



**TETRA TECH**

*Vertical Profiling Using the Color-Tec® Method to  
Identify Source Releases and Delineate CVOC Soil  
and Groundwater Plumes at the Former Naval  
Construction Battalion Center Davisville in North  
Kingstown, Rhode Island*

Presented to: ***International Conference and Training –  
Triad Investigations – New Approaches and  
Innovative Strategies***

**June 11, 2008 – Amherst, Massachusetts**

Presented by:

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Written by:

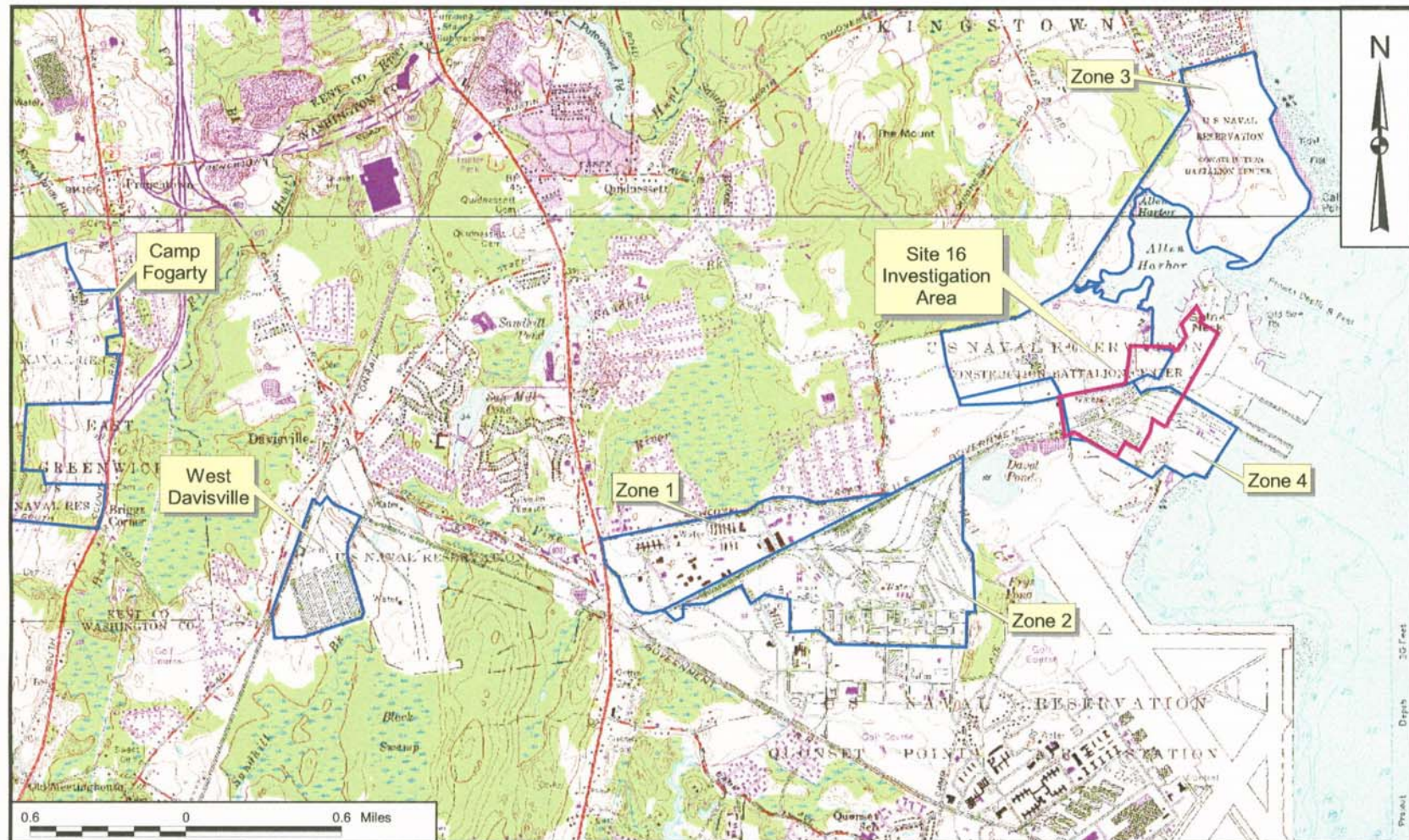
**Scott R. Anderson, John Wright, Lee Ann Sinagoga,  
Curtis A. Frye and Dave Barney**


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**CLEAR SOLUTIONS™**



# Site Locus Map

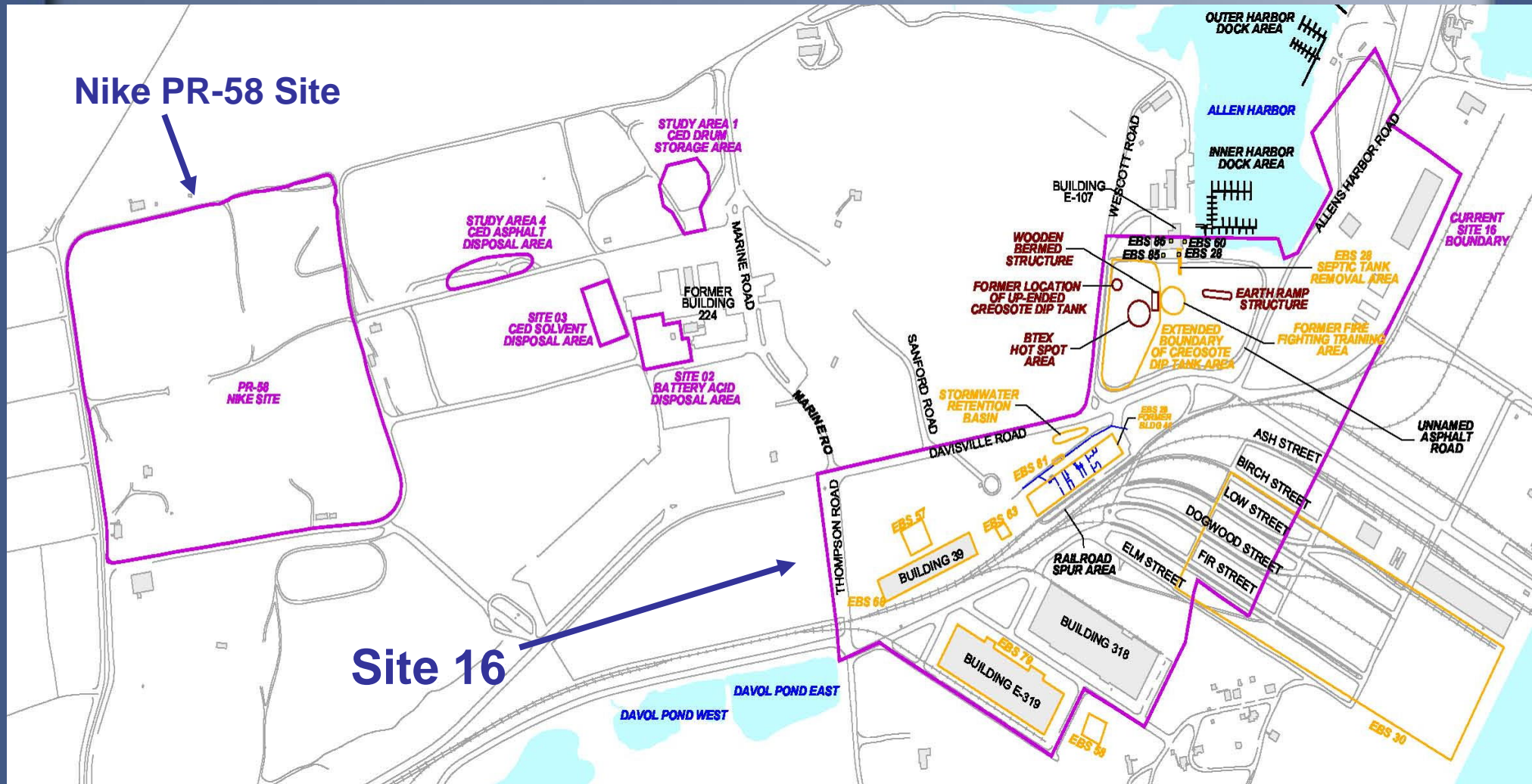


DRAWN BY C. SPEHAR		DATE 3/3/06	<div> Tetra Tech NUS, Inc.</div>	CONTRACT NUMBER N62472-03-D-0057		OWNER NUMBER _____	
CHECKED BY L. SINAGOGA		DATE 7/13/06		APPROVED BY _____		DATE _____	
COST/SCHEDULE-AREA <div><div></div><div></div><div></div></div>		APPROVED BY _____					
SCALE AS NOTED		APPROVED BY _____					
<div>SITE LOCUS MAP</div> <div>PHASE III RI QAPP FOR INSTALLATION RESTORATION PROGRAM SITE 16</div> <div>FORMER NCBC DAVISVILLE FACILITY</div> <div>NORTH KINGSTOWN, RHODE ISLAND</div>			DRAWING NO.		REV		
			FIGURE 1 - 1		0		

P:\GIS\DAVISVILLE NCBC\MAPDOCE\APR\SITE16 PHASE III RI APR SITE LOCATION LAYOUT 7/13/06 SS



# Areas of Interest



# Site 16 - Environmental History

- Placed on the National Priority List (NPL) of sites in 1989.
- Federal Facilities Agreement executed in 1992.
- Identified as a Installation Restoration (IR) Site primarily because of:
  - Former Creosote Dip Tank Area (polycyclic aromatic hydrocarbon [PAH] contamination)
  - Former Fire Fighting Training Area (PAH and trichloroethene contamination)
  - Trichloroethene plume extending from the former Bldg 41 area northeast to Allen Harbor and east to Narragansett Bay.
  - Western third of former Bldg 41 was used for degreasing activities and included a degreasing unit and a solvent recovery still.

# Previous Investigations Conducted at Site 16

- **Environmental Baseline Survey (EBS) Investigations (1996 – 1998)**
- **Phase I Remedial Investigation (RI) (1999 – 2001)**
- **Phase II Remedial Investigation (2002 – 2003)**
- **Phase II Screening Level Ecological Risk Assessment (SLERA) (2004)**
- **Supplemental Phase II Study and HRC Pilot Study (2004)**
- **Two soil removal actions also conducted in the North Central area of Site 16 (PAH contamination).**
- **Pre-Phase III Investigations included:**
  - **Installation of over 200 monitoring wells at 68 well clusters.**
  - **Advancement of over 50 soil borings during Phase I/Phase II RIs.**
  - **60 Sediment samples from Allen Harbor (environmental forensics).**

# 2007-2008 Phase III Investigation for Site 16

## ■ Objectives:

- Address *data gaps* identified based on review of available EBS, Phase I RI, and Phase II RI data. For example....
  - Identify ***significant*** sources of trichloroethene plume.... A final comprehensive attempt to locate contaminant sources!
  - Delineate ***trichloroethene*** groundwater plume boundary.
  - Determine if plume is potentially ***discharging to Allen Harbor***.
- *Attempt to collect all necessary RI data in one final field investigation event!*



# 2007-2008 Phase III Investigation for Site 16

- Investigation included (but not limited to):
  - Establishment of *soil screening grids* for the North Central area and areas south of Davisville Road and east of Allens Harbor Road.
  - Systematic screening of soil samples for volatile organic contamination using both *Color-Tec®* screening tool and *photo-ionization detector (PID)*.
  - Selection of soil samples for fixed-base lab analysis based on screening.
  - Installation of *additional* borings (i.e., “stepping out on the grid”) based on soil screening results. *TRIAD APPROACH...DECISION MAKING IN REAL TIME!*
  - Installation of new groundwater monitoring wells (*screened interval to be based, in part, on soil screening data*) and sampling of select existing wells and all newly installed wells.
  - Logging and tracking *data electronically* as data are collected.

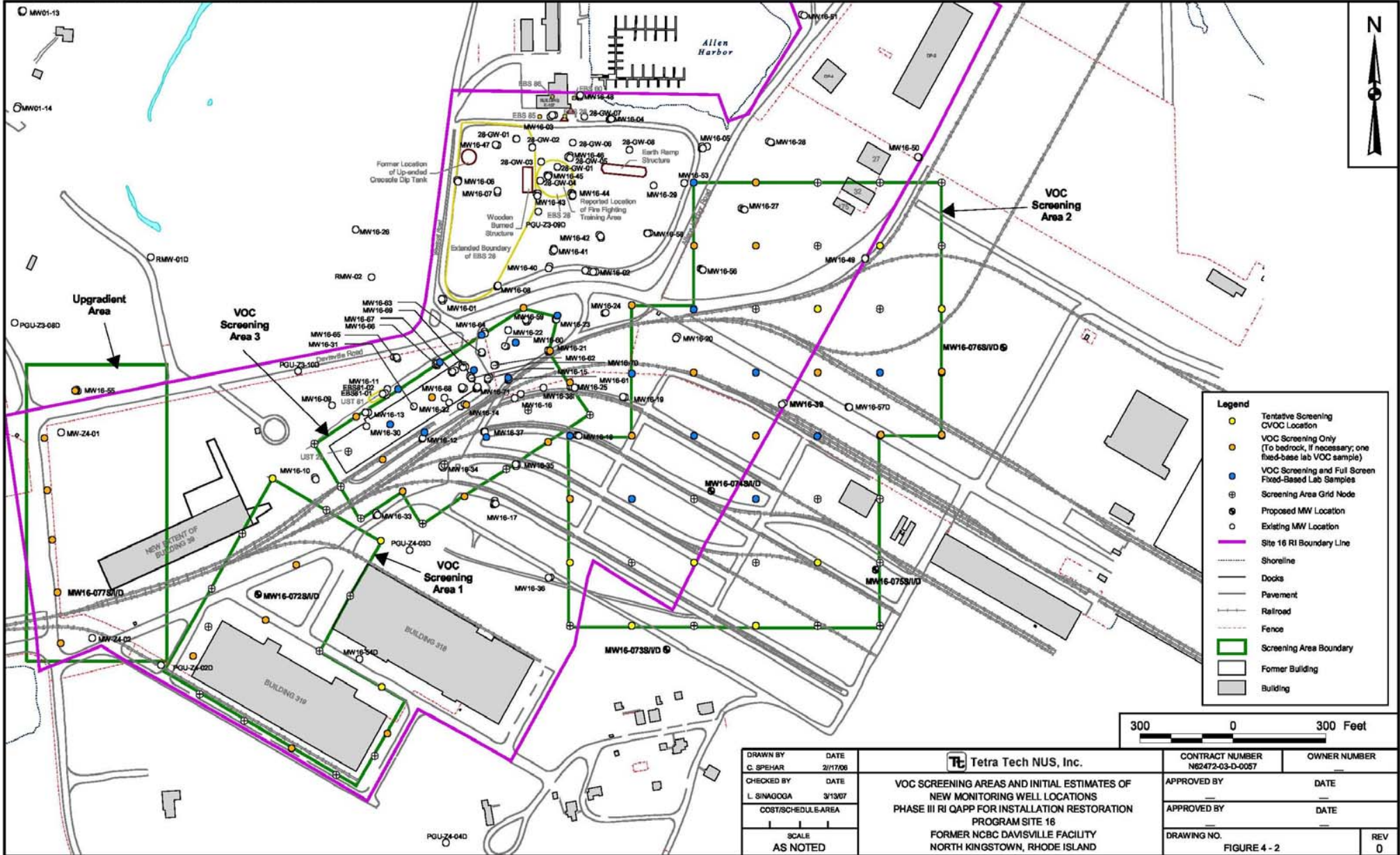
## P:\GIS\DAVISVILLE NC\RCMAPDOCE\APR\SITE16 SUPP PHASE III RI OLD APR REVISED PROPOSED SR LOC LAYOUT 3/22/07 KM





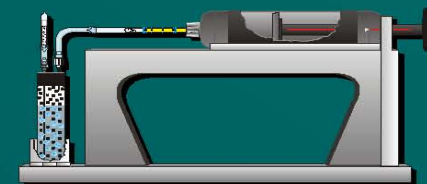
# Proposed Soil Locations – VOC Screening Areas

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# Color-Tec® Methodology/Background

## AQR Color-Tec Method



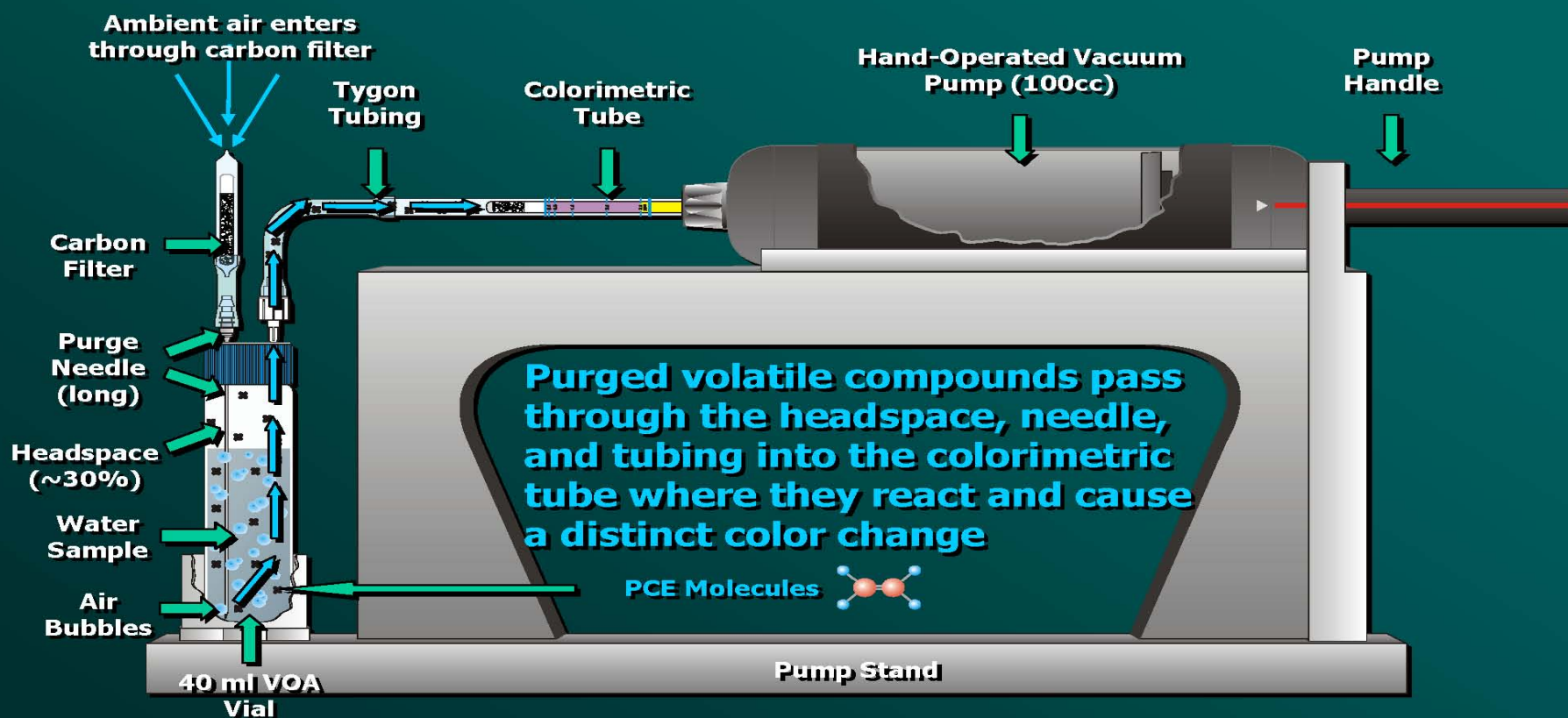
- ◆ Field-based analysis of water and soil samples
  - Combines **sample purging** with colorimetric detector tubes
  - Detects low concentrations (**< 5 ppb**) of chlorinated compounds
  - Provides **qualitative analysis**
  - Provides **tentative quantification** of total chlorinated compounds (approximate concentrations)





# Color-Tec® Methodology/Background

## AQR Color-Tec Method Purge and Analysis

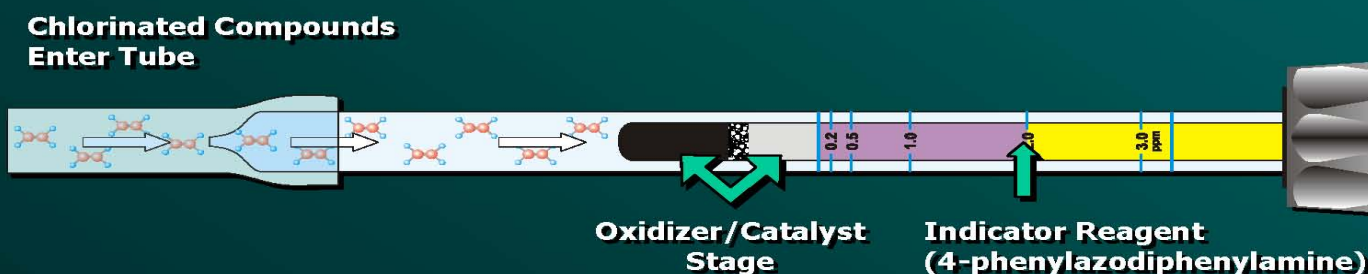




# Color-Tec® Methodology/Background

## Colorimetric Tube Detection Principal

- ◆ Pump draws the air sample through the tube
- ◆ Purged contaminant vapor enters tube
- ◆ Chlorinated compounds are decomposed in the oxidizer/catalyst stage
- ◆ Converted HCl enters reagent phase causing a color change.
- ◆ The concentration is read at the interface of the reacted to un-reacted reagent



# Color-Tec® Methodology/Background

## Potential Method Limitations

### ◆ Possible Chemical Interferences

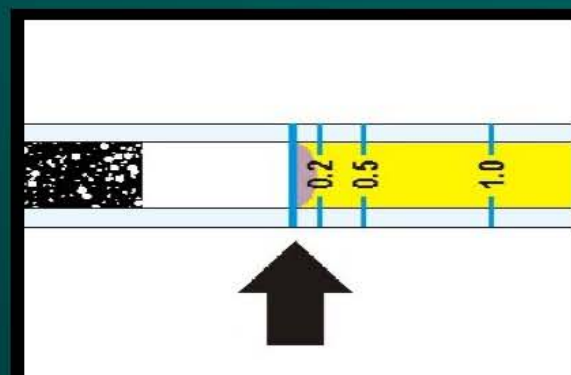
- Free Chlorine
- HCL
- Other Chlorinated VOHs
- Airborne contaminants
- Toluene
- Xylenes

**Positive Interference**

**Negative Interference**

### ◆ Possible Physical Limitations

- Subtle color change at low levels
- Temperature



# Colorimetric Tubes Used During Investigation



- 3 GasTec® Colorimetric Tubes used during investigation
  - LL Tube (ND to Low Level Concentrations)
    - Response range is 0 to 3
  - L Tube (Low Level to Mid Level Concentrations)
    - Response range is 0 to 25
  - M Tube (Mid Level to High Level Concentrations – not NAPL)
    - Response range is 0 to 100



# Use of Color-Tec® at Site 16 RI Investigation

- Approximately 1250 soil samples and 200 groundwater samples screened for presence of CVOCs using Color-Tec® methodology (primary target parameter was TCE).
- At a minimum, one soil sample was collected every 10 linear feet from approximately 150 soil borings (most every 5 linear feet).
  - Soil borings ranged in depths from less than 10 feet to 70 feet bgs with an average total depth of approximately 50 feet.
- Based on preliminary Color-Tec® and PID responses, additional soil samples were collected from sub-zones of some borings.
  - 3 or more samples over a 5 foot DPT section within various lithologies.
- Soil sampling methodology standardized to mimic fixed-base laboratory sampling methodology (50% soil to water ratios).

# Use of Color-Tec® at Site 16 RI Investigation

- Screening and lithology information collected and tracked electronically in real-time (use of Panasonic TOUGHBOOK® field computers).
- Field investigation data routinely shared with BRAC Clean-up Team (BCT) members (EPA Region I, State of Rhode Island) via weekly E-mail updates, bi-weekly TRIAD teleconferences, and posting of field data to EPA-host website.
- Screening data used to make real-time investigative decisions..
  - Which soil sample from boring (i.e., which soil interval) should be analyzed at fixed-base laboratory??
  - Where should the next “step out” boring go??
    - Total number of borings nearly doubled in Former Building 41 area
  - What is the best screen interval for this new well??

# Comparison of Color-Tec® to Laboratory Results Soils (LL Tube)

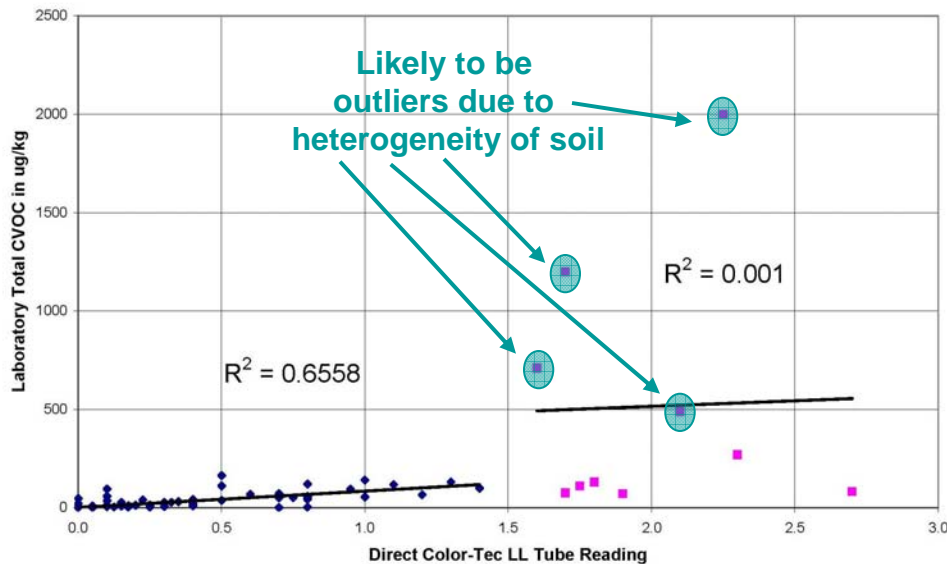
## Evaluation of Non-Detects

- 161 of 187 Color-Tec® non-detects confirmed by fixed-base laboratory data
  - 86% success/match rate
- 24 of 26 Positive laboratory detections vs. Color-Tec® non-detects were less than 10 ug/kg (positive laboratory detects ranged from 0.70 to 9.1 ug/kg)
  - 98.9% of the Color-Tec® non-detects equate to results less than 9.1 ug/kg total CVOC based on laboratory data.
- Noteworthy Color-Tec® false negatives...
  - One detection of 20.6 ug/kg,
  - One detection of 46 ug/kg. However, TCE not detected in this sample (other volatile organic chemicals were detected).
- Regarding Color-Tec® false negatives...
  - Arithmetic average of 26 laboratory detections is 5.31 ug/kg.
  - Geometric mean of 26 laboratory detections is 2.86 ug/kg.
- Non-Detects on L Tube were re-run with LL Tube (LL Tube data used), no non-detects on M Tube

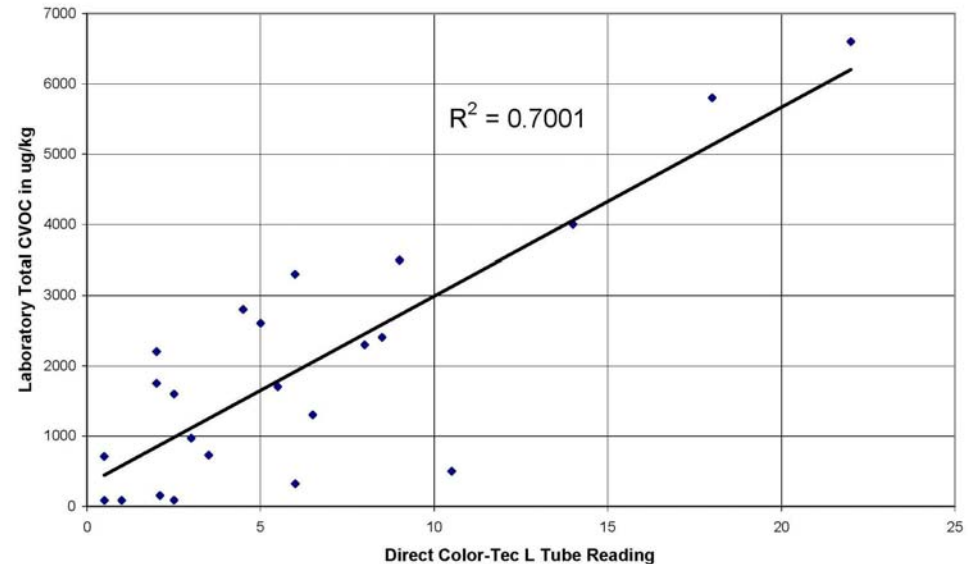


# Comparison of Color-Tec® to Laboratory Results – Soils

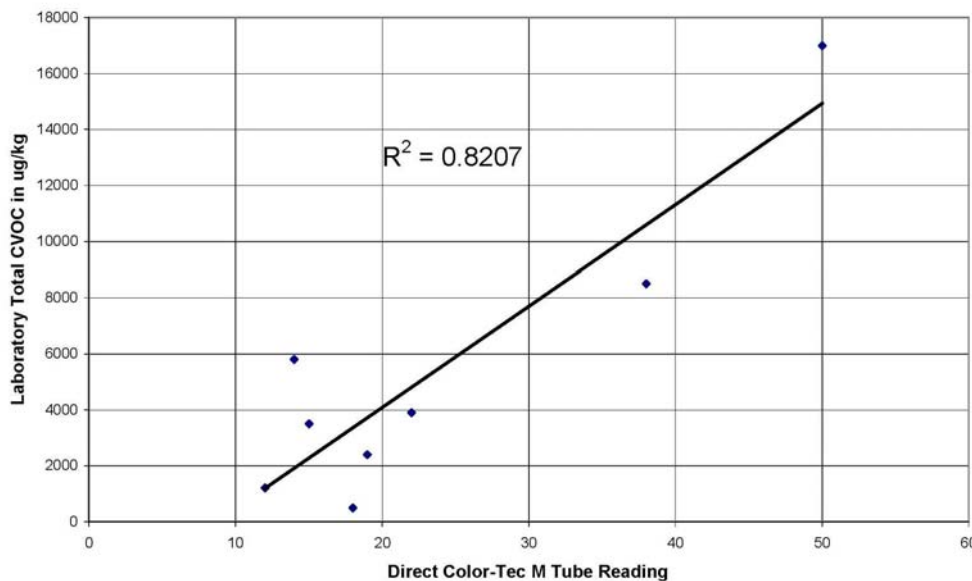
Comparison of Color-Tec to FBL results for LL GasTech Tube



Comparison of Color-Tec to FBL results for L GasTech Tube



Comparison of Color-Tec to FBL results for M GasTech Tube



- 107 of 108 Color-Tec® Detections Verified against Laboratory
  - 99% Success/Match Rate
  - 1 false positive
- Reasonable correlation for each tube type (correlation increasing with concentration). Occasional outliers noted.

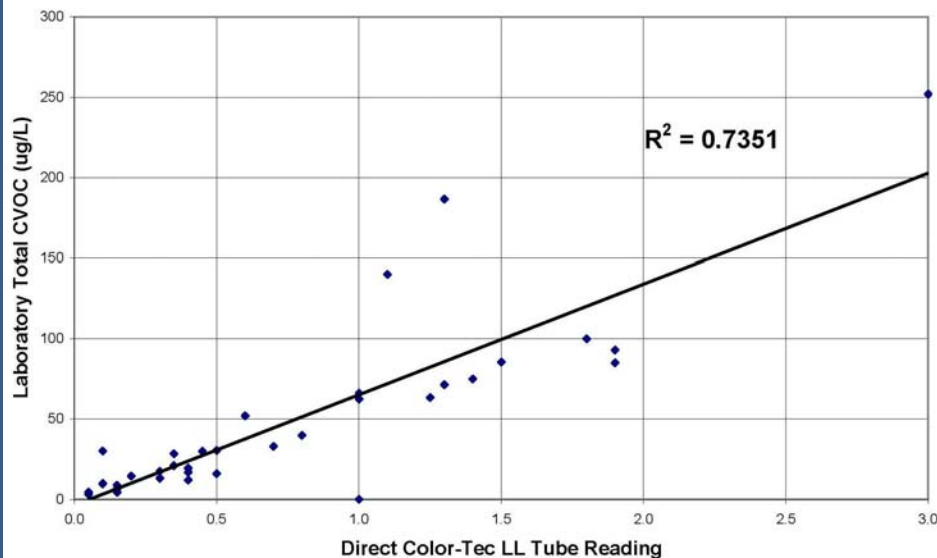
# Comparison of Color-Tec® to Laboratory Results Groundwater (LL Tube)

## Evaluation of Non-Detects

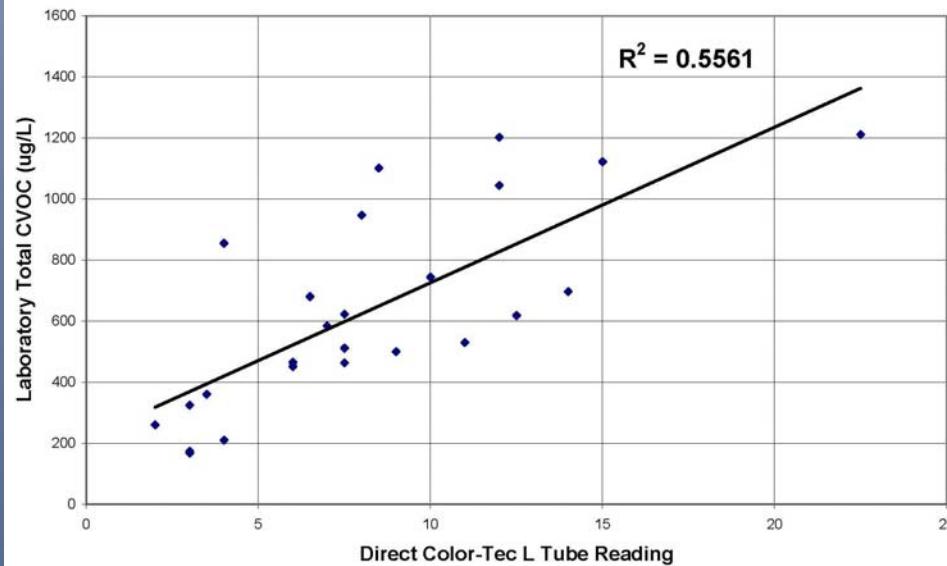
- 40 of 56 Color-Tec® non-detects confirmed by fixed-base laboratory data
  - 71% success/match rate.
- Of the 16 positive laboratory detections (with associated Color-Tec® non-detects), concentrations ranged from 0.12 ug/L to 3.57 ug/L.
- Regarding Color-Tec® false negatives...
  - Arithmetic average of 16 laboratory detections is 1.39 ug/L.
  - Geometric mean of 16 laboratory detections is 1.04 ug/L.
- 100% of Color-Tec® non-detects were associated with laboratory results of less than 5 ug/L total CVOCs.
- No non-detects observed on either L or M Tubes

# Comparison of Color-Tec® to Laboratory Results – Groundwater

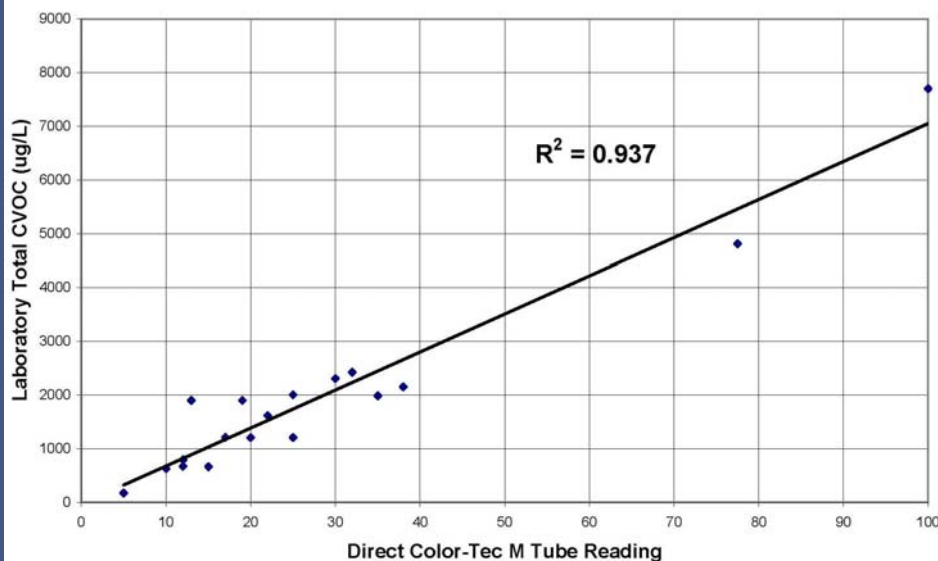
Comparison of LL Tube Responses to Lab Data - Groundwater



Comparison of L Tube Responses to Lab Data - Groundwater



Comparison of M Tube Responses to Lab Data - Groundwater



- 78 of 79 Color-Tec® Detections Verified against Laboratory
  - 98.7% Success/match Rate
  - 1 false positive
- Reasonable correlation for each tube type.
- Method designed for groundwater.



# Comparison of Color-Tec®, PID and Laboratory Data – Soils

- Headspace PID readings collected with 10.6eV PID (calibrated to 100 PPM Isobutylene) from 8 oz jar covered with aluminum foil (soil sample heated for 15 minutes).
- Real-time PID readings collected with same PID probe from soils directly from split-spoons.
- Headspace PID of clean silica sand (saturated with DI water) = 2.5

Sample ID	Sample Elevation (ft MSL)	Gastec Tube Type	Tube Value	Estimated Value (ug/kg)	Lab Value (ug/kg)	Headspace PID	Real-Time PID
SB16-A2-31/MW16-88I-SO-2931	-20	LL	0.1	16		0.7	0.0
SB16-A2-31/MW16-88I-SO-3537	-26	LL	2.1	260		1.7	0.0
SB16-A2-31/MW16-88I-SO-3941	-30	LL	ND	ND		0.3	0.1
SB16-A2-31/MW16-88I-SO-4547	-36	LL	ND	ND		0.5	0.0
SB16-A2-31/MW16-88I-SO-4951	-40	LL	ND	ND		0.5	0.1
SB16-A2-31/MW16-88I-SO-5353	-43	L	3.5	860		11.7	0.6
SB16-A2-31/MW16-88I-SO-5557	-46	L	6.5	860	1600	15.8	1.0
SB16-A2-31/MW16-88I-SO-5961	-50	LL	ND	ND		1.4	0.2
SB16-A2-31/MW16-88I-SO-6567	-56	LL	ND	ND		0.8	0.0
SB16-A2-31/MW16-88I-SO-6971	-60	LL	ND	ND	ND	0.5	0.0
SB16-A2-31/MW16-88I-SO-745795	-67.5	LL	ND	ND		1.2	0.0

## **Conclusions:**

# **Comparison of Color-Tec® to Laboratory Results**

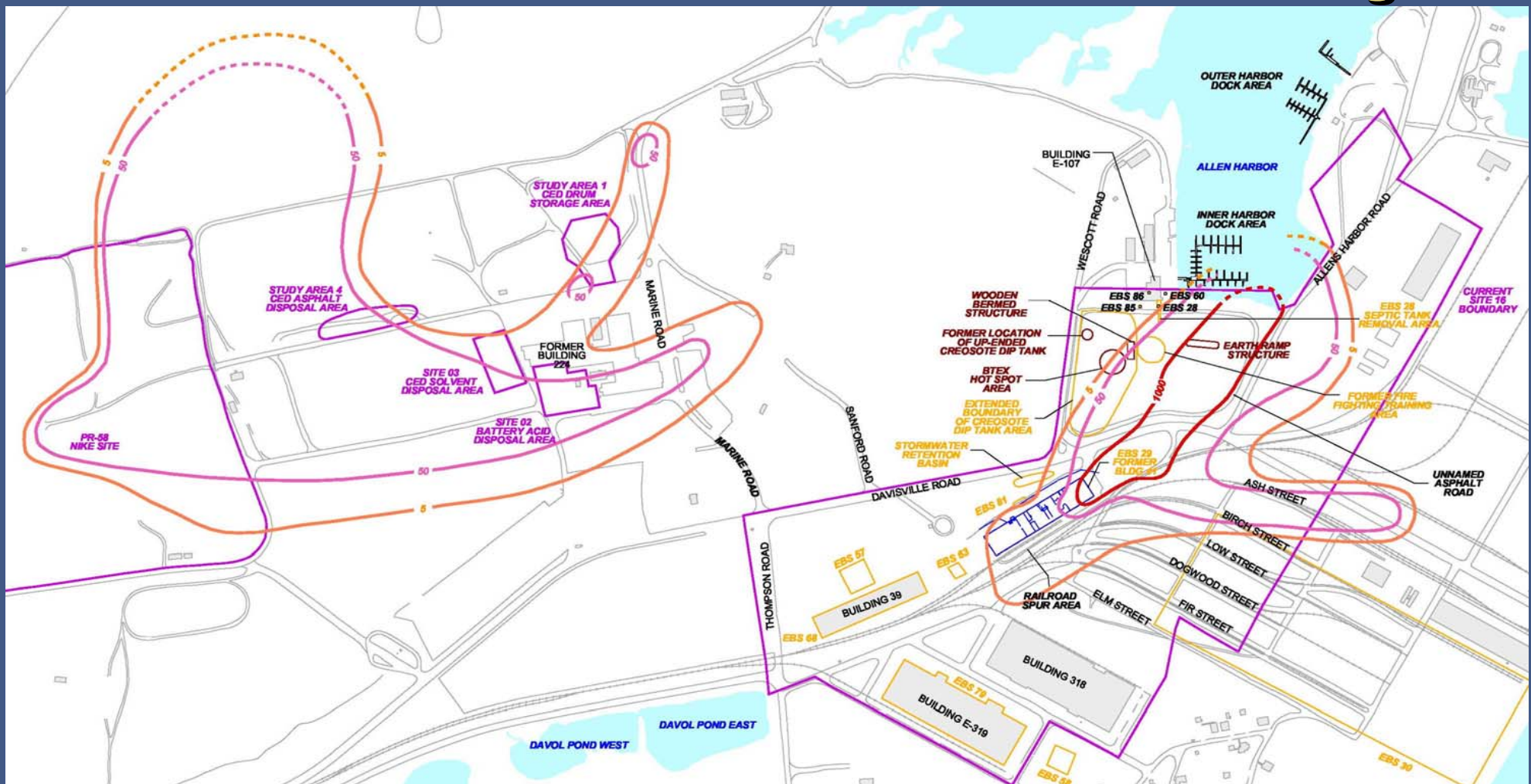
- Success rate of matched pairs in excess of 98%.
- Laboratory data confirmed 86% Color-Tec® non-detects in soils and 71% Color-Tec® non-detects in groundwater!
- For Soil, most Color-Tec® false negatives (24 of 26) were associated with positive laboratory results less than 10 ug/kg and for groundwater, Color-Tec® false negatives were associated with positive laboratory results less than 4 ug/L.
- Reasonable correlation between Color-Tec® screening data and fixed-base laboratory data.
  - Degree of correlation increases with increasing concentrations for both soil and groundwater.
- Color-Tec® screening more sensitive to and specific for CVOCs versus PID screening alone.
  - PID not effective until approximately 1000 ug/kg assuming no interferences with other chemical constituents (other VOCs - mainly BTEX) or moisture.

# Application of Color-Tec® Data to Delineate CVOC Plume - Estimating CVOC Concentrations from Color-Tec® Responses

- While correlation between Color-Tec® responses and fixed-base laboratory results were quite reasonable, Color-Tec® responses were not directly translated to a fixed-base laboratory concentration in real-time during the field investigation.
- Rather, tube responses were estimated based on distribution of data and strength of correlation – geometric means were used for estimated values.
  - LL Tube for Soils
    - Response of 0 estimated to be non-detect
    - Responses from 0.05 to 1.5 estimated to be 16 ug/kg
    - Responses from 1.5 to 3.0 estimated to be 260 ug/kg
  - L Tube for Soils
    - Responses from 0 to 10 estimated to be 860 ug/kg
    - Responses from 10 to 25 estimated to be 5400 ug/kg
  - M Tube for Soils
    - Responses from 0 to 25 estimated to be 2200 ug/kg
    - Responses from 25 to 100 estimated to be 12000 ug/kg
  - While this method may over- or under-estimate the correlated fixed-base laboratory concentration, method is effective in tracking impacts in real-time allowing for quick decisions to be made.



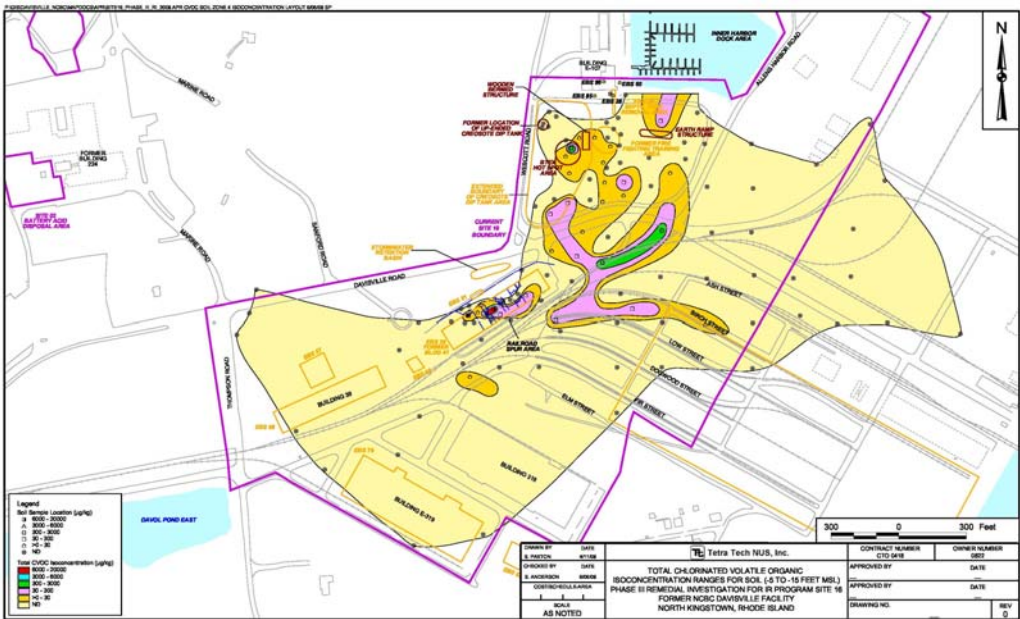
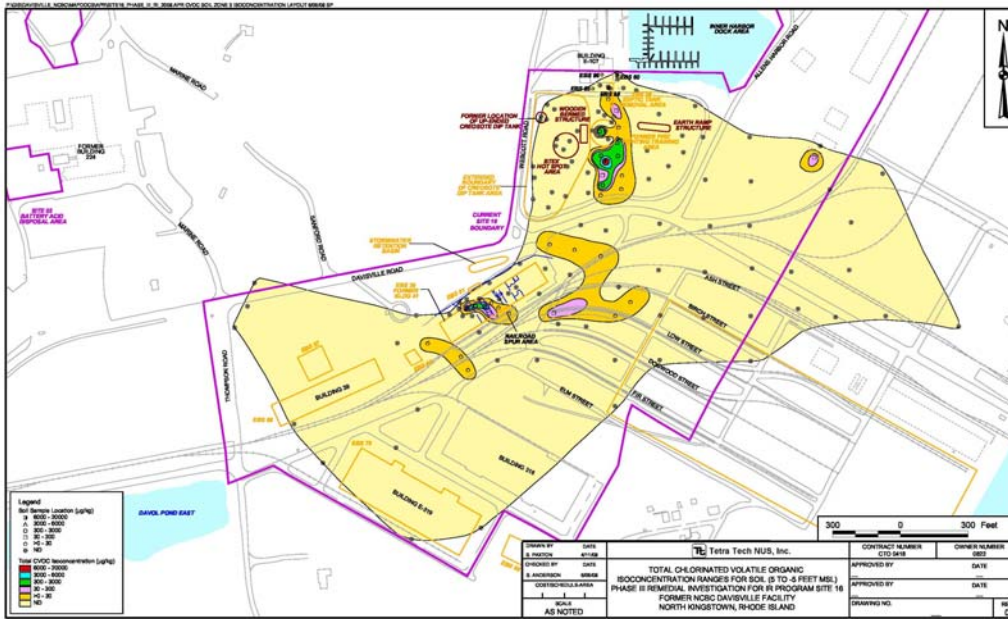
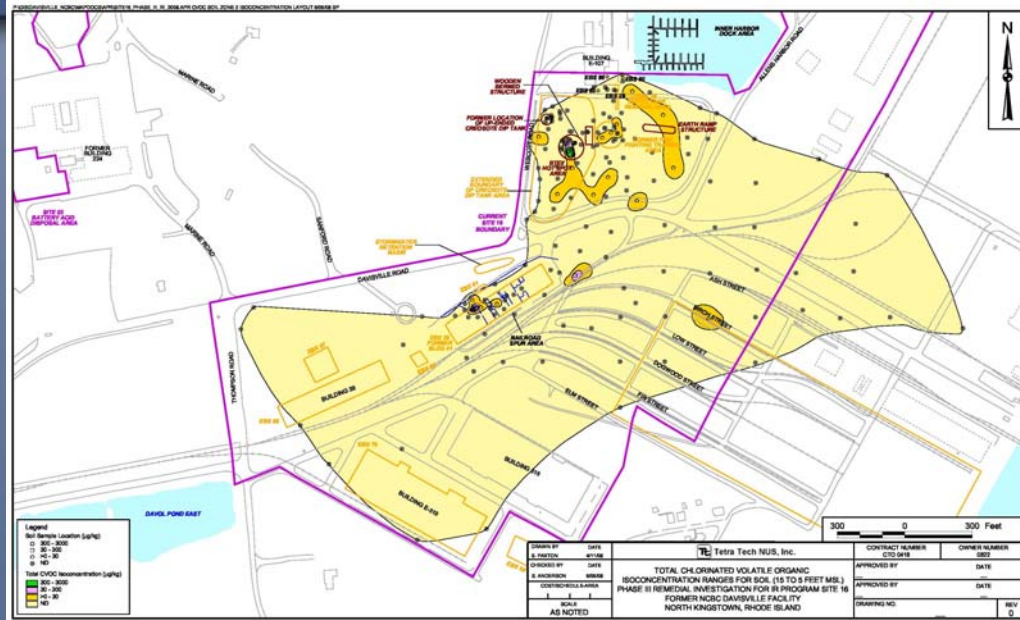
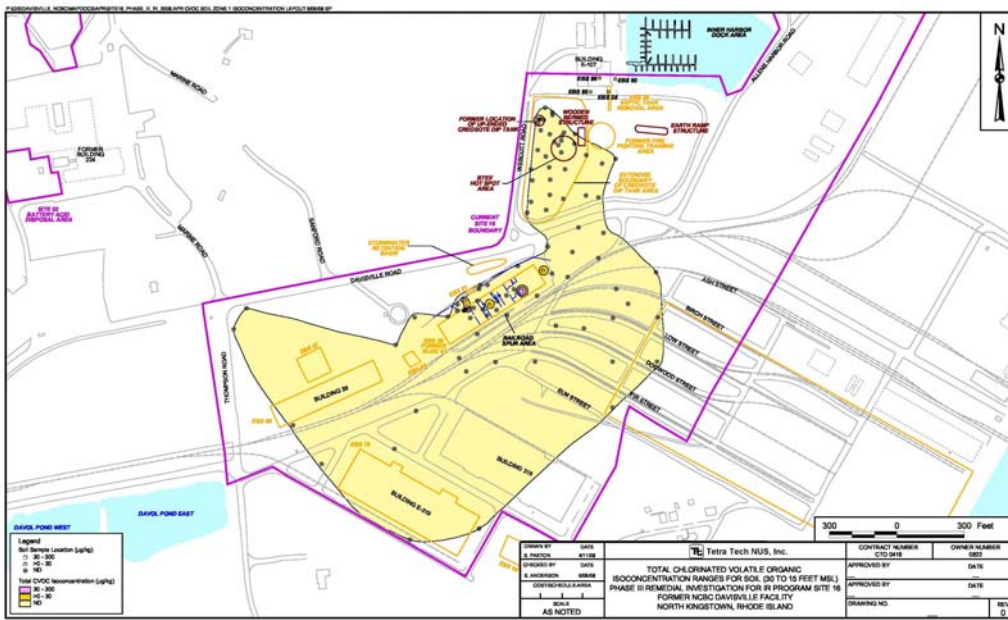
# Extent of CVOC Plumes Prior to Phase III Investigation



- CVOC Extents based on Groundwater in Deep Overburden/Upper Bedrock.
  - Over 90% of Mass in these zones, very little contributions thought to occur in upper zones
- Insufficient soil data across site to assist in delineation of extent of contamination (only shallow data in north, only deep data in south)

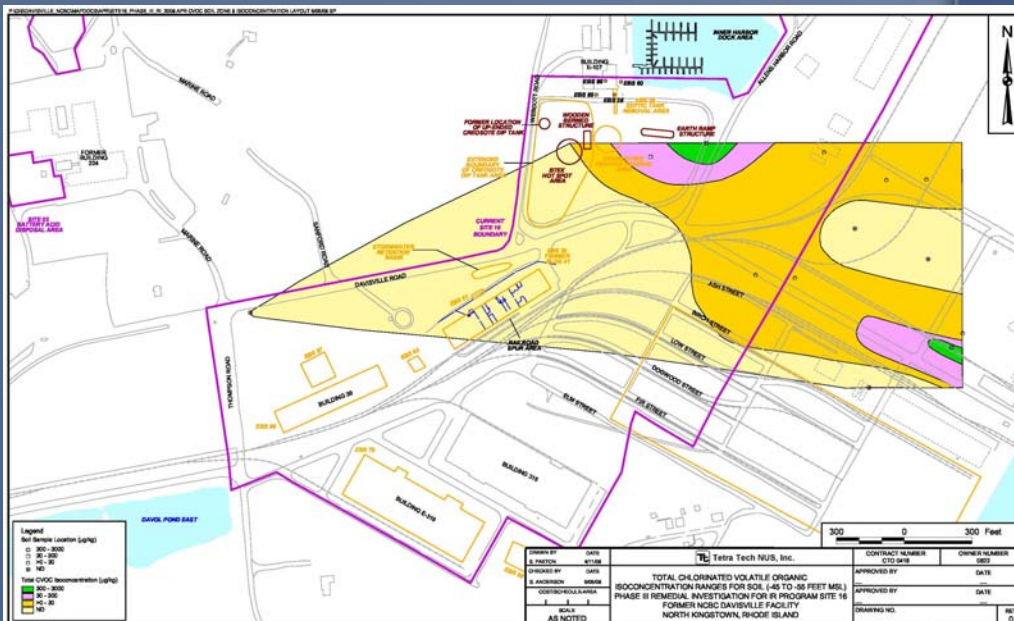
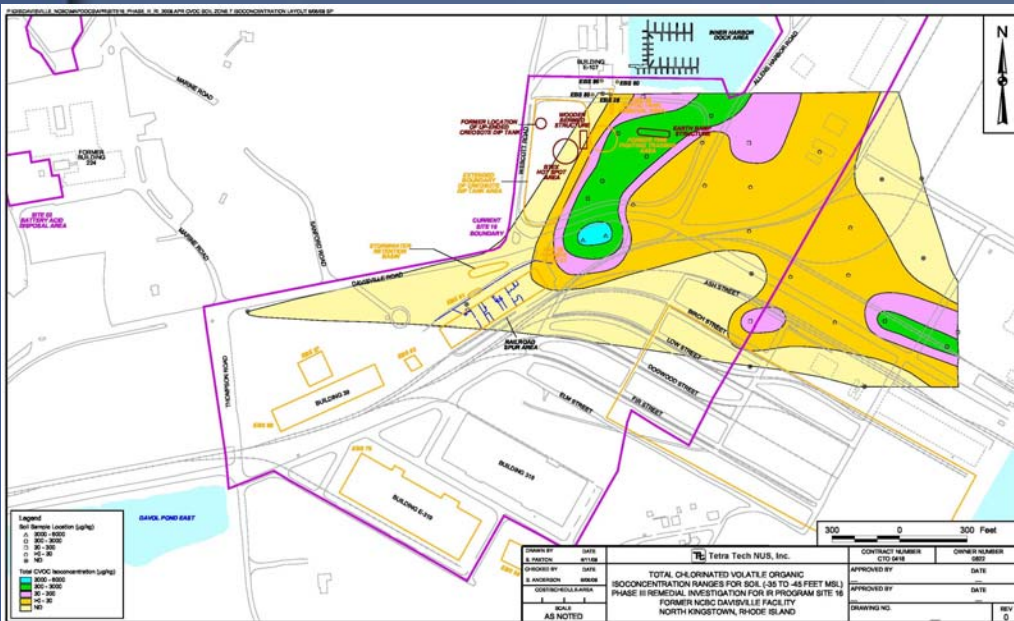
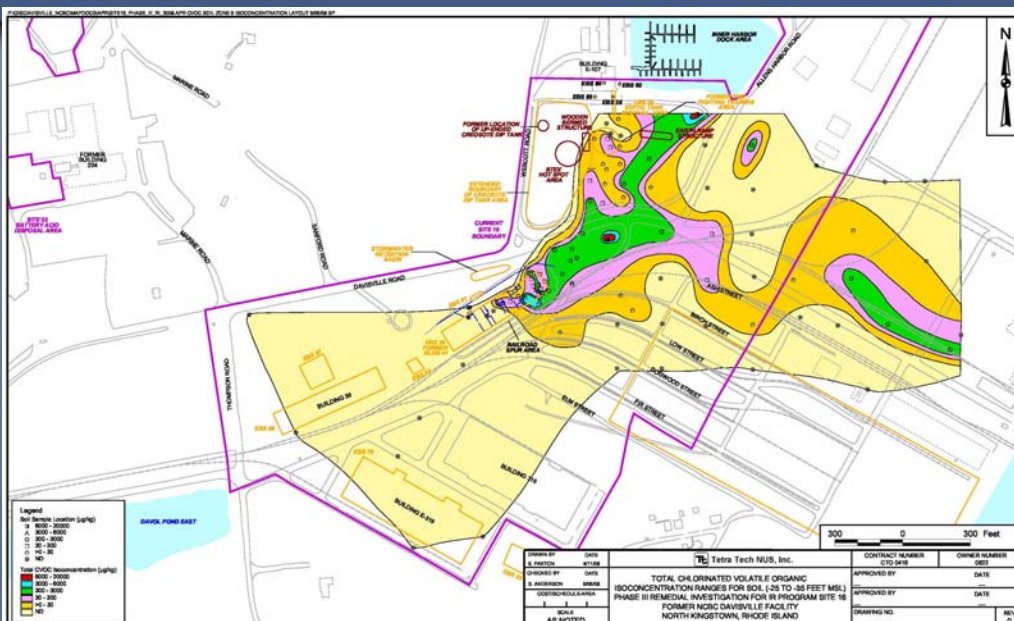
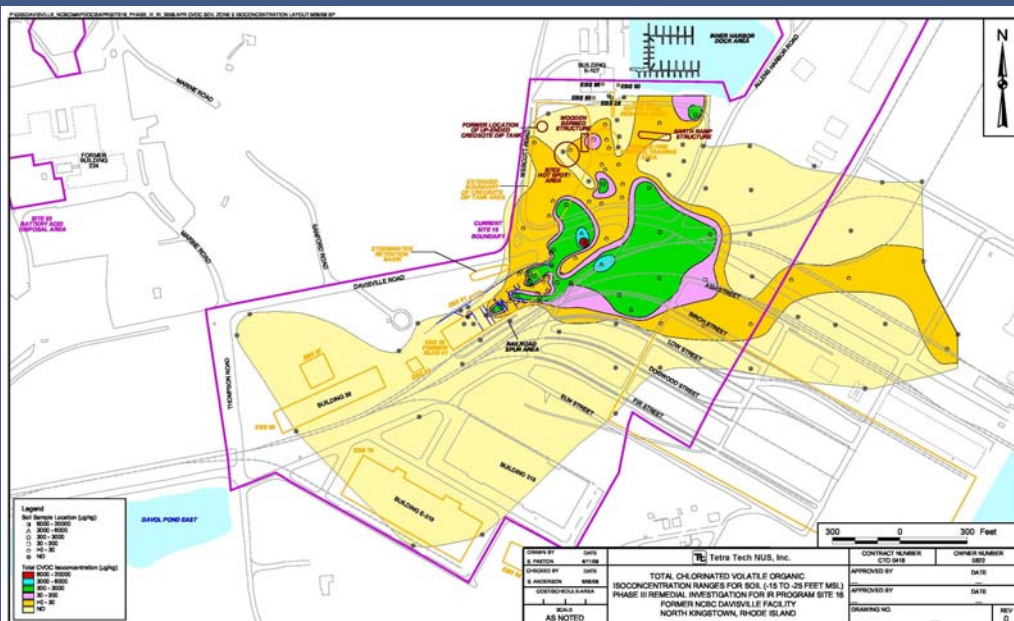


## Phase III Investigation Results using Color-Tec® Data for Soils



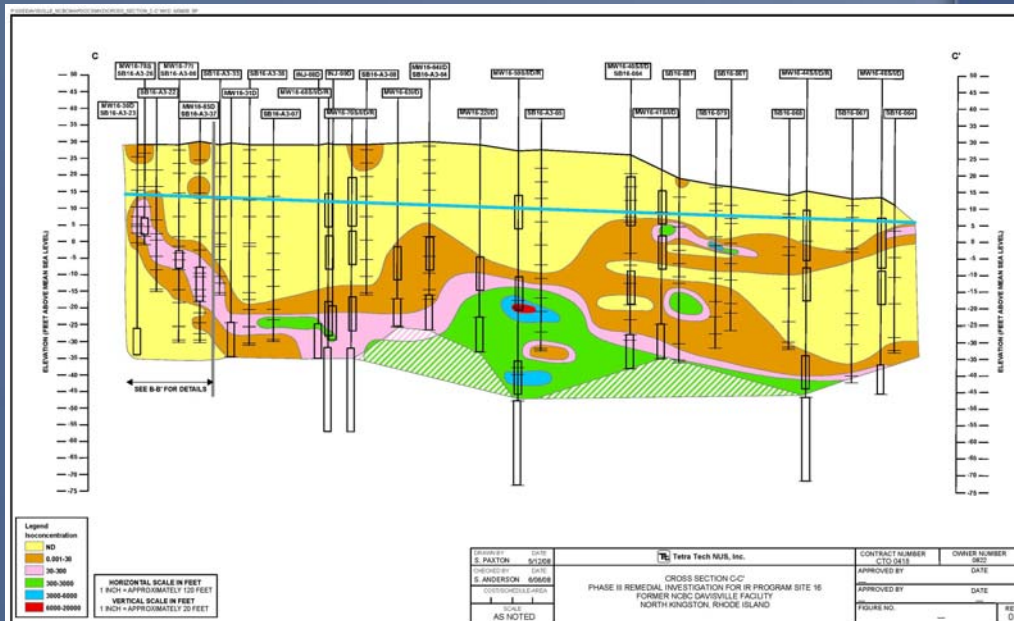
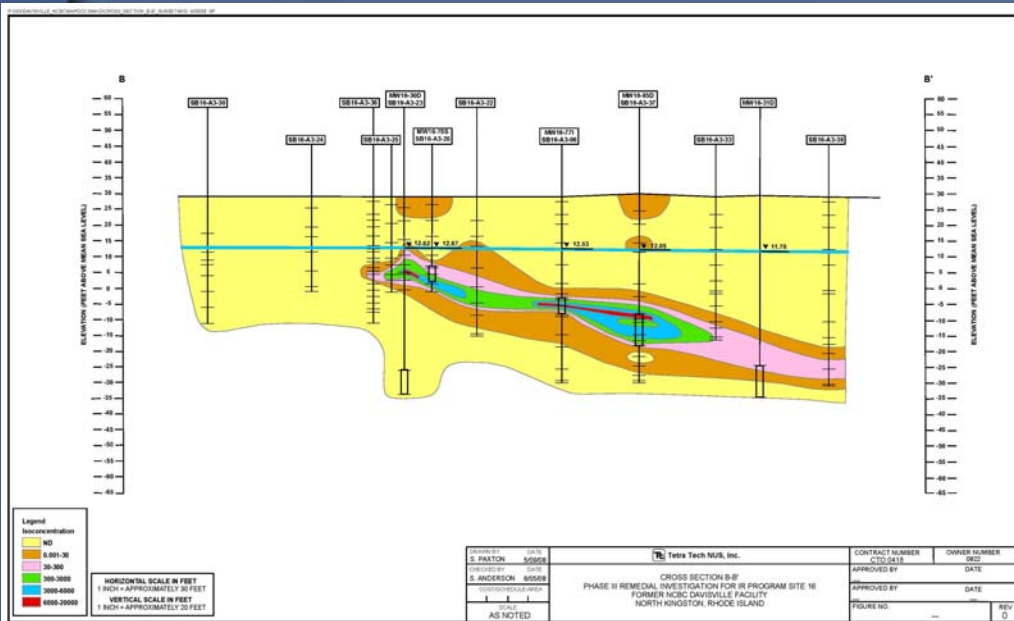
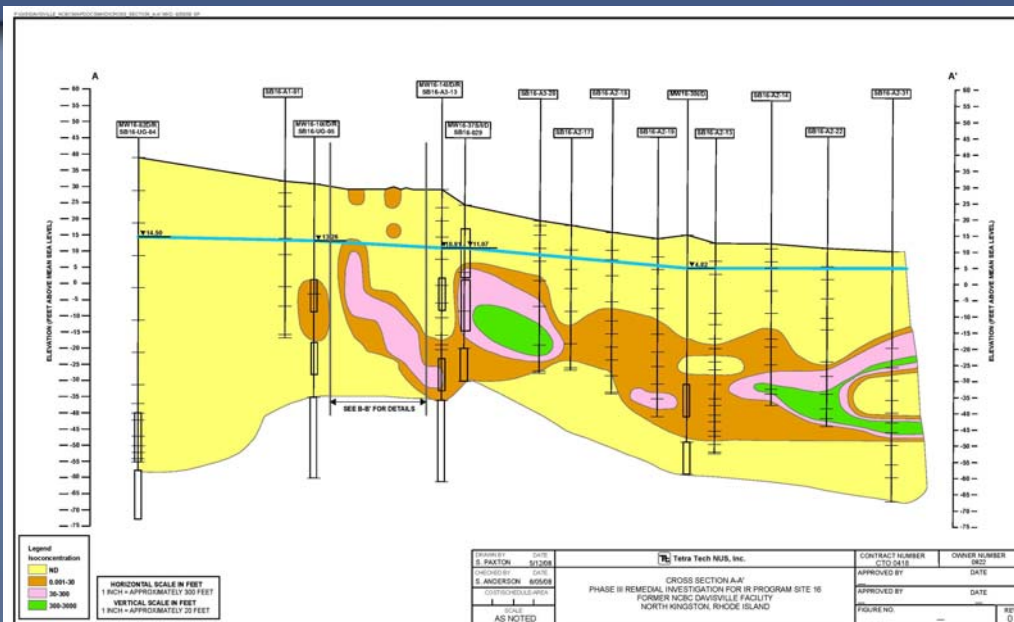
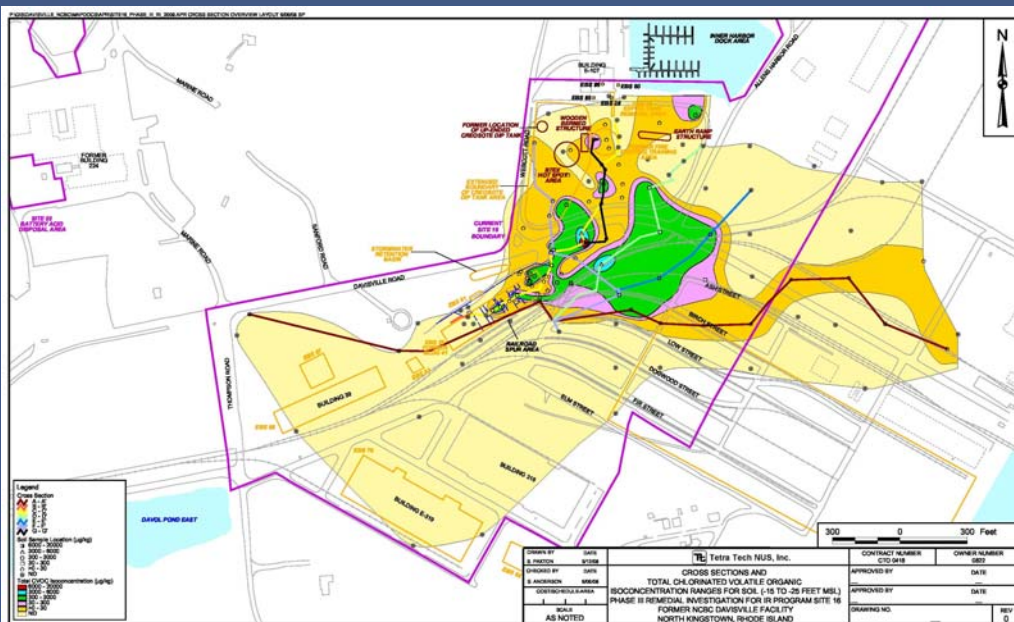


# Phase III Investigation Results using Color-Tec® Data for Soils

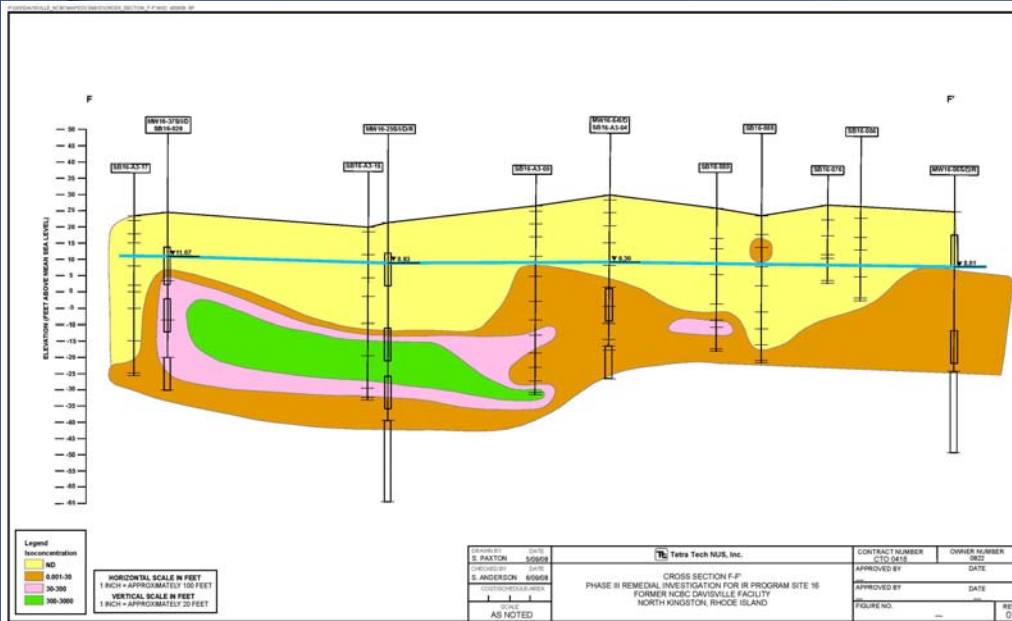
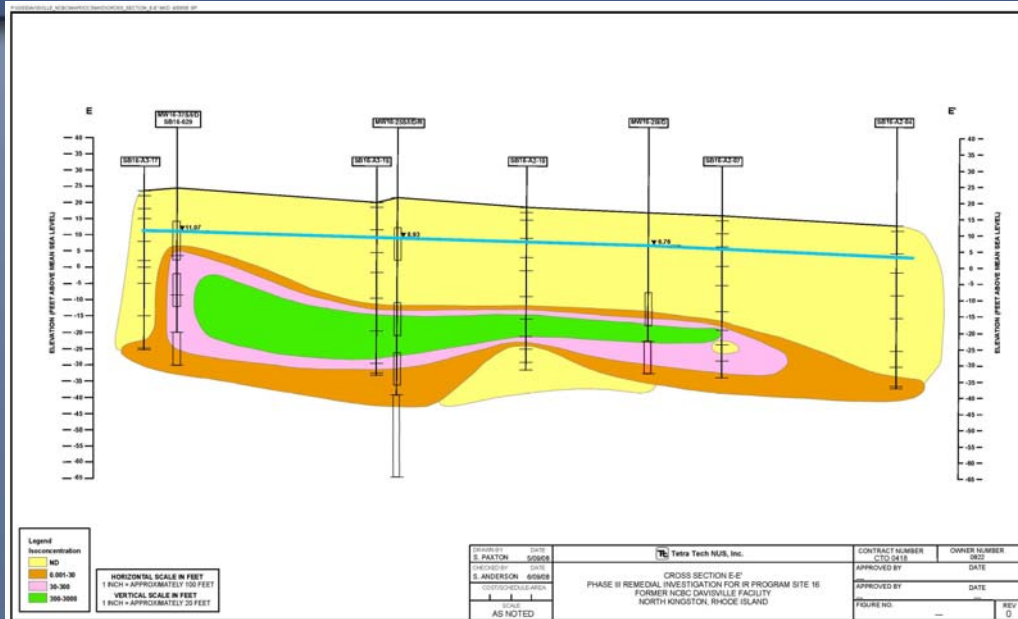
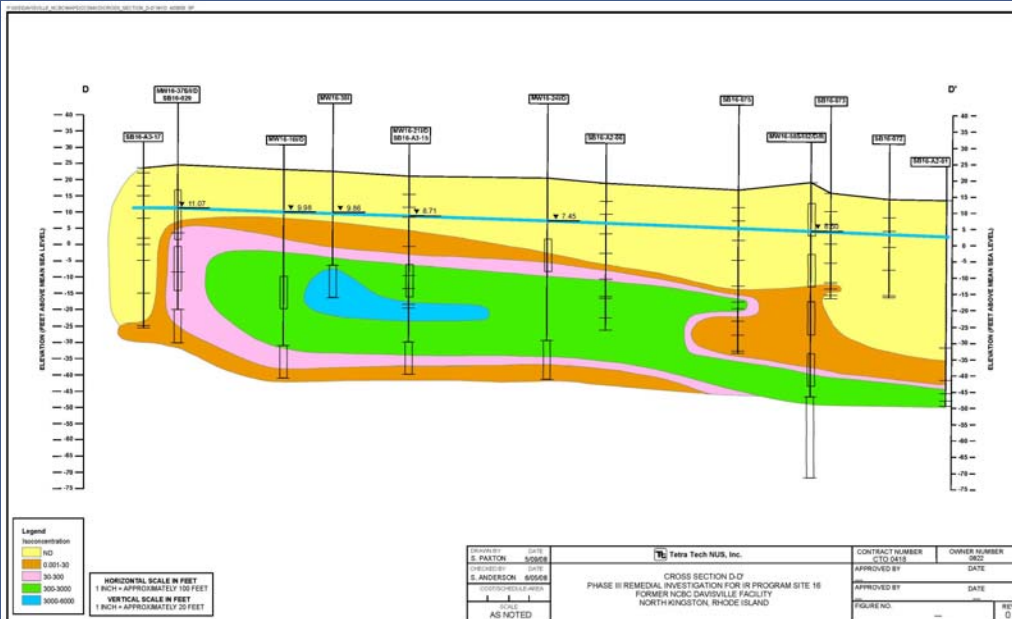




# Phase III Investigation Results using Color-Tec® Data for Soils



# Phase III Investigation Results using Color-Tec® Data for Soils



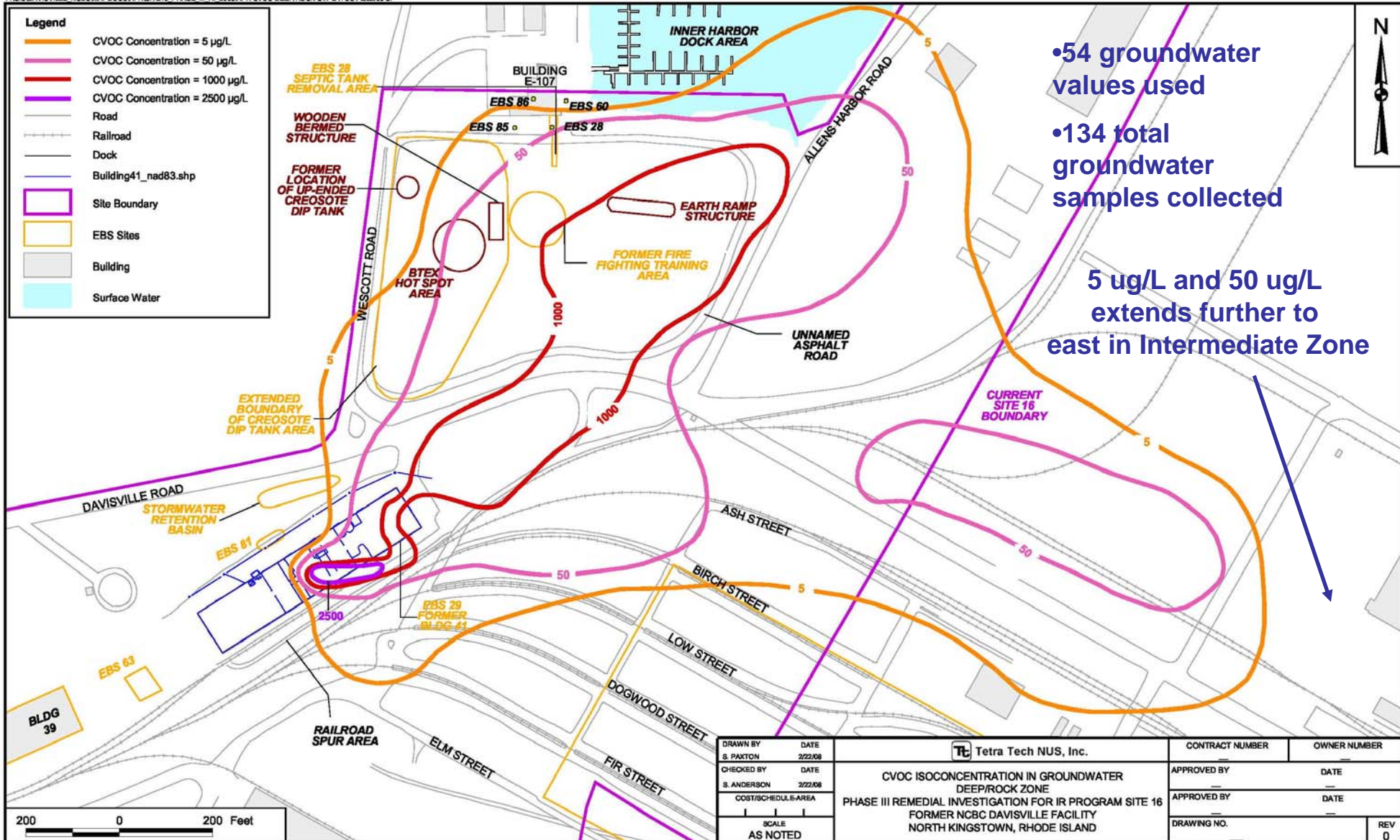
## Overall Conclusions of Soil Data

- CVOC much more spatially extensive and much more complicated
- Significant source(s) emanating from former Building 41
- Most data gaps have been filled in order to finalize RI



# Phase III Investigation Results for Groundwater - Laboratory Data for Deep and Upper Bedrock

PGIS\DAVISVILLE\_NCB\MAPDOCS\IR\SITE16 PHASE III RI 2008\APR CVOC DEEP/ROCK GW LAYOUT 2/22/08 SP





# Application of Color-Tec® Data to Delineate CVOC Soils Contamination and Plume

- Allowed for more precisely defined vertical extent of contamination (in unsaturated and saturated zones)
  - Demonstrated CVOC variability over short vertical distances (possibly due to changes in lithology/CVOC transport effects), transitioning from non-detects to highest impacted area, back to non-detects.

Sample ID	Sample Elevation (ft MSL)	Gastec Tube Type	Tube Value	Estimated Value (ug/kg)	Lab Value (ug/kg)
SB16-A3-06-SO-0102	27.5	LL	ND	ND	ND
SB16-A3-06-SO-0506	23.5	LL	ND	ND	
SB16-A3-06-SO-0809	20.5	LL	ND	ND	ND
SB16-A3-06-SO-1415	14.5	LL	ND	ND	
SB16-A3-06-SO-2122	7.5	LL	ND	ND	
SB16-A3-06-SO-2728	1.5	LL	ND	ND	
SB16-A3-06-SO-3031	-1.5	LL	0.1	16	3.9
SB16-A3-06-SO-3233	-3.5	L	7.7	860	500
SB16-A3-06-SO-3435	-5.5	M	50	12000	17000
SB16-A3-06-SO-3738	-8.5	LL	0.5	16	
SB16-A3-06-SO-4344	-14.5	LL	1.6	260	
SB16-A3-06-SO-4748	-18.5	LL	ND	ND	ND
SB16-A3-06-SO-5455	-25.5	LL	ND	ND	
SB16-A3-06-SO-5859	-29.5	LL	ND	ND	

# Application of Color-Tec® Data to Delineate CVOCs Soils Contamination and Plume

- Allowed for detection of low level CVOC concentrations only possible previously with lab analysis or more elaborate screening technologies

Sample ID	Sample Elevation (ft MSL)	Gastec Tube Type	Tube Value	Estimated Value (ug/kg)	Lab Value (ug/kg)
SB16-A3-14-SO-0102	21.5	LL	ND	ND	ND
SB16-A3-14-SO-0506	17.5	LL	ND	ND	
SB16-A3-14-SO-0910	13.5	LL	ND	ND	9.1
SB16-A3-14-SO-1213	10.5	LL	2.3	260	269
SB16-A3-14-SO-2122	1.5	LL	ND	ND	
SB16-A3-14-SO-2930	-6.5	LL	ND	ND	
SB16-A3-14-SO-3940	-16.5	LL	0.15	16	
SB16-A3-14-SO-4545	-22	LL	1.7	260	
SB16-A3-14-SO-4950	-26.5	LL	0.2	16	
SB16-A3-14-SO-5455	-31.5	LL	0.1	16	

# Conclusions from using Color-Tec® Field Screening: What did we learn??

- CVOC plume much more spatially extensive than previously understood, particularly in eastern portion of site (plume extending towards Narragansett Bay - especially in Intermediate zone).
- Vertical distribution of CVOC soil contamination and plume much more complicated than previously understood.
  - Preferential flow in more permeable lithologies.
- Significant source(s) identified in former Building 41 area, emanating from solvent recovery still operations and eastern portion - an area not previously considered due to lack of PID readings and limited historical sampling.
  - Current “hot spot” located downgradient of solvent recovery still, other “hot spots” may also exist (soils are 17000 ug/kg, groundwater is 7700 ug/L).
- Most data gaps have been filled in order to finalize RI
  - Data Gaps would likely still occur if Color-Tec® had not be used
    - Vertical distribution and comprehensive extent of plume would not be known.
    - Best samples may not have been selected for lab analysis since PID not as sensitive.



# Cost Savings and Efficiency using Color-Tec® Screening

Task	Color-Tec	Fixed-Base Laboratory
Equipment Costs	\$1,500	None
Cost per Analysis	\$10	\$100
Time to Prepare Samples for Analysis (includes packing, COC preparation, etc.)	< 5 minutes (no packing and shipping necessary)	1 hour per 10 samples
Shipping/Transportation Costs	None	\$75 per cooler
<b>Total Estimated Costs for 1300 soil samples</b>	<b>\$14,500</b>	<b>\$131,500</b>
Estimated time from sample collection to results available	approximately 10 minutes	No less than 10 to 14 business days

- Since a “traditional” Remedial Investigation would not include the collection of 1300 soil samples, additional costs and time may be incurred for such items as:
  - Preparation, Review and Response to Comments on Data Package
  - DQO meetings and preparation of QAPP Addendum
  - Additional field work and fixed-base laboratory costs
- *Color-Tec® data cost is less than 10 percent the cost of fixed-base laboratory and can avoid costly future addendum work!*

# PROs and CONs using Color-Tec® Screening Methodology

## PROs:

- High fixed-base laboratory verification rates.
- 10 ug/kg effective detection limit in soil (98.9% confidence). Low level detection of CVOCs in unsaturated and saturated zone soils. 5 ug/L effective detection limit for groundwater.
- Reasonable correlation between field screening and lab data.
- Methodology facilitates *VERTICAL* and horizontal delineation of contamination.
- Methodology demonstrates greater sensitivity than headspace or real-time PID readings.
- Easy, Fast and Cheap!!
- Petition regulatory reviewers to accept data for contaminant delineation with limited confirmatory sampling (particularly non-detect results)??

## CONs:

- Interferences with other CVOCs and VOCs:
  - BTEX can significantly suppress response.
- Relatively new, non-standard method (obtaining regulatory approval may be difficult).
- Potential need for pilot study to demonstrate site-specific efficacy.

## Points of Contact

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All Technical Questions and Comments Welcome!

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