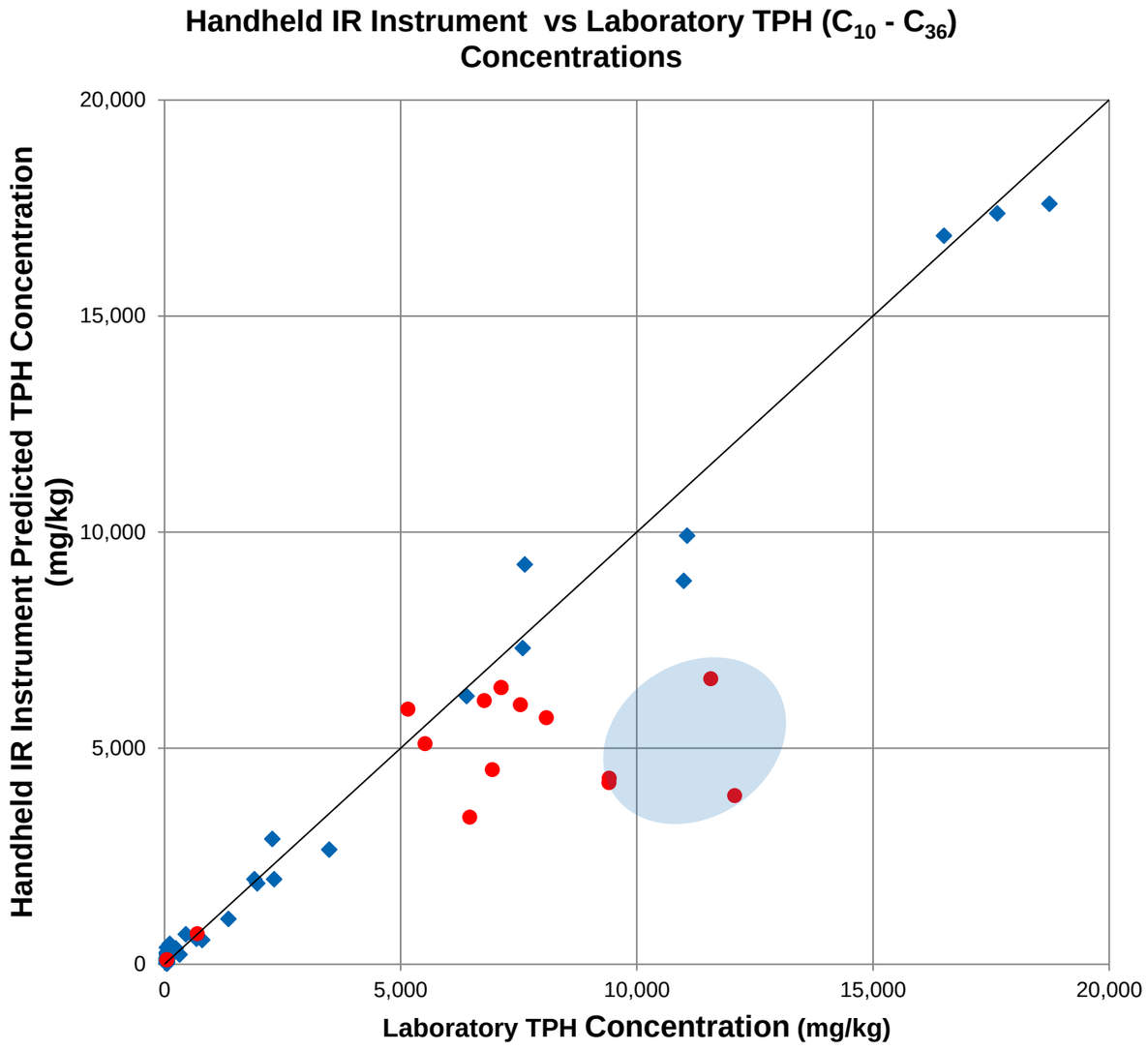
Calibration model completed with 111 soil samples from Field A at TPH range 0-120,000 mg/kg

Using calibration model A vs. GCFID Data for validation Test

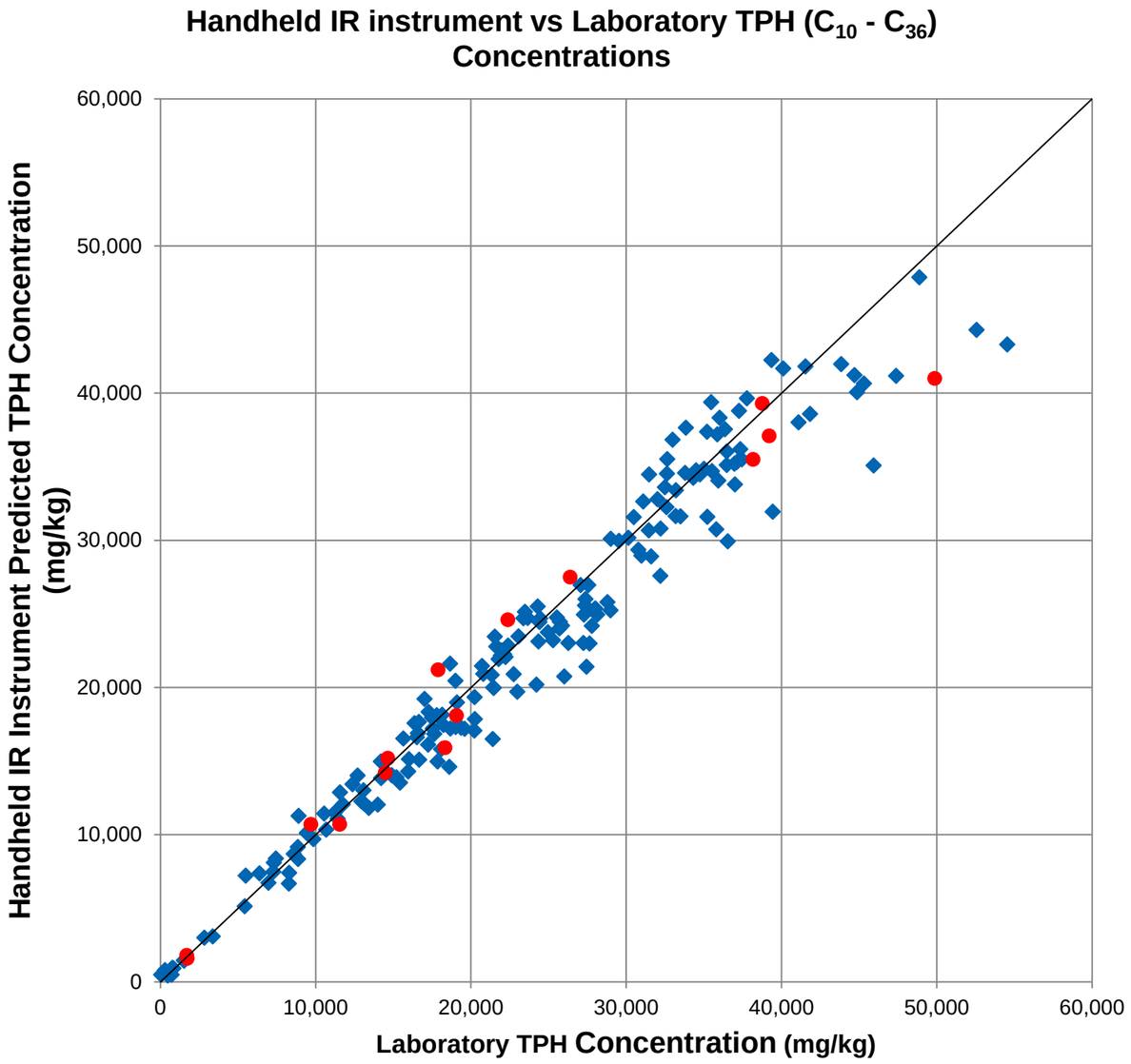
Validation Samples (•)& Calibration Samples (◆)

Outliner analysis - spectrum suggests the high clay contents of those samples

Detection limit of this model - 170 mg/kg



Pilots Studies Results Evaluation – Field B



Calibration model completed with 200 soil samples from Field B at TPH range 0-50,000 mg/kg

Using calibration model B vs. GCFID Data for validation Test

Validation Samples (•)& Calibration Samples (◆)

Detection limit of this model- 380 mg/kg

Accuracy for Various Assay Ranges for Calibration Samples for Soils in Two Different Oil Fields (A & B)

Field A (wide range of calibration up to 12%)

Assay Ranges (mg/kg TPH)	RMSECV mg/kg TPH	Correlation Coefficients (r^2)
0 - 3,000	170	0.92
3,000 - 5,000	184	0.96
5,000 - 15,000	410	0.98
15,000 - 30,000	803	0.99
30,000 - 120,000	2,375	0.99

Field B (limited calibration up to 5%)

Assay Range (mg/kg TPH)	RMSECV (mg/kg TPH)	Relative Standard Deviation* (%)
0 - 5,000	376	n/a
5,000 – 15,000	930	≤ 19
15,000 – 20,000	1,390	≤ 9
20,000 – 30,000	2,107	≤ 11
30,000 – 50,000	2,815	≤ 9

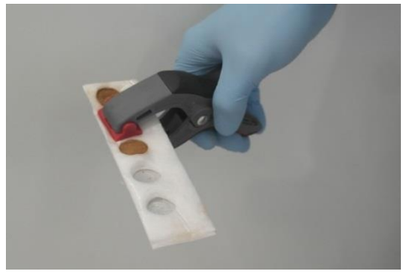
RMSECV: Root-mean-square Error of Cross-Validation

Field Application- For Existing Soil Stockpiles

✓ RemScan works best when the soil is dry & sample is measured directly on site

Field Application- What Can We do to Meet the 5% Free Moisture Requirement?

- ✓ if the soil is wet, measurement can be done after drying the sample



Or

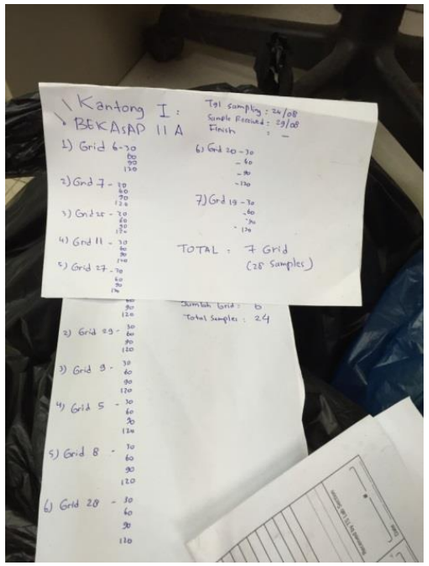
- ✓ Press the soil sample into the drying tray and use the drying box to dry the sample in 30 minutes/36 samples
- ✓ Samples put in drying in the morning can be measured for TPH in the afternoon

Field Application

How RemScan is used in different operational settings

✓ Other scenario: when the sample is wet, measurement can be done after drying the sample.

Collection of samples from multiple sites

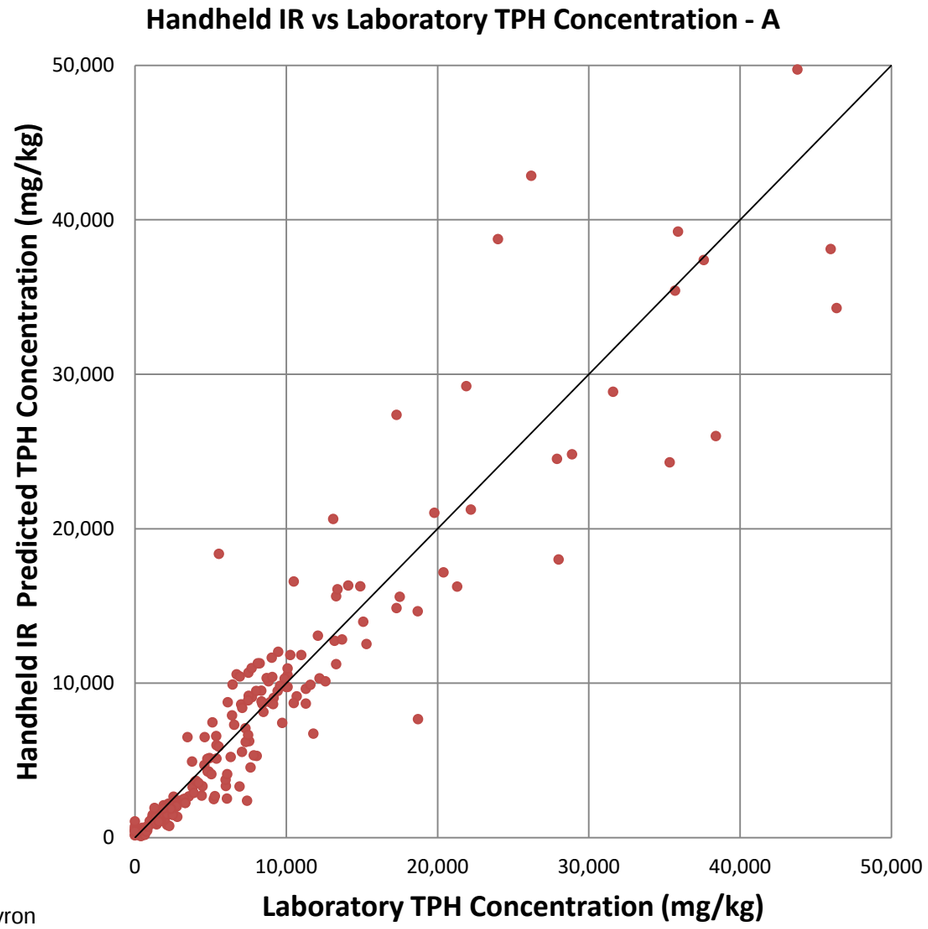


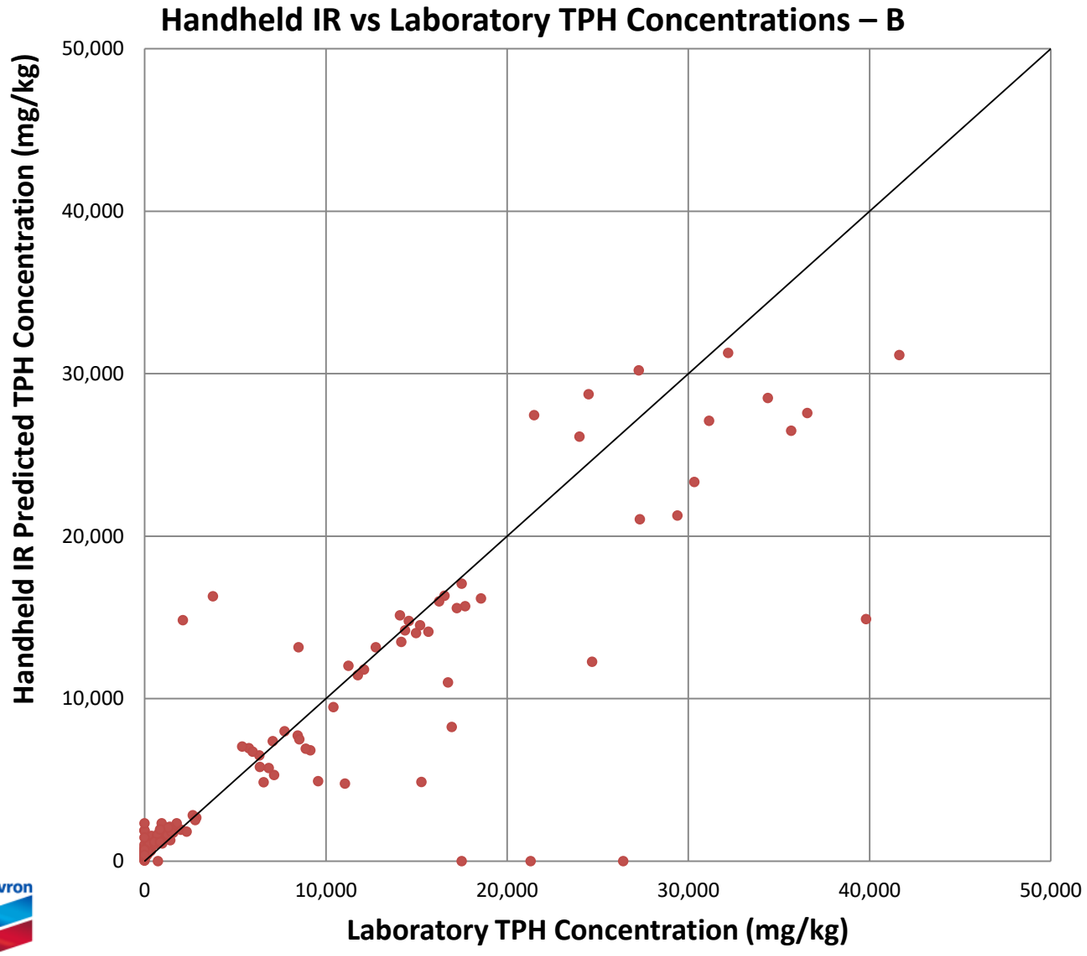
Measurement at office

✓ For samples that need longer drying time, RemScan is not readily available on site, and the result is reported the next day

Field Deployment – Model Performance Check

- 3-5 RemScan units deployed for field TPH measurements
- Monthly split sampling program established to monitor the accuracy
- 70% of the handheld IR measured data are within +/- 30% of Lab GCFID results





Data Check - Precision Evaluation

Precision evaluation:

- Homogenize samples and divide into 5 sub-samples
- Measure each sub-sample 3 times
- Test with RemScan using the same sample to check precision and repeatability

Sample ID	Soil Type	Color	REMSCAN		RSD (%)
			%	mg/Kg	
DR-01	Clayey Silt	Dark Brown	2.36	23,600	6.02
DR-02	Clayey Silt	Dark Brown	2.54	25,400	9.05
DR-03	Clayey Silt	Dark Brown	1.99	19,920	10.86
DR-04	Clayey Silt	Dark Brown	1.92	19,220	2.45
DR-05	Clayey Silt	Dark Brown	2.29	22,860	5.20
DR-06	Clayey Silt	Light Brown	0.25	2,473	9.60
DR-07	Clayey Silt	Brown	1.23	12,340	5.52
DR-08	Clayey Silt	Dark Brown	2.67	26,747	11.80

Summary

❖ This portable handheld IR Instrument will enable rapid and accurate delineation of sites & allows real time process monitoring for different remediation technologies

- **Significant time reductions**
  - Real-time process monitoring
  - Rapid, field-based testing
  - Improve data density for site assessment
  - Less waiting time for soil excavation and transport
- **Improved Safety**
  - Prevents worker exposure and generation of waste by eliminating the use of solvents (used in the lab and in other field test methods)
- **Potential Cost Savings**

Acknowledgements

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