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#### Former Naval Petroleum Reserve No. 1 Environmental Restoration Project

#### RCRA Facility Investigation at the Elk Hills Oil Field

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- Systematic oil field environmental assessment approach
- The unexpected nature and extent of arsenic contamination in soil
- Rapid site characterization tools and techniques
- The value of partnerships in multiple stakeholder decision making







#### Ahtna Facility Services Inc.



- Ahtna Facility Services Inc. (AFSI) is a wholly-owned subsidiary of Ahtna, Incorporated, an Alaska Native Corporation (ANC).
- Ahtna is one of the original 13 regional ANCs
- 100 % Native Shareholder-owned. Focus on land stewardship, and maintaining tribal heritage
- 14 Subsidiaries offering a variety of services
- 38 years on the Trans-Alaska pipeline System
- Diverse Federal Government and Commercial Client Base









#### Former Naval Petroleum Reserve No. 1 (NPR-1)





#### Former Naval Petroleum Reserve No. 1





# NPR-1 (Elk Hills) History



- 1910 Lakeview Gusher
  - 18 month eruption released 9 million barrels of crude oil
  - Largest accidental oil spill in history
- 1911 Discovered by Associated Oil Company
- 1912 President Taft executive order set aside NPR
- Held as a reserve until the mid-1970's
- 1973-1974 Arab Oil Embargo: Navy opened up the oil field to development through private contractors



#### **Project History**



- 1975: Transferred from the Navy to Department of Energy (DOE)
- 1996: Public Law 104-106 required DOE to sell the United States' lands and hydrocarbon interests in NPR-1
- 1997: DOE Federal interests sold to Occidental Petroleum Corporation via competitive bidding process
- 1997- 1998: California Department of Toxic Substances Control (DTSC) completed a Resource Conservation Recovery Act (RCRA) Facility Assessment



#### **Project History**



- 2008: DOE/DTSC Corrective Action Consent Agreement
- 131 Solid Waste Management Units and Areas of Concern (AOC)
- Further investigations and corrective measures for protection of the environment and public health
- Currently operated by California Resources Corporation with Chevron an active land owner
- One of the largest active oil fields in the lower 48 states
- Largest gas producing oil field in California



#### **Current Status**



- 2010: AFSI, under contract to DOE, developed Work Plans, Decision Objectives and AOC closure pathway, supported by sampling efforts
- Most initial characterization work completed
  - Multi-increment surface soil sampling (ISM)
  - Discrete surface and soil boring sampling
- California Desert Environment
  - Exempt Aquifer: No water impacts or sampling required
- No further action status on 74 of the 131 AOCs
- Remediation phase based on identified risks to human health

#### NPR-1 - 131 Areas of Concern





































#### Waste Management







### Tanks/Facilities







# Well Pad(s)









- Quality Assurance Program Plan and SOPs
- Background Metals Study and Protocol
- Human Health Risk Assessment (HHRA) Protocol Document
  - Risk-based screening levels (RBSL)
  - Risk evaluation protocol
  - Petroleum hydrocarbons from crude oil sources don't require action if PAH concentrations are less than RBSLs



#### **Chemicals of Potential Concern**



- Polycyclic aromatic hydrocarbons (PAHs)
- Heavy metals (Arsenic, Cadmium, Chromium, Lead)
- Hexavalent Chromium
- No refined petroleum products except at a few dispensing locations
- Isolated occurrences of chlorinated hydrocarbons (solvents)
- Dioxins (burn sites)





#### Polycyclic aromatic hydrocarbons (PAHs)

- May be present in crude oil at concentrations above RBSLs
- Widespread presence of crude oil in surface soils and disposal areas
- Highly weathered in the natural environment
- Primarily at concentrations below RBSLs
- Some remediation required mostly in sumps







- W-41: Sodium Arsenite 41% arsenic
- Corrosion inhibitor used from the 1920s through the early 1970s
- Reportedly used in closed loop systems for rod pump extraction wells
- 764 former or current well pads identified as possibly impacted by the use of W-41
- Disposal areas (catch basins/sumps) also impacted
- Soil is transported throughout the environment through natural processes and oil field activities





- Naturally occurring in native soil at concentrations greater than RBSLs
  - 0.11 mg/kg residential, 0.24 mg/kg commercial/industrial: 1.0E-06 risk factor
- Site-specific background levels approved by DTSC using a novel two tiered approach
  - Arsenic Background = 16 mg/kg: Upper limit – clean up goal: 1.5E-04 Risk Factor
  - Arsenic Action Level = 26 mg/kg: Upper prediction limit: 2.4E-04 Risk Factor



Initial AOC 130 Assessment Arsenic at well pads



- Sampled random selection of 40 out of 764 well pads
- Analyzed surface soil samples for arsenic, cadmium, chromium and lead
- Arsenic 26 mg/kg action level; RBSLs for others
- Arsenic concentrations in 18 out of 40 composite samples (45%) > 26 mg/kg
- Cadmium, chromium and lead < RBSLs</p>











### EPA's Triad Methodology Applied





#### **Systematic Planning**



- Developed XRF arsenic method in lieu of offsite EPA Method 6020A analysis
- Evaluated different sampling and sample processing strategies to address heterogeneity issues
- Used findings to prepare Work Plan designed to:
  - Assess arsenic at 764 well pads with minimal mobilizations
  - Eliminate well pads from further action consideration
  - Inform future corrective measure approaches







- California Division of Oil, Gas & Geothermal Resources (DOGGR) well coordinates uploaded to our GIS
- Grid sampling design
- Sample homogenization/processing
- Real-time XRF method protocol
- Data management and reporting systems
- Dynamic field decisions step out sampling
- Robust QA/QC protocols



# Heterogeneity is the Norm The Nugget Effect



- Contaminants adsorbed to distinct particles form "nuggets" of high concentration
- Depending on where the XRF beam is directed, or the laboratory "scoop" is taken, the analysis may include more or less of the arsenic nuggets.

Arsenic (whitish color) sorbed to iron hydroxide particles





#### Particulates in Solid Matrices



# "Micro-Heterogeneity"



- Non-uniformity within the sample container
- Contamination is heterogeneous at the same spatial scale as sample analysis

ITRC, ISM-1, Section 2.5.2



#### Sampling Size Induced Error





ITRC, ISM-1, Section 2.5.2



# Managing Uncertainty



- Dry samples
  - Soil moisture can "suppress" XRF response
  - Wet samples don't homogenize well
- Sieve and homogenize samples (< 2 mm)</p>
  - Reduce micro-scale variability
  - Enhance comparability with EPA Method 6020A
- Multiple analyses on each sample
  - Obtain average sample concentration from replicate measurements (30 second scan time/analysis)



### **Real Time Measurement**



- Scale-up considerations; 28,000 samples in 6.5 months!
- Hand-held GPS integrated with GIS
- Barcode sample and location identifications
- Field XRF protocol (SOP) based on EPA Method 6200
  - Definitive, representative, decision quality data
- Data processing and management
- Staffing: 8 full time staff plus office support



# Comparison of XRF/ICP-MS



# XRF (EPA Method 6200/SOP)

- No sample digestion
- 30 second measurement
- 5 gram sample (approximately)
- Factory calibration
- Highly linear response no dilutions required
- 4-10 mg/kg reporting limit
- Non-destructive test
- Low cost/analysis
- Moderate instrument cost

#### ICP-MS (EPA Method 6020A)

- Sample digestion
- 24 hour (or longer) turnaround
- 1 gram sample
- Lab calibration
- Dilutions required due to high salt or arsenic concentrations
- 1 mg/kg RL (0.26 MDL)
- Destructive
- \$15-20/sample
- High instrument cost



### **XRF Method Protocol**



- Create instrument-specific calibration curve
  - Regression analysis between EPA 6020A and XRF values
- Daily calibration verification using certified reference material (10, 111 and 500 mg/kg, blank)
- Triplicate XRF analysis using 30 second sample scan
- Samples stayed in the zip seal bag
- Mixed sample between analyses
- RSD > 25%, additional triplicate analysis
- Convert XRF average value to a "lab equivalent" concentration using calibration curve



#### **XRF** Calibration Curve



#### **Instrument A Arsenic Calibration Curve Ver9**



As (mg/kg) by 3050B/6020A



# QA - Split Sample Results



- 2200 (10 %) split samples analyzed by XRF and EPA Method 6020A
- Average calculated RPD = 24%
- 20% of the RPDs were greater than 35% and were reanalyzed
- 34% reanalyzed split samples were within 35% RPD
- Sample heterogeneity is the primary contributor to variance between split samples



#### Well Pad Identification







#### **Aerial View of Well Pads**







#### Well Pad Identification







# Determine Well Pad Boundary







### **Establish Sampling Grid**







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### **Sample Collection**







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# Sample Location Coordinates Ahtna Facility Services, Inc.







### Field Mapping

Ahtna Facility Services, Inc.





# Sample Processing







### **Sample Processing**

Facility Services, Inc.





### Sample Processing





#### Sample Analysis Facility Services, Thermo Scientific Niton XL3-950











### Sample Analysis







#### Sample Analysis







#### Field Data Processing







DataPkg\_130\_022

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### AOC 130 Investigation Summary

- Arsenic concentrations ranged from 4.3 to 3500 mg/kg
- 77 well pads proposed for NFA due modified land surface
- 190 well pads proposed for NFA due to sample results less than 26 mg/kg arsenic
- 497 well pads proposed for further action due to sample results greater than or equal to 26 mg/kg
  - 50 of the 497 well pads: Greater than 5000 sf areas above 26 mg/kg. Current investigation ongoing
  - 447 well pads: Less than 5000 sf areas above 26 mg/kg. Remedial action plan under regulatory review



### **Other Arsenic Evaluations**



- 110 AOCs have been sampled for arsenic
- 38% discrete sample results > 26 mg/kg
- 50/110 have received NFA approval
- 16 NFAs under review
- 30 are under further investigation
- 14 have planned or completed remedial actions



### NPR-1 Project Summary



#### Systematic approach to AOC closure

- Historical information
- Prioritized closure approaches
- Comprehensive investigation strategies DQOs
- COPC identification and evolution
- PAHs and TPH risk management
- Arsenic issues due to W-41. Widespread impacts
  - Well pads
  - Disposal areas
- Triad Methodology: Systematic planning, real-time measurement, dynamic work strategies
  - Reduced costs, fast characterization, good decisions



### NPR-1 Success Factors



#### Partnerships

- Regular in-person meetings
- Consensus and trust building
- Planning
- Adaptability
- Dynamic risk evaluation strategies
- Innovative investigation and field techniques
- Integrated information services
  - Geographic Information System
  - Relational database
  - Collaboration Site (Share Portal)
- Document Quality



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# **Questions?** Comments?

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