New Mexico Environment Department Project Update For Kirtland Air Force Base Aviation Fuel Cleanup

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Sand and gravel deposited by the ancestral Rio Grande is the host material for a major aquifer in the Albuquerque area

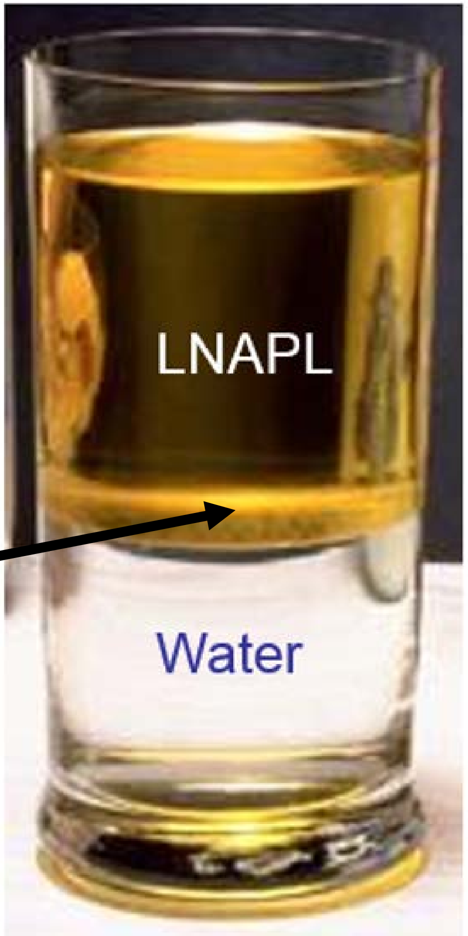
What is LNAPL?

NAPL = Non-Aqueous Phase Liquid

- Does not mix with water, remains as a separate phase
- NAPL constituents can dissolve into water

LNAPL = Light NAPL

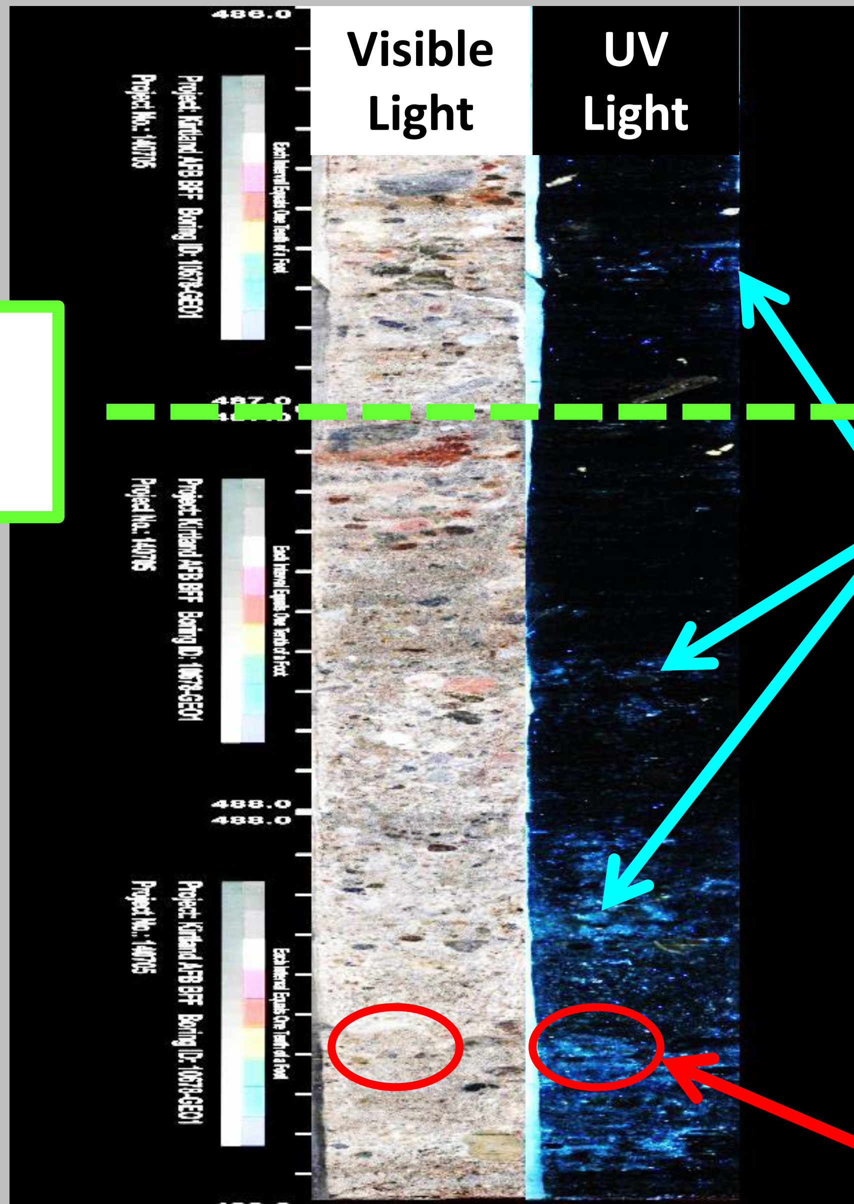
- **L**ess dense than water
- gasoline, diesel, jet fuel



LNAPL floating on the water surface can be observed inside the casing of monitoring wells.

In an aquifer, however, LNAPL coexists with groundwater in porous earth material at various percentages of saturation.

LNAPL in KAFB Soil Cores

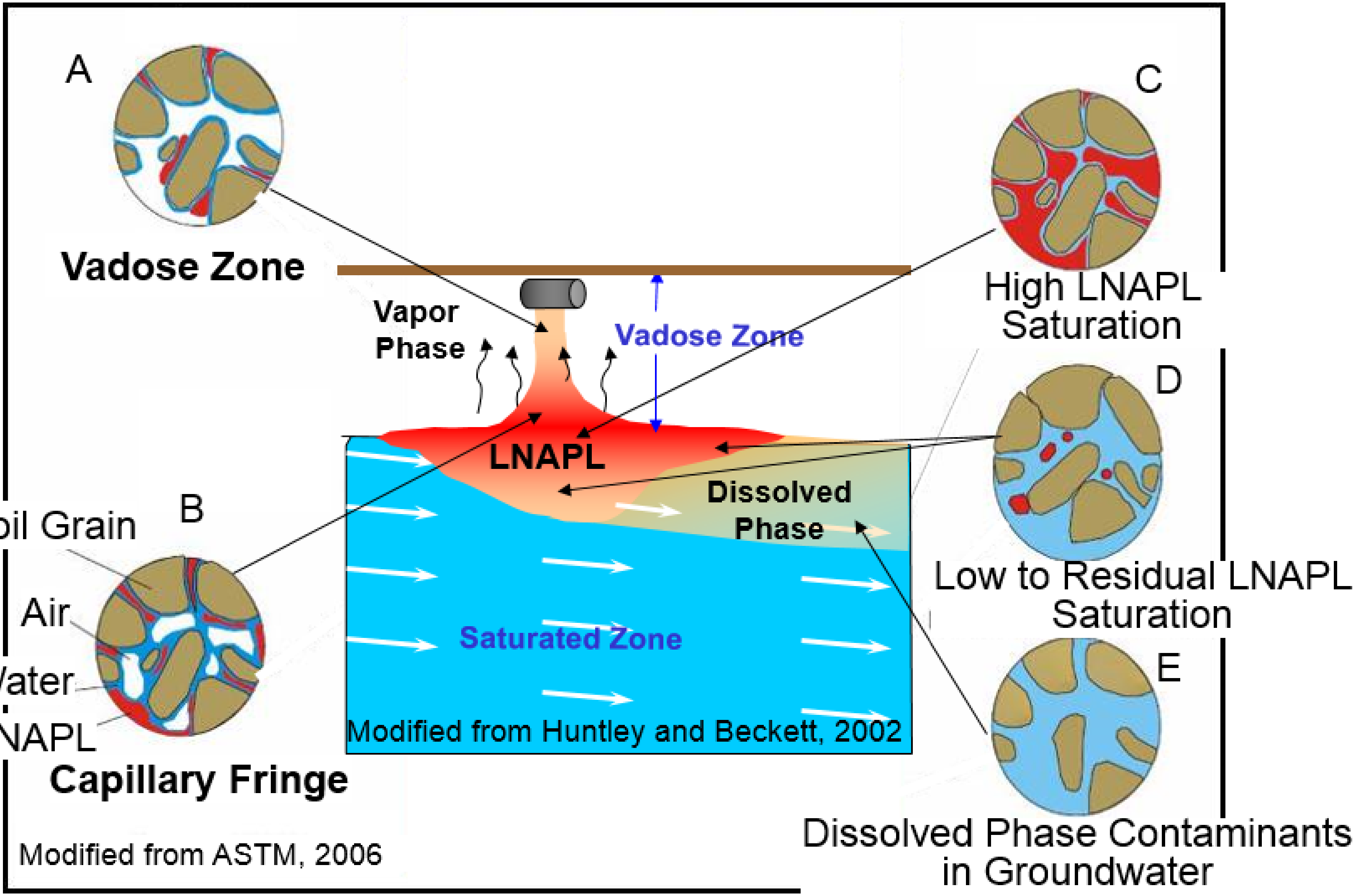


Groundwater Table

LNAPL Under UV Light Fluoresces Blue

LNAPL accumulates in coarse grained sediment

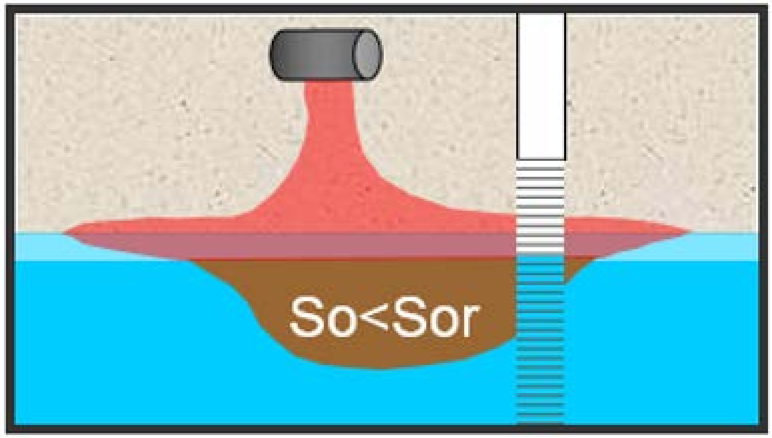
Soil Pore-Scale LNAPL Distribution



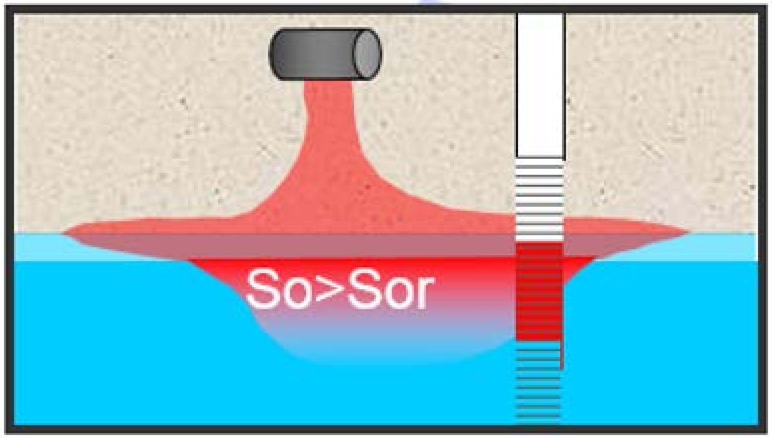
LNAPL Saturation

__LNAPL Saturation (So)__ = percent of soil pore space occupied by LNAPL (oil)

__Residual LNAPL Saturation (Sor)__ = LNAPL that will not freely drain from the soil into a monitoring well



LNAPL saturation less than residual saturation
LNAPL does not flow into well



LNAPL saturation greater than residual saturation
LNAPL flows into well

Residual LNAPL at the KAFB site provides an ongoing source of dissolved groundwater contaminants, and is a major data gap that will be addressed during 2018.

2018 NMED Strategic Plan

***Goal*: Protect Albuquerque's aquifer and drinking water supply wells in the area of the fuel leak**

Strategies to Achieve the Goal

In 2018, NMED and the Air Force will continue to:

1. **Implement a robust site monitoring and wellhead protection program**
2. **Monitor the natural attenuation of fuel contamination in soil and groundwater, and identify potential opportunities for enhancement thru interim corrective measures**
3. **Deploy multiple engineered technologies, both simultaneously and sequentially as interim corrective measures, to clean up soil and groundwater**
4. **Meet or exceed all requirements for providing public information and involvement**

Strategy 1 – Implement Robust Site Monitoring and Wellhead Protection

- **No detections of EDB in drinking water wells or sentinel wells**
- **Cone of depression persists in groundwater extraction area**
- **EDB plume capture analysis is being rigorously updated**
- **Soil coring will fill data gaps on residual LNAPL**
- **Effects of rising water level on direction of groundwater flow and contaminant migration are being evaluated**
- **Data gaps caused by water level rise are being filled by:**
  - Drilling new monitoring wells
  - Monitoring previously dry soil-vapor wells that now contain groundwater

EDB will not be allowed to adversely impact any drinking water supply wells

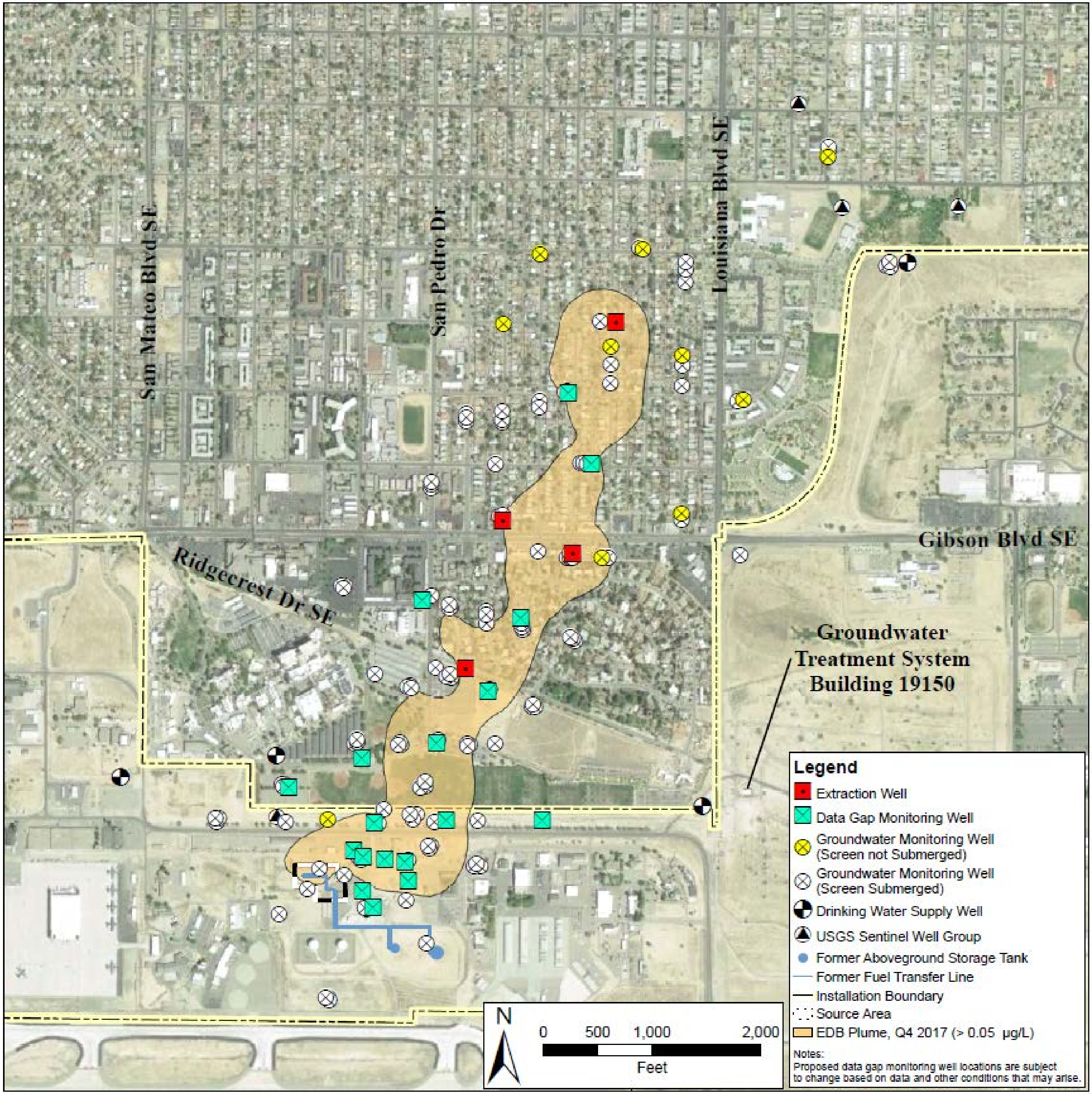
At Least 18 (up to 26) New Wells to Fill Data Gaps

Six monitoring wells will be drilled.

Five, and possibly up to 8, LNAPL coreholes will be completed as monitoring wells.

At least seven, and likely up to 12, previously dry soil-vapor or groundwater wells now have water due to rising water table (using these existing wells will save up to $5.25 million in drilling costs).

Thanks to the Air Force and Army Corps of Engineers for thinking outside the box to fill data gaps and reduce cost to taxpayers!

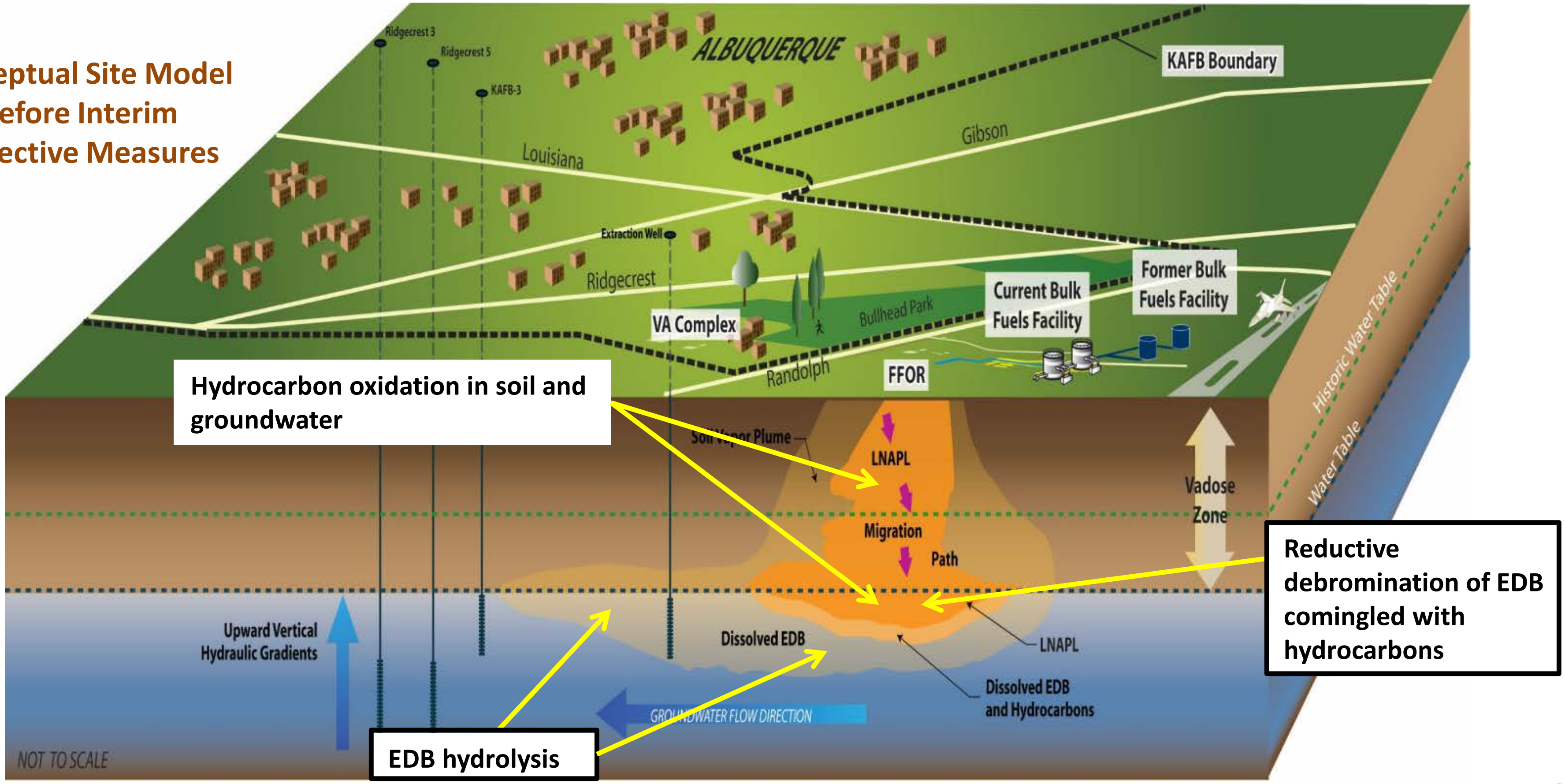


Strategy 2 – Monitor Natural Attenuation & Identify Opportunities for Enhancement

- **Site monitoring has identified ongoing natural degradation processes including hydrocarbon oxidation, EDB hydrolysis, and EDB reductive debromination.**

- **Interim corrective measures include engineered cleanup technologies to enhance natural degradation processes.**

Conceptual Site Model Before Interim Corrective Measures

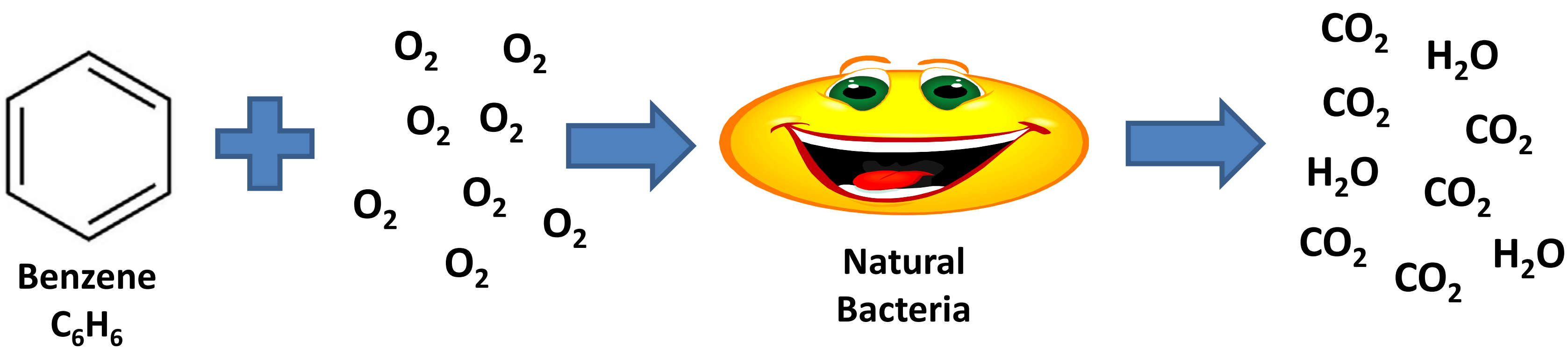


2. Examples of Natural Degradation

Contaminant	Degradation Process	Degradation Indicators
Petroleum hydrocarbons	Oxidation – Naturally occurring bacteria in soil and groundwater consume (oxidize) hydrocarbons for energy and cell growth; can occur under aerobic and anaerobic conditions	Byproducts: carbon dioxide, alkalinity, iron, manganese, acetone, acetophenone Decreased dissolved oxygen, nitrate
EDB	Reductive Debromination – Groundwater bacteria are also biodegrading EDB that is comingled with the oxidizing hydrocarbons	Byproducts bromoethane, ethane, and bromide
EDB	Hydrolysis – Chemical reaction(s) where EDB is degraded by interaction with water, the hydrogen ion (H^+), or the hydroxyl ion (OH^-)	Various potential byproducts depending on hydrolysis reaction(s) occurring

2. Hydrocarbon Biodegradation

Naturally occurring soil and groundwater bacteria can oxidize petroleum hydrocarbons, such as benzene, into carbon dioxide and water.

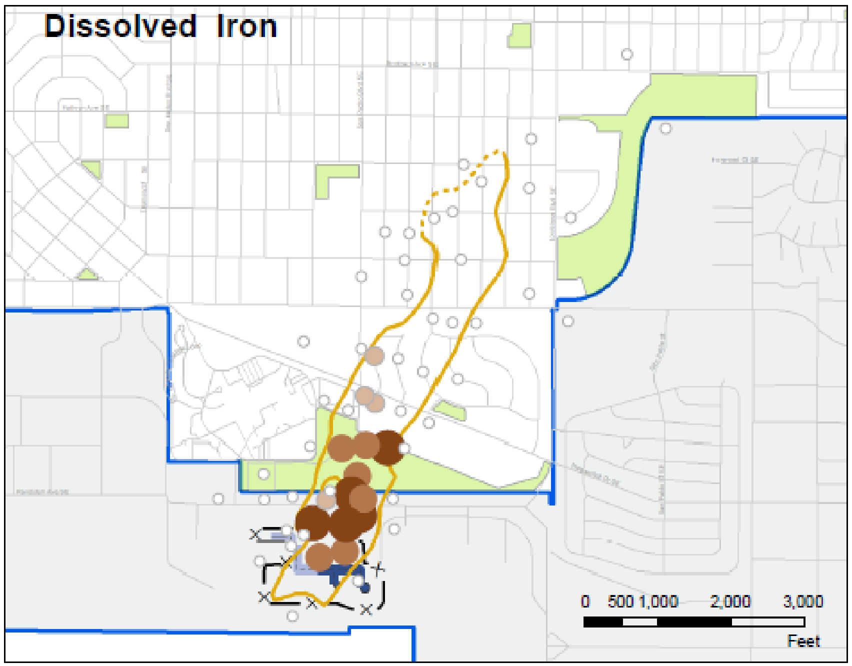


$$C_6H_6 + 7.5\,O_2 \rightarrow 6\,CO_2 + 3\,H_2O$$

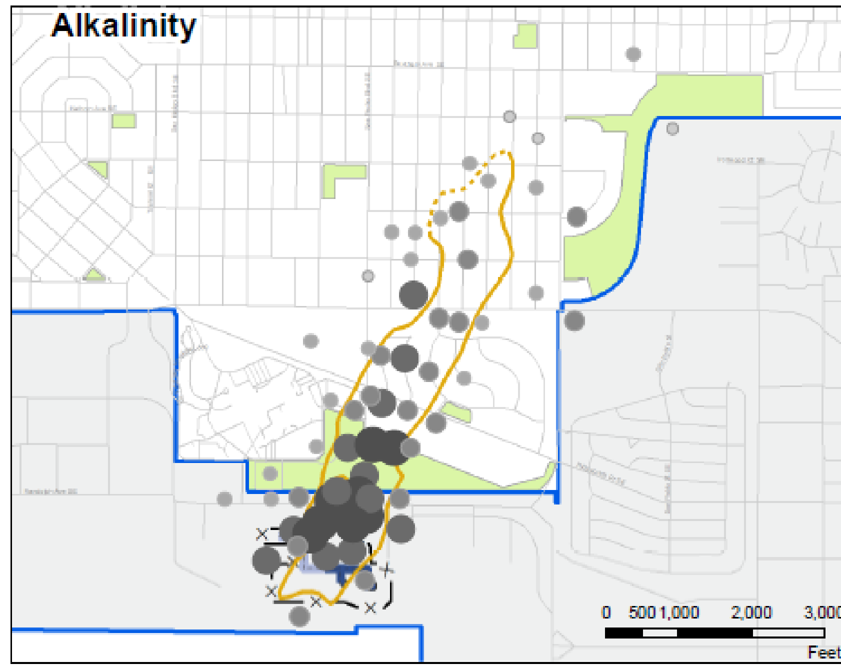
Aerobic Benzene Biodegradation

2. Indicators of Natural Biodegradation

Changes in the following parameters can provide evidence of biodegradation of fuel contaminants: decreases in dissolved oxygen, nitrate, and sulfate; and increases in alkalinity, manganese, iron, methane, and bromide.



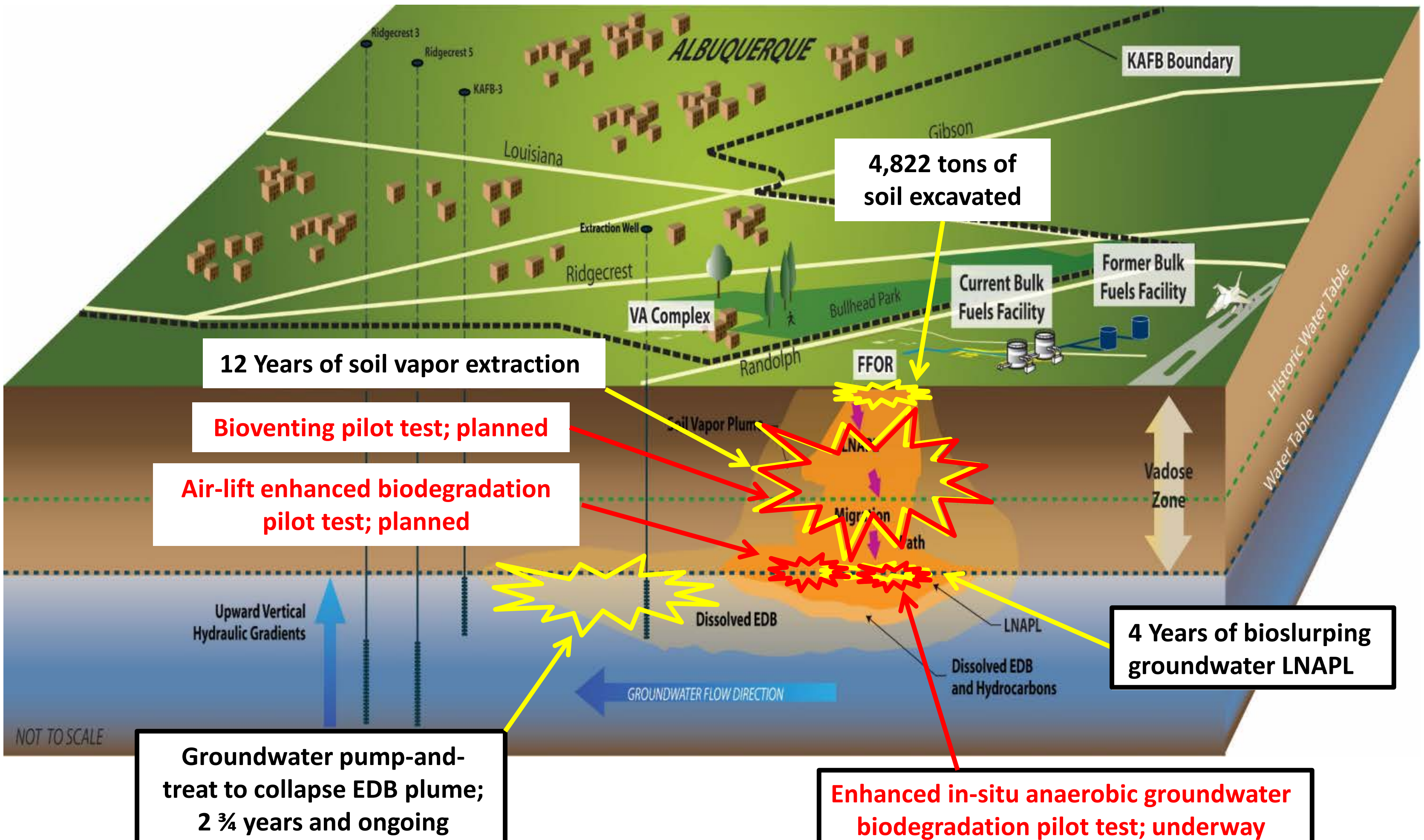
Native bacteria that are oxidizing petroleum hydrocarbons can respirate iron oxides in the soil and aquifer matrix, causing soluble iron to be released into groundwater.



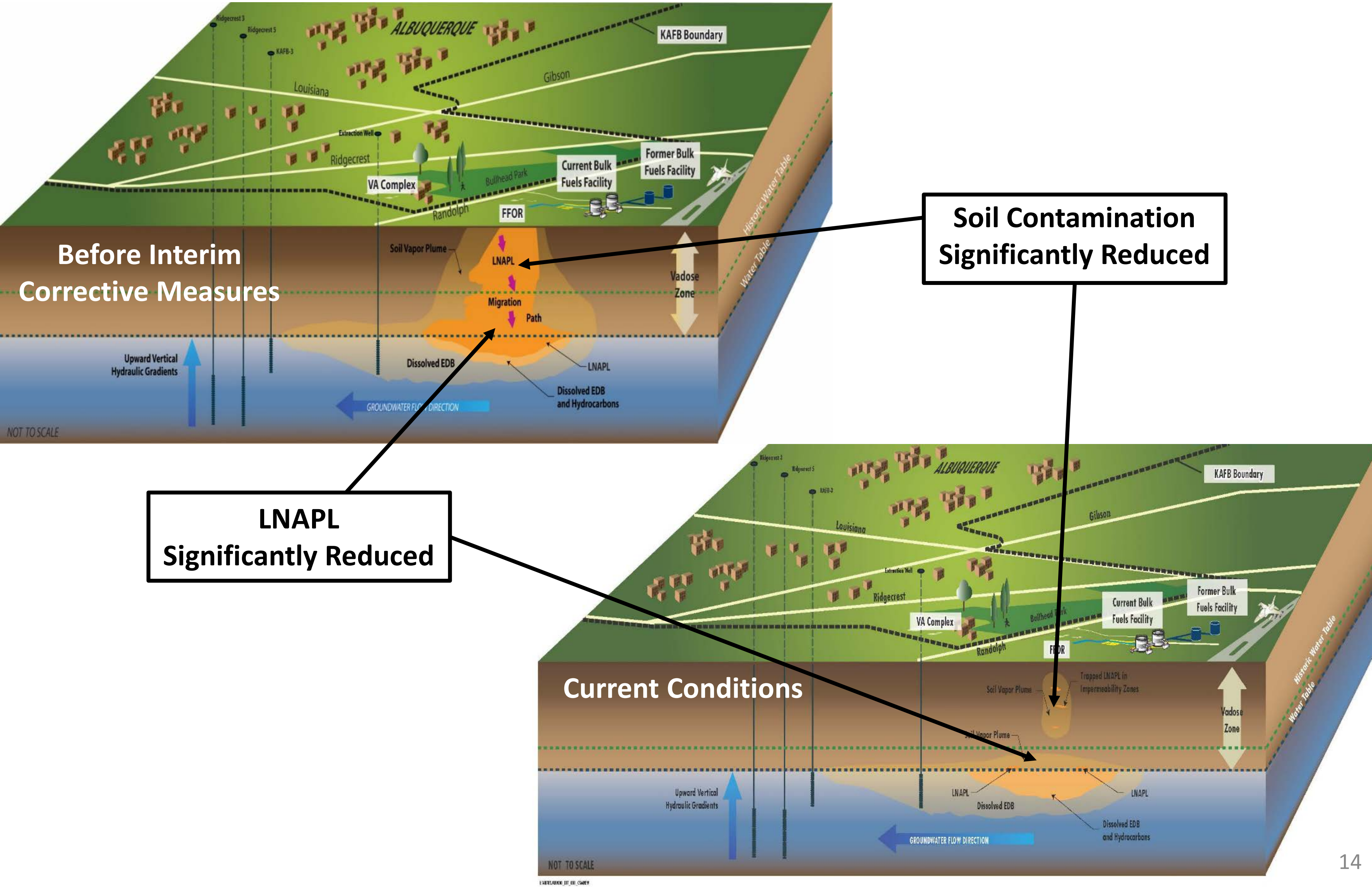
Carbon dioxide generated by the biodegradation of petroleum hydrocarbons can transform to bicarbonate and increase groundwater alkalinity.

Strategy 3 – Deploy Multiple Engineered Cleanup Technologies, Simultaneously and Sequentially

Activities in 2018 will include interim corrective measures such as: enhanced in-situ anaerobic groundwater biodegradation, soil bioventing, and air-lift enhanced biodegradation.



Strategy 3 – Before and After Interim Corrective Measures



3. Anaerobic Biodegradation Pilot Test

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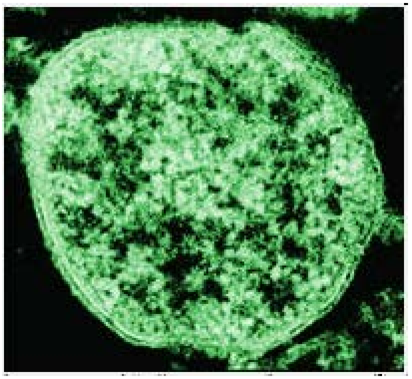
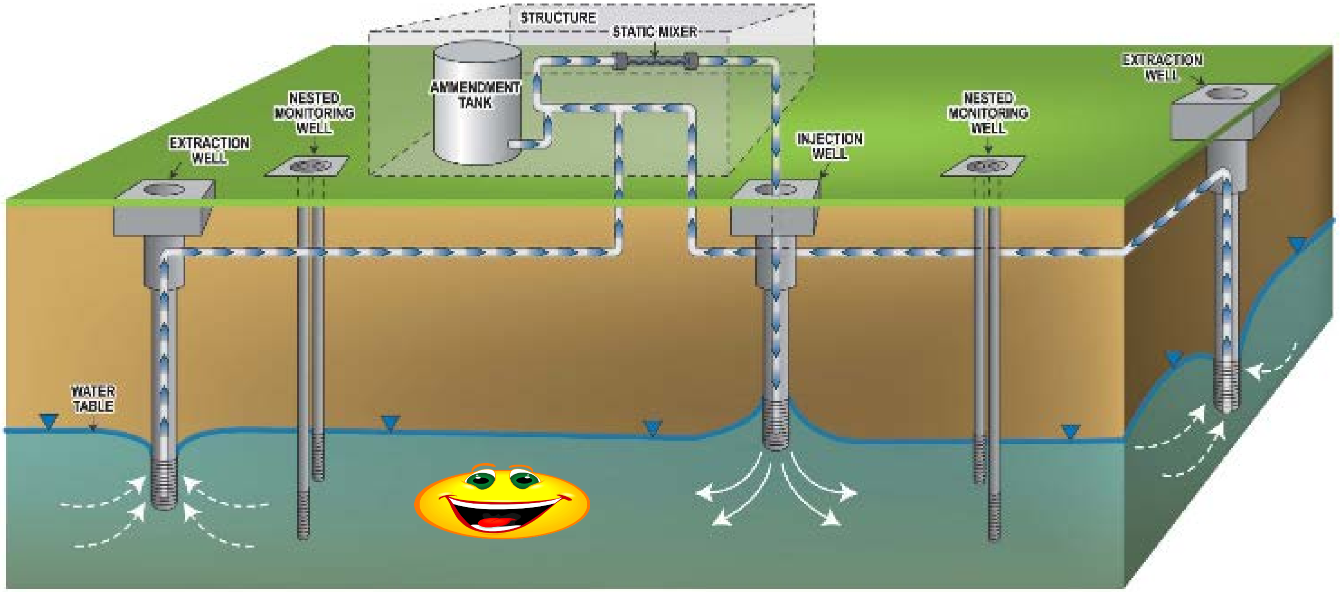
- Laboratory tests demonstrated biodegradation, and were used to design this pilot field test
- Phase 1 – Baseline definition, tracer test circulation, passive monitoring (completed)
- Phase 2 – Bio-stimulation by adding nutrients and lactate (commenced December 2017)
- Phase 3 – Bio-augmentation by adding bacteria such as dehalococcoides (scheduled for summer 2018)
- Phase 4 – Long-Term Passive Monitoring



Dehalococcoides – a bacterium known to degrade halogenated pollutants including EDB
(University of Alberta BacMap Genome Atlas, http://wishart.biology.ualberta.ca/BacMap/index.html)

3. EDB In Situ Biodegradation Pilot Test

Tara Kunkel, APTIM



- Multi-part data driven pilot test.
- Began Phase 1 in October 2017 - GW extracted and injected for 30 days with non-toxic tracers approved by NMED to evaluate transport times throughout the pilot test area
- Completed passive part of Phase 1 from Nov – Dec 2017
- Phase 1 showed effective distribution of tracers at the site and provided opportunity to evaluate EDB concentrations and native bacteria already present

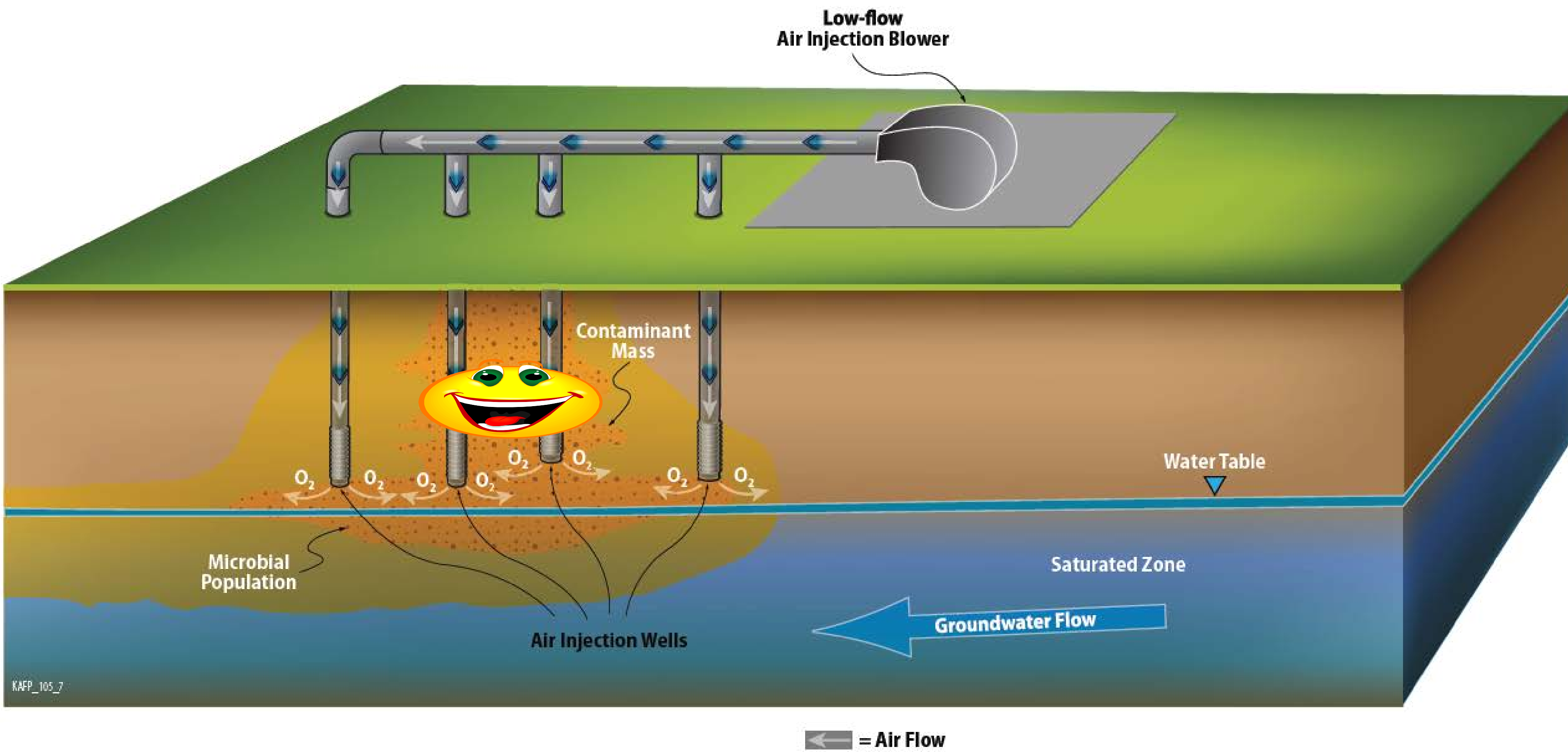
3. EDB In Situ Biodegradation Pilot Test

Tara Kunkel, APTIM

- Began Phase 2 in Dec 2017 - GW extracted and injected for ~30 days with addition of treatment amendments and tracer
- Began passive part of Phase 2 in Feb 2018
- Will be completing several sampling events throughout passive period
- Will begin Phase 3 – Bioaugmentation – in May/Early June 2018
- Phase 3 will include extraction/injection of GW for ~30 days with addition of treatment amendments and bacterial culture that degrades EDB
- Phase 3 will also be followed by a period of passive monitoring

3. Bioventing

Air will be blown into the soil to deliver oxygen to naturally occurring bacteria and enhance their ability to biodegrade petroleum hydrocarbons



Strategy 4 - Public Outreach Schedule

The Air Force and NMED are conducting public outreach and involvement activities related to investigation and cleanup of the Kirtland Air Force Base aviation fuel contamination in accordance with the public notice and community relations requirements of the N.M. Water Quality Control Commission and federal Resource Conservation and Recovery Act Permits. Additionally, NMED will prepare and implement a Public Involvement Plan pursuant to NMED Policy 07-13, https://www.env.nm.gov/wp-content/uploads/2018/02/NMED-Policy-and-Procedure-07-13.pdf.

Date	Description
March 21, 2018	ABCWUA Governing Board Meeting, project update
March 22, 2018	Regular Public Meeting with Technical Poster Session
March 24, 2018	Groundwater Treatment System Open House
April 13, 2018	New Mexico Geological Society, Spring Conference, Socorro, NM
June 29, 2018	NMED Public Involvement Plan to be finalized
July 12, 2018	Regular Public Meeting with Technical Poster Session
November 15, 2018	Regular Public Meeting with Technical Poster Session

NMED and the U.S. Air Force welcome invitations from neighborhood associations, civic organizations, environmental groups, and local government agencies.

About NMED's Strategic Plan

- NMED's annual Strategic Plans are not regulatory documents, but serve to communicate goals and strategies with the public.
- NMED's Strategic Plans summarize the detailed, and often highly-technical, regulatory permits, workplans, engineering specifications, schedules, and approval letters that can be accessed from the NMED Hazardous Waste Bureau website: https://www.env.nm.gov/hazardous-waste/kafb/#KAFBBulkFuelsFacSpill.
- NMED's Strategic Plans for 2015, 2016, 2017 and 2018 are available online: https://www.env.nm.gov/kafbfuelplume/kafb-fuel-plume-documents/
- Kirtland Air Force Base jet fuel remediation website: https://www.kirtlandjetfuelremediation.com/
- Drinking Water Watch contains information and drinking water test results for public water systems in New Mexico, including Albuquerque Bernalillo County Water Utility Authority, Kirtland Air Force Base, and Veterans Administration Hospital: https://dww.water.net.env.nm.gov/NMDWW/
- NMED does not discriminate on the basis of race, color, national origin, disability, age or sex in the administration of its programs or activities.