Kirtland Air Force Base
Bulk Fuels Facility Leak Cleanup

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New Mexico Tech Engineering
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Site History

- The Kirtland Air Force Base (KAFB) Bulk Fuels Facility (BFF) is located in the northwestern portion of the base and began operation in 1953.
- BFF was the fueling area for the installation and received bulk shipments of fuel from railcars and trucks.
- An underground pipeline extending from the fuel off-loading area to the fuel pump house gradually leaked jet fuel into the ground.
- The leak was discovered in 1999 and KAFB sealed off the underground pipe and removed it from service.
- The KAFB fuels facility was replaced in 2011 with all above-ground piping and tanks along with state-of-the-art leak detection technology.

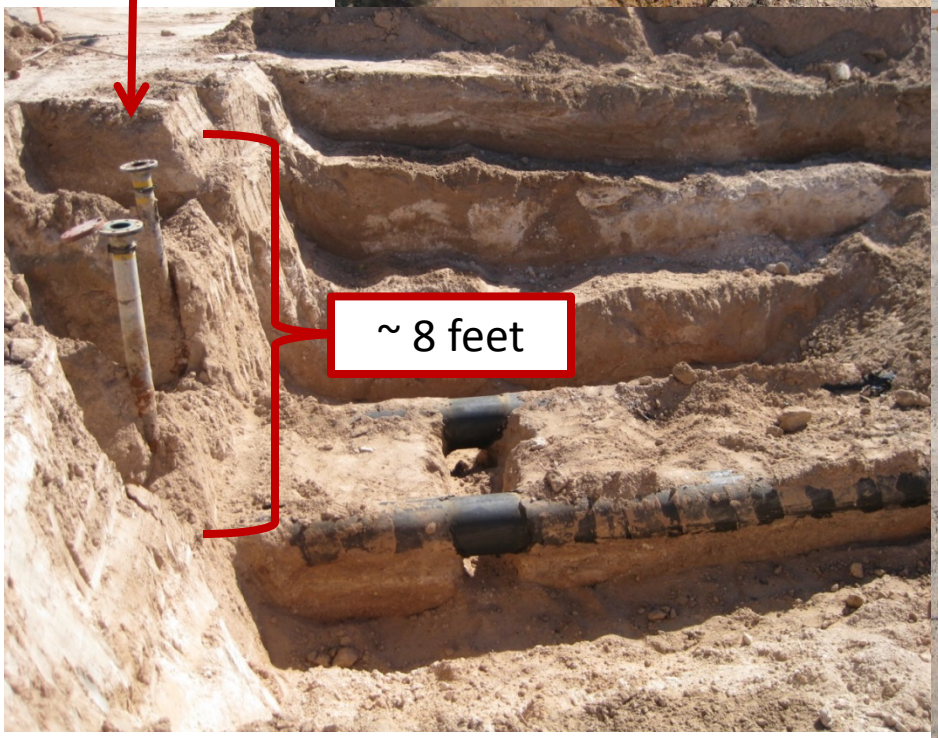
1999 Leak Photos at BFF

Metal Stair Step

Removal of Piping 2010 Photos

Hole in Bottom of Transfer Pipe

Pipe Connect into the Pump House Building

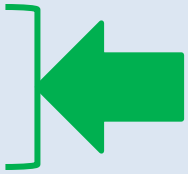


~ 8 feet

Pipe Bent when Removed from Trench

Regulatory Framework

- The New Mexico Environment Department (NMED) governs the fuel leak site through the administration of two federal acts:
  - Safe Drinking Water Act (SWDA)
  - Resource Conservation and Recovery Act (RCRA)
- Site activities are being completed under the Corrective Action provision of RCRA and KAFB's permit:
  - Site Investigation
  - Interim Measures (IMs)
  - Corrective Measures Evaluation (CME)
  - Corrective Measures Implementation (CMI)



The BFF project is here

Timeline

2015 we are here 2016 2017

Site Assessment and Characterization

RFI

Corrective Measures Evaluation

Drilling

Drilling

Drilling

Site Soil and Groundwater Monitoring Program

INTERIM CLEANUP MEASURES

SVE Operation

CSI

Bioventing Pilot Test

EDB Plume Collapse (Groundwater Treatment System)

LNAPL Lab Tests

CSI

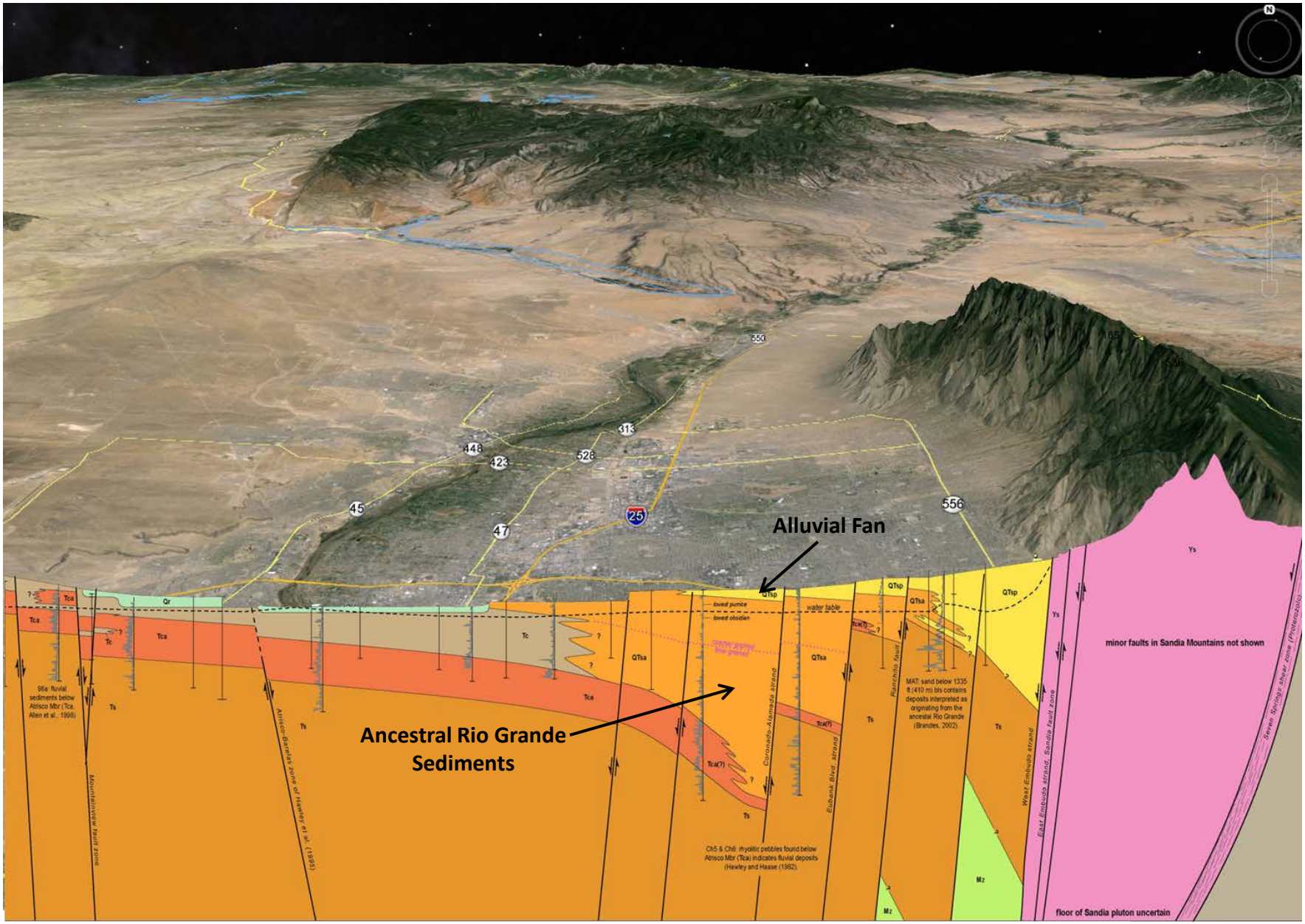
LNAPL Enhanced Bioremediation Pilot Test

Site Permitting

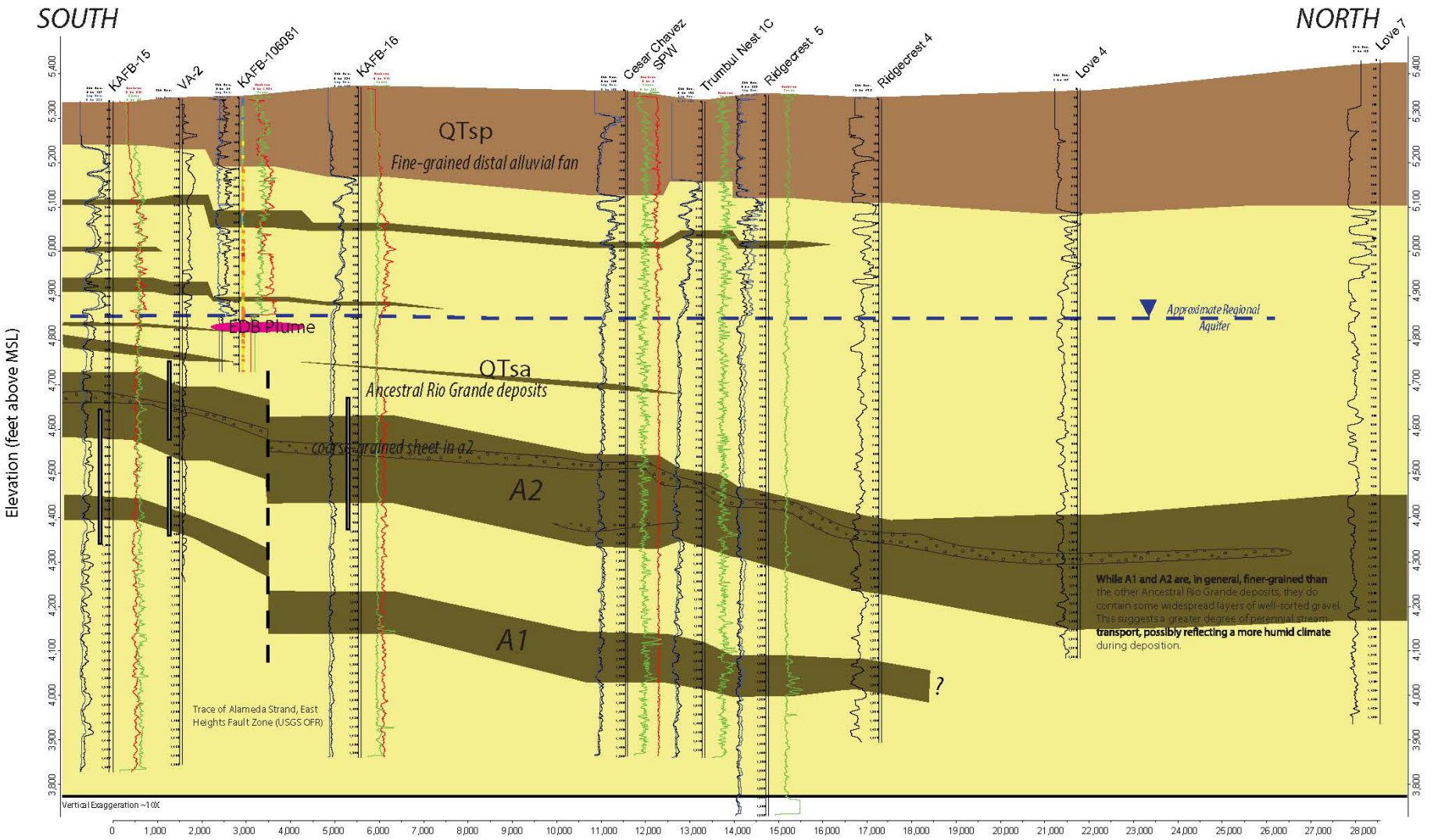
Public Meetings, Field Trips, and Outreach

CSI - Complex Site Initiative • EDB - Ethylene Dibromide • LNAPL - Light Non-Aqueous Phase Liquid • RFI - RCRA Facility Investigation Report • SVE - Soil Vapor Extraction

Understanding the Hydrology



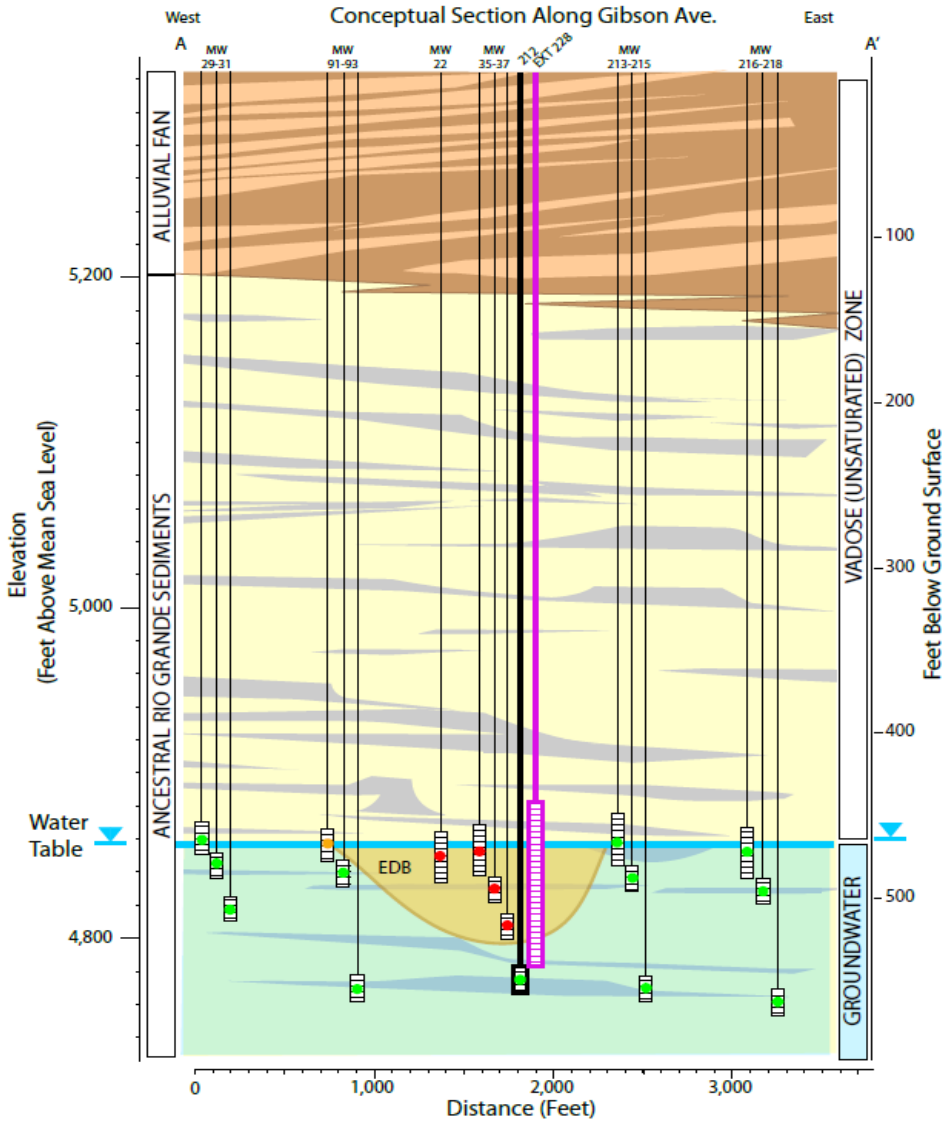
Regional Scale Geology



Understanding the Geology

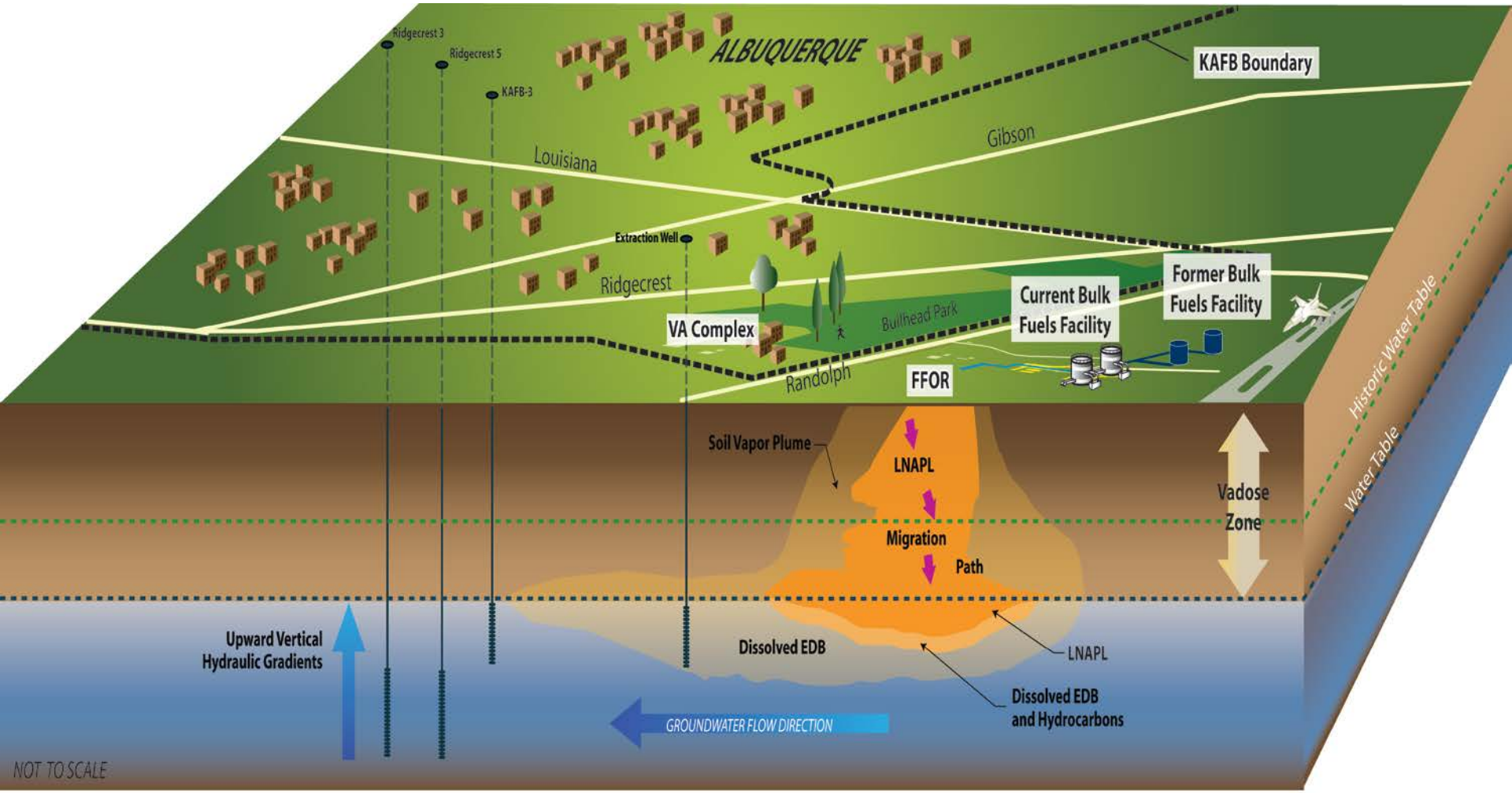
Alluvial Fan Deposits

Ancestral Rio Grande Braided River Deposits



Conceptual Site Model

A dynamic understanding

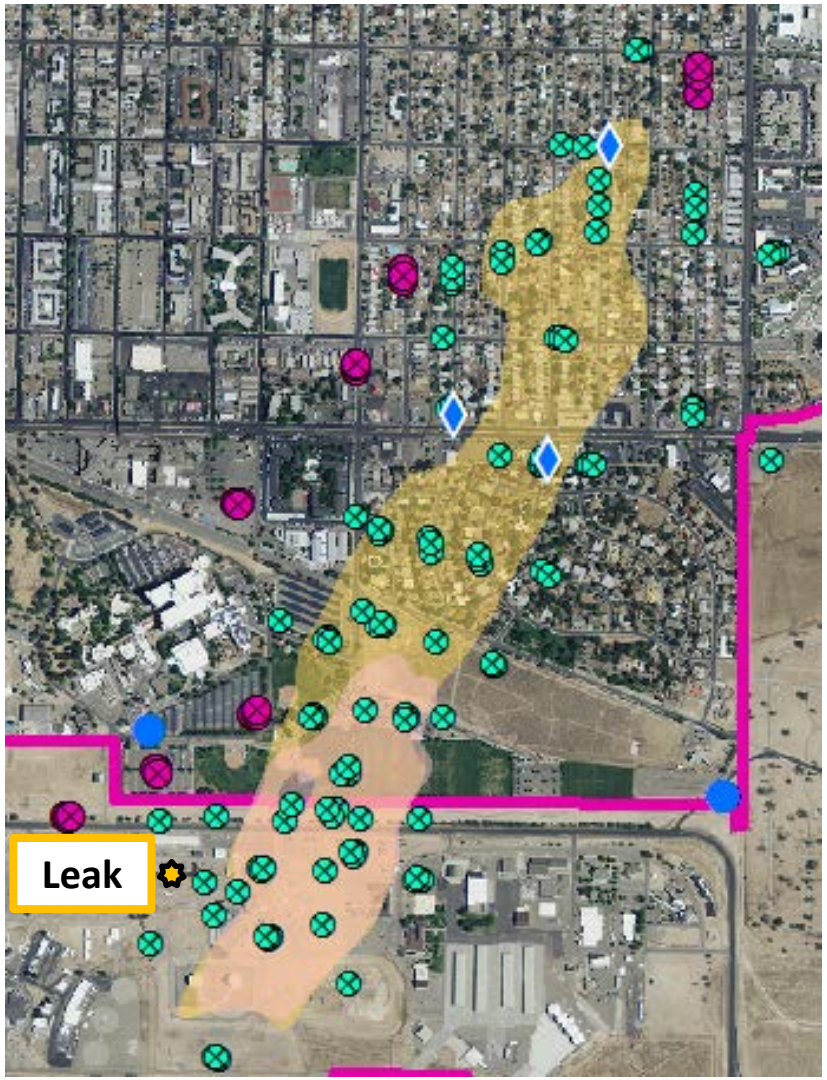


Conceptual Site Model
A dynamic understanding

- As we continue to collect data, we are able to further refine the conceptual site model
  - *Vadose zone*: Results of ongoing respiration and rebound test results inform understanding of active aerobic hydrocarbon degradation, limited microbial activity, and hydrocarbon “hot spots”.
  - *Groundwater*: Sample results from the four newest groundwater monitoring wells indicate a final data gap remains in the northwestern edge of the EDB plume.

Plume Anatomy

- No biodegradation



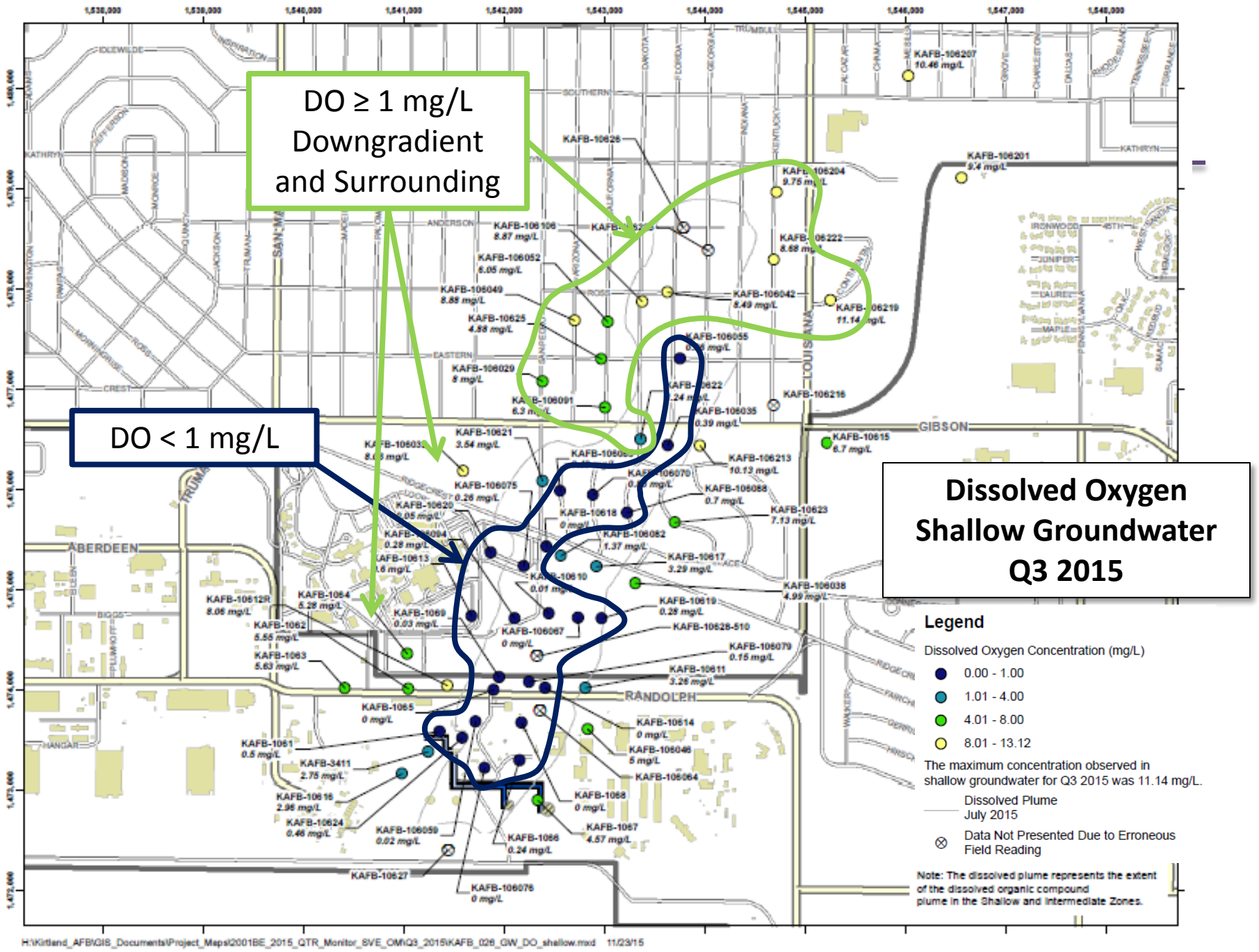
Plume Geochemistry

Redox Conditions

- Lines of evidence for redox conditions:
  - Dissolved oxygen < 1 mg/L → anaerobic
  - Dissolved oxygen ≥ 1 mg/L → aerobic
  - Anaerobic redox conditions require further definition through evaluation of nitrate, manganese, iron, sulfate, and carbon dioxide.

Redox Take-Away:

Understanding redox conditions is crucial for understanding the occurrence and degradation of plume constituents.


DO ≥ 1 mg/L
Downgradient
and Surrounding
DO < 1 mg/L
Dissolved Oxygen
Shallow Groundwater
Q3 2015
Legend
Dissolved Oxygen Concentration (mg/L)
0.00 - 1.00
1.01 - 4.00
4.01 - 8.00
8.01 - 13.12
The maximum concentration observed in shallow groundwater for Q3 2015 was 11.14 mg/L.
Dissolved Plume
July 2015
Data Not Presented Due to Erroneous Field Reading
Note: The dissolved plume represents the extent of the dissolved organic compound plume in the Shallow and Intermediate Zones.
ABERDEEN
RANDOLPH
GIBSON
H:\Kirtland_AFB\GIS_Documents\Project_Maps\2001BE_2015_QTR_Monitor_SVE_OM\Q3_2015\KAFB_026_GW_DO_shallow.mxd 11/23/15

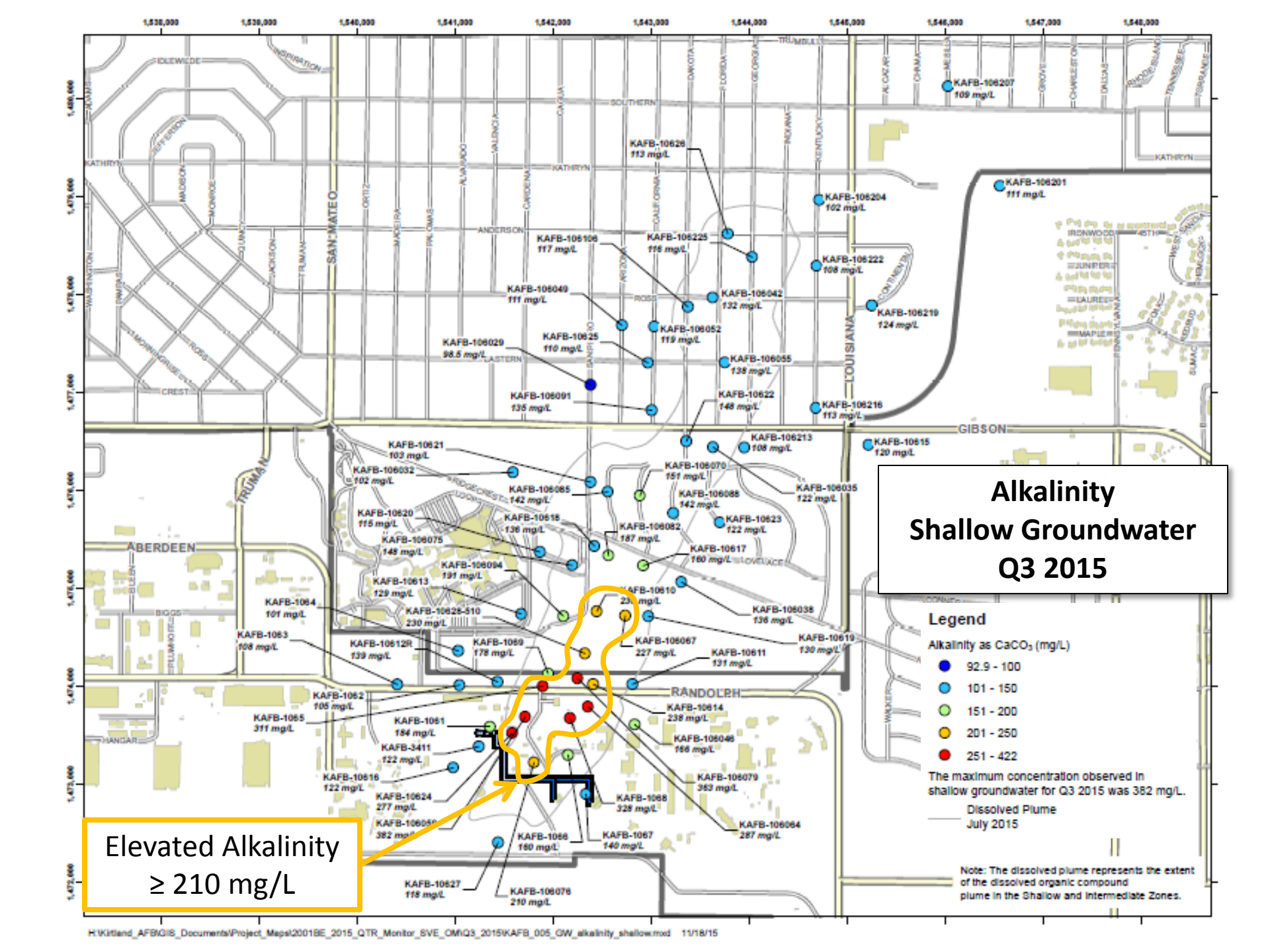
Plume Geochemistry

Degradation

- Hydrocarbons can undergo biological degradation
- Lines of evidence for biodegradation
  - Elevated alkalinity (> 210 mg/L)
  - Elevated bromide
  - Redox conditions
  - Decreased O_2 and hydrocarbon concentration

Degradation Take-Away

Multiple biodegradation processes can occur and each process results in different degradation rates for individual hydrocarbon compounds.


Alkalinity
Shallow Groundwater
Q3 2015
Legend
Alkalinity as $CaCO_3$ (mg/L)
92.9 - 100
101 - 150
151 - 200
201 - 250
251 - 422
The maximum concentration observed in shallow groundwater for Q3 2015 was 382 mg/L.
Dissolved Plume
July 2015
Note: The dissolved plume represents the extent of the dissolved organic compound plume in the Shallow and Intermediate Zones.
Elevated Alkalinity
≥ 210 mg/L
KAFB-106207 109 mg/L
KAFB-10626 113 mg/L
KAFB-106201 111 mg/L
KAFB-106204 102 mg/L
KAFB-106106 117 mg/L
KAFB-106225 116 mg/L
KAFB-106222 108 mg/L
KAFB-106049 111 mg/L
KAFB-106042 132 mg/L
KAFB-106219 124 mg/L
KAFB-106052 119 mg/L
KAFB-10625 110 mg/L
KAFB-106029 98.5 mg/L
KAFB-106055 138 mg/L
KAFB-106091 135 mg/L
KAFB-10622 148 mg/L
KAFB-106216 113 mg/L
KAFB-10621 103 mg/L
KAFB-106213 108 mg/L
KAFB-10615 120 mg/L
KAFB-106032 102 mg/L
KAFB-106070 151 mg/L
KAFB-106085 142 mg/L
KAFB-106088 142 mg/L
KAFB-106035 122 mg/L
KAFB-10620 115 mg/L
KAFB-10618 136 mg/L
KAFB-106082 187 mg/L
KAFB-10623 122 mg/L
KAFB-106075 148 mg/L
KAFB-10617 160 mg/L
KAFB-106094 191 mg/L
KAFB-10613 129 mg/L
KAFB-10610 230 mg/L
KAFB-1064 101 mg/L
KAFB-10628-510 230 mg/L
KAFB-106038 136 mg/L
KAFB-1063 108 mg/L
KAFB-10612R 139 mg/L
KAFB-1069 178 mg/L
KAFB-106067 227 mg/L
KAFB-10619 130 mg/L
KAFB-10611 131 mg/L
KAFB-1062 105 mg/L
KAFB-1065 311 mg/L
KAFB-10614 238 mg/L
KAFB-1061 184 mg/L
KAFB-106046 156 mg/L
KAFB-3411 122 mg/L
KAFB-10616 122 mg/L
KAFB-106079 363 mg/L
KAFB-10624 277 mg/L
KAFB-1068 328 mg/L
KAFB-106059 382 mg/L
KAFB-106064 287 mg/L
KAFB-1066 160 mg/L
KAFB-1067 140 mg/L
KAFB-10627 118 mg/L
KAFB-106076 210 mg/L
SAN MATEO
TRUMAN
LOUISIANA
GIBSON
ABERDEEN
RANDOLPH
SOUTHERN
ANDERSON
KATHRYN
RIDGECREST
LOVELACE
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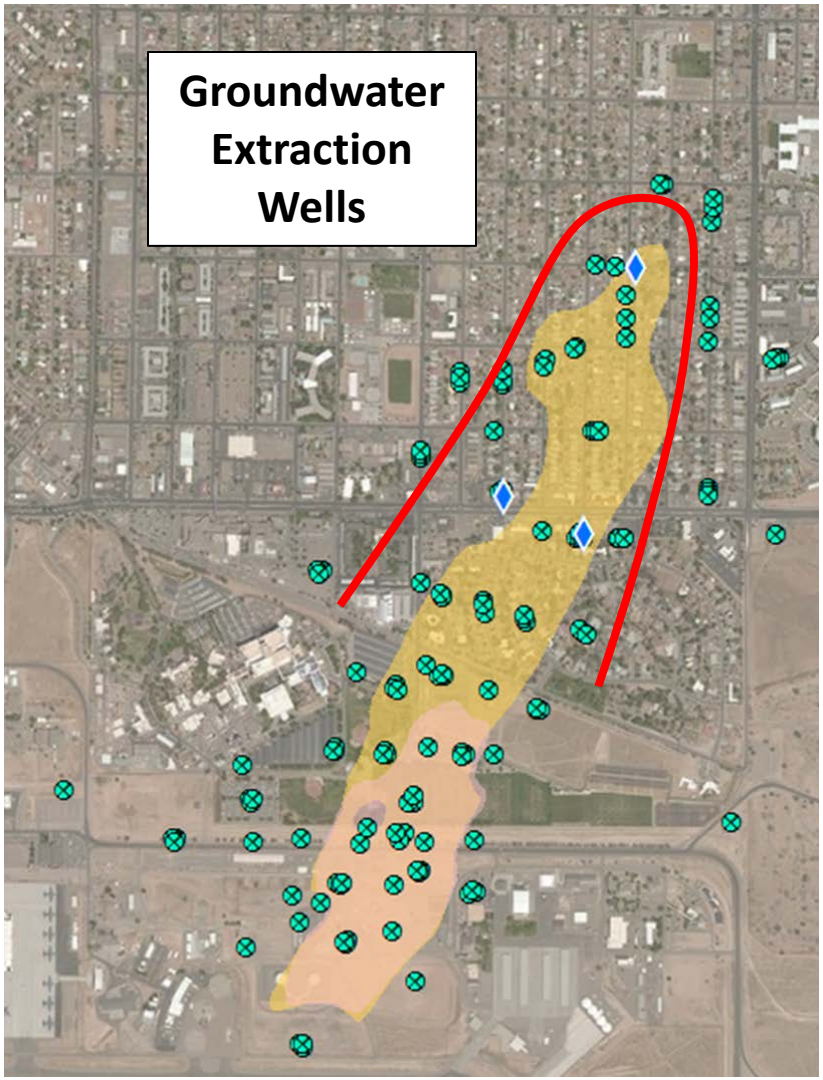
Interim Measure Strategies at BFF

Source Removal

near the dissolved plumes



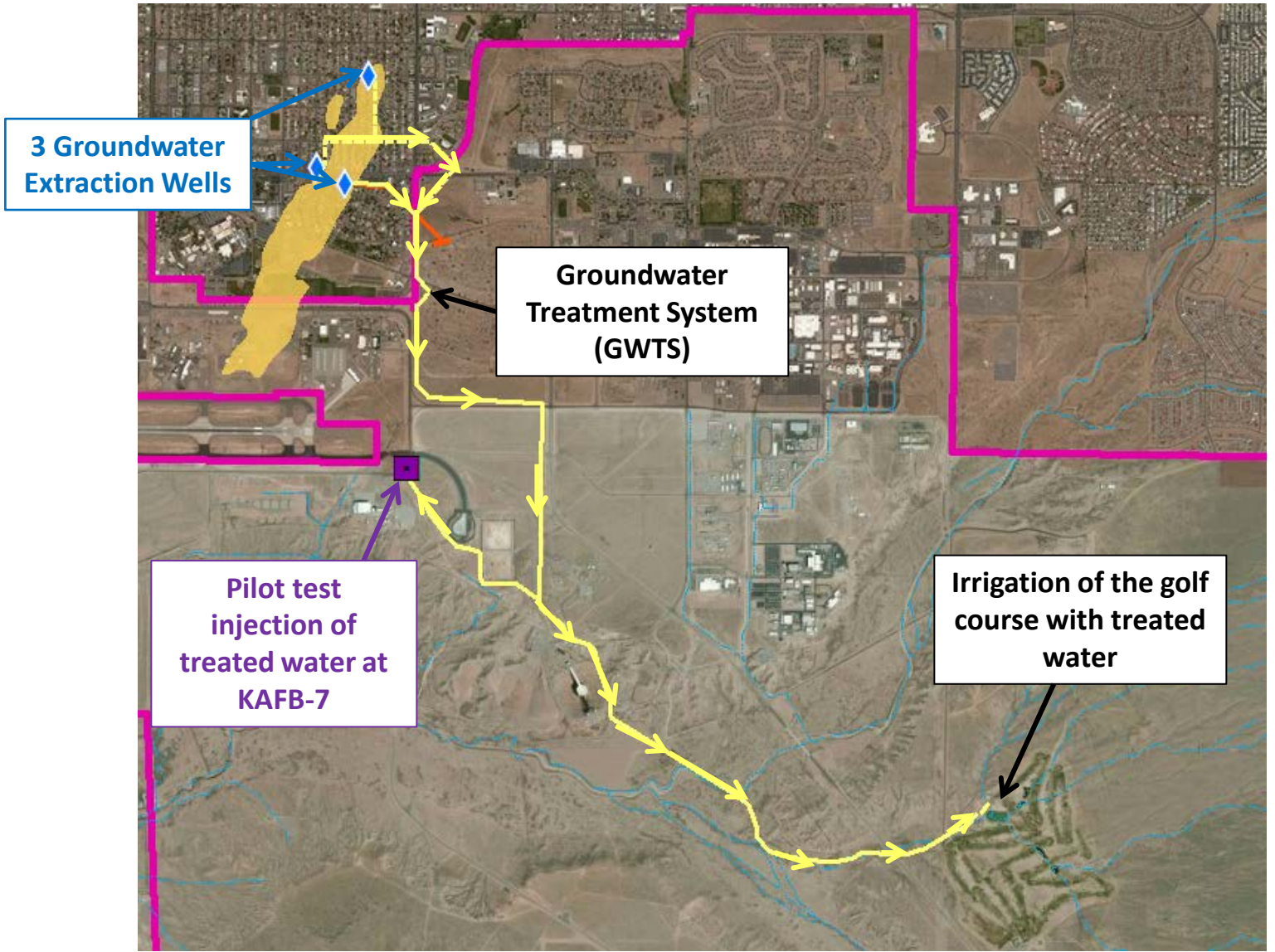
Groundwater Remediation

- Technical working groups met to resolve two issues:
  - Source control (primary and secondary)
  - Protection of human health and the environment through cleanup to regulatory standards
- Technologies evaluated include:
  - Pump and treat
  - Air sparging
  - Permeable reactive barriers
  - Monitored natural attenuation
  - Enhanced bioremediation - recirculation

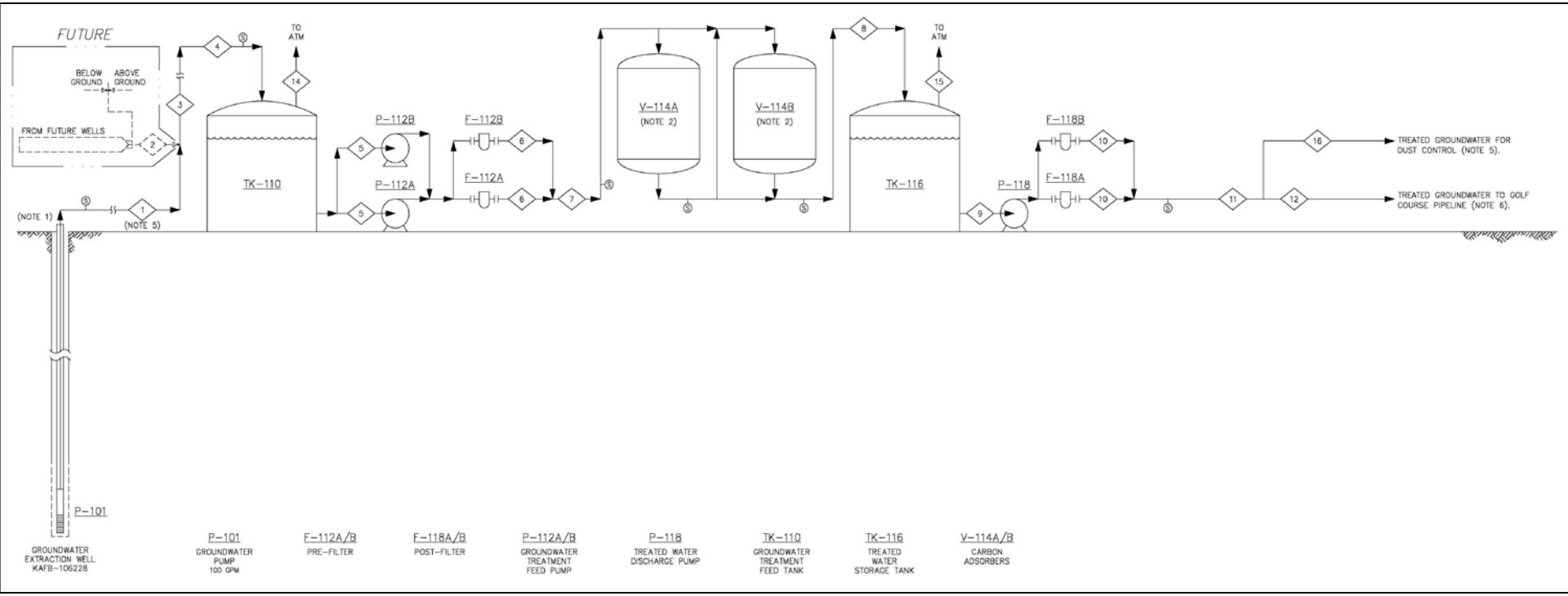
Remediation is **NOT** one-size fits all. Key factors include:

- Site geology and hydrology
- Depth of contamination
- Infrastructure requirements
- Cost

EDB Plume Collapse

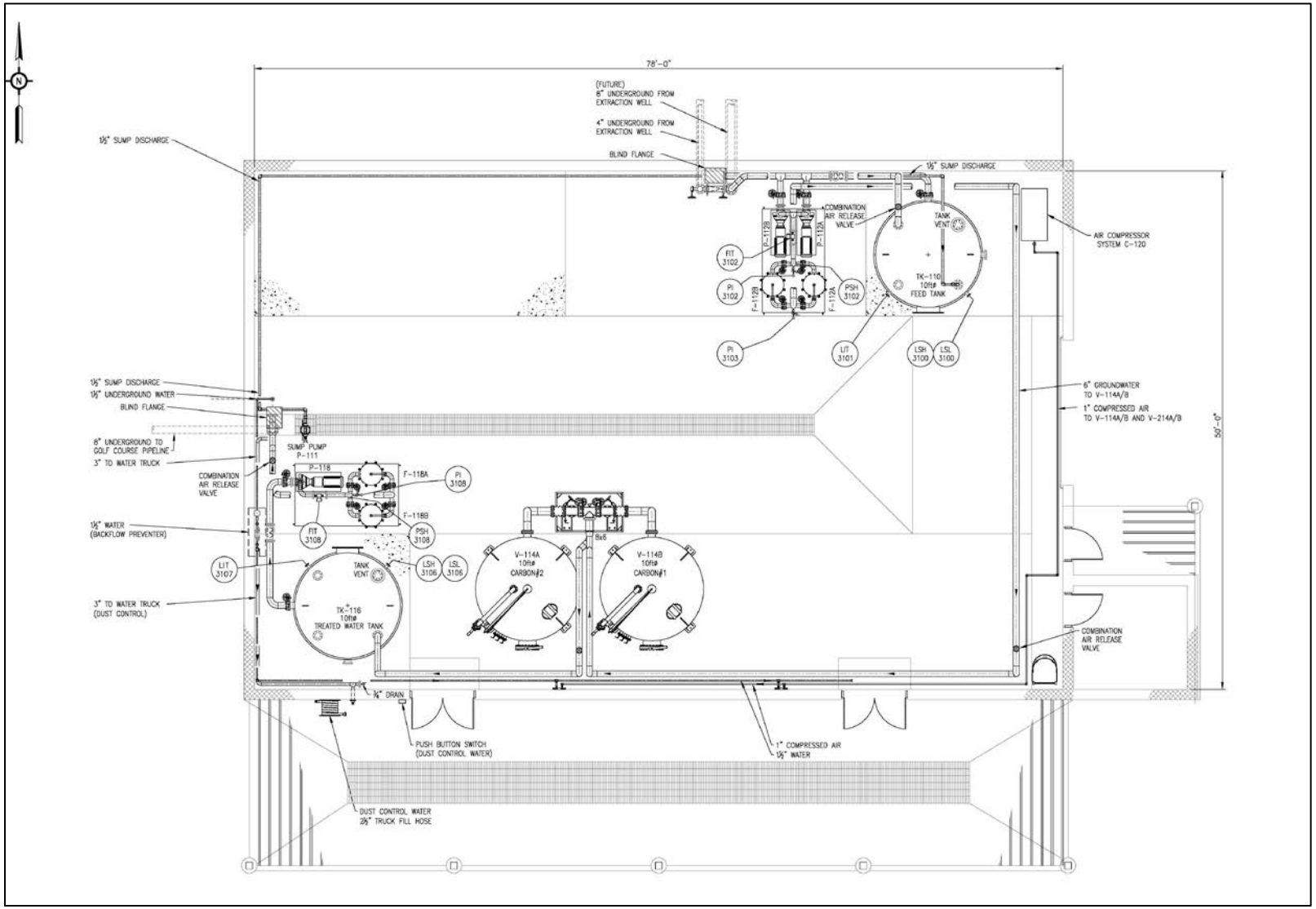


GWTS Process Flow Diagram



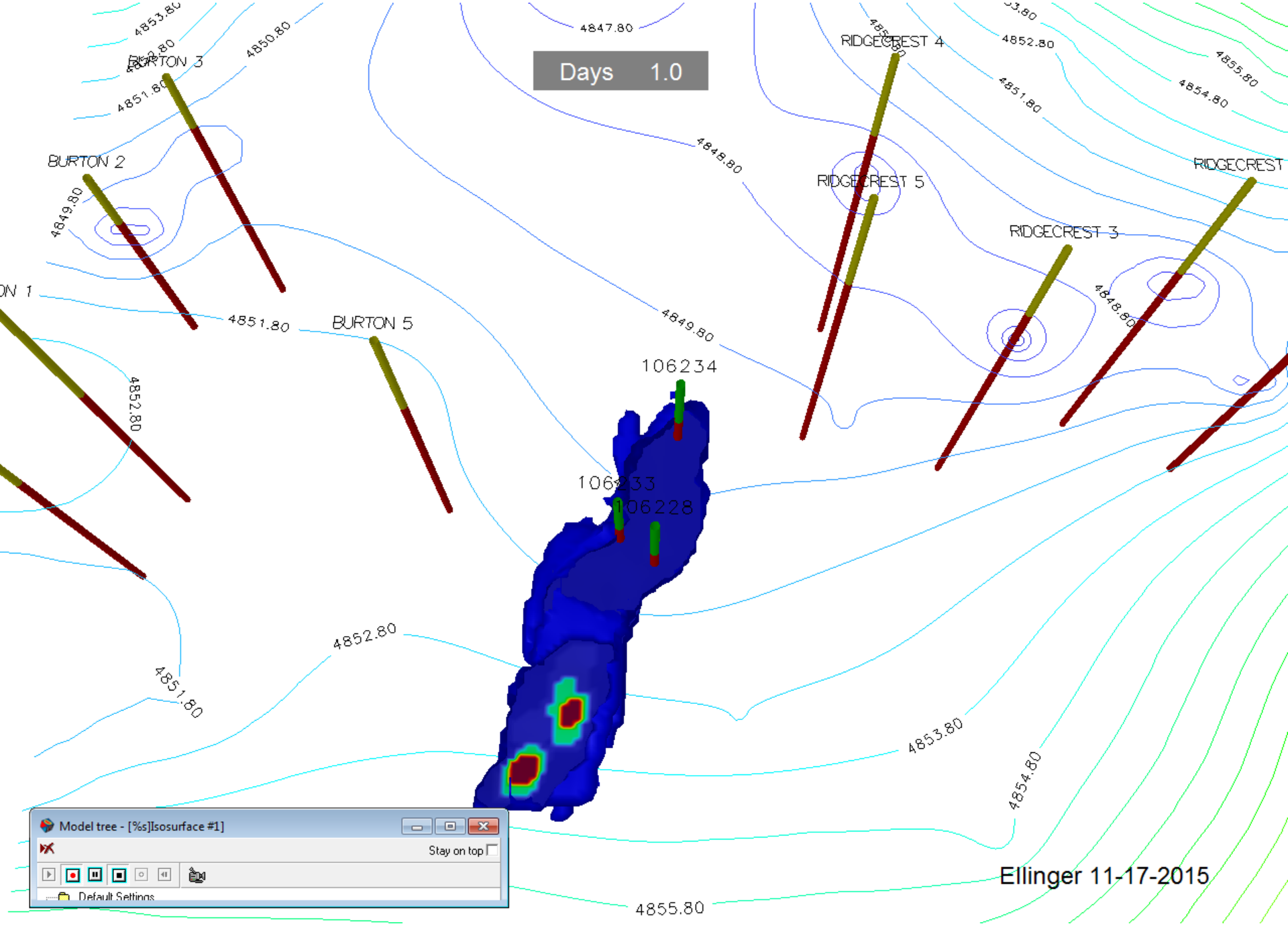
STREAM NO. / COMPONENT		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		
		KAFB-106228 TO GWTS	FUTURE WELLS TO GWTS	WELL FIELD TO GWTS	INFLUENT TO FEED TANK	GWTS FEED PUMPS	PRE-FILTER	CARBON ABSORPTION INLET	TREATED WATER	DISCHARGE PUMP	POST-FILTER	TREATED GROUNDWATER	TREATED GROUNDWATER		GROUNDWATER TREATMENT FEED TANK VENT	TREATED WATER STORAGE TANK VENT	TREATED WATER TO DUST CONTROL CONNECTION		
LIQUID FLOW (DESIGN)	gpm		300	400	400	200	400	400	400	400	400	400	400				100 (NOTE 4)		
LIQUID FLOW (average)	gpm	100																	
AIR FLOW	acfm (scfm)																		
ETHYLENE DIBROMIDE (EDB) (NOTE 3,4)	ug/L	2	2	2	2	2	2	2	LT 0.05	LT 0.05	LT 0.05	LT 0.05	LT 0.05						
PRESSURE	psig (ATM)	25	25	25	25	5	25	25	25	5	25	25	25		(12.05)	(12.05)			
TEMPERATURE	°F	58	58	58	58	58	58	58	58	58	58	58	58		68	68			
DENSITY (AT 70°F)	lb/ft^3	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4	62.4		0.061	0.061			

GWTS Equipment Layout

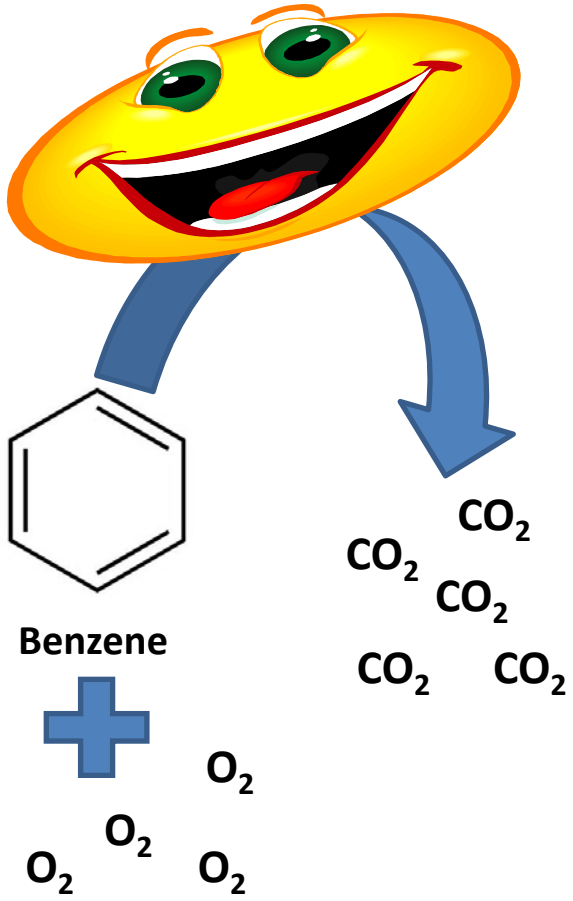


GWTS Operation

- The full-scale GWTS came online, with three extraction wells, in December 2015
- Current extraction rates average at 400 gallons per minute
- Treated water is discharged at the KAFB Golf Course main pond or KAFB-7


Days 1.0
BURTON 3
BURTON 2
BURTON 5
RIDGECREST 4
RIDGECREST 5
RIDGECREST 3
RIDGECREST
106234
106233
106228
4847.80
4848.80
4849.80
4850.80
4851.80
4852.80
4853.80
4854.80
4855.80
Model tree - [%s]Isosurface #1
Stay on top
Default Settings
Ellinger 11-17-2015

Bioremediation



Testing for Biodegradation

In Situ Respiration Testing

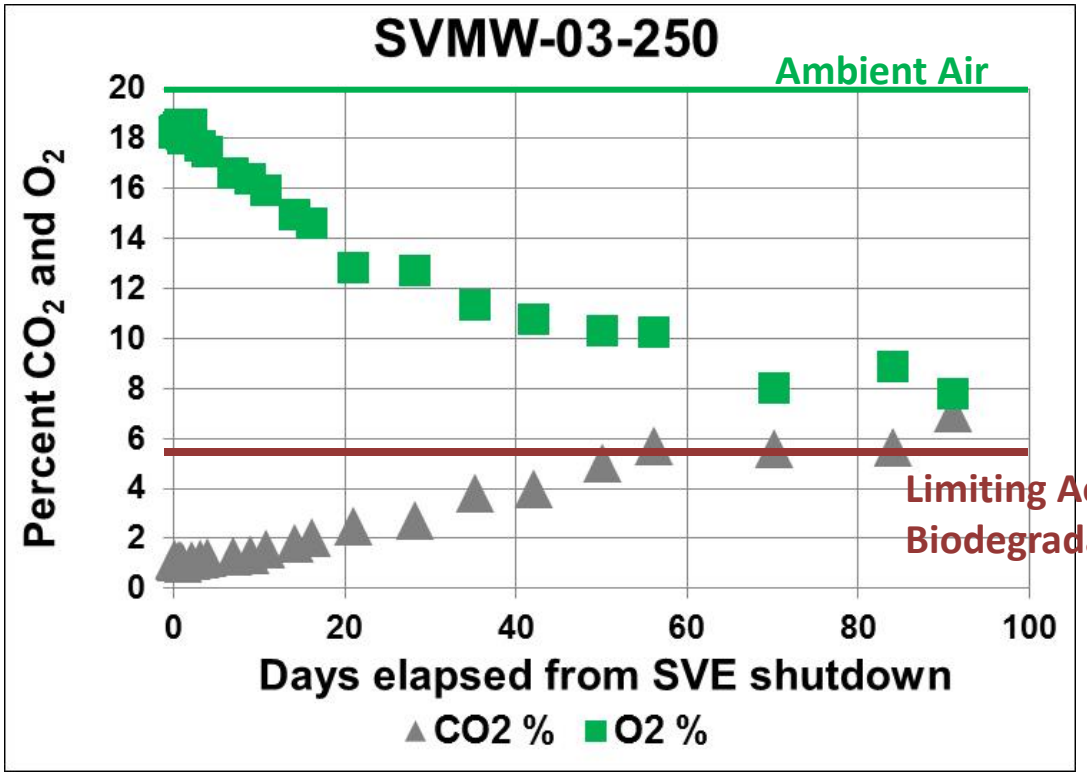
- Measure concentrations of oxygen, carbon dioxide, and hydrocarbons over time

Laboratory Microcosm Studies

- Experiments run in a laboratory using groundwater and soil from the site
- Identify potential technologies for degradation of hydrocarbons, including EDB

In Situ Respiration Testing
Preliminary Observations

- Changes in O2 and CO2 indicates aerobic hydrocarbon degradation
- Some locations indicate microbial activity limited due to relative humidity

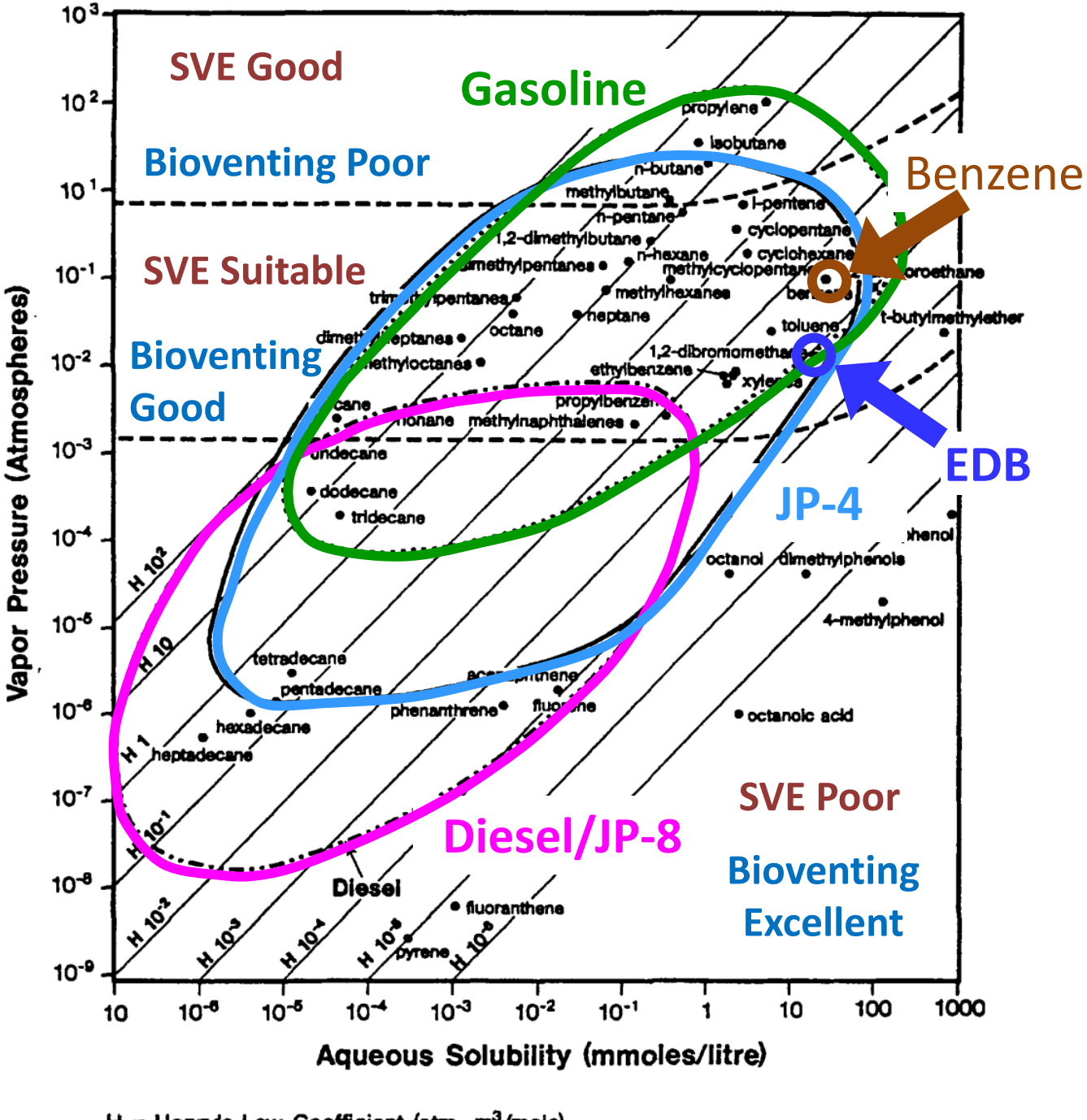


Vadose Zone Remediation

- A technical working group specific to the vadose zone was tasked with addressing:
  - Source removal
  - Protection of human health and the environment
- Currently evaluating multiple technologies:
  - Soil Vapor Extraction
  - Bioventing
  - Natural attenuation

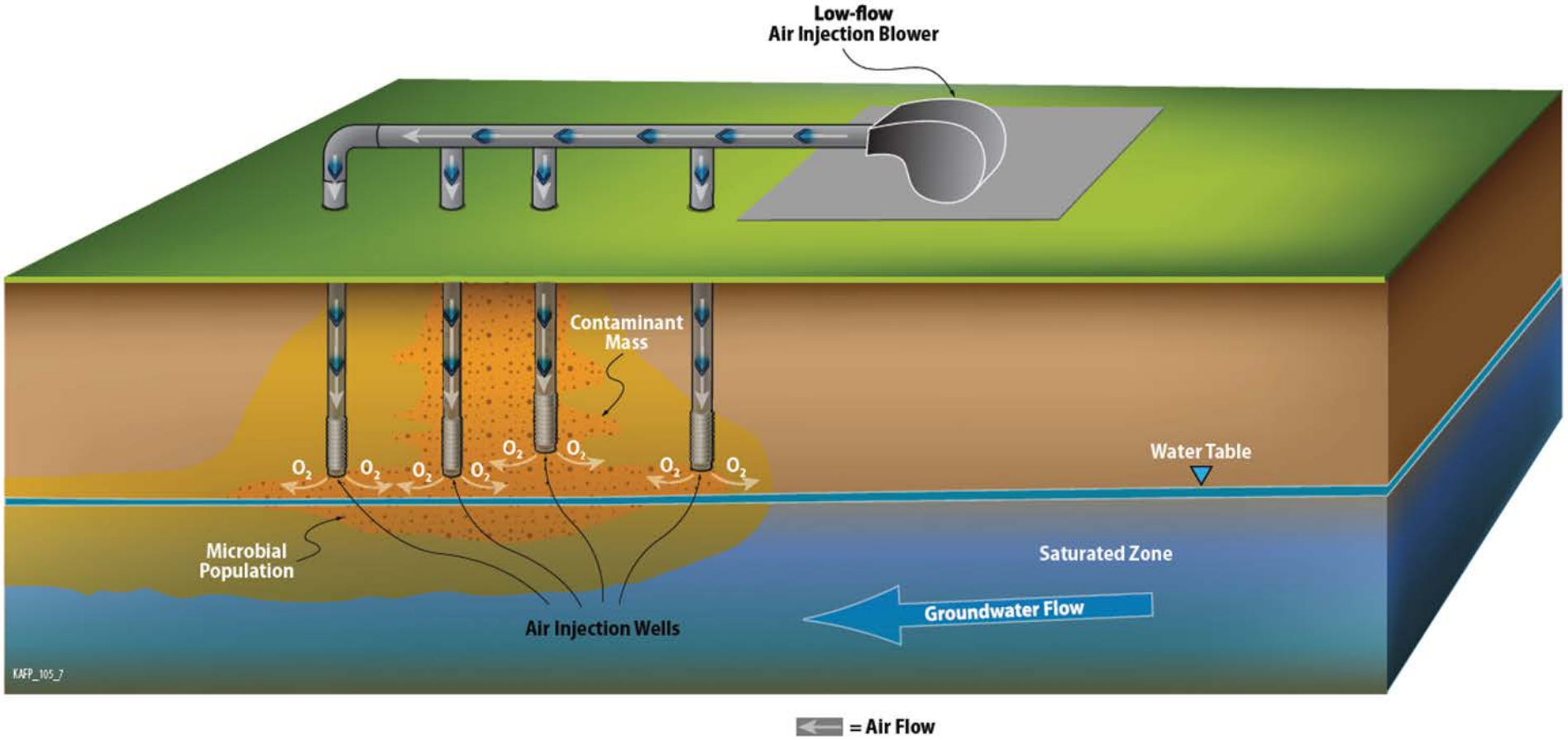
Remediation is **NOT** one-size fits all and evolves as the contaminant is cleanup overtime. Key factors include:

- Natural Conditions (aerobic vs anaerobic)
- Effectiveness and Efficiency
- Sustainability and Cost

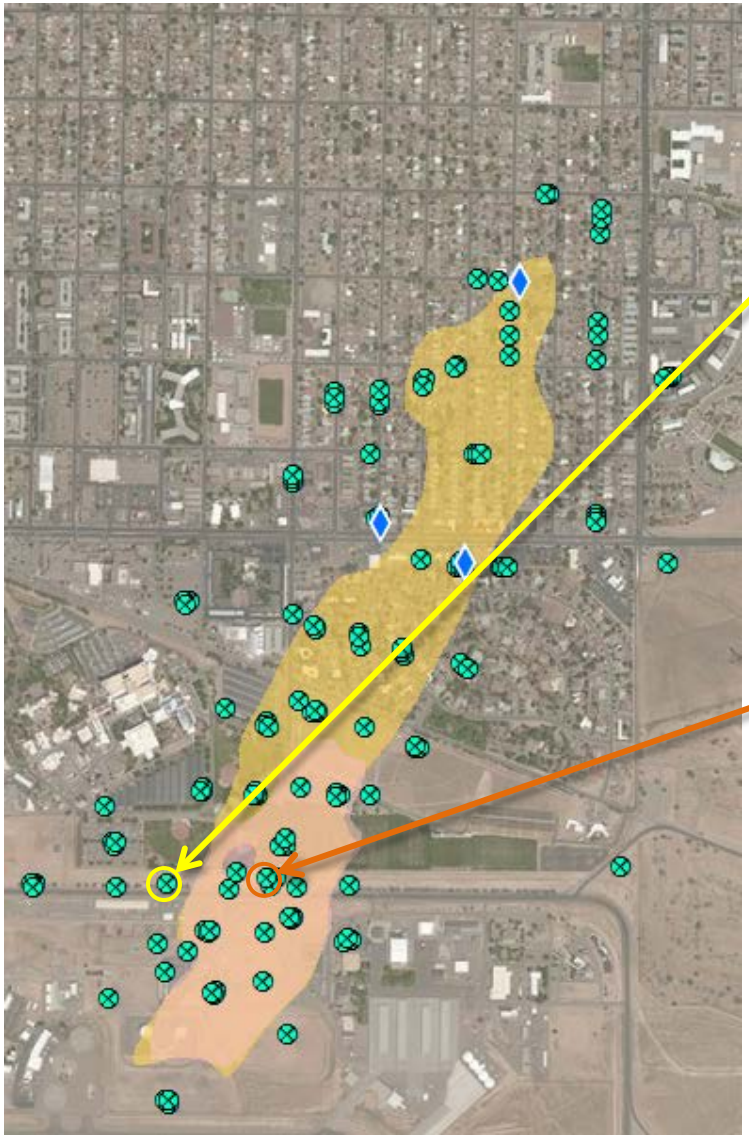

SVE Good
Gasoline
Bioventing Poor
Benzene
SVE Suitable
Bioventing Good
EDB
JP-4
SVE Poor
Diesel/JP-8
Bioventing Excellent
Diesel
Vapor Pressure (Atmospheres)
Aqueous Solubility (mmoles/litre)
H = Henry's Law Coefficient (atm • m³/mole)
propylene
isobutane
n-butane
methylbutane
n-pentane
1,2-dimethylbutane
n-hexane
methylcyclopentane
methylhexanes
heptane
octane
toluene
ethylbenzene
propylbenzene
methylnaphthalenes
undecane
dodecane
tridecane
tetradecane
pentadecane
hexadecane
heptadecane
phenanthrene
fluoranthene
pyrene
octanol
dimethylphenols
4-methylphenol
octanoic acid
cyclopentane
cyclohexane
1-pentene
t-butylmethylether
H 10²
H 10
H 1
H 10⁻¹
H 10⁻²
H 10⁻³
H 10⁻⁴
H 10⁻⁵
H 10⁻⁶

Bioventing

In-situ remediation technology that enhances the activity of indigenous bacteria to degrade contaminants of concern in the vadose zone by injection air or adding amendments



Laboratory Microcosm Testing



Two Areas of Plume Studied

collected groundwater from the same well

Microcosm Summary

Side Gradient

Aerobic

- Complete BTEX and nearly complete EDB degradation

Anaerobic

- Complete EDB degradation when *Dehalococcoides* added
- Minimal EDB degradation with added lactate, sulfate, Fe, and/or nutrients

Source Area

Aerobic

- Completed BTEX and partial EDB degradation

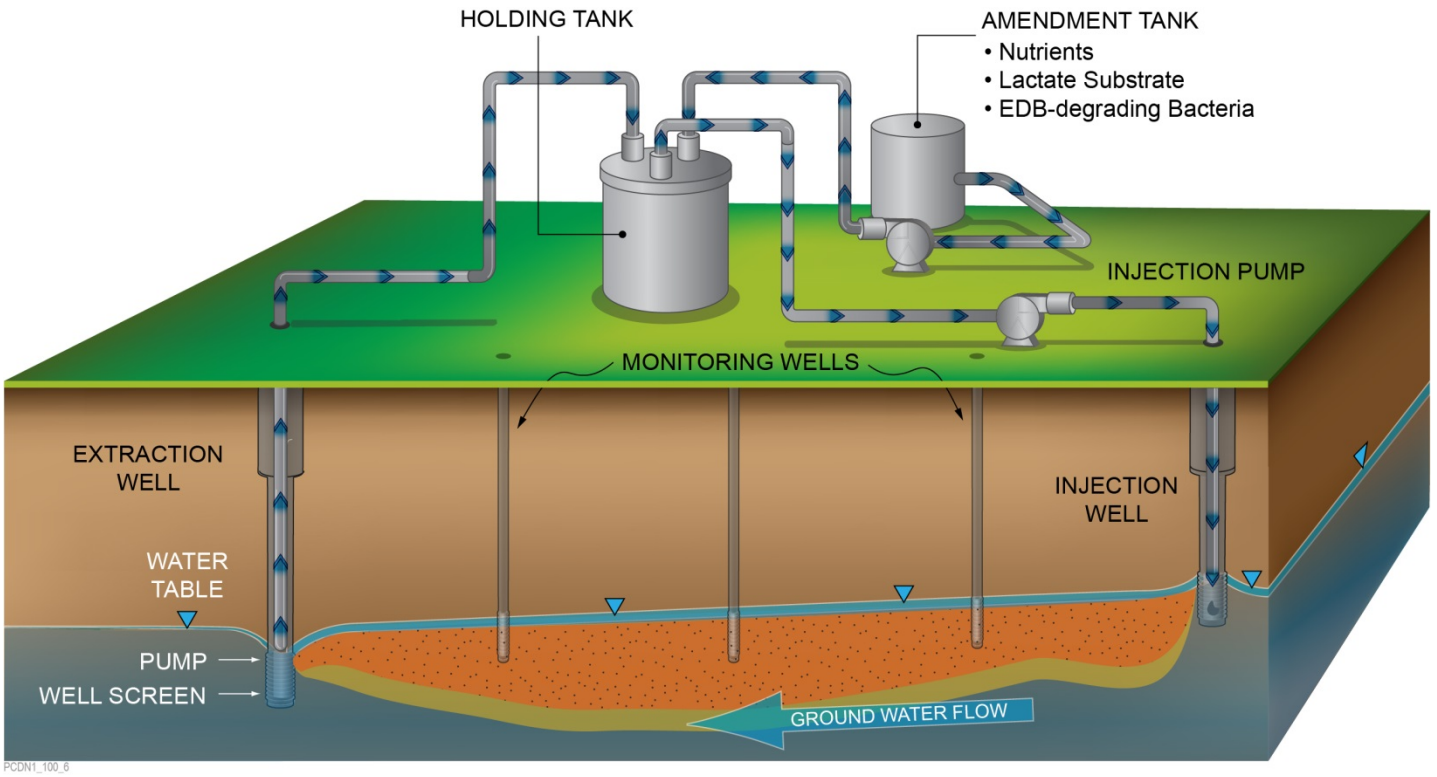
Anaerobic

- Completed EDB degradation when *Dehalococcoides* added
- Minimal EDB degradation with added lactate, sulfate, Fe, and/or nutrients

Anaerobic Biodegradation

Groundwater Recirculation

- Pump groundwater and add amendments in phases
- Inject amended water up-gradient to create a recirculation cell
- Supports anaerobic degradation of EDB



What's in Store for 2016?

- Drilling and installation of four data gap groundwater monitoring wells (Summer)
- Drilling, installation, and testing of a 4th extraction well south of Gibson (Summer/Fall)
- Construction and operation of anaerobic biodegradation interim measure (Summer)
- Aquifer testing of the 2nd and 3rd extraction wells (Fall/Winter)
- Design and construction of bioventing interim measure (Winter)
- Continuous coring in the source area (Winter)

About Kate

Laboratory and the Pentagon

About Diane

- Grew up in northeastern Colorado
- Received Bachelor's of Science in Geology from New Mexico Tech in 2003
- Received Master's in Hydrology from New Mexico Tech in 2006
- Worked in Dr. Bruce Harris' soils lab throughout undergrad and most of grad school
- Internship at Sandia National Labs in geomechanics lab
- Started her career in environmental consulting in 2005
- Started working for the New Mexico Environment Department in August 2015

Discussion