MEETING SUMMARY

Marine Corps Base (MCB) Camp Lejeune Restoration Advisory Board (RAB) Meeting Minutes

MEETING DATE:	August 28, 2024
LOCATION:	Coastal Carolina Community College, Business Technology Building, Jacksonville, North Carolina
ATTENDEES:	Laura Spung/MCB Camp Lejeune Thomas Richard/MCB Camp Lejeune Jennifer Tufts/EPA Laura Bader/RAB Co-Chair Rob Johnson/RAB member Thomas Mattison/RAB member Michael Curtis/RAB member Riley Lewis/Coastal Carolina River Watch Laarni Cooper/NAVFAC Betsy Collins/CH2M Matt Louth/CH2M
FROM:	Matt Louth/CH2M
DATE:	August 28, 2024

I. Welcome and Introductions

Mr. Richard began the meeting, introduced the team, and explained the purpose of the RAB.

II. Innovative Technologies: Site 88 and Site 89

Objective: The purpose of this agenda item is to review the MCB Camp Lejeune Environmental Restoration Program's history of innovative technologies, discuss upcoming pilot studies at Sites 88 and 89, and provide a schedule.

Overview: A presentation was reviewed by Ms. Collins.

An overview of the evolution of environmental remediation technologies over time was presented, starting with the establishment of regulations in the 1970s and 1980s, to ex-situ treatment into the 1990s, shifting to in-situ physical and aerobic bioremediation technologies through the early 2000s, followed by in situ anaerobic bioremediation. Starting around 2010, the industry focused on combined technology approaches and sustainability for site management. Research and development continues today in hopes of developing improved methods for environmental remediation.

MCB Camp Lejeune has a history of applying innovative technologies that serves as a bridge between academia and field application. Since the 1990s, MCB Camp Lejeune has implemented dozens of pilot studies/removal actions, with technologies including low temperature thermal desorption (Site 89), electrical resistance heating / low-temperature thermal desorption (Site 89), surfactant-enhanced aquifer remediation (Site 88), soil mixing (Sites 88 and 89), hydraulic fracturing with ZVI (Site 89), air sparging (Sites 35, 49, 69, 73, 78, 82, 86, and 89), biosparging (Site 6 and 78), enhanced reductive dechlorination (Sites 35, 36, 73, 78, 82, 86, 88, and 89), in situ chemical oxidation (Sites 35, 86, and 88), aerobic degradation (Sites 3 and 78), subgrade biogeochemical reactors (Sites 82 and 93), enhanced pump and treat (Site 78), sewer ventilation (Site 88), and soil vapor extraction (Site 96).

By investing in innovative technologies, contaminant mass is reduced, accelerating the time to site closure. Work at MCB Camp Lejeune has supported the advancement of the remediation industry and has been presented at conferences around the country, including the Annual Conference on Soils, Sediments, Water, and Energy; the Battelle International Conference on Remediation of Chlorinated and Recalcitrant Compounds; the Design and Construction at Hazardous Waste Sites (DCHWS) Symposium; the Clemson Hydrogeology Symposium; and Contaminated Site Clean-Up Information (CLU-IN). Additionally, MCB Camp Lejeune has been recognized nine times for the Secretary of the Navy Award for Environmental Restoration and three times for the Secretary of Defense Award for Environmental Restoration. However, challenges remain. The less complicated sites have been completed and better solutions are needed for remaining contamination, due to site heterogeneity, multiple/recalcitrant contaminants, long timeframe since release, physical site properties, and challenging expectations. Additional factors include climate change and extreme weather, increasing costs, carbon footprint considerations, and time to achieve cleanup levels.

Electrical current enhanced remediation was introduced as the next tool for the remediation toolbox. Electrokinetic (EK) BIO technology is being used at Site 88 to evaluate its effectiveness to enhance substrate distribution of a vegetable oil substrate in a controlled manner. Bioelectrochemical (E-Redox) technology is being tested at Site 89 to evaluate its ability to treat a newly identified source area.

The Site 88 background was reviewed, including the site history, contaminants of concerns (COCs) and remedy-in-place for each zone. A pilot study is being conducted in Zone 1, where the remedy-in-place is enhanced reductive dechlorination via vertical injection wells, because previous injection events were challenged by daylighting, interception with storm sewer, and low flow rates. Future injection events may experience the same limitations. The objective of the pilot study is to evaluate the effectiveness of Geosyntec's EK-BIO technology to enhance substrate distribution in a controlled manner. EK-enhanced amendment delivery uses low-voltage direct current (DC) to uniformly transport amendments through clays and silts. EK transport mechanisms (electromigration and electro-osmosis) are related to soil's electrical properties, and, therefore, not substantially affected by soil hydraulic conductivity. The proposed pilot test area within Zone 1 at Site 88 is based on elevated volatile organic compound concentrations, ideal conductivity as observed during previous injection events, and to minimize impact to the adjacent office and parking area. The exact location will be determined following a field visit to verify locations of overhead and underground utilities, nearby hydrants, and existing stainless-steel wells, which may interfere with the electromagnetic fields. The system layout is anticipated to be 25 feett by 25 feet and will include anode/cathode well heads (estimated 3 each). System installation will include well installation and surveying, establishing electrical and water connections, and connecting wells to system trailer and water/amendment tank. Operation will be conducted in stages: 5-6 months of operation and monitoring, followed by 1-2 months downtime to allow for biodegradation, and then 5-6 months of operation and monitoring, under reversed electric field. The Pilot Study Tech Memo Work Plan is anticipated to be finalized in May 2025; field implementation is expected to occur between June 2025 and August 2026; and a Pilot Study Tech Memo will be prepared in the Winter of 2026. Mr. Curtis asked if this technology had been applied at Camp Lejeune before. Ms. Collins indicated that it had not been tried at Camp Lejeune but has been used at EPA sites. Ms. Tufts confirmed this technology has been used at EPA sites and the EPA is really impressed by the technology demonstrating effective results.

The Site 89 background was reviewed, including the site history, COCs, and current remedy-in-place. The current conceptual site model was reviewed, including the recent discovery of a source area in the surficial aquifer, with impacts to the Castle Hayne aquifers. In the surficial aquifer, the source area is not being treated by current remedies (AS and monitored natural attenuation) and could serve as a continuing source of groundwater contamination if unaddressed. In the Castle Hayne aquifer, COC concentrations indicative of dense non-aqueous phase liquid (DNAPL) are also not being treated by

current remedies (air sparging and monitored natural attenuation) and DNAPL is present in in higher conductivity zones than in the surficial aquifer. An Engineering Evaluation/Cost Analysis (EE/CA) is being conducted to evaluate removal action alternatives for addressing source areas in the surficial aquifer and DNAPL in the Castle Hayne aquifer. After completion of EE/CA and removal action, the site-wide remedial strategy will be re-evaluated. Technologies being considered in the EE/CA for the surficial aquifer include in situ thermal treatment, excavation, in-situ chemical reduction (ISCR) or enhanced reductive dechlorination via soil mixing, targeted excavation with zero valent iron (ZVI) injections via fracturing, and bioelectrochemical remediation. In the Castle Hayne aquifer, technologies being considered in the EE/CA include expanded air sparging, ISCR/ enhanced reductive dechlorination injections, groundwater extraction and treatment via air stripper and granular activated carbon (GAC), and groundwater extraction and treatment via subgrade biogeochemical reactor (SBGR). A comparative analysis of technologies being considered for the surficial aquifer was reviewed, showing bioelectrochemical remediation being comparably or more favorably implementable, effective, and sustainable than the other technologies, for the lowest price.

E-Redox-I is a patented technology developed by Advanced Environmental Technologies, LLC (AET, Fort Collins, CO) that generates a low-voltage gradient electric field in between electrodes, uniformly inducing redox reactions within the impacted matrices. Degradation is achieved through multiple reactions, including enhanced reductive dechlorination (biological hydrogenous and abiotic beta-elimination), contaminant desorption, and increased microbial activity. A pilot study of E-Redox is planned because bioelectrical remediation is a cost effective and sustainable technology successfully implemented at 50 sites but has not yet been applied at MCB Camp Lejeune. The objective of the pilot study is to evaluate the effectiveness of bioelectrochemical remediation to treat principal threat waste in two areas. The general approach is to install 3 electrode wells and 1 groundwater monitoring well in each area, then operate for 1 year. Performance monitoring will be conducted during 3 events (baseline event, after six months of operation, and after 12 months) and will include the collection of two groundwater and 18 soil samples for analysis of site-specific volatile organic compounds. The Pilot Study Tech Memo Work Plan is anticipated to be finalized in December 2024; field implementation is expected to occur between January 2025 and January 2026; and a Pilot Study Tech Memo will be prepared in the Summer of 2026.
Mr. Curtis asked to clarify absorption into clay and Ms. Collins confirmed its desorption of compounds from the clay. Ms. Lewis asked how much electrical charge is applied in the treatment process and Ms. Collins responded it's the equivalent of a charge for a light bulb.

IV. RAB Business

Mr. Richard asked for questions or any topics the RAB was interested in the next meeting. Mr. Curtis asked about the Camp Davis airfield opening back up and were environmental investigations conducted. Mr. Richard responded yes PFAS remedial investigations have been ongoing at Camp Davis and can brief the RAB once the report is completed. Ms. Lewis asked process for being added as a RAB member. Mr. Richard answered to complete the RAB application form and then the RAB conducts a vote for the new member to the board. Ms. Lewis also asked about the recent wastewater spill at Camp Lejeune. Mr. Richard conveyed our RAB meetings don't cover wastewater as it's handled by a separate department, but he will follow up internally to provide her an update on the status. Ms. Lewis noted the Coastal Carolina River Watch is working on an upcoming river project and would be happy to talk to the RAB about it. Mr. Mattison noted there are no crab pots where the wastewater treatment plant discharges into the river.

The next RAB meeting is planned for November 20, 2024.

CAMP LEJEUNE
HOME OF
EXPEDITIONARY
FORCES IN READINESS

Innovative Technologies: Site 88 and Site 89

MCB Camp Lejeune

Restoration Advisory Board Meeting

August 28, 2024

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

MARINE CORPS INSTALLATIONS COMMAND EAST

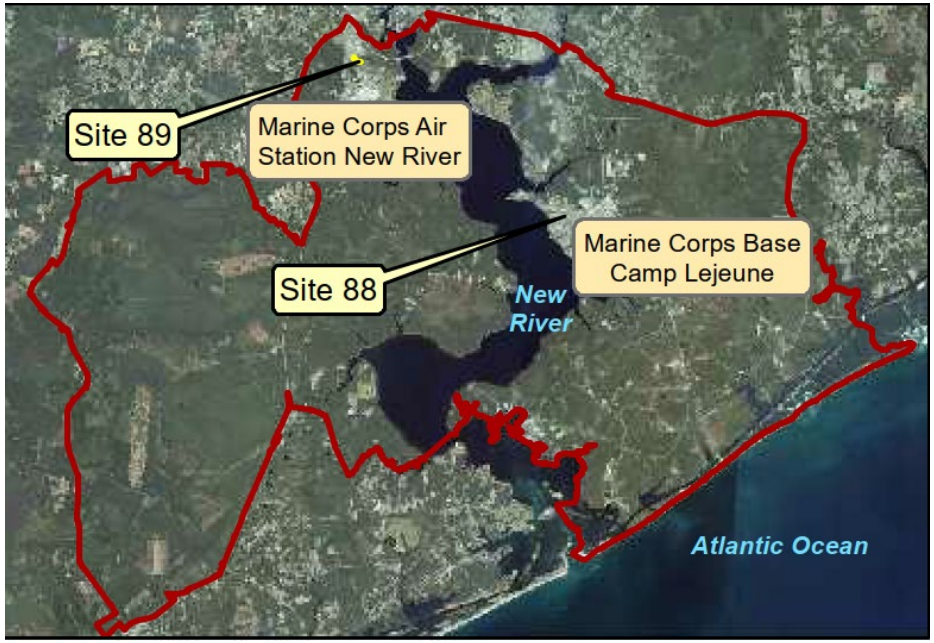
NAVFAC

NC Environmental Quality

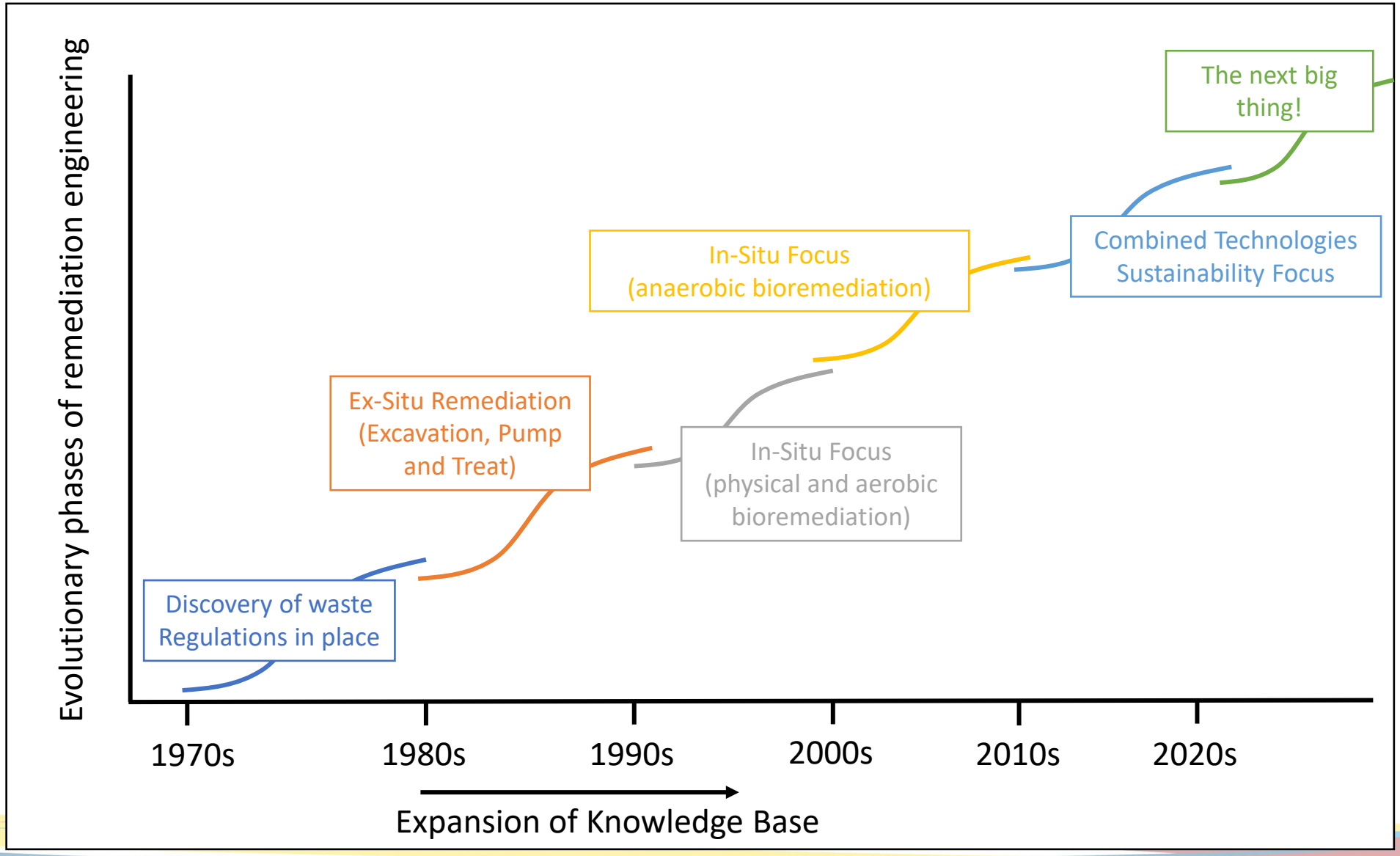
ch2m SM

Objectives

- Review MCB Camp Lejeune Environmental Restoration Program History of Innovative Technologies
- Discuss Upcoming Pilot Studies at Sites 88 and 89
- Present Schedule



Remediation Technologies Over Time



From Concept to Reality: The bridge between academia and field application

- Camp Lejeune Pilot Studies
  - Low Temperature Thermal Desorption - Site 89
  - Electrical resistance heating / low-temperature thermal desorption – Site 89
  - Surfactant-enhanced aquifer remediation – Site 88
  - Soil mixing – Sites 88, 89
  - Hydraulic fracturing with ZVI – Site 89
  - Air sparging – Sites 35, 49, 69, 73, 78, 82, 86, 89
  - Biosparging – Site 6
  - Enhanced reductive dechlorination – Sites 35, 36, 73, 78, 82, 86, 88, 89
  - In situ chemical oxidation – Sites 35, 86, 88
  - Aerobic degradation – Site 3, 78
  - Subgrade biogeochemical reactors – Sites 82, 93
  - Enhanced pump and treat – Site 78
  - Sewer ventilation – Site 88
  - Soil vapor extraction – Site 96

Why are we invested in innovative technologies?

- Benefits achieved
  - Reduce contaminant mass
  - Accelerate time to site closure
- Other benefits of industry leadership
  - Work at Lejeune has supported advancement of remediation industry and been presented at conferences around the country including:
    - Annual Conference on Soils, Sediments, Water, and Energy
    - Battelle International Conference on Remediation of Chlorinated and Recalcitrant Compounds
    - Design and Construction at Hazardous Waste Sites (DCHWS)
    - Clemson Hydrogeology Symposium
    - Contaminated Site Clean-Up Information (CLU-IN)
  - Recognized through Awards
    - Secretary of the Navy Award for Environmental Restoration (9 times)
    - Secretary of Defense Award for Environmental Restoration (3 times)
- Challenges Remain
  - Easy work is done and better solutions needed for remaining contamination
    - Heterogeneity
    - Multiple/recalcitrant contaminants
    - Long time frame since release
    - Physical site properties
    - Challenging expectations
  - Additional factors
    - Climate change/extreme weather
    - Increasing costs
    - Carbon footprint considerations
    - Time to achieve cleanup levels

What's the next tool for the toolbox?

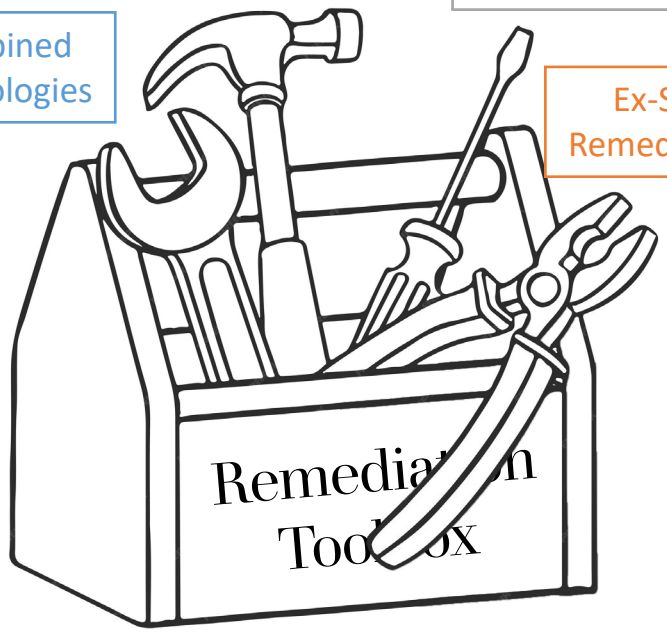
What's the next tool for the remediation toolbox?

anaerobic bioremediation

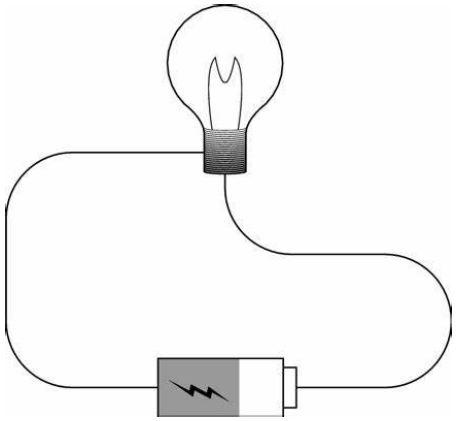
aerobic bioremediation

Combined Technologies

Ex-Situ Remediation

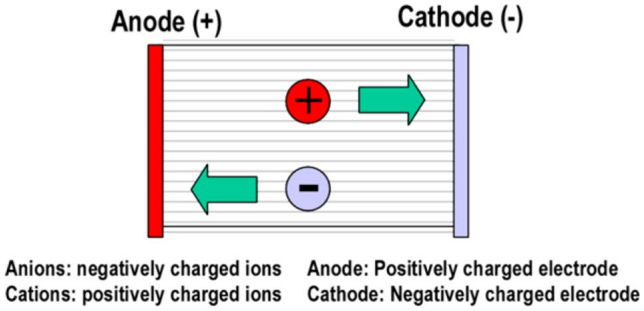


Electrical Current Enhanced Remediation!

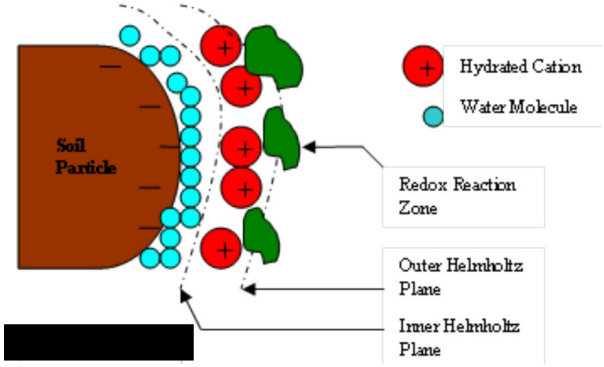


Two Ongoing Pilot Studies

- Electrokinetic (EK) BIO technology is being used at **Site 88** to evaluate its effectiveness to enhance substrate distribution of a vegetable oil substrate in a controlled manner.



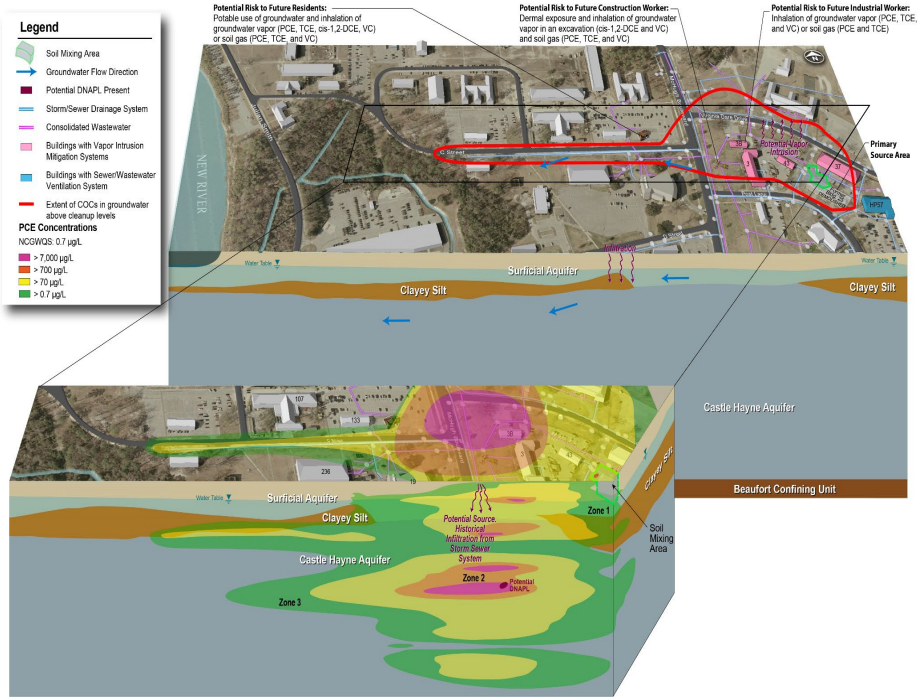
- Bioelectrochemical (E-Redox) technology is being tested at **Site 89** to evaluate its ability to treat a newly identified source area.



Site 88 EK BIO Pilot Study

Site 88 Background

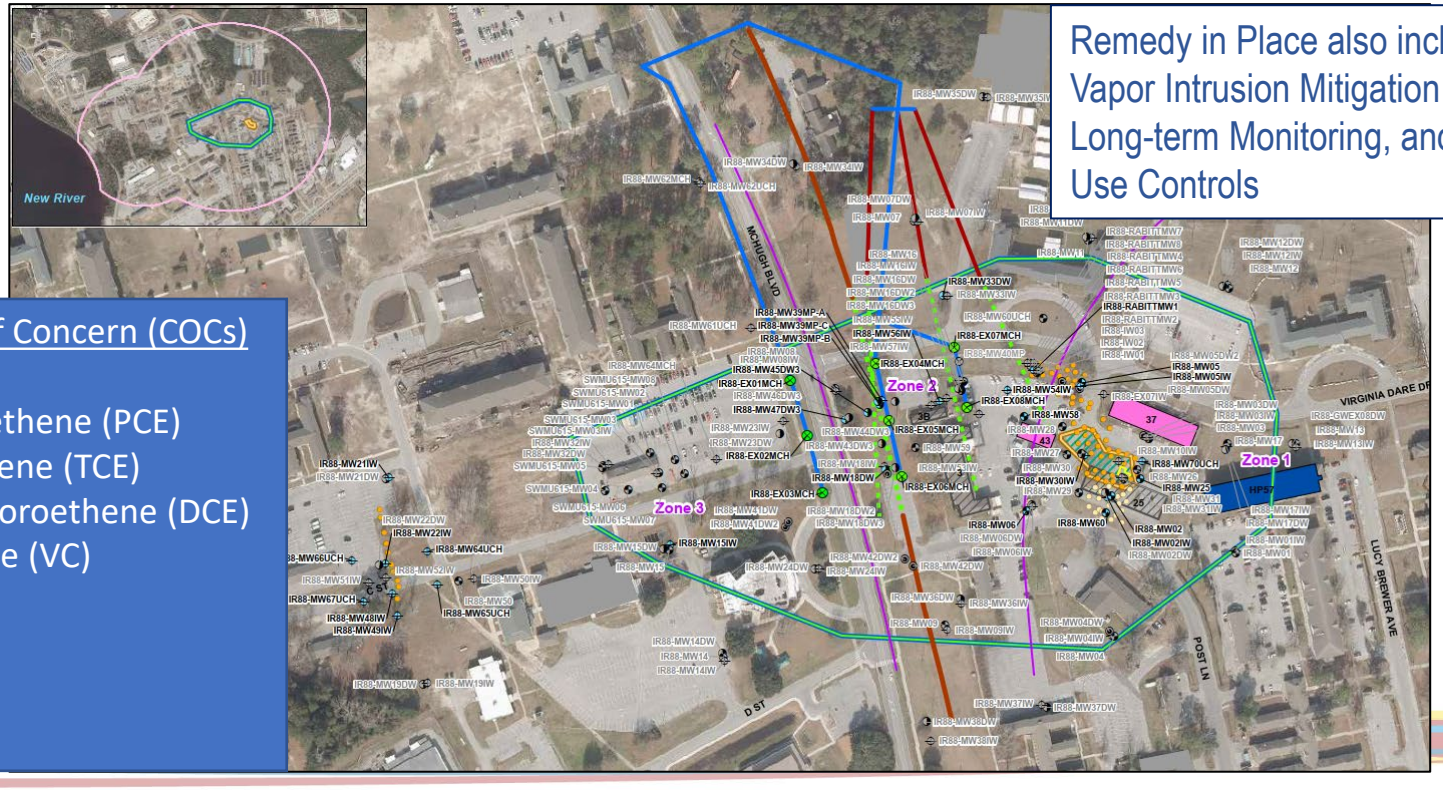
- Former Dry Cleaning Facility (Former Building 25)
  - Volatile organic compounds (VOCs) in groundwater



1995	• Underground Storage Tank Removal
1998	• Focused Remedial Investigation
1999-2001	• Source Area Pilot Studies
2003-2004	• Supplemental Site Investigation
2007	• Remedial Investigation
2006-2010	• Soil Mixing Removal Actions, Groundwater Pilot Studies
2011	• Vapor Intrusion Investigation, Phase I Limited Site Assessment, Site-wide Groundwater Sampling
2012	• Vapor Intrusion Mitigation System Installation
2014	• Baseline Geophysical Mapping, Site-wide Groundwater Sampling
2015-2017	• Tracer Study, Sewer Ventilation Pilot Study
2018-2019	• Feasibility Study, Proposed Plan, Record of Decision, Treatability Studies
2020-2022	• Remedial Design, Remedial Action

Site 88 Background

- Site divided into three zones to facilitate investigation, studies, and removal actions
  - Zone 1: Initial source area, relatively high concentrations in groundwater at 5 to 60 feet below ground surface (bgs)
    - Remedy in Place – Enhanced Reductive Dechlorination via Vertical Injection Wells
  - Zone 2: Downgradient of Zone 1, elevated concentrations from 40 to 180 feet bgs
    - Remedy in Place – In Situ Chemical Oxidation via Horizontal Directionally Drilled Injection Wells and Recirculation
  - Zone 3: Downgradient portion of plume, with lower concentrations limited to 40 to 60 feet bgs
    - Remedy in Place – Enhanced Reductive Dechlorination Biobarrier via Vertical Injection Wells



Remedy in Place also includes Vapor Intrusion Mitigation Systems, Long-term Monitoring, and Land Use Controls

Constituents of Concern (COCs)

Groundwater:

- Tetrachloroethene (PCE)
- Trichloroethene (TCE)
- Cis-1,2-dichloroethene (DCE)
- Vinyl chloride (VC)

Soil Gas:

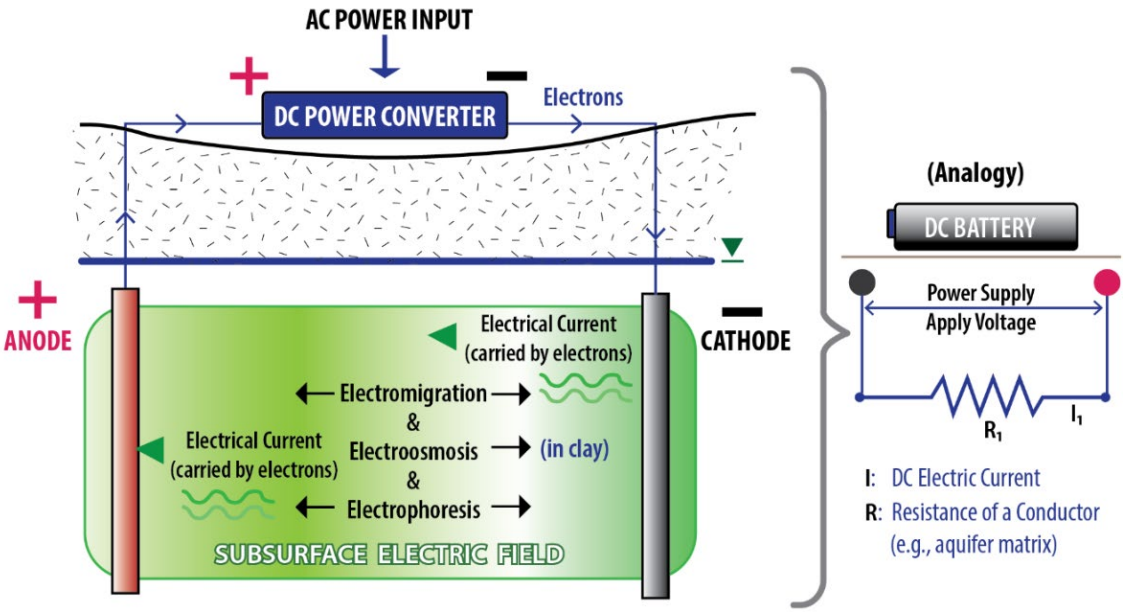
- PCE
- TCE
- VC

Zone 1 Pilot Study

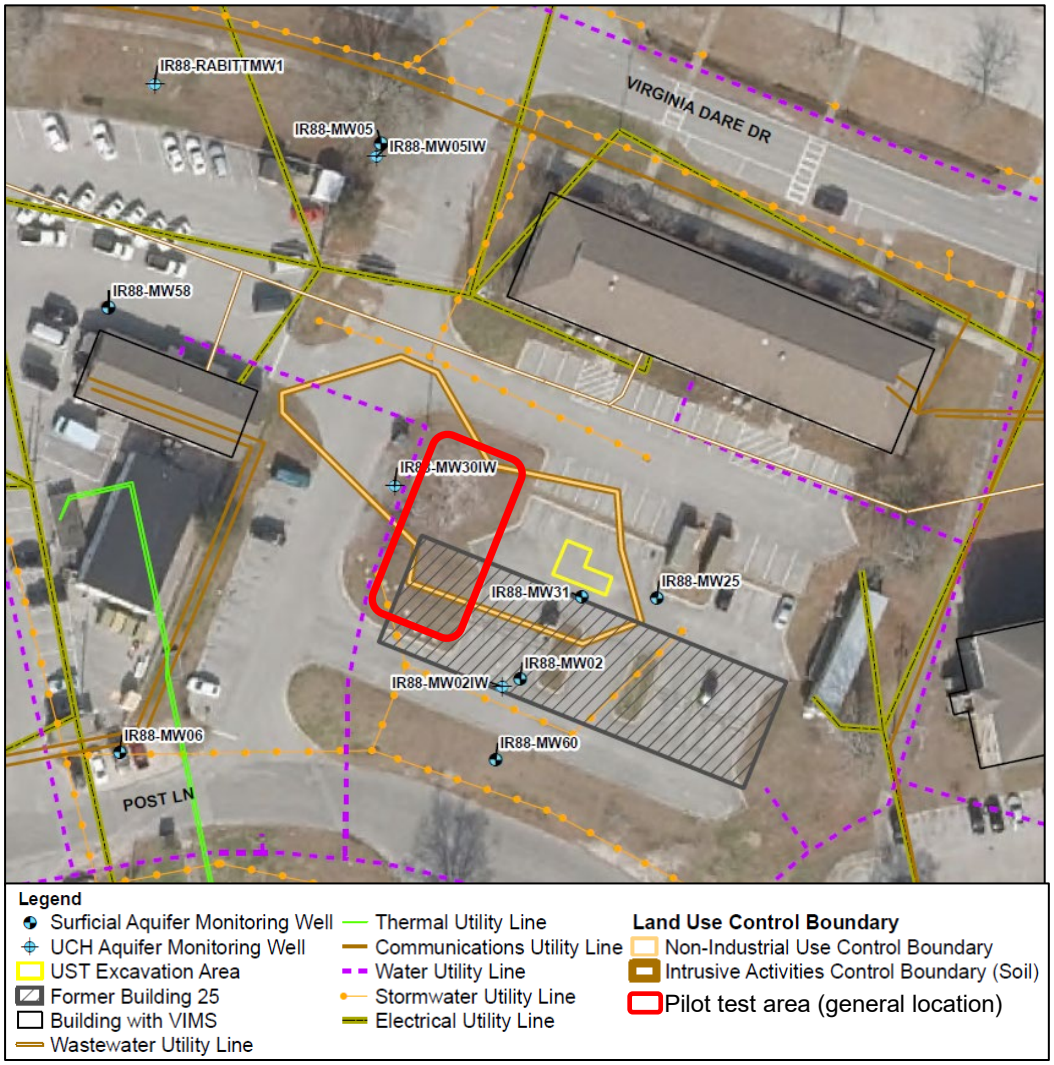
- Rationale:
  - Previous injection events in Zone 1 challenged by:
    - Daylighting
    - Interception with storm sewer
    - Low flow rates
  - Re-injection events may experience same limitations
- Objective:
  - To evaluate effectiveness of Geosyntec's Electrokinetic (EK)-BIO technology to enhance substrate distribution in a controlled manner

EK Bio Basics

- Electrokinetic (EK) enhanced amendment delivery uses low-voltage direct current (DC) to uniformly transport amendments through clays and silts
- EK transport mechanisms (electromigration and electro-osmosis) are related to soil's electrical properties, and, therefore, not substantially affected by soil hydraulic conductivity



Proposed Pilot Test Area



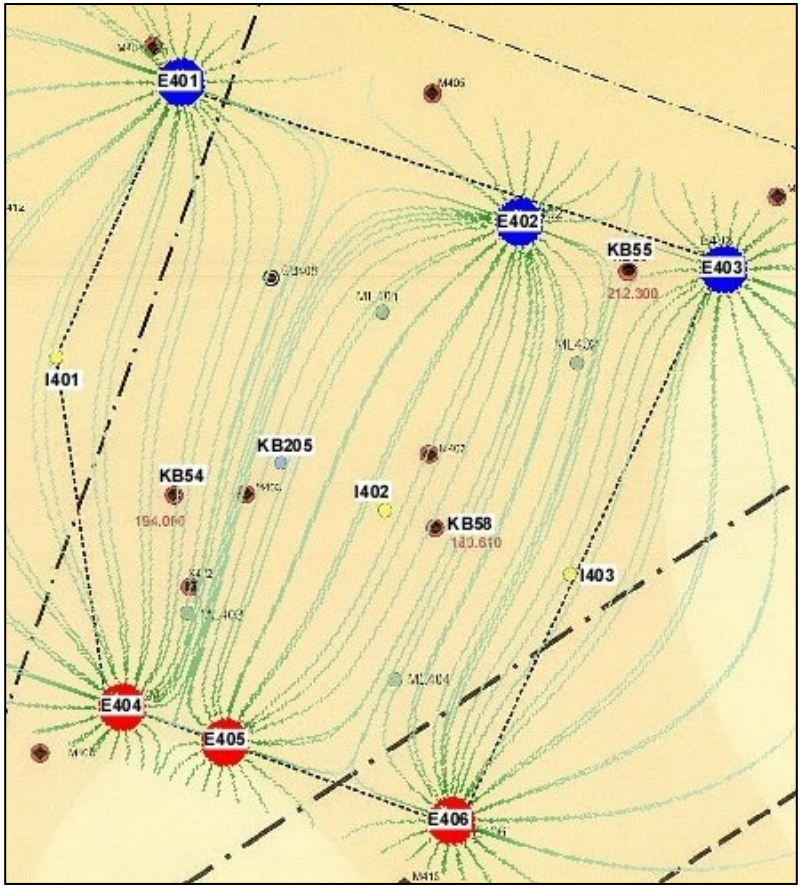
Basis for Location Selection:

- Highest VOC concentrations
- Ideal conductivity based on EVO injection rates
- Minimal impact to nearby office and parking

Exact location will be determined following a field visit to verify locations of overhead and underground utilities, nearby hydrants, and existing stainless-steel wells

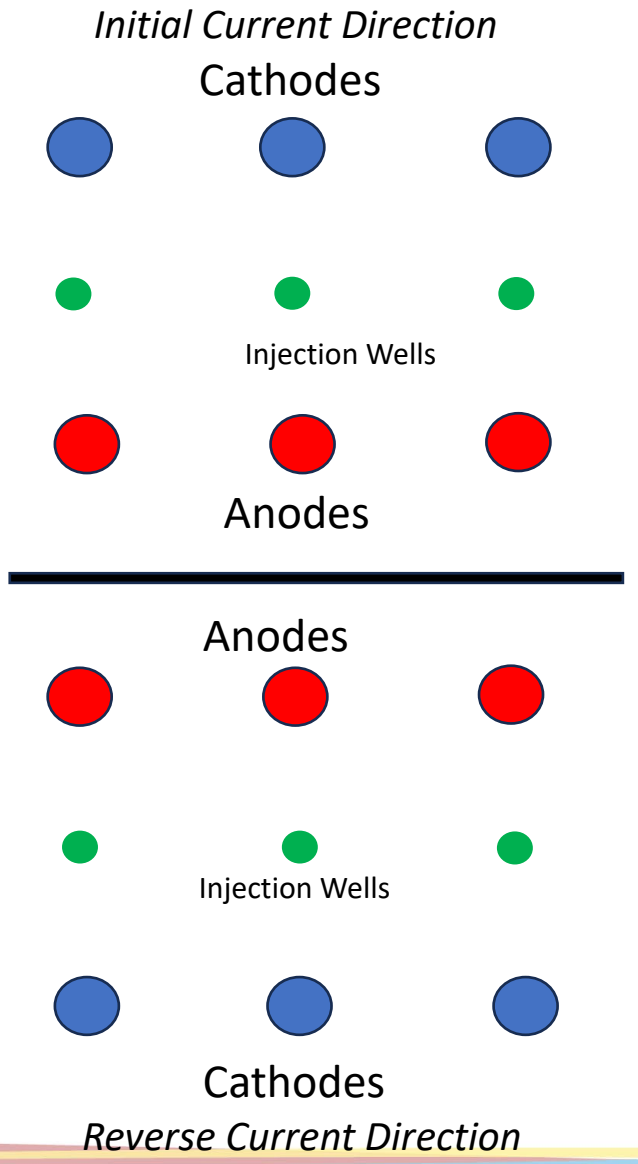
General System Layout

- Preliminary size estimate for pilot test plot: 25 ft x 25 ft
- Anode/cathode well heads (estimated 3 each)
- Electrical field not anticipated to impact existing (metal) subsurface utilities, based on depth of target treatment zone



System Installation and Operation

- System Installation
  - Well Installation and surveying
  - Establish electrical and water connections
  - Connect wells to system trailer and water/amendment tank
- Operation
  - Initiate Staged Operation and Monitoring
    - 5-6 months operation and monitoring
    - 1-2 months downtime to allow for biodegradation
    - 5-6 months operation and monitoring, under reversed electric field

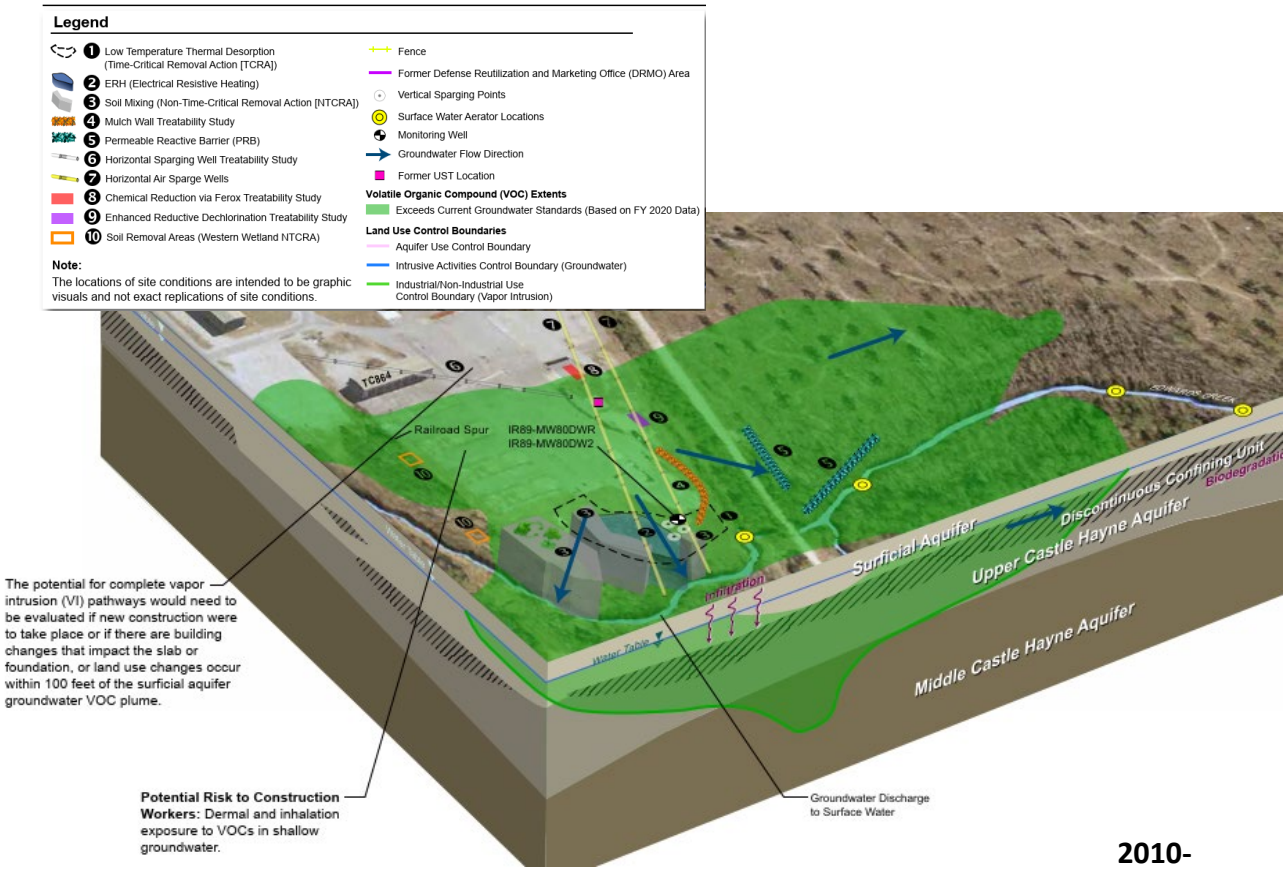


Schedule

- **Pilot Study Tech Memo Work Plan**
  - Draft to Navy/Base – December 2024
  - Draft to USEPA/NCDEQ – February 2025
  - Final – May 2025
- **Pilot Test Fieldwork: June 2025 – August 2026**
- **Pilot Study Tech Memo: Winter 2026**

Site 89 E-Redox Pilot Study

Site 89 – Former Base Motor Pool (DRMO)



- **Source**
  - Base motor pool and Defense Reutilization and Marketing Office
- **Potential Risks**
  - Human health risks from volatile organic compounds in groundwater
- **Current Status**
  - Remedy-in-place
    - Groundwater:
      - Air sparging
      - Permeable Reactive Barriers (PRBs)
      - Monitored Natural Attenuation (MNA)
    - Surface water:
      - Aerators
      - MNA
    - Land Use Control (LUCs)

1996–1999 Remedial Investigation

1999–2005 Long-Term Monitoring

2000 Pilot Study

2004 Pilot Study

2006–2008 Remedial Investigation

2008–2009 Soil Mixing

2009 Sediment Removal

2010–2011 Feasibility Study

2012 Remedy Selection and Design

2013 Remedy in place

2017 –2022 Supplemental Investigation

1996 2000 2005 2010 2015 2020

18

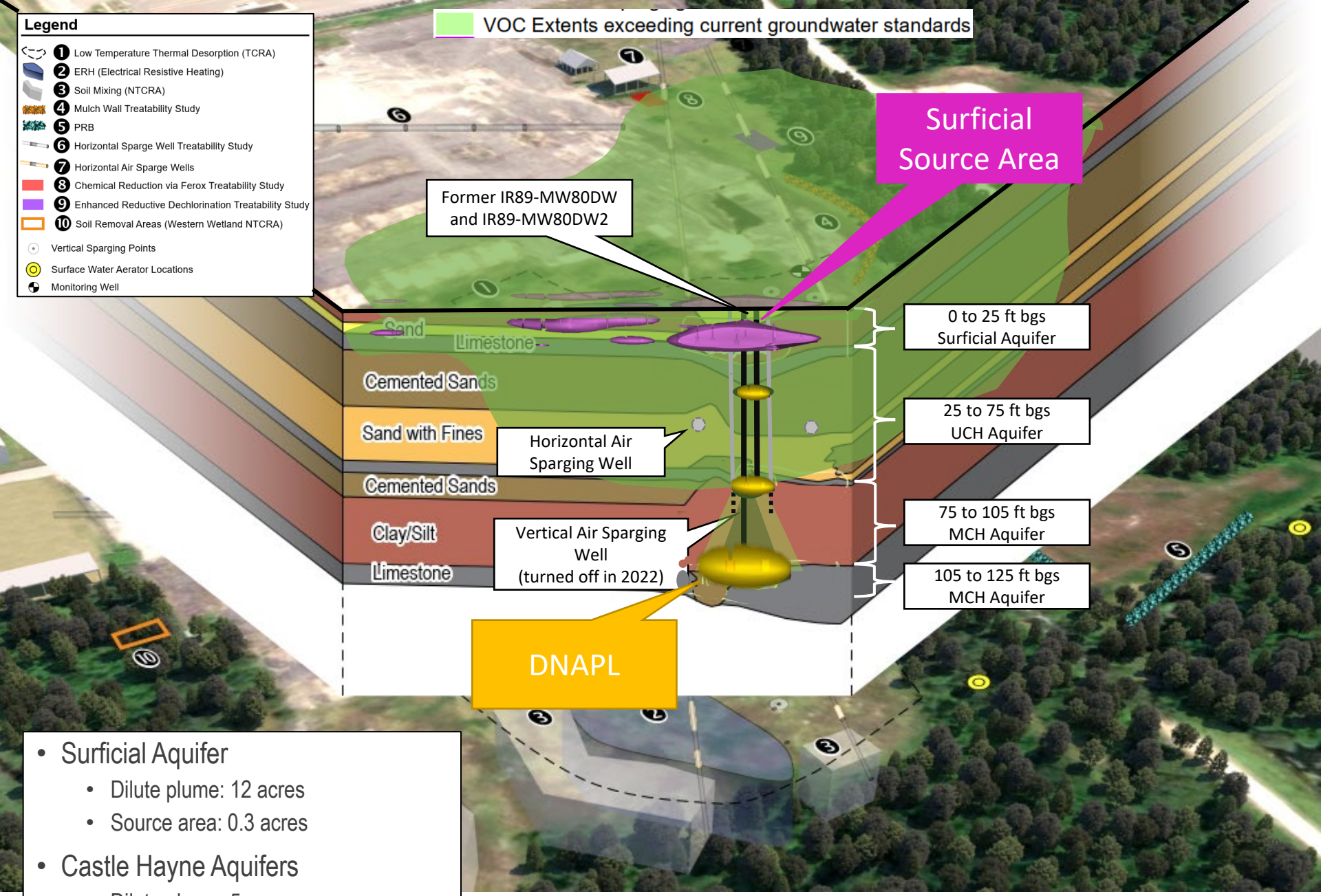
Remedies in Place

Constituents of Concern (COCs)

Groundwater: VOCs (1,1,2,2-tetrachloroethane [1,1,2,2-PCA]; 1,1,2-trichloroethane [TCA]; 1,2- dichloroethane [DCA]; tetrachloroethene [PCE]; trichloroethene [TCE]; cis-1,2-dichloroethene [DCE]; trans-1,2-DCE; vinyl chloride [VC])

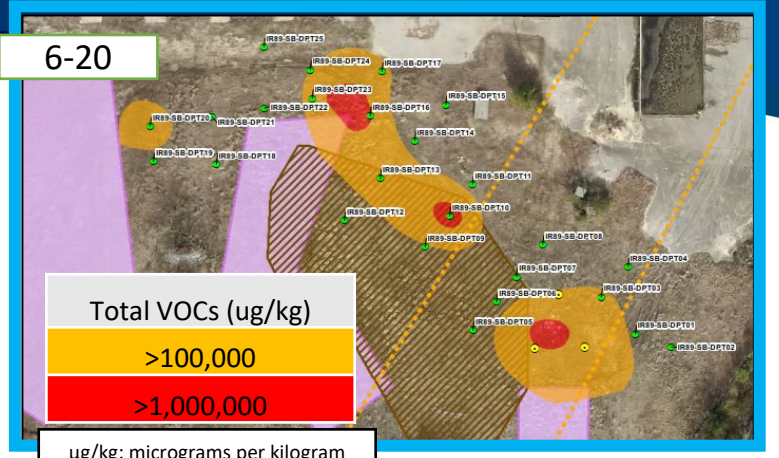
Surface water: VOCs (1,1,2,2-PCA; TCE; VC)

- AS (Source Area)
  - Since system start-up in (2013), system has operated ~81 percent of the time
  - COC concentrations in groundwater near horizontal air sparging wells are stable to decreasing, with isolated areas of increasing concentrations
    - Vertical air sparging wells were turned off in 2022 because they were not functioning as intended
- PRB (Downgradient Area)
  - Concentrations are reducing as groundwater passes through PRBs
  - Geochemical conditions remain favorable for anaerobic biodegradation
- Aerators (Surface Water)
  - No COCs detected above cleanup levels at most downstream sampling location, indicating aerators are effectively treating surface water and no contamination is migrating offsite
- MNA
  - Overall, concentrations outside of active treatment areas are generally stable to decreasing in both concentration and extent

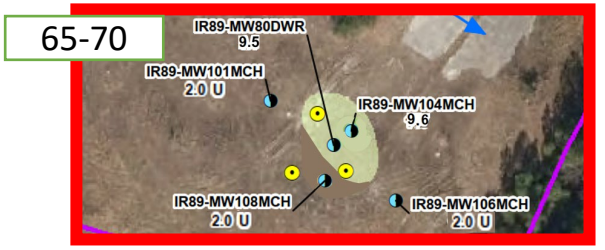


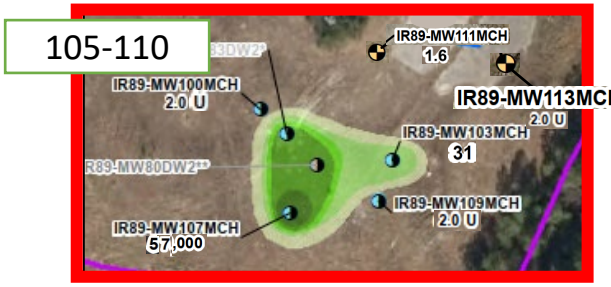
- Surficial Aquifer
  - Dilute plume: 12 acres
  - Source area: 0.3 acres
- Castle Hayne Aquifers
  - Dilute plume: 5 acres
  - DNAPL concentrations: 0.1 acres

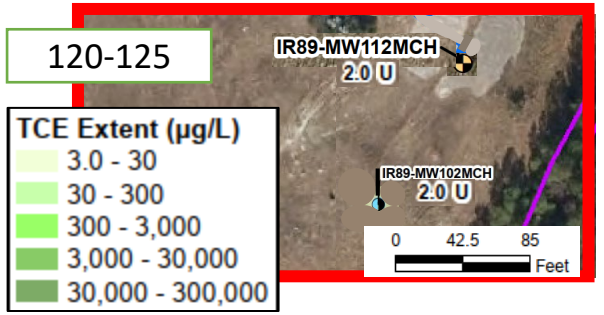
Remedy Implications



- Surficial Aquifer
  - Surficial source area not being treated by current remedies (AS and MNA)
  - Continuing potential source of groundwater contamination
- Castle Hayne Aquifer
  - DNAPL level concentrations not being treated by current remedies (AS and MNA)
  - DNAPL in higher conductivity zones than surficial aquifer
- Path Forward
  - Complete an Engineering Evaluation/Cost Analysis (EE/CA) to evaluate removal action alternatives for addressing source areas in surficial aquifer and DNAPL in Castle Hayne aquifer
  - After completion of EE/CA and removal action, evaluate site-wide remedial strategy







Technologies for Consideration

- Surficial Aquifer
  - In situ thermal treatment
  - Excavation
  - In-situ chemical reduction (ISCR) or enhanced reductive dechlorination (ERD) via soil mixing
  - Targeted excavation with zero valent iron (ZVI) injections via fracturing
  - Bioelectrochemical remediation
- Castle Hayne Aquifer
  - Expanded Air Sparging
  - ISCR/ERD Injections
  - Groundwater extraction and treatment via air stripper and granular activated carbon (GAC)
  - Groundwater extraction and treatment via subgrade biogeochemical reactor (SBGR)

Comparative Analysis of Surficial Aquifer Alternatives

Criteria	Alternative SA1 In Situ Thermal Treatment	Alternative SA2 Excavation	Alternative SA3 Soil Mixing	Alternative SA4 Targeted Excavation and Hydraulic Fracturing	Alternative SA5 Bioelectrochemical Remediation
Implementability	◕	○	◐	○	●
Effectiveness	●	●	◕	◐	◐
Cost	$5,256,000	$7,742,000	$2,503,000	$4,912,000	$1,282,000
Sustainability	○	◐	◕	◕	●

Notes:

○ = low ability to meet requirements of criterion

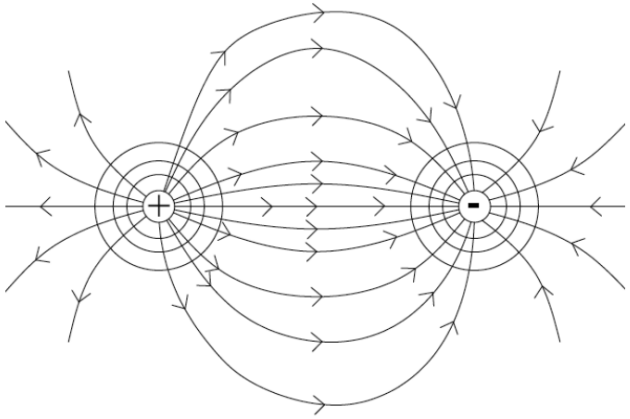
◑ = Low to moderate ability to meet requirements of criterion

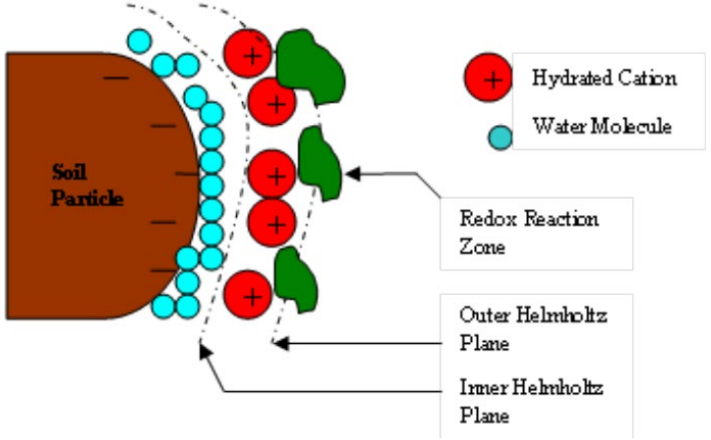
◕ = Moderate to high ability to meet requirements of criterion

● = high ability to meet requirements of criterion

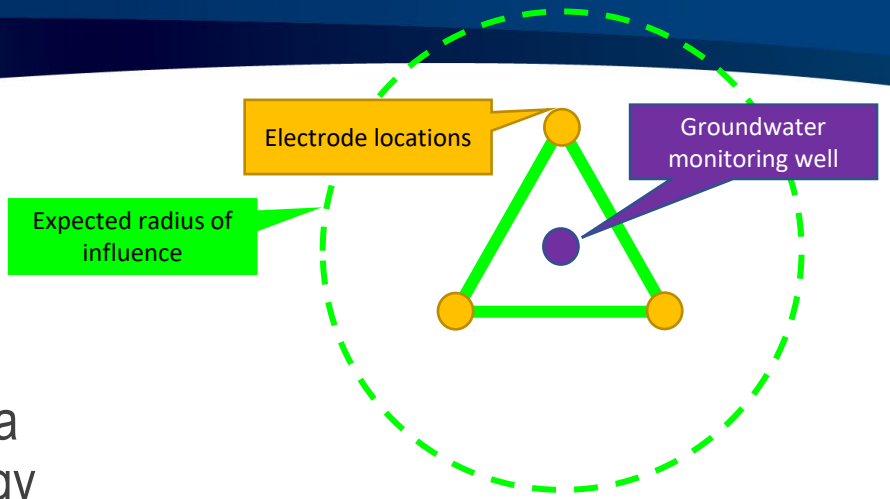
Bioelectrochemical Basics

- E-Redox-I is a patented technology developed by Advanced Environmental Technologies, LLC (AET, Fort Collins, CO)
  - Generates a low-voltage gradient electric field in between electrodes
  - Uniformly inducing redox reactions within the impacted matrices
- Degradation is achieved through multiple reactions:
  - Enhanced reductive dechlorination (biological hydrogenous and abiotic beta-elimination)
  - Contaminant desorption
  - Increased microbial activity

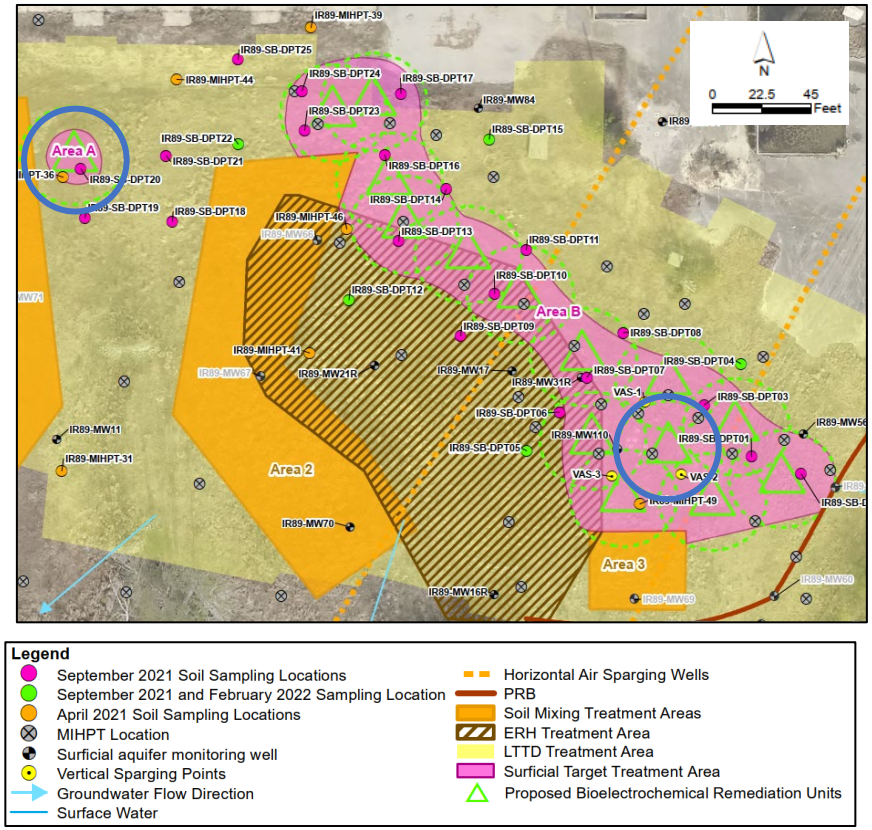




Surficial Aquifer: Bioelectrochemical Pilot Study



- **Rationale:** Bioelectrical remediation is a cost effective and sustainable technology successfully implemented at 50 sites, but not used at MCB Camp Lejeune
- **Objective**: Evaluate effectiveness of bioelectrochemical remediation to treat principal threat waste in 2 areas
- **General Approach**:
  - Install 3 electrode wells and 1 groundwater monitoring well in each area
  - Operate for 1 year
  - Collect two groundwater and 18 soil samples during 3 events (baseline event, after six months of operation, and after 12 months) for site-specific VOCs



Schedule

- **Pilot Study Tech Memo Work Plan**
  - Draft to Navy/Base – August 2024
  - Draft to USEPA/NCDEQ – October 2024
  - Final – December 2024
- **Pilot Test Fieldwork: January 2025 to February 2026**
- **Pilot Study Tech Memo: Spring/Summer 2026**