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Innovative Remediation Solutions and Stakeholder Engagement to Aggressively Remediate LNAPL Plumes



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October 27, 2020

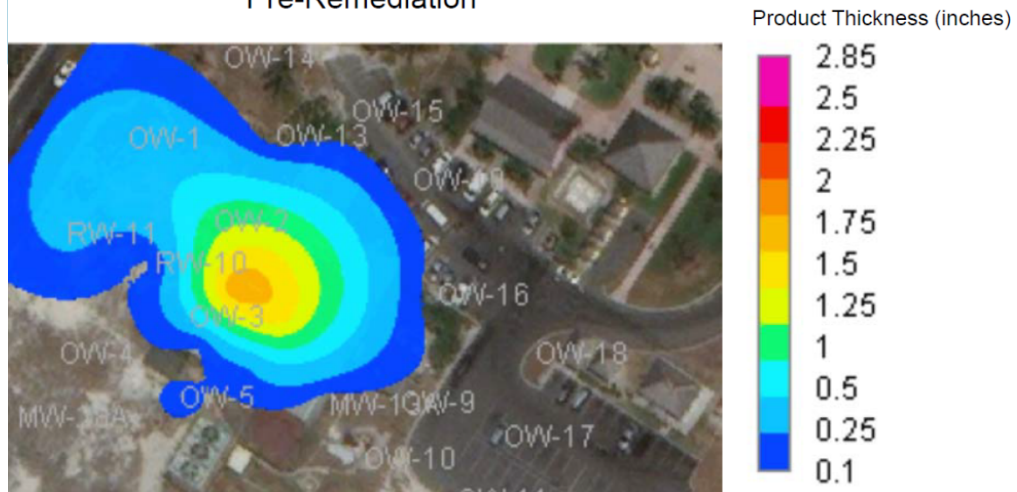
- Site Assessment – 2017-2018
- System Design – November 2018
- System Construction – January 2019
- System Installation – February 2019
- System Start-Up – March 2019
- System Shut-Down and Closure – August 2019

Case Study #1 Large Diesel Oil Plume

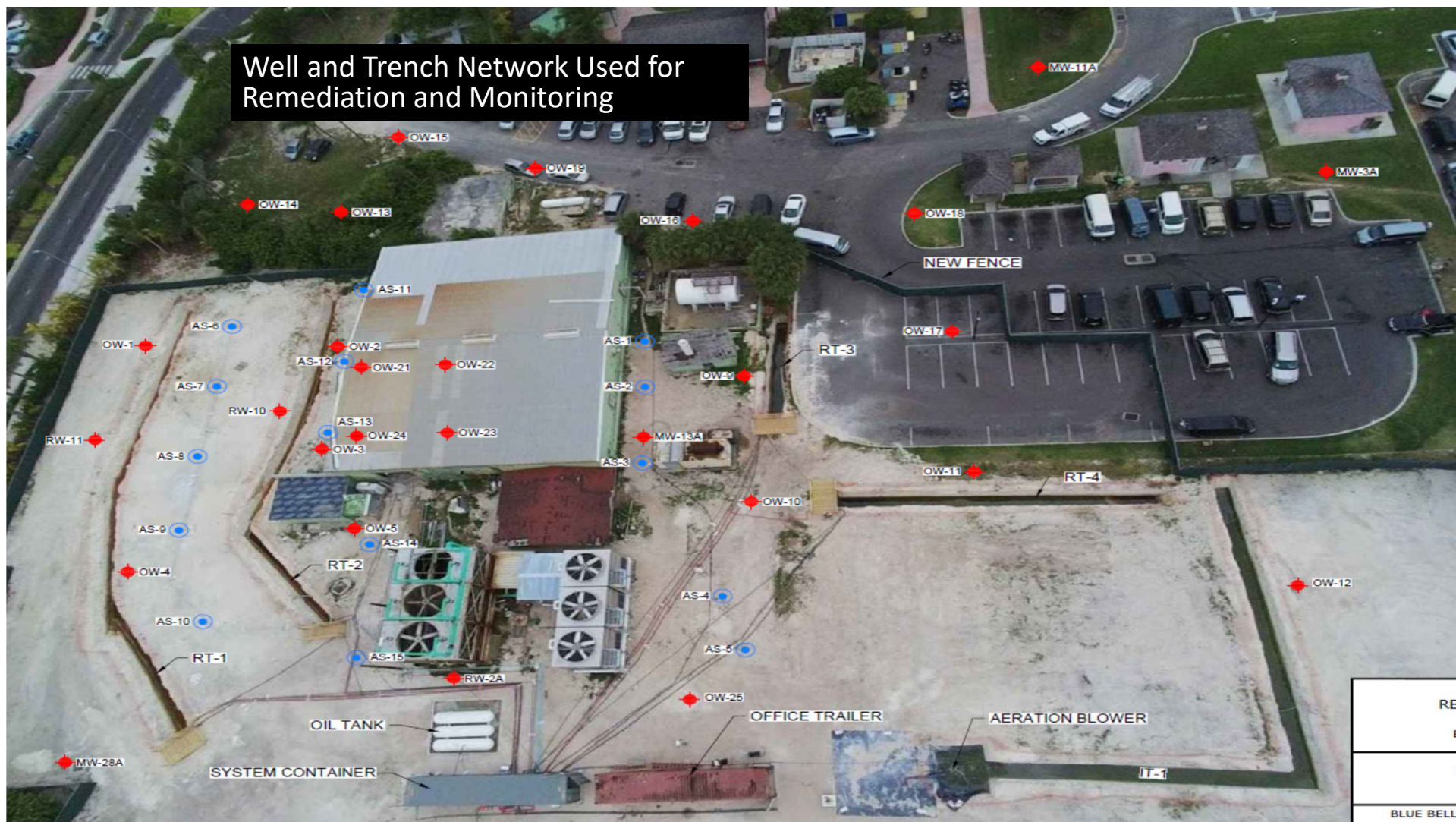
Remediation to Residential Clean-Up Standards
in 5 Months



March 12, 2019
Pre-Remediation



Well and Trench Network Used for Remediation and Monitoring



REI

B

BLUE BELL

Many Remediation Technologies to Clean Up Subsurface Oil, Groundwater, & Soil Impact

- Groundwater & Oil Recovery & Separation
- High-flow Groundwater Recovery
- Soil Vapor Extraction
- Vacuum-Enhanced Oil Recovery
- Air Sparging
- Surfactant Injection
- Water Flushing
- Bioremediation Enhancement
- Ex-Situ Soil Remediation



System Built With Sensors, Actuating Valves, VFDs, and Other Monitoring or “Adjustable” Controls

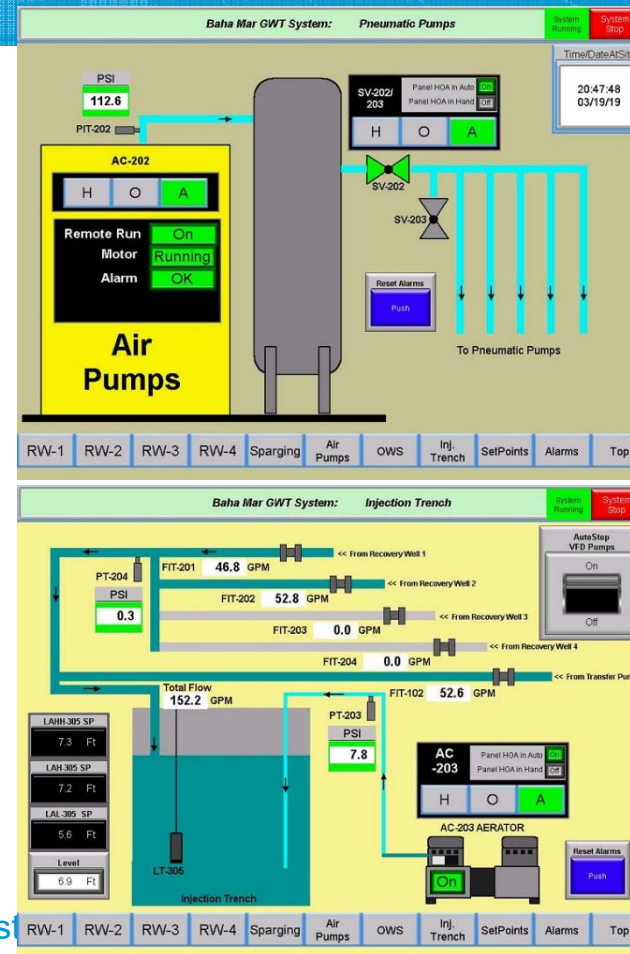
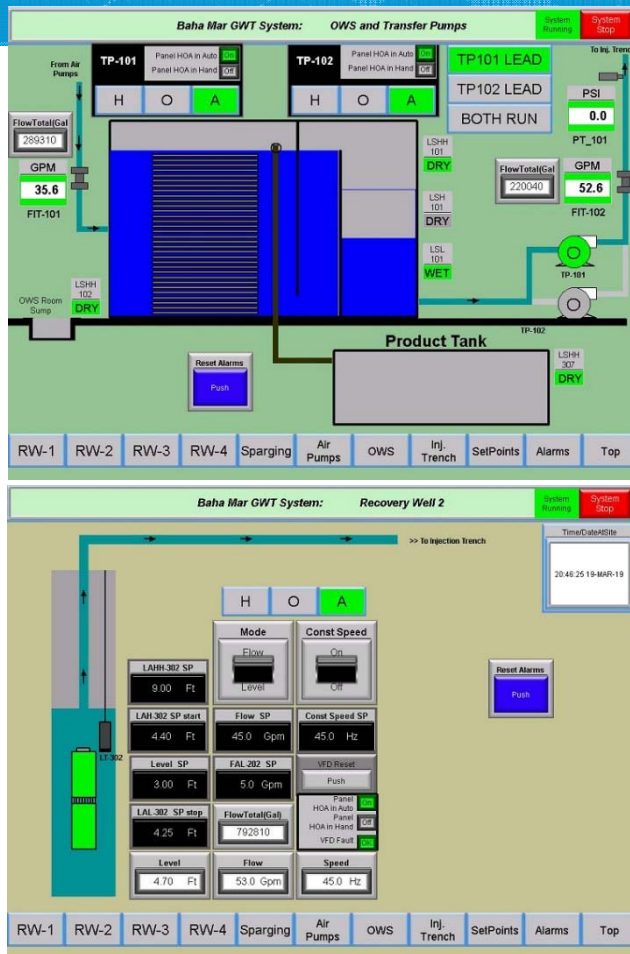
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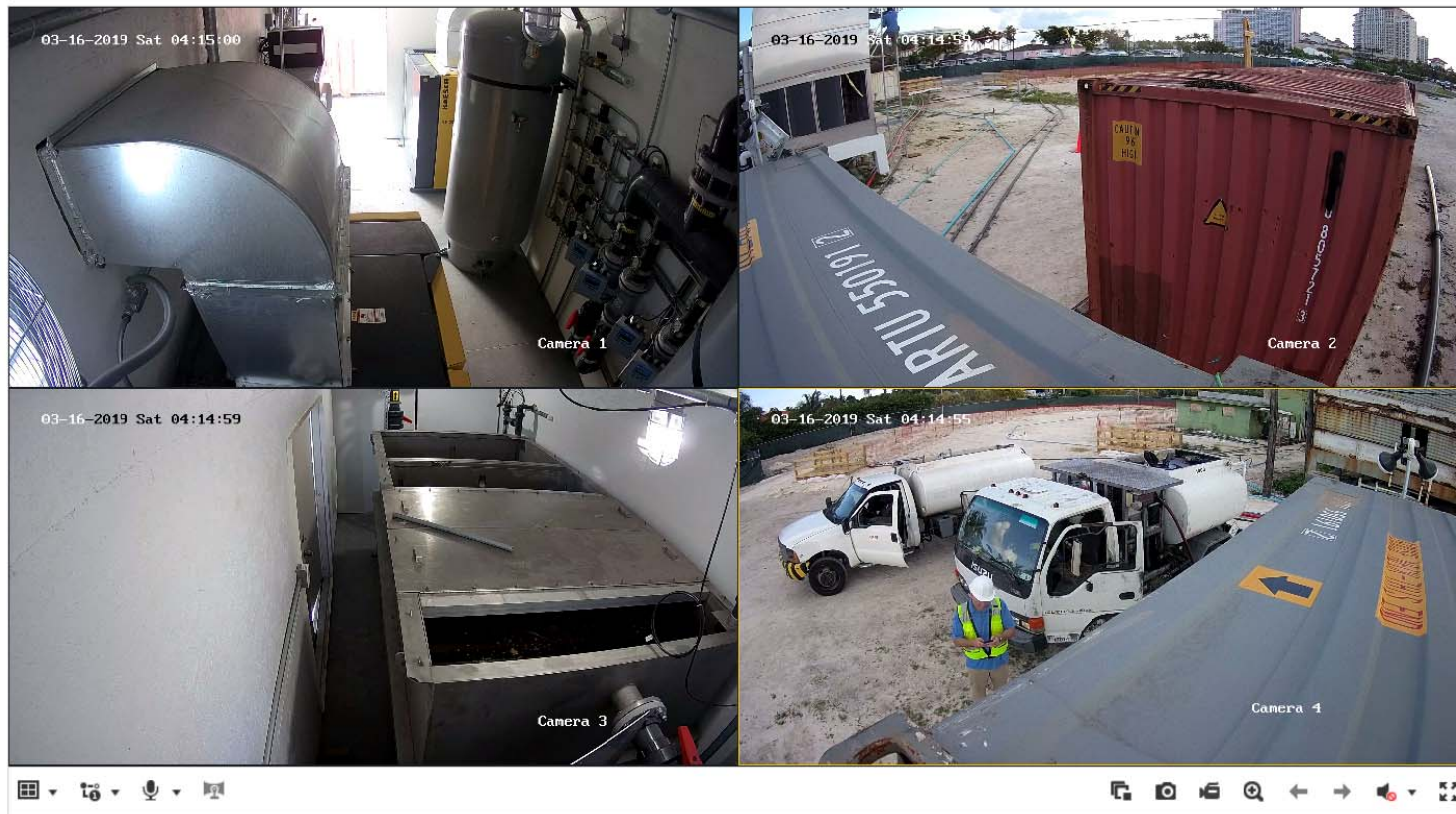
Remote Monitoring of System – To Optimize Performance

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Real-Time Monitoring of the Site

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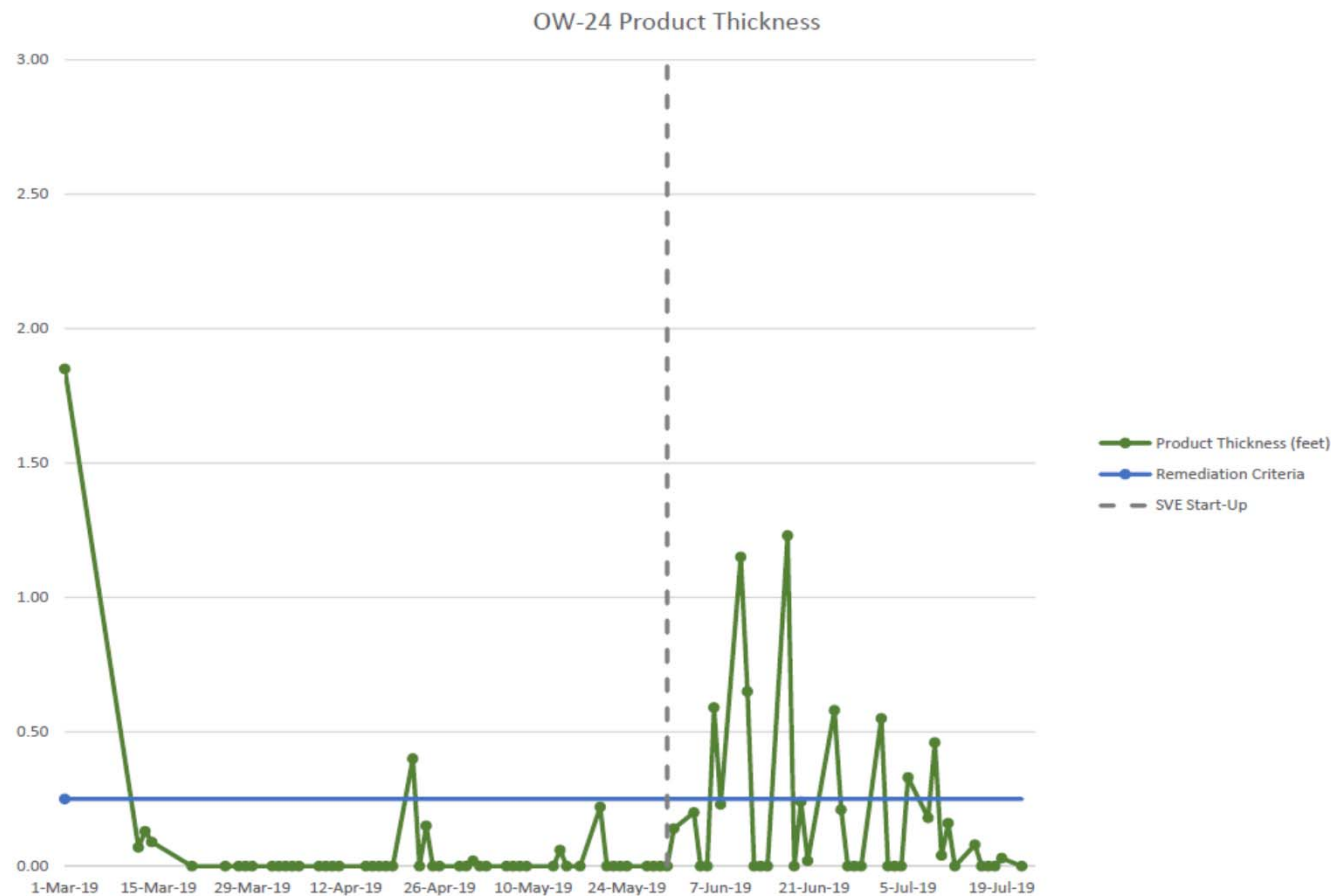
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Summary of Remediation Activities

- Total fluids (oil and groundwater) recovery from wells and trenches
- High-flow groundwater recovery from four trenches (recovered/treated/recirculated over 20 Mil gallons of water)
- Vacuum-enhanced oil/groundwater recovery
- Soil vapor extraction of ex-situ soil (enhanced landfarming)
- Recovered and recycled over 4,000 gallons of oil
- Treated hydrocarbons in-situ via
 - SVE
 - Air sparging
 - Bioremediation (high DO from aerated groundwater recirculation and air sparging)
 - Surfactant injection

SVE System Helped Increase Oil Recovery at Pumping Wells (Provides Vacuum-Enhanced Recovery) – OW-24 Example

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Air Sparging to Influence

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Plume Over Time – During Remediation

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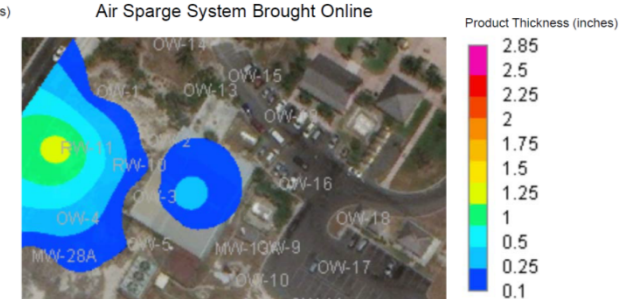
March 12, 2019
Pre-Remediation



March 27, 2019
Two Weeks into Remediation



April 13, 2019
Air Sparge System Brought Online



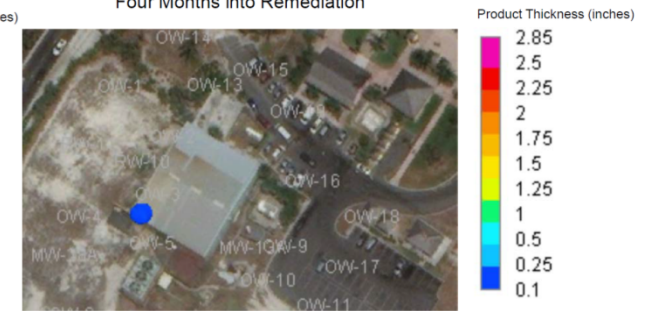
May 12, 2019
Two Months into Remediation



May 31, 2019
SVE Connected to Building Recovery Wells

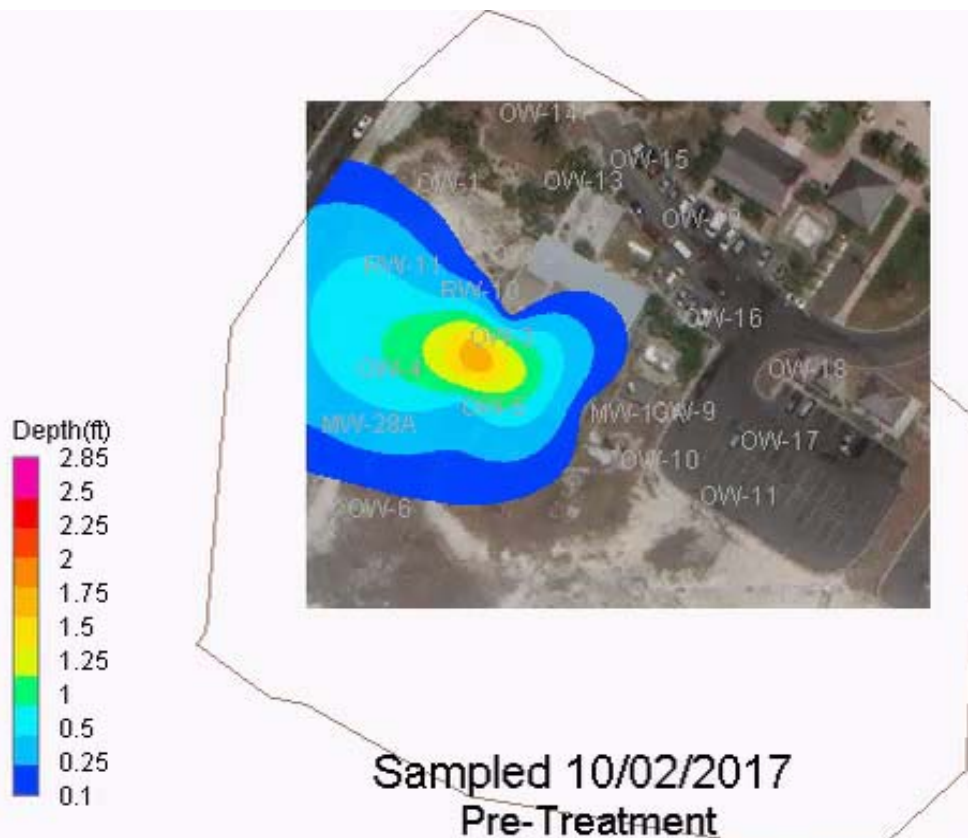


July 9, 2019
Four Months into Remediation



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Case Study #1 - Oil Plume Animation Over Time



The remediation system effectively remediated the site to clean-up goals within 5 months of operation.

Worked w/ stakeholders to develop cleanup goals based on LNAPL risk and mobility analyses.

Obtained “no further remediation action” letter following review of the site closure report. Ministry of Environment involved every step of the way.

Case Study #2
Oil Plume Migration,
Stopped Oil Migration to the Ocean



Years of Oil Migration Into The Ocean



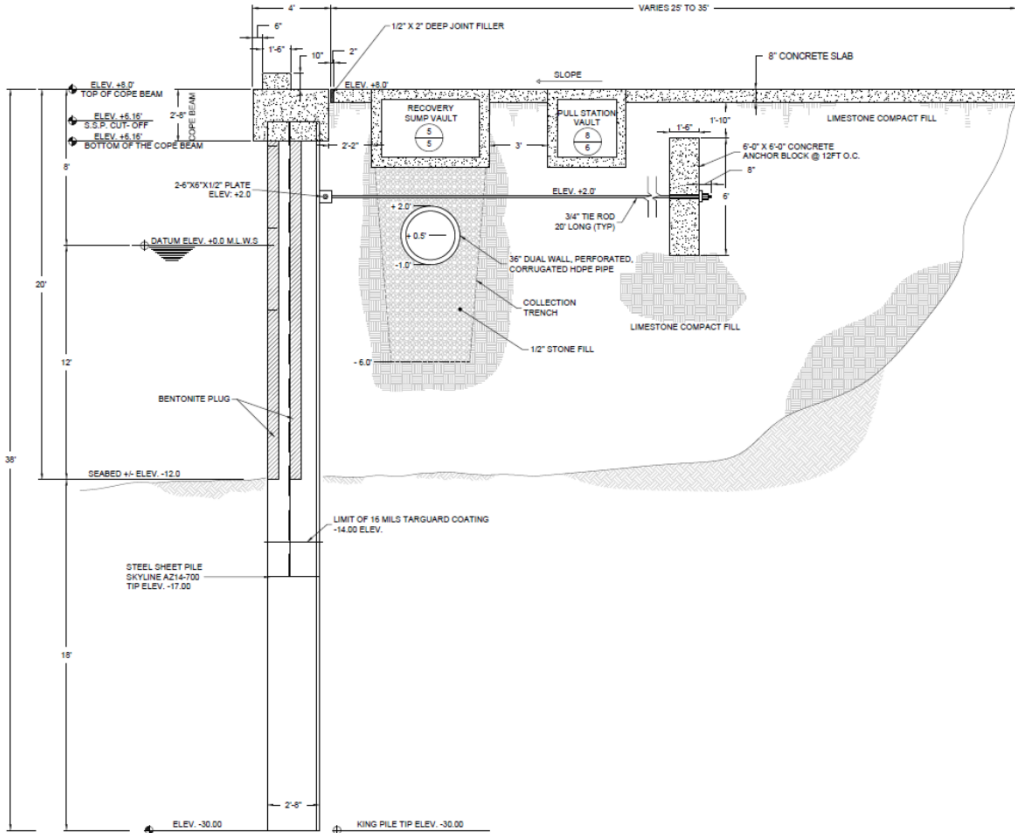
Stakeholders came together to develop a plan to stop oil migration and recover significant subsurface oil.

- Caves, voids, and fractures provided direct pathways for LNAPL migration into the ocean.

Barrier Wall Systems Clifton Pier –
Trench and Wall Cross-Section

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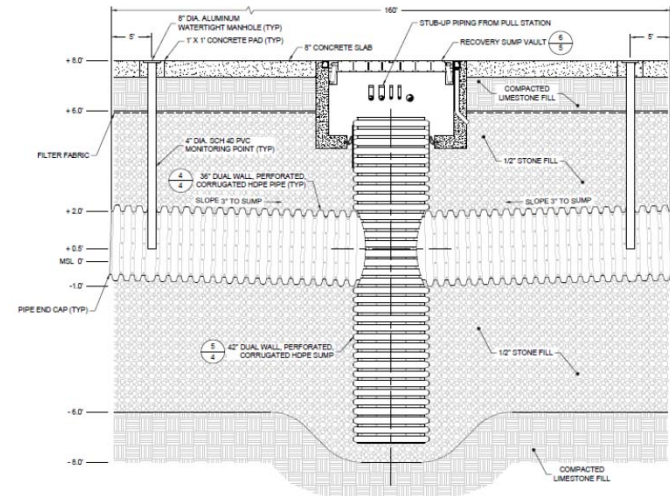
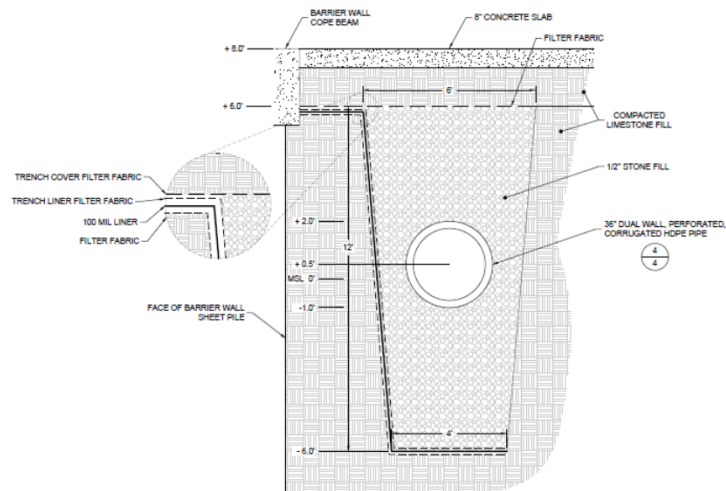
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Barrier Wall System Construction in Progress



Trench Cross-Section w/ Liner – Multiple Lines of Defense!

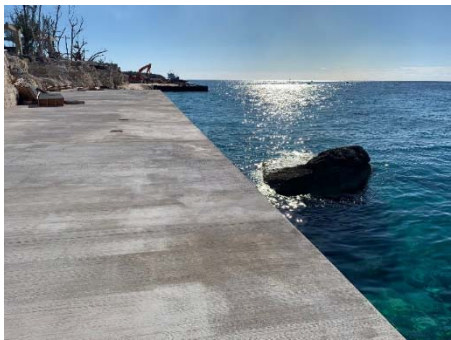
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Barrier Wall, Outfall, & Backfilling/Surfacing

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Barrier System Design for Storm Impact

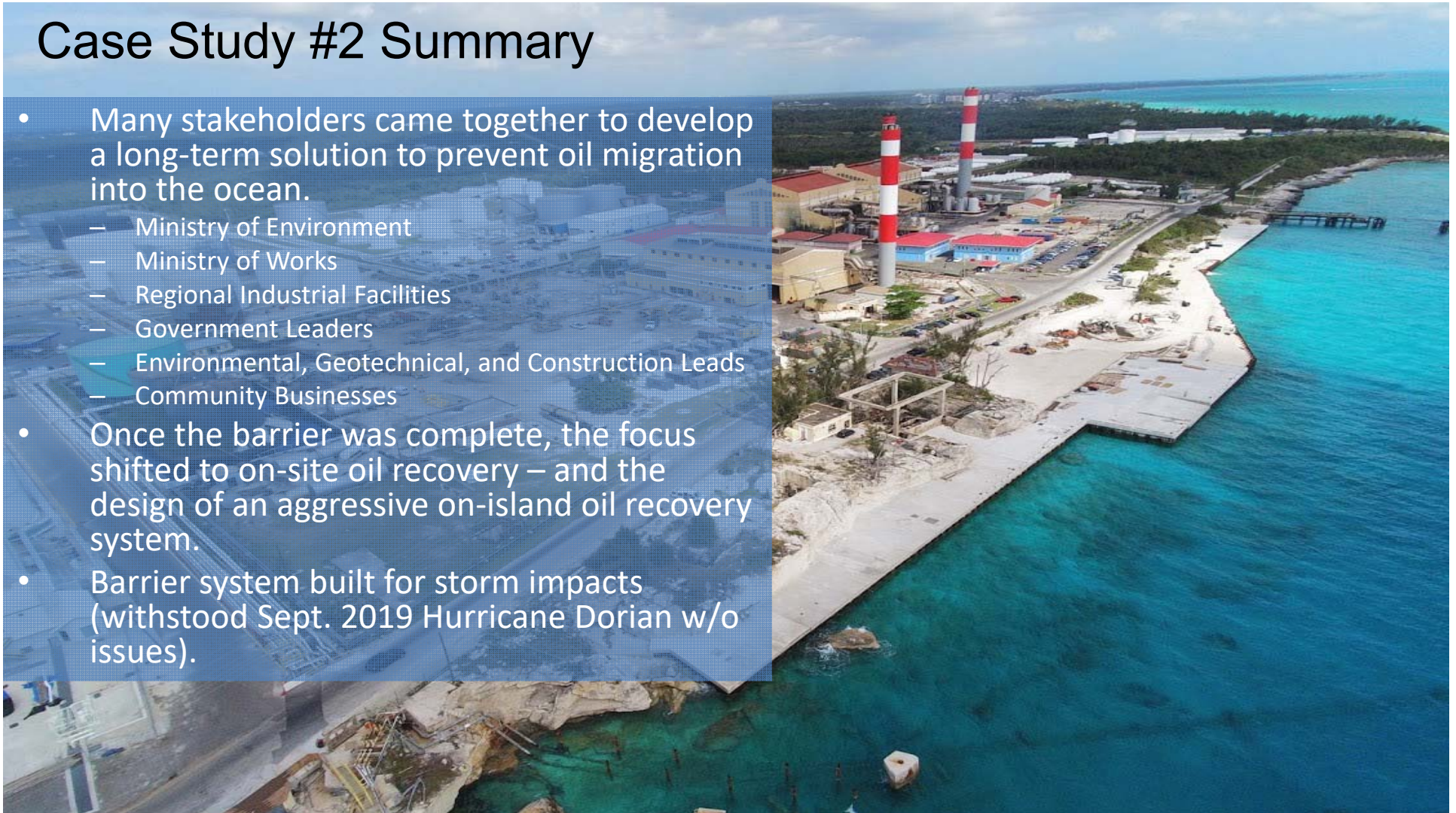
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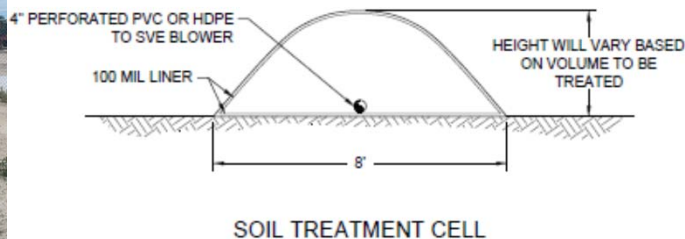
Case Study #2 Summary

- Many stakeholders came together to develop a long-term solution to prevent oil migration into the ocean.
 - Ministry of Environment
 - Ministry of Works
 - Regional Industrial Facilities
 - Government Leaders
 - Environmental, Geotechnical, and Construction Leads
 - Community Businesses
- Once the barrier was complete, the focus shifted to on-site oil recovery – and the design of an aggressive on-island oil recovery system.
- Barrier system built for storm impacts (withstood Sept. 2019 Hurricane Dorian w/o issues).



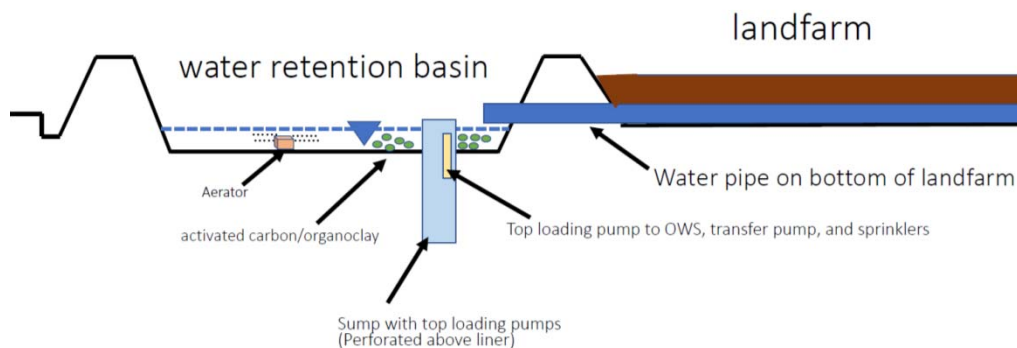
Ex-Situ Soil Treatment Biocell and Landfarming Remediation – Used Effectively at Many Sites

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Soil Treatment Cells and “Enhanced” Landfarming – treatment can occur via **enhanced bioremediation, soil vapor extraction, air/ oxygen /ozone injection, heat, water/surfactant flushing**, or other techniques.

The addition of organic material will help with the enhanced bioremediation (in some cases, mulch is added to help with increasing permeability and providing material for bio growth).



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Current Landfarming Construction

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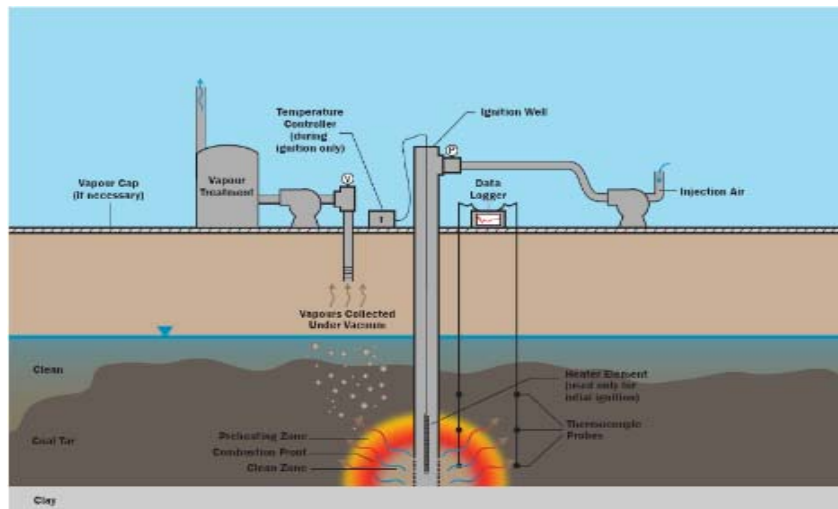


Thermal Treatment by “Smoldering” – Used Effectively Internationally for Crude Oil Remediation

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STAR

- In situ (below water table)
- Applied via wells in portable in-well heaters



STAR_x

- Ex situ (above ground)
- Soil piles placed on “Hottpad” system



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Crude Oil “Smoldering Example

Treated sludge/soils (before and after)



Before



After



Compound	“Before” Concentration (mg/kg)	“After” Concentration (mg/kg)
BTEX	ND	ND
TPH C ₆ -C ₉	ND	ND
TPH C ₁₀ -C ₁₄	356	ND
TPH C ₁₅ -C ₂₈	25,400	ND
TPH C ₂₉ -C ₃₆	9,750	ND
Total	35,506	ND



- All projects involved stakeholder and regulatory engagement every step of the way.
 - Helped to obtain feedback and suggestions “real-time”
 - Expedited approvals (from cleanup goals to remediation plans and discharge permits)
 - Involved the experience from every perspective
 - Allowed for community engagement and updates
 - Provided “transfer of knowledge”
- Used the most-appropriate technology (or technologies) at each site
- Designed for optimization & flexibility
- Real-time monitoring along with optimization tools reduced cleanup times and progress



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