Using Environmental Visualization System (EVS) Modeling to Develop Remediation Alternatives

The Time Oil Well 12A Superfund Site Case Study

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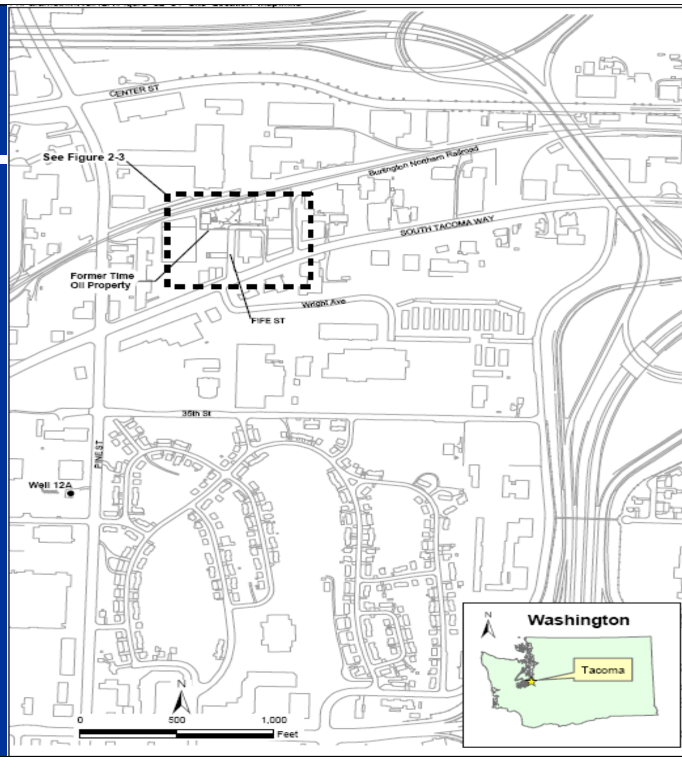
Presentation Topics

- General Description of Time Oil Well 12A Superfund Site, Tacoma, WA
- Geostatistical 3-D data analysis/visualization to determine present site conditions (CSM)
- Application of CSM to evaluate in place remedy


CENTER ST
See Figure 2-3
Burlington Northern Railroad
SOUTH TACOMA WAY
Former Time
Oil Property
Wright Ave
FIFE ST
35th St
PINE ST
Well 12A
N
0
500
1,000
Feet
N
Washington
Tacoma

Site Background – Well 12A Superfund Site

- Chlorinated organic solvents were detected in Well 12A above drinking water criteria in 1981
- Time Oil site identified as major source to groundwater contamination
- Soil contamination from filter cake disposal/ site practices also present
- Site located within the South Tacoma Ground Water Protection District

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1983 ROD Remedial Action Objectives (RAOs)

- Tiered cleanup goal alternatives in the ROD in order of increasing length of treatment time and cost:
  - » Treat ground water at the source (the Time Oil property) ***meet requirements for storm sewer discharge***
  - » Treat the ground water at the source such that untreated Well 12A ground water could be used (***after dilution*** with water from the rest of the well field) ***as drinking water***
  - » Treat the ground water at the source such that Well 12A ground water concentrations would satisfy the 1x10-6 risk level ***with no dilution***
  - » Treat the ground water such that ***all ground water*** within the property boundary ***satisfies the 1x10-6 risk level***
- Final goal to be based on treatment performance data after two years of implementation

Well 12A Site Status Summary

- ROD amendments 1985, 1987
- Remedy implemented 1988 - today
  - » Groundwater Extraction Treatment System (GETS): 550 million gallons of groundwater extracted/treated, removed 16,000 pounds VOCs - ongoing
  - » Vapor Extraction System (VES): Removed 54,100 pounds VOCs
  - » Filter cake/contaminated soil removal: Excavated 6,200 CY of filter cake
- Five year reviews 1993, 1998, 2003, 2008

Triad Activities

- Conducted Systematic Planning to:
  - » Refine CSM
  - » Identify uncertainties
  - » Refine exit strategy toward site closure
  - » Develop targeted remedial goals to help achieve goals

- Will be using real-time analytical methods and dynamic work strategies, including performance based measurements during remedy implementation

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Systematic Planning: Identifying Unresolved questions

- Is the GETS containing the GW plume?
- First two tiers of objectives met – can we meet the rest?
- How long will we have to keeping treating?
- What will happen if drinking well pump rate or duration is increased?
- Will other drinking water wells become impacted?
- Is there any direct contact risk from residual soil contamination?

CSM Needs to help Resolve Uncertainty

- Data analysis to bring years of data together for a comprehensive integrated analysis of site
- Identify and delineate specific areas that still need action to help achieve RAOs and identify related uncertainties
- Screen and evaluate technologies to modify treatment
- Based on technology selection, set interim goals for realistic achievement of site closure

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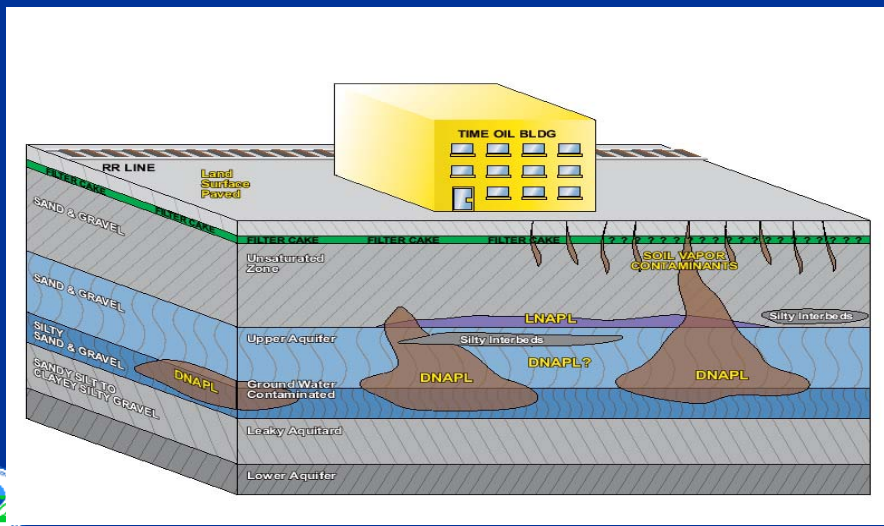
CSM Prior to Geostatistical 3-D Data Analysis /Visualization



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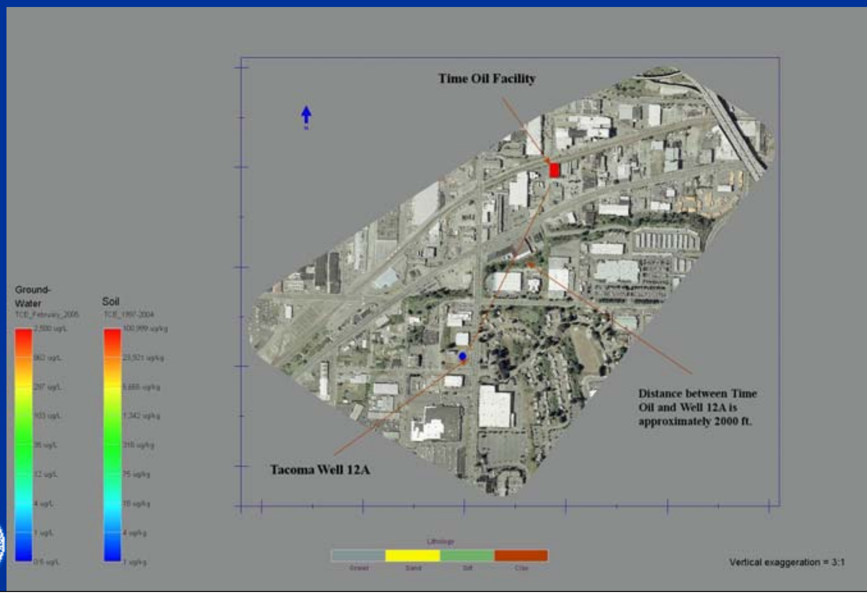
Reason for Using 3-D Geostatistical Data Analysis/Visualization at 12A

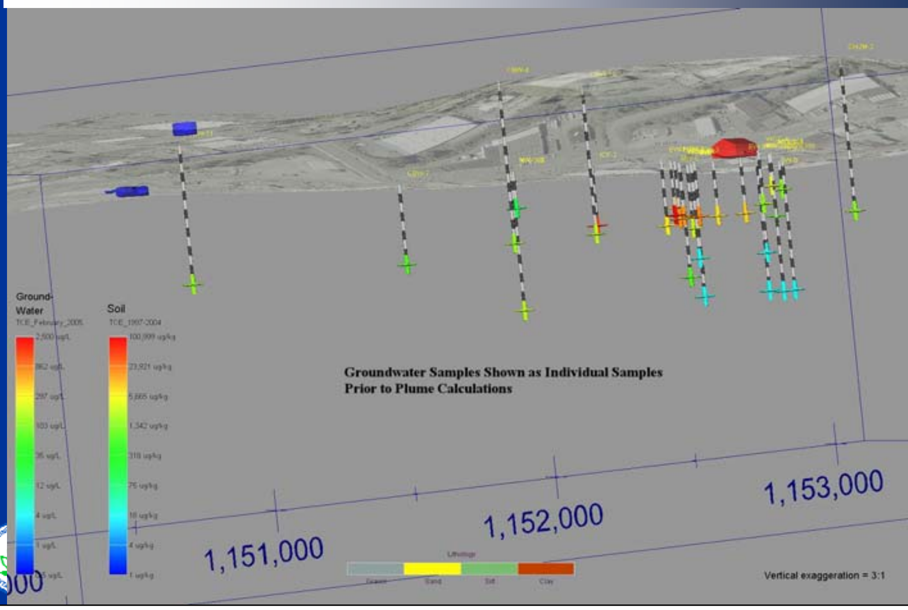
- Bring ***all data together in one format for CSM development*** to document remedy performance and make informed decisions
  - » At start, years of data in tables, differing mapping formats, differing scales from a variety of sources – ***can't see*** the issues

- 3- D Geostatistical Analysis Allows Us to Do this
  - » Branch of statistics focusing on ***spatiotemporal*** datasets.

Location Map for Source (Time Oil) and Receptor (Tacoma Well 12A)



Data Are Entered from Excel or Databases – Example: Groundwater Data from one sampling period



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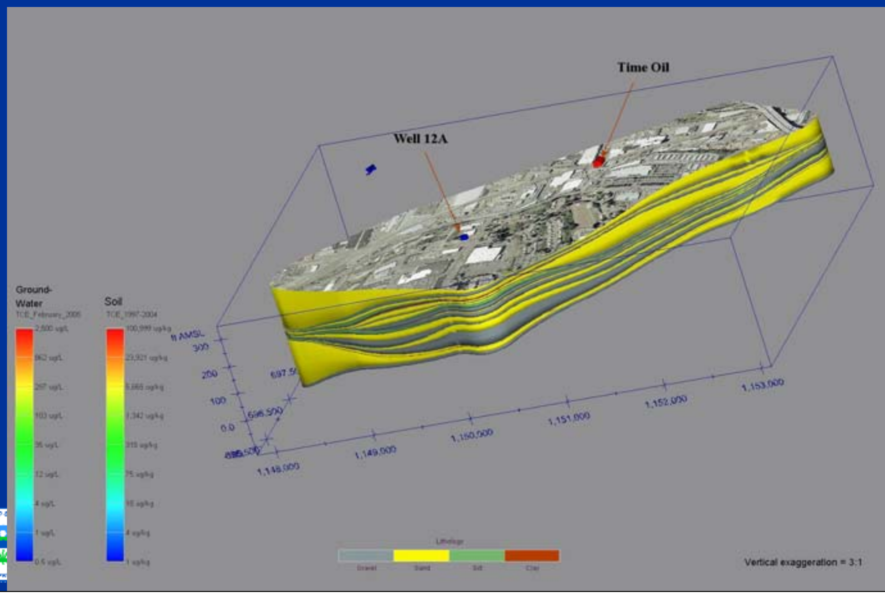
Geology: Vadose and Saturated Zone Dominated by Higher Permeability Sands and Gravels – Silts and Clays Play Role in Contaminant Migration



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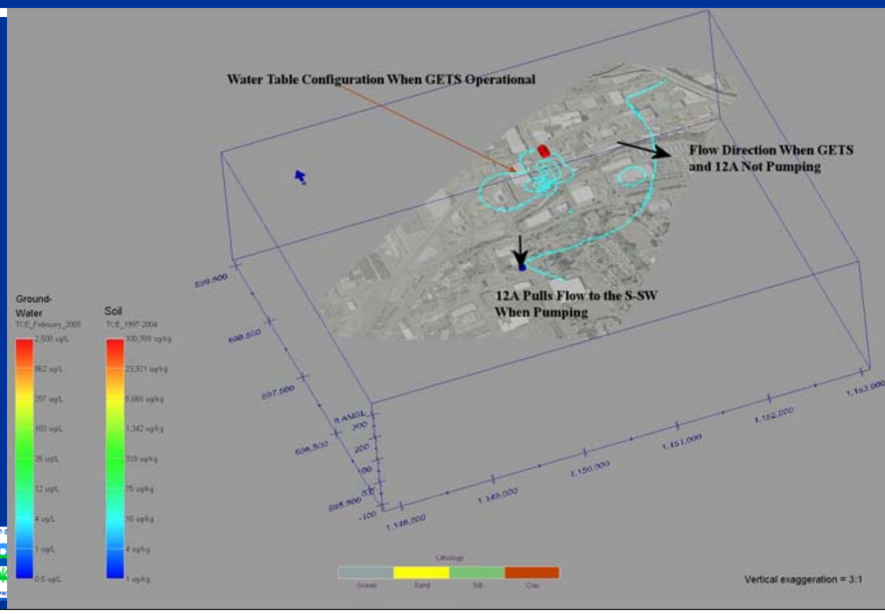
Water Level Data used to Define Flow Directions, Gradients, and Delineation of Vadose Zone



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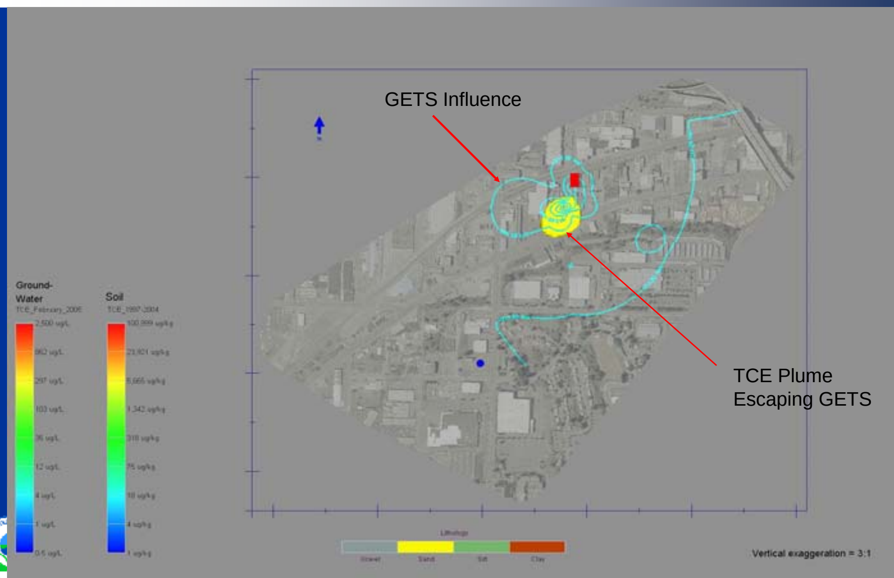
3-D integration and analysis of contaminant and water level data showed TCE GW plume escaping GETS



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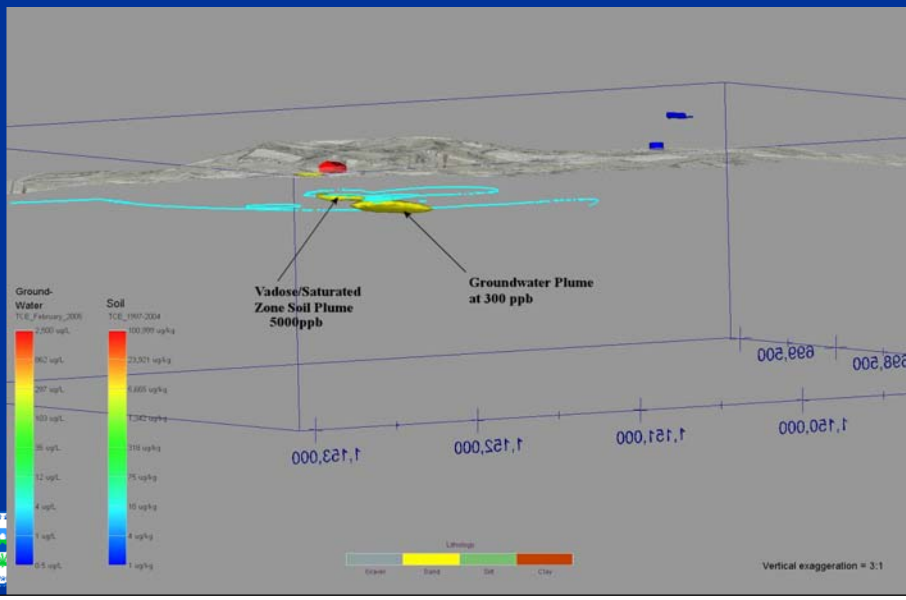
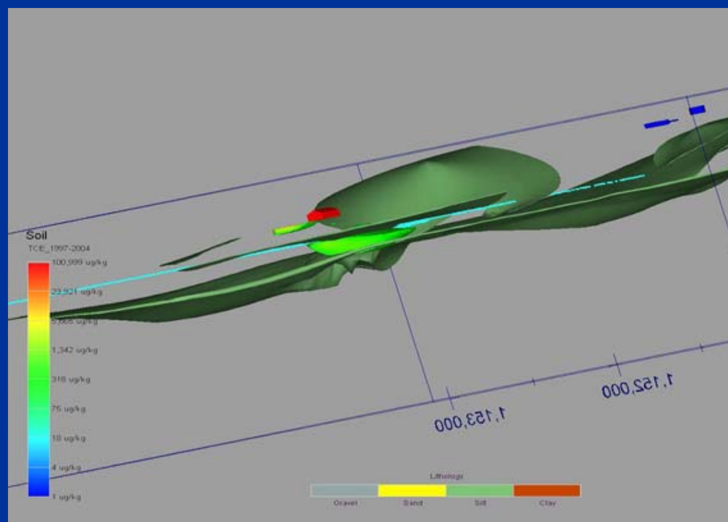
Integration of Soil, Groundwater Chemistry, and Water levels show Plume is sourced by Vadose/Saturated Zone Soil Contamination



Integration of Soil Contaminant Data and Geology Indicate Distribution of Soil Contamination at Vadose/Saturated Zone is Impacted by Silt Layers



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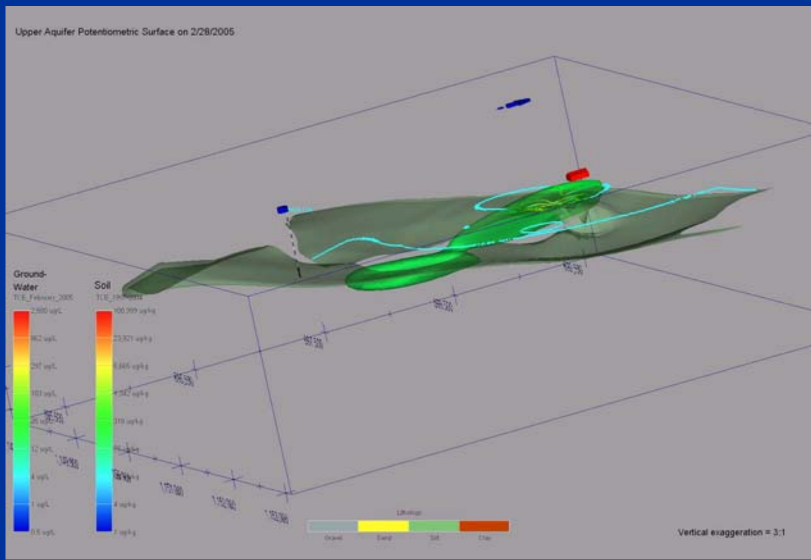
Integration of Geology and Plume Data: Low Level TCE Plume Configuration Is Impacted by Silt Units in Saturated Zone



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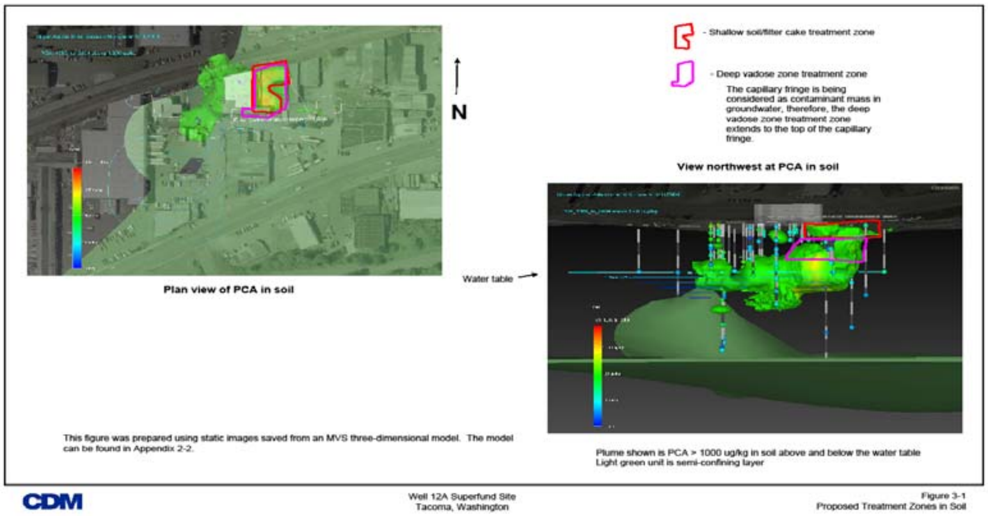
Treatment Zones: Filter Cake and Soil



Soil Mass Calculation

Concentration (µg/kg)	PCA		TCE	
	Volume (cubic-yards)	Chemical Mass in Soil (kg)	Volume (cubic-yards)	Chemical Mass in Soil (kg)
>1000	33,886	416	38,940	1,014
>3000	16,740	375	18,920	966
>5000	11,890	349	13,590	937
>10000	6,417	293	8,250	882

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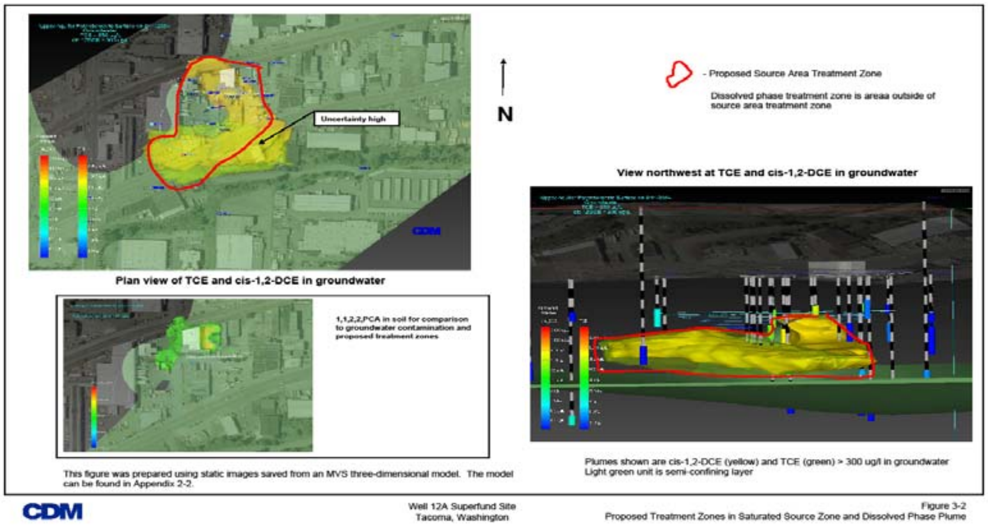
Remedial Action Objectives Groundwater



Dissolved Phase Mass Calculation

Concentration (µg/kg)	Cis 1,2 DCE Aquifer* Volume (acre-feet)	Cis 1,2 DCE Chemical Mass in Groundwater (kg)	TCE Aquifer* Volume (acre-feet)	TCE Chemical Mass in Groundwater (kg)
>200	159	38	220	70
>300	119	34	135	64
>500	72	28	89	58
>1000	24	15	51	47.7

Concentration (µg/kg)	Total Indicator VOCs Aquifer* Volume (acre-feet)	Total Indicator VOCs Chemical Mass in Groundwater (kg)	1,4 Dioxane Aquifer* Volume (acre-feet)	1,4 Dioxane Chemical Mass in Groundwater (kg)
>200	471	197	35	37
>300	346	186	13.6	1.8
>500	238	170	NA	NA
>1000	143	146	NA	NA

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Refined Remedial Action Objectives Filter Cake and Soil

- **Filter Cake/Shallow Soil**
  - » Eliminate risk of direct contact with filter cake at and near the surface. (EPA addressing vapor intrusion under a separate activity after targeted soil and groundwater contamination is addressed)
  - » Prevent or minimize the migration of contamination from highly contaminated shallow source areas into deeper vadose zone to prevent further degradation of deep soil and groundwater
- **Deep Vadose Zone Soil**
  - » Eliminate/minimize the mass of contaminants to reduce the mass flux from deep soils into groundwater

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Refined Remedial Action Objectives: Groundwater

- **Source Area Saturated Soil and Groundwater Zone**
  - » Reduce mass flux by 90% from source area soils through a specific plane into the dissolved phase treatment zone. The proposed plane defined by current location of 300 ug/l isonconcentration.
- **Dissolved Phase Plume**
  - » Reduce contaminant concentrations so concentrations at the plume perimeter meet MCLs

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CSM Refinements Built With 3-D Geostatistical Data Analysis/Visualization

- Remedy in place not controlling migration of TCE plume nor cleaning soil contamination feeding plumes
- Now know the position, dimensions, hosting units, mass, and volume of soil source term feeding the plume for evaluating remedy modification to eliminate the source
- Use depictions to pinpoint key areas of uncertainty related to remedial decisions
- Can continue to use system to create interim goals and revised RAOs to evaluate future remedies

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Advantages and Limitations of 3-D Analysis

- Advantages
  - » *Integrates all CSM data to same format*
  - » *Comprehensive picture of site for optimizing decision making*
  - » *Simple Images Backed by Large Understandable Databases with Confidence Calculations*
- Limitations
  - » *Results are only as good as data going in*
  - » *Success of approach is often operator dependent – must incorporate data quality and representativeness issues*
  - » *Geostatistical expertise required*

EPA OSWER Technology Transfer Material Under Development

- Memo: **"Strategies for Contracting Geostatistical 3-D Data Analysis/Visualization Services in EPA Superfund Investigations"**

- Video: **"Use of 3-D Geostatistical Data Analysis/Visualization in Superfund Remedial Investigations"**

Acknowledgements

- Kira Lynch, EPA Region 10 RPM, Well 12 A site
- Steve Dyment, EPA HQ Office of Superfund Remediation and Technology Innovation Technology Integration and Information Branch
- Aaron Fritz, CDM

Characterizing a Complex TCE Groundwater Plume Eliminating Source Areas, and Reducing Costs
Shaw AFB, Sumter SC

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Initial Process

- Site identified when TCE (below MCLs) found in base drinking water well
- Tier I Team weighed benefit of conventional versus Triad investigation approach

Conventional Approach

- Draft, Draft Final and Final Work Plans, each followed by a comment and response process
- Install wells near suspected sources and where contaminants were discovered
- Remobilize for additional phases of investigation if needed
- AOC-N could have required up to 80 wells to characterize the shallow and confined aquifers, a process that could have taken 3 years requiring multiple mobilizations to complete

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Systematic or strategic planning brings together all of the stake holders to develop the conceptual site model, data quality objectives, and key decision points. **This is the most important step of the Triad Approach**. By bringing together all of the stake holders for the initial planning, each has an investment in the process, the scope and goals of the project are established early, and early agreements are reached on the degree of uncertainty that can be tolerated in the decision making process.

> At AOC-N the systematic planning meetings established the CSM requirements, the sampling and analytic program, data sharing procedures, and what criteria needed to be met for an acceptable degree of site characterization

The dynamic work strategies are logic diagrams that allow sampling decisions to be driven down to the field level. This means that a Triad project needs very competent field leadership, and that these individuals need to be involved in developing the work plans. Most of the decision logic is worked out between the stake holders before the Work Plan is issued.

Real-time measurements provide the data needed for the dynamic work strategy to be successful.

> At AOC-N we used decision trees which determined if additional deeper samples need ed to be collected, an on-line Map Viewer for dissemination of analytical results and periodic summary reports and to arrive at team decisions regarding the need for additional characterization and when characterization was complete

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Triad Approach

- Triad Team stakeholders included representatives from
  - SCDHEC
  - Air Force
  - USACE
  - Shaw E&I
  - Stone Environmental
- Collaboration builds trust between stakeholders

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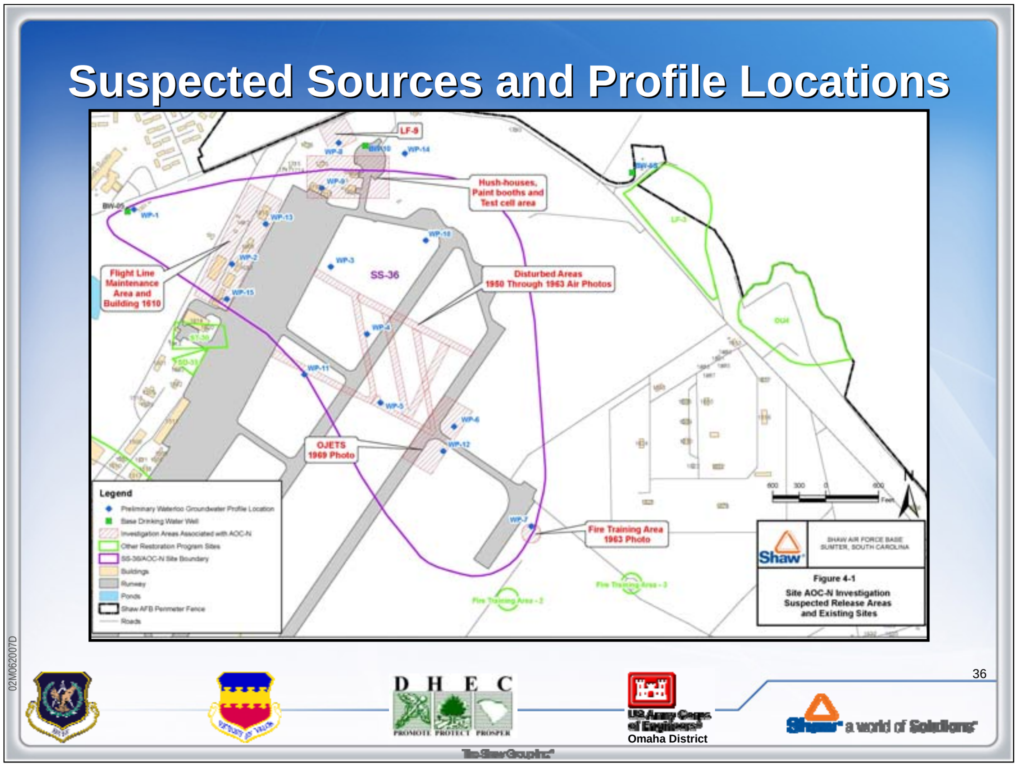
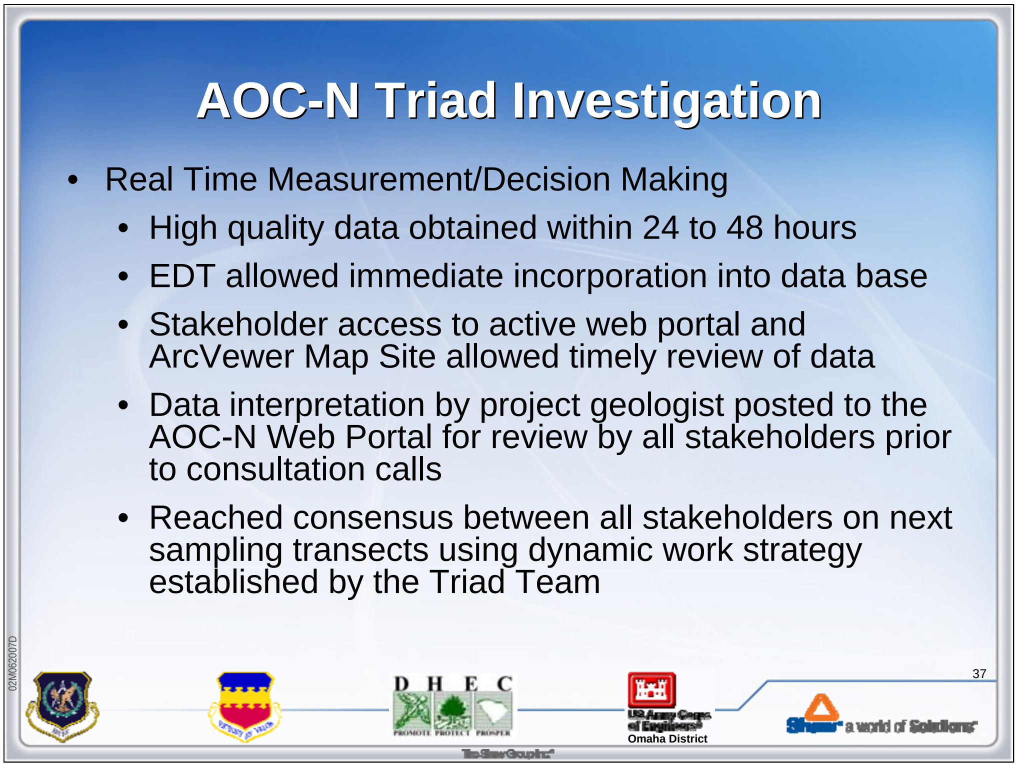
AOC-N Triad Investigation

- Systematic/Strategic Planning Meeting Feb 2006
- Dynamic Work Strategy Optimization
  - Conceptual Site Model identified six potential source areas across large and complex area
  - Identified initial sampling transects with clear decision rules for next sample locations
  - Draft to Final Approval; Triad Team approach allowed work plan to be developed and approved without multiple drafts

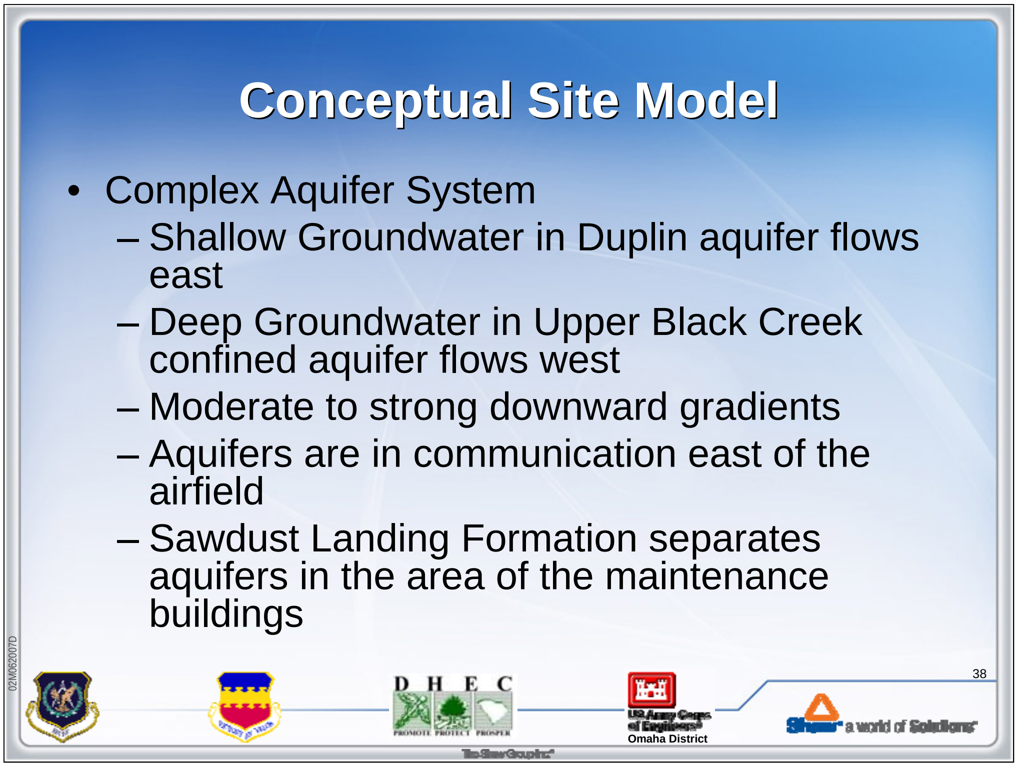


CSM potential sources and initial Modified Waterloo (Waterloo AMS) profile locations



The Mobile Laboratory used for the initial profiling phase was NELAP certified, SCDHEC agreed this was definitive data.

Because of the sample depths and difficult lithology, sample rate was low, so the Team made the decision to send DPT samples to fixed base lab for 24 hour turn



CSM components for similar sites at Shaw AFB investigated since the late 1980s incorporated into the AOC-N CSM

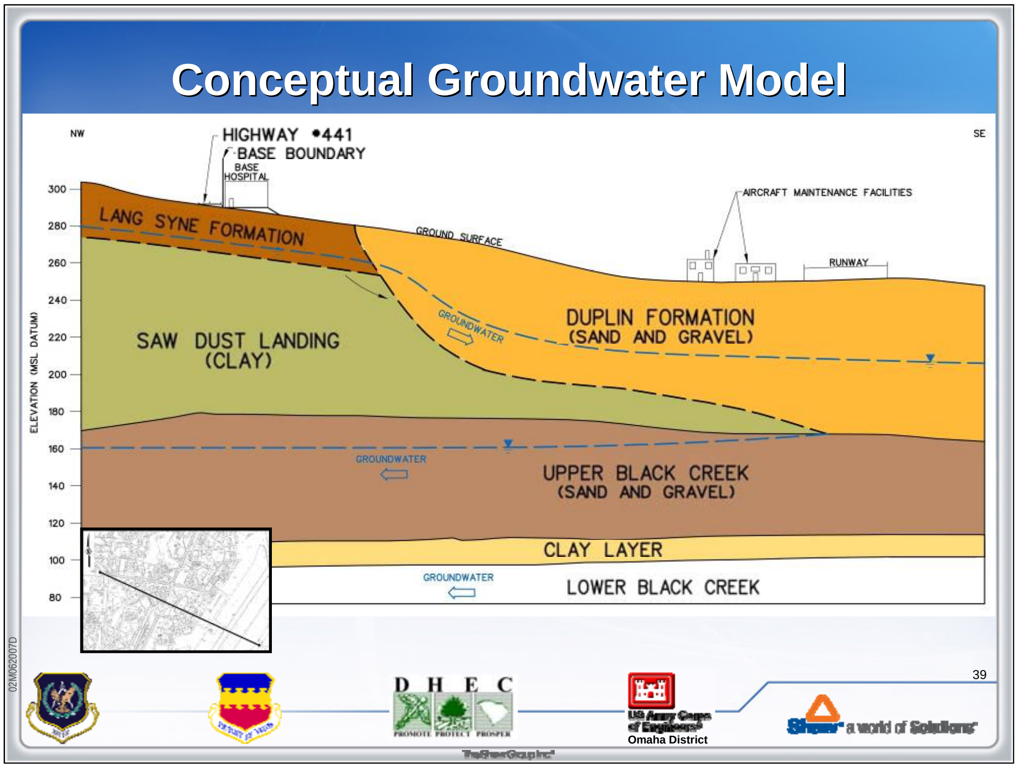
Shallow Groundwater in Duplin aquifer flows east

Deep Groundwater in Upper Black Creek confined aquifer flows west

Moderate to strong downward gradients

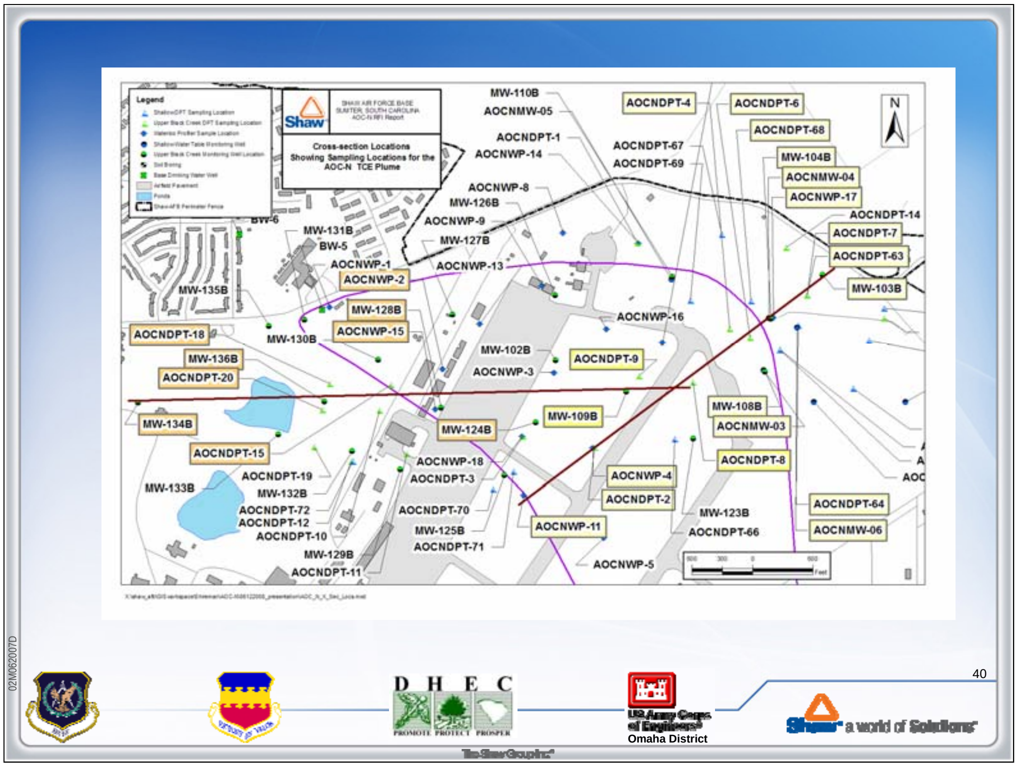
Aquifers are in communication east of the airfield

Sawdust Landing Formation separates aquifers in the area of the maintenance buildings



Inset shows line of section. Perpendicular to topographic gradient and structural grain, and crosses the run ways

- Recharge area for the Black Creek Aquifer where the SDL pinches out, 100 foot clay may be absent to the east of the runway area;
- 140 to 200 feet to the UBC
- Main flow zone is in center of the UBC
- Shallow Groundwater in Duplin aquifer flows east
- Deep Groundwater in Upper Black Creek confined aquifer flows west
- Moderate to strong downward gradients
- Aquifers are in communication east of the airfield
- Sawdust Landing Formation separates aquifers in the area of the maintenance buildings



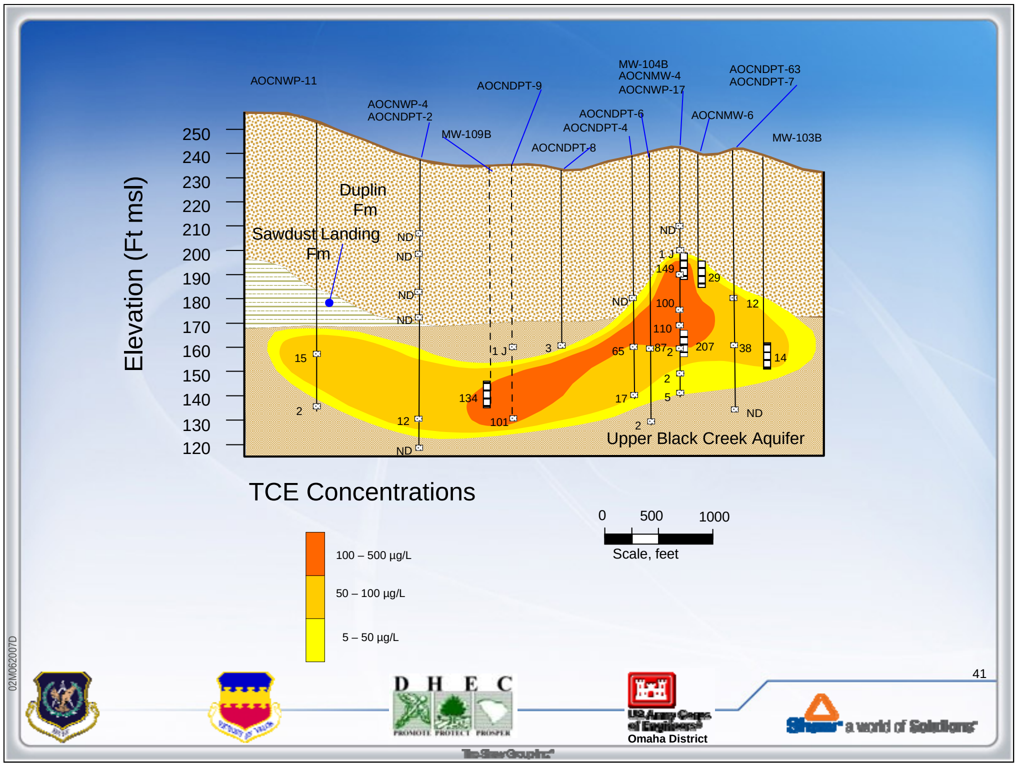
Lines of section and sample locations.

All data is definitive, however the WP and DPT data was not validated.

Data projected orthogonally to the line of section.

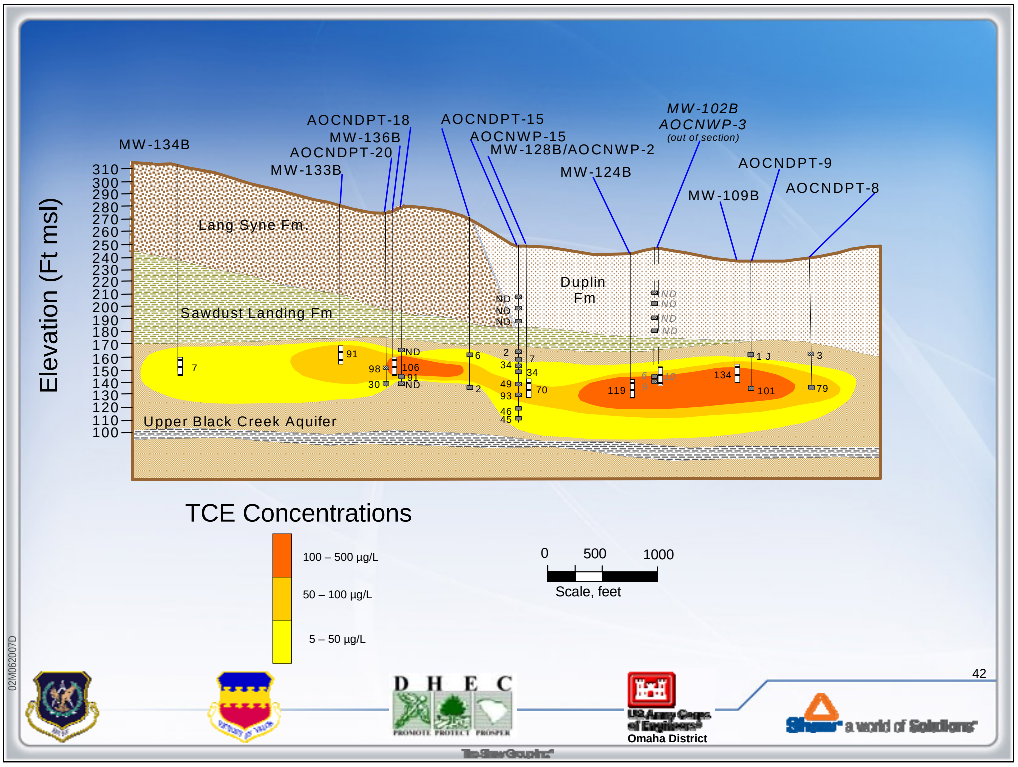
Some wells used in the section only for guidance to provide an understanding of the 3-D nature of the plume

The intersection of the section lines is where the plume makes its turn and heads west



NE-SW Section will shows TCE plume enters the UBC from the Duplin

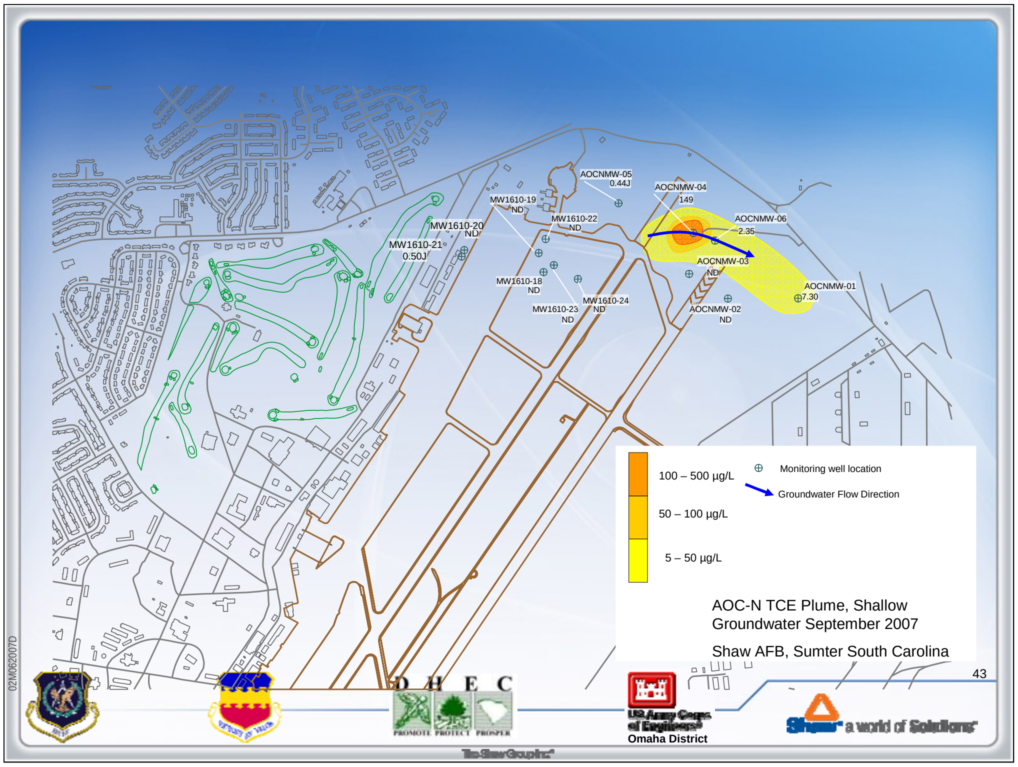
Once in the UBC western flow begins to dominate and the plume migrates west, out f the plane of the section



E--W Section shows TCE plume dominate transport is between 160 to 140 ft MSL. Apparent dissection of the plume is due to flow pattern in and out the line of section.

Sample locations AOCNDPT-8, AOCNDPT-9, and MW104B are shared with the NE-SW line of Section, representing the main turn in the flow direction in the UBC

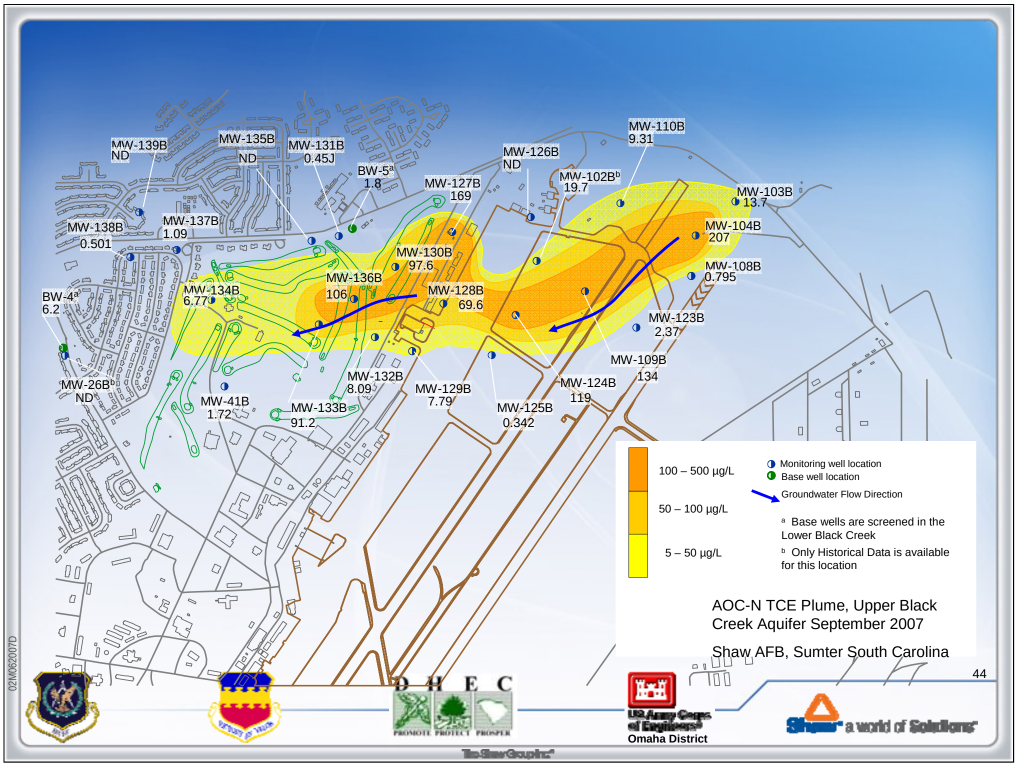
The profiling identified the dominate flow zone in the UBC, DPT provided fewer samples but because the flow zone was identified, there was a high confidence in the resulting 3-D plume characterization



The plume in the Duplin was characterized using the real measurements, well locations were optimized so the plume could be accurately reproduced.

The plume configuration confirms and refines the CSM for the Duplin

Source was between the runway approaches, and the plume tails in the direction of the groundwater flow direction



The plume in the Upper was characterized using the real-time measurements in the runway and maintenance building areas, however, because of the difficult geological conditions to the west, profiling and DPT sampling to over 150 feet was not possible. But based on the data available the plume migrating pathway could be projected and the final well locations were cited based on the projections.

Well locations in the Runway and Maintenance areas were optimized using the profiling and DPT data.

The plume configuration confirms and refines the CSM for the Upper Black Creek Aquifer

The plume enters the UBC between the runway approaches, at or near the source in the Duplin. The TCE plume exhibits moderate lateral dispersion, and concentrations remain above 100 µg/l along a significant length of the plume.

Investigation Results

- All six initially identified potential sources were eliminated
- Plume geometries in shallow and confined aquifers reflect dominant groundwater flow patterns
- Located previously unidentified contaminant source area in the north runway area
- Confirmed the connection between the shallow and confined aquifer

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Advantage of Profile Approach

- Identified the target depth for the confined aquifer sampling zone
- Revealed plume geometry and flow direction in both aquifer zones
- Reduced the number of wells needed for an optimized LTM

Investigation Results

- Source for the AOC-N plume is an undocumented release in the north runway area between the runway approaches
- TCE plume in both aquifers adequately characterized by DPT data in the airfield to optimize monitoring well locations

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Triad Team Decisions

- Collaborative effort between all stakeholders streamlined the investigation and decision making process
- Selected monitoring well locations for the shallow and confined aquifer in the north airfield area based on plume definition from DPT points
- Installed monitoring wells into the confined aquifer west of the maintenance area based on projecting DPT data from within the plume core

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RFI Findings

- Existing monitoring wells adequately provide data for tracking plumes
- AOC-N TCE plume concentrations in the confined aquifer decrease to below MCLs before reaching base boundary
- AOC-N has been adequately characterized to finalize the RFI and begin the corrective measures study process

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Cost savings can be some what subjective. The savings here are based on the following:

Historical costs associated with the response to comment and document revision process form Draft, Draft-Final to Final

Historical costs associated with multiple characterization efforts

Installing unnecessary wells because of incomplete characterization

This is a more sober estimate or the cost "avoidance" than originally offered.

There are other cost considerations that are more difficult to quantify or estimate, and so are left out of this estimate.

The costs avoided by the compressed investigation schedule

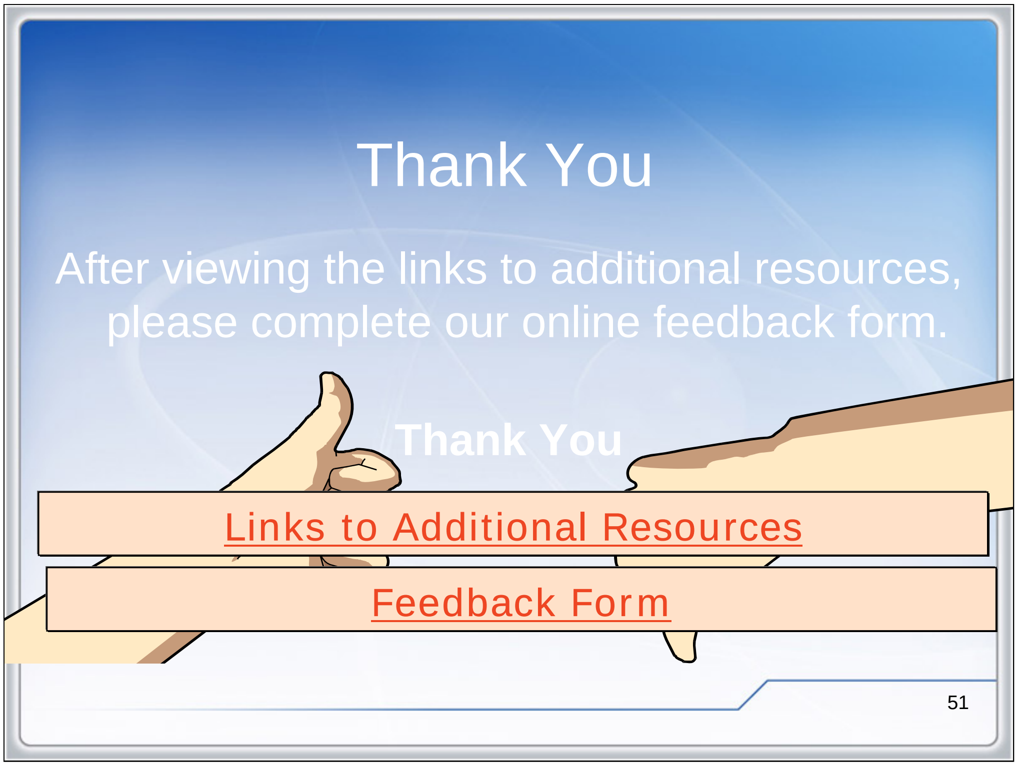
Reports that are deemed technically inadequate in review because of incomplete characterization

Additional work plans for secondary and possibly tertiary characterization efforts,

Costs associated with remobilization, delays and administrative efforts

Could these unquantified costs drive the cost to the initially estimated $1.5 million? Certainly 10 to 15 years ago. At Shaw AFB we have been using real-time measurements to optimize our investigations for years, so some of the cost "avoidance" associated with incomplete characterization were already being realized. The $120 thousand in savings is directly due to the Triad Approach investigation process. It is possible that the compressed investigation could be cited for an additional 3 X that amount, but that is too speculative to put up there.

The fact remains that this project is among the most ambitious Triad Investigations to date and the cost savings were just one of the benefits of using this approach.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