# Lessons Learned from Using Mass Discharge as a Regulatory Compliance Goal

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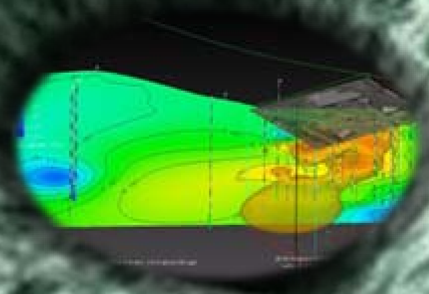
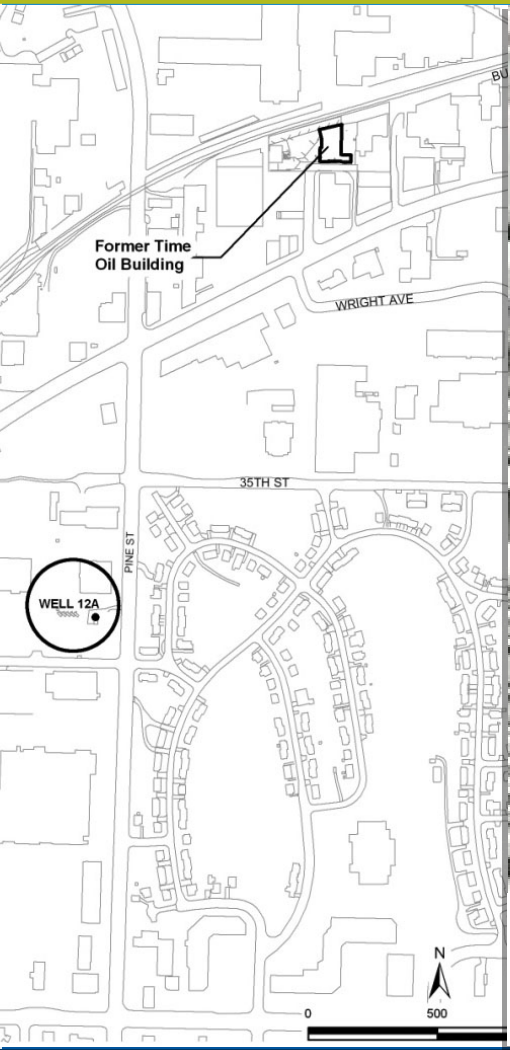
CDM Smith

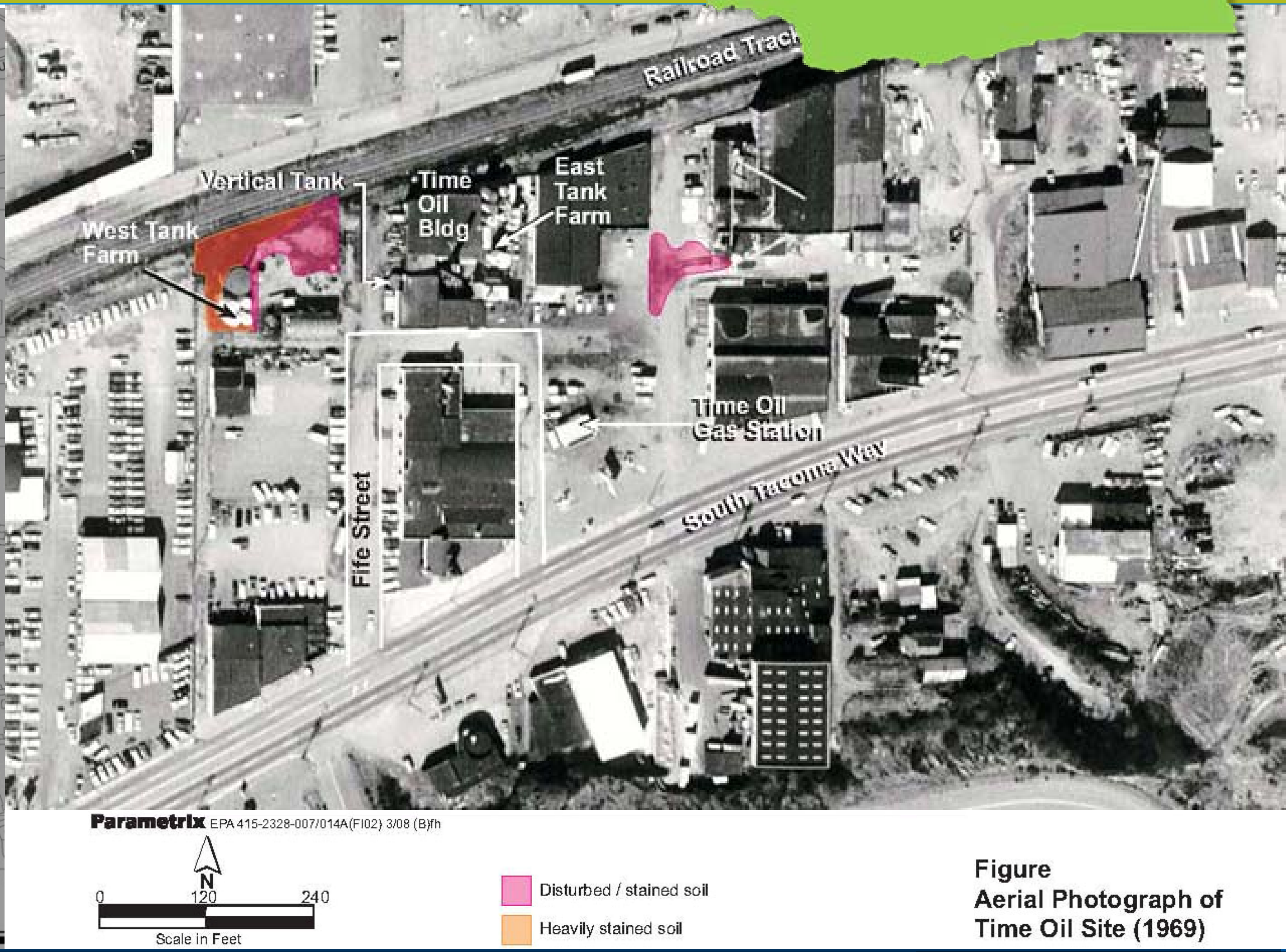
# Premise

- Complex sites, such as those containing dense nonaqueous phase liquids (DNAPLs), are some of the most difficult to clean up.
- Often, the case for clean up to stringent groundwater criteria is difficult to make.
- How do you efficiently construct a remedy and set goals at these Sites?



# Well 12A Superfund Site

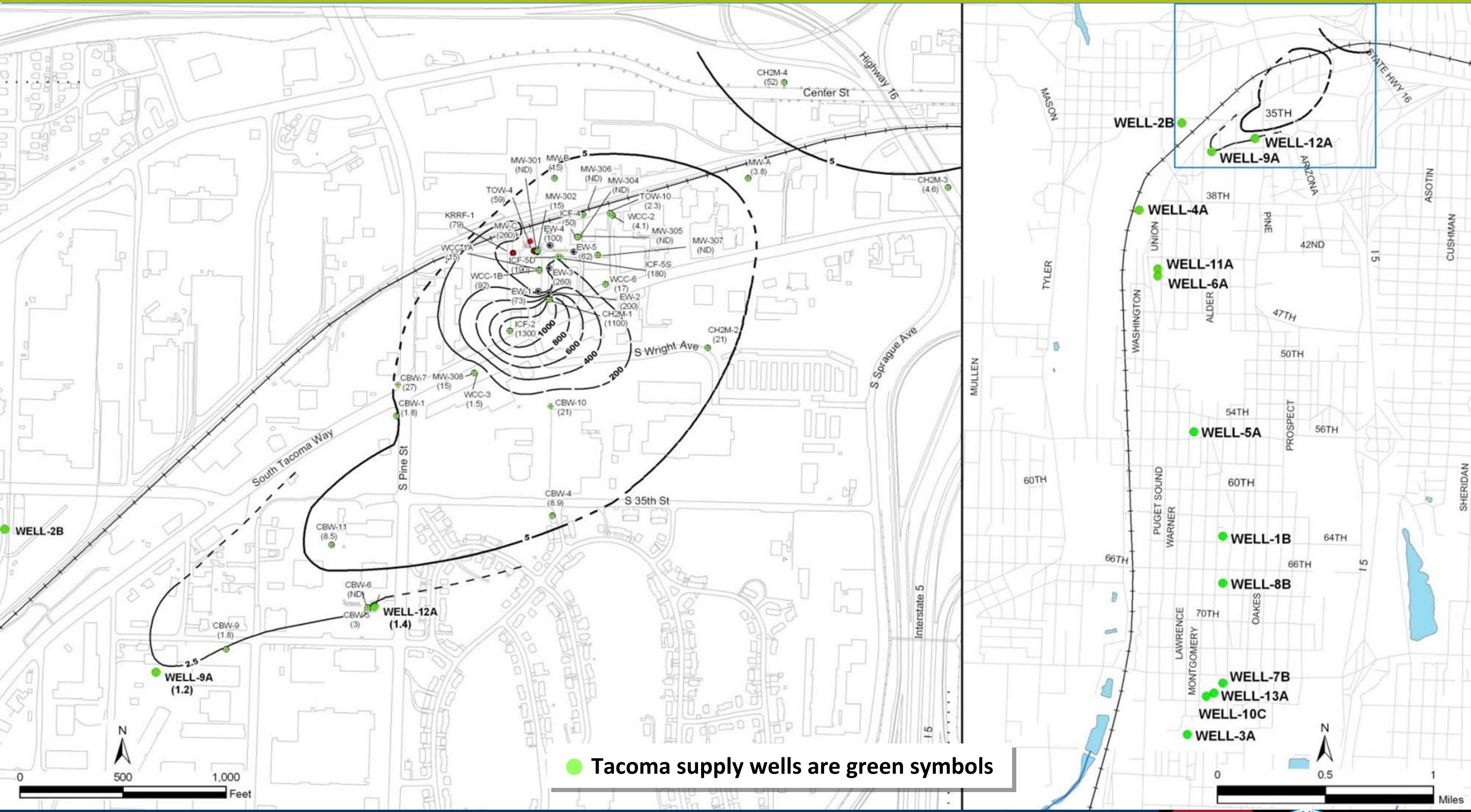




*Developing Successful Management Strategies for Complex Contaminated Sites*

# Contamination Summary

- Six primary contaminants of concern (COCs) in soil and groundwater
  - Tetrachloroethene (PCE)
  - Trichloroethene (TCE)- ubiquitous
  - cis-and trans-1,2 Dichloroethene (DCE)
  - Vinyl Chloride (VC)
  - 1,1,2,2-tetrachloroethane (PCA)
- Additional COCs include total petroleum hydrocarbons (TPH) including nonaqueous phase liquid (NAPL), lead, polychlorinated biphenyls (PCBs)
- Time Oil Building hazardous building materials including Asbestos, PCBs, Lead, Mercury

# 2D Perspective: TCE Plume

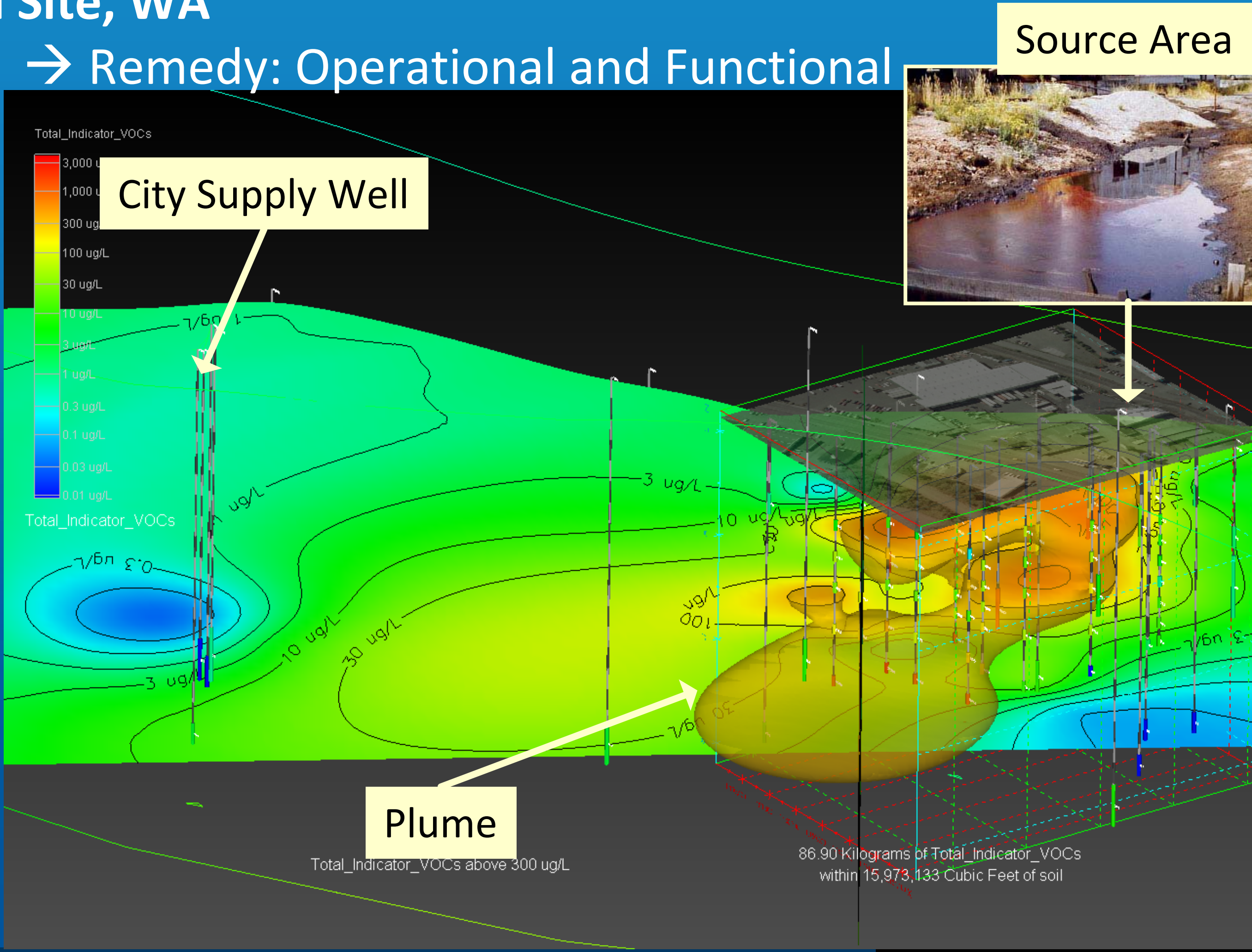


# Well 12A: Mass Discharge (Md) as an Interim Remedial Goal for Source Area Treatment

## Well 12A Superfund Site, WA

Performance Metric → Remedy: Operational and Functional

- **Focused Feasibility Study evaluation:** *Reduce source strength (Md) by 90%, MNA sufficient to achieve compliance*
- **ROD amendment:** *Multi-component remedy — reduce source discharge Md by 90% and transition technology (if necessary)*

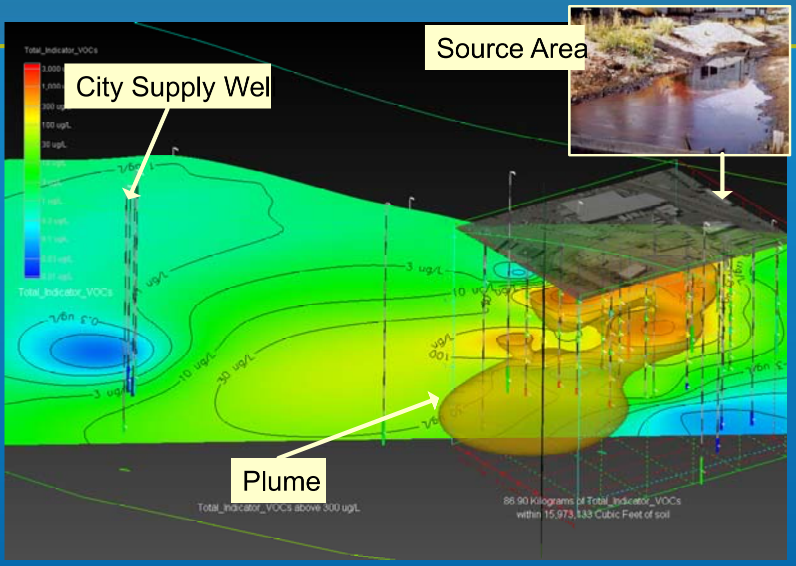


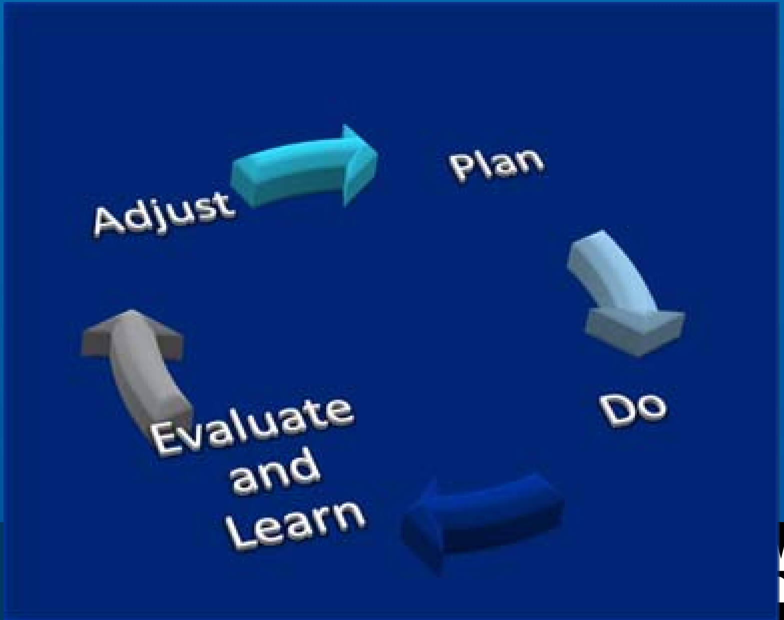
# Well 12A: 2009 ROD-Amendment #2, Remedial Action Objectives

- **Source Goal:** reduce risk from contaminated surface soils and achieve a contaminant discharge reduction of at least 90% from the Source to the dissolved-phase contaminant plume.
  - Remedy operational and functional.
  - Operations and maintenance of the Well12A OU1 will be turned over to the State of Washington
- **Multi-component remedy technologies to achieve this goal:**
  - **Excavation- remove tars and underground storage tanks**
  - **In situ thermal remediation (ISTR)- address NAPL**
  - **Enhanced anaerobic bioremediation (EAB)- address concentrated plume**
  - **Groundwater extraction and treatment system (GETS)- existing source pump and treat**

# Well 12A: Mass Discharge (Md) as an Interim Remedial Goal for Source Area Treatment

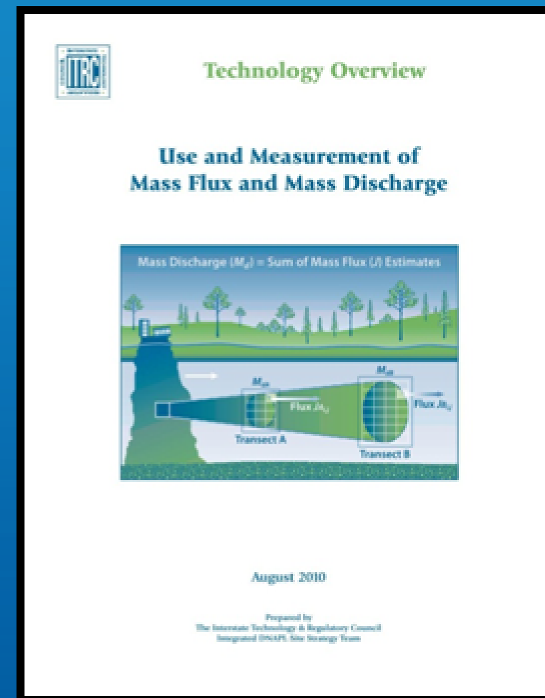
- ROD provided the framework but the specifics had to be developed and agreed to:
  - Getting concurrence on the mass discharge method
  - Getting concurrence on where and how technologies applied



# Five Methods for Mass Discharge

- ***Method 1:*** Transect Method
- ***Method 2:*** Well Capture/Pumping Methods
- ***Method 3:*** Passive Flux Meters
- ***Method 4:*** Using Existing Data (Isocontours)
- ***Method 5:*** Solute Transport Models


Technology Overview

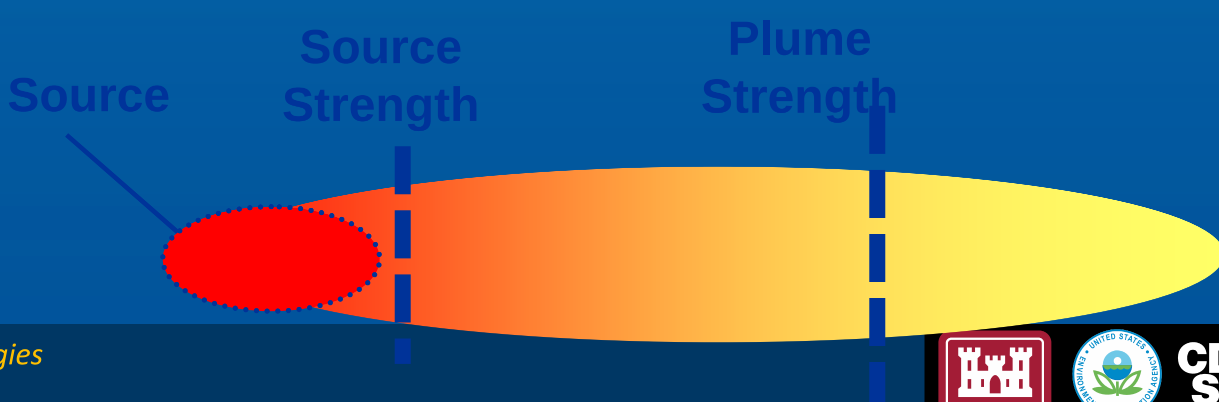
Use and Measurement of
Mass Flux and Mass Discharge

Mass Discharge ($M_d$) = Sum of Mass Flux ($J$) Estimates

August 2010

Prepared by
The Interstate Technology & Regulatory Council
Integrated DNAPL Site Strategy Team

***All methods are "ready to go"***



# Developing a Robust Conceptual Site Model

- Delineate the soil contamination extent in the vicinity of Time Oil building to reduce uncertainty in the CSM and support delineation of treatment zones.
- Evaluate contaminant distribution relative to site stratigraphy.
- Evaluate transport pathways and mass flux and discharge.
- Target treatment areas based on maximizing contaminant mass removal and mass discharge.
- Evaluate hydraulic groundwater system.

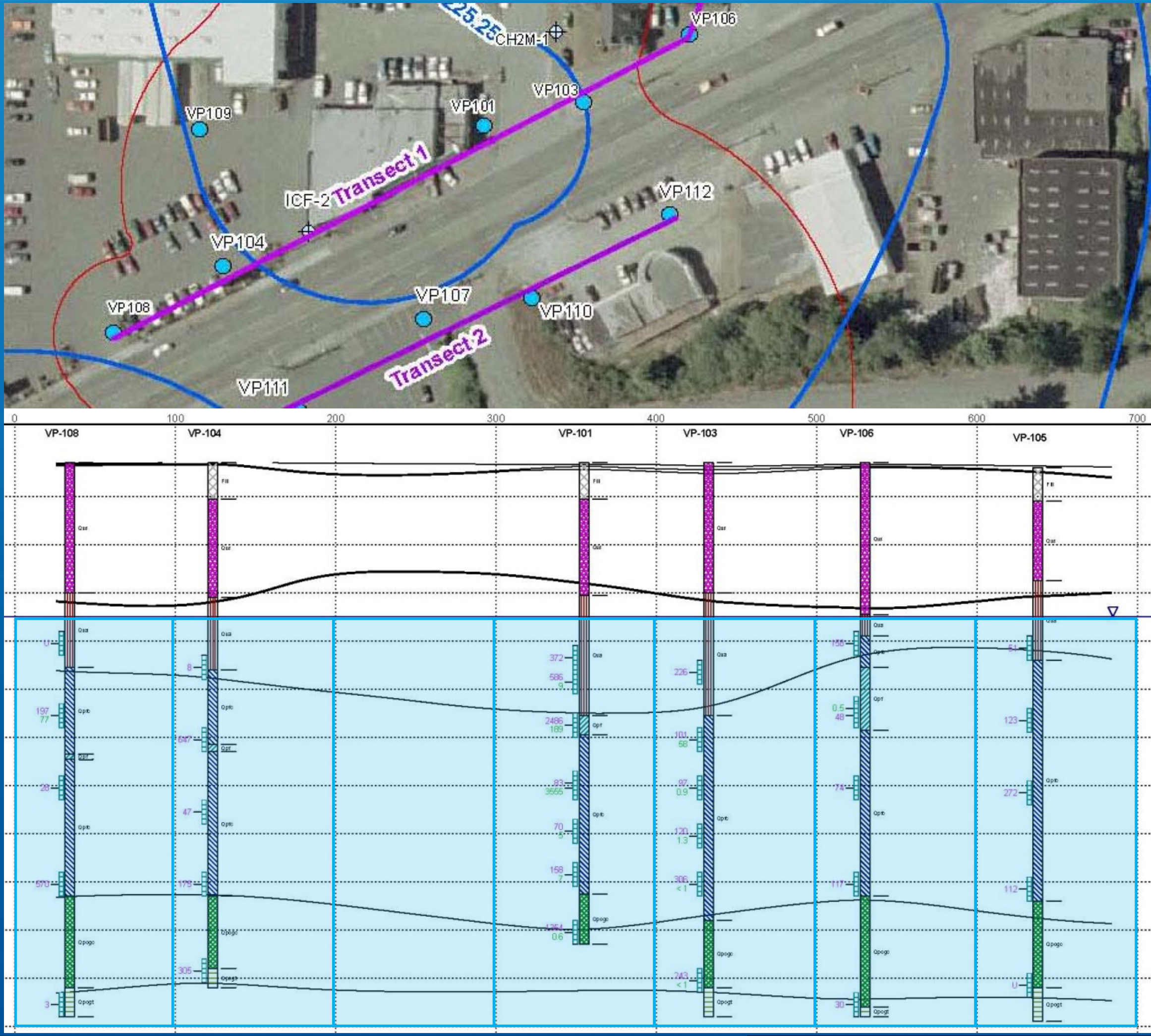
# Calculating Mass Discharge: Transect Method

**Steps for Well 12A:**

1. Draw polygons (use Thiessen)
2. Calculate Darcy velocity (q) for each polygon: q=K•I
3. Characterize polygon flux ($Mf=q•C_n$)
4. Determine area (W•b = A)
5. Evaluate mass discharge:

$$M_d = \Sigma (Mf• A_n)$$

$M_f$ = Mass flux
$M_d$ = Mass discharge
$C_n$ = concentration in polygon n
$A_n$ = Area of segment n



# Summary of Site Characterization

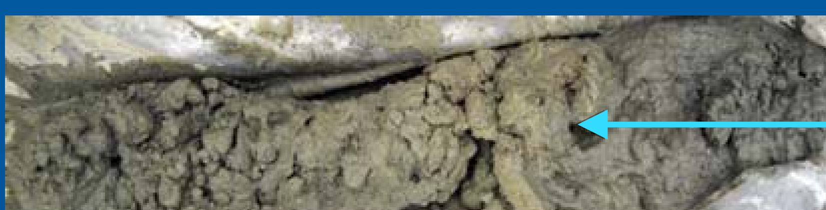
- 34 soil borings to reduce uncertainty and delineate sources
- 12 locations for vertical profiling
- Depth discrete samples:
  - Groundwater
  - Soil
  - Slug testing
  - Stratigraphy
- Gradient assessment

# Vertical Characterization

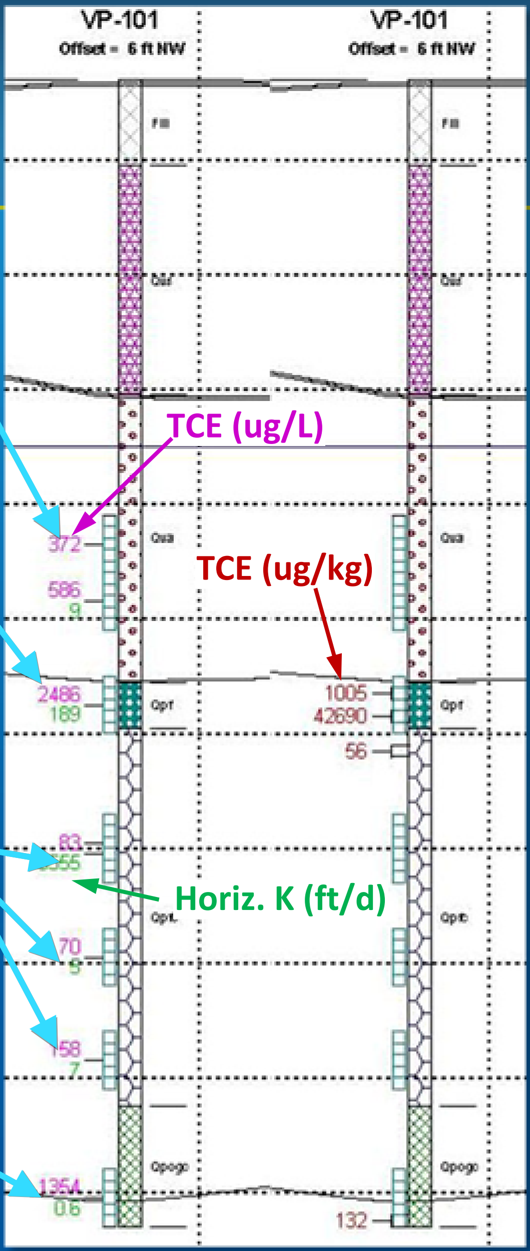
**Qva:** medium grained sand with rounded gravel and lesser amounts of silt

**Qpf:** fine-grained silt layer

**Qpfc:** highly variable, coarse grained sand and gravel with varying amounts of silt and intermittent layers of saturated silty gravel. Silt content generally observed to increase with depth.



**Qpogc:** gravel silt and slightly clayey fines



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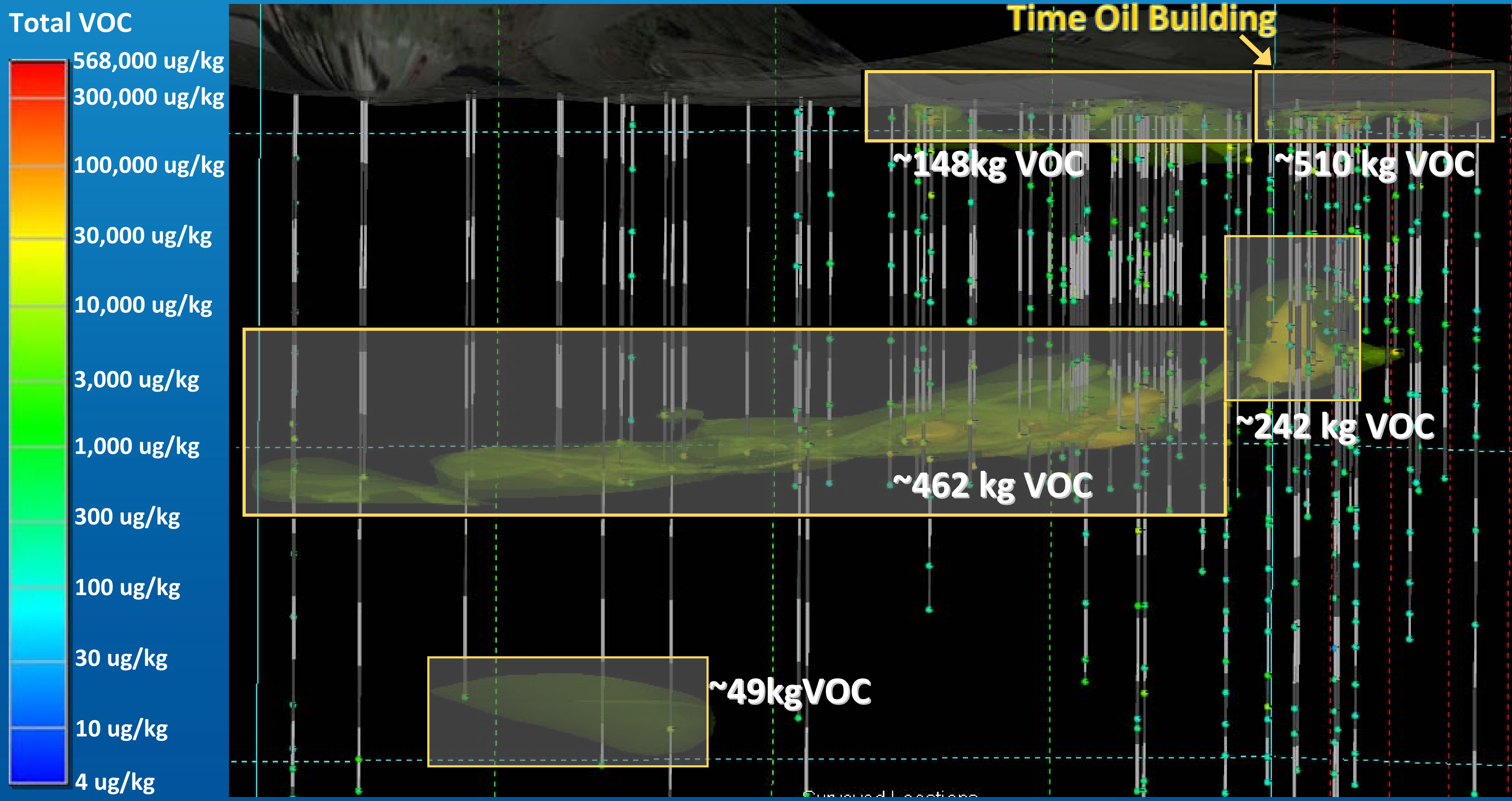
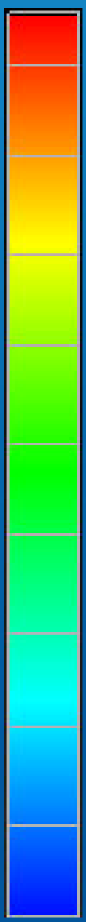
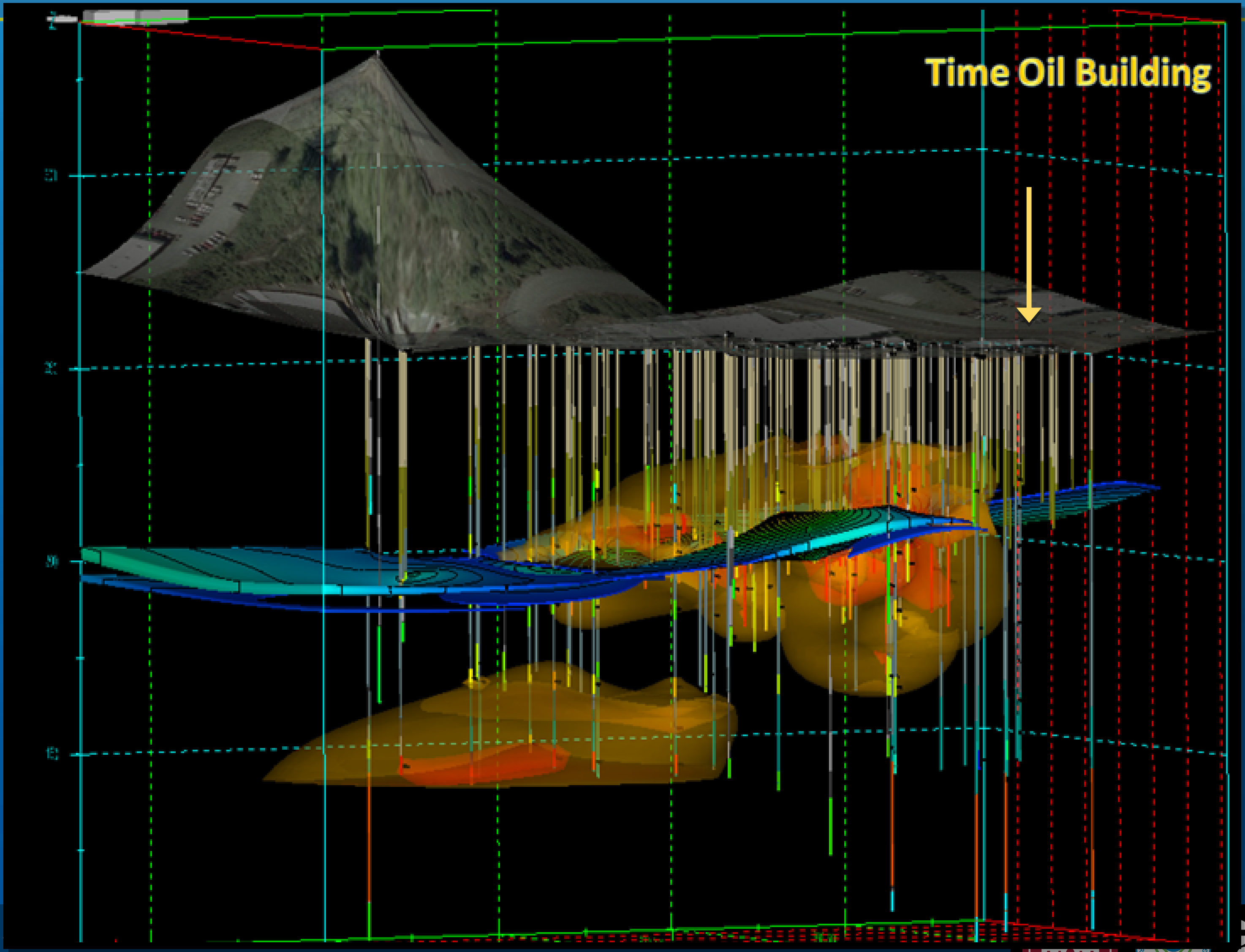
# Cross Section of Soil Contamination



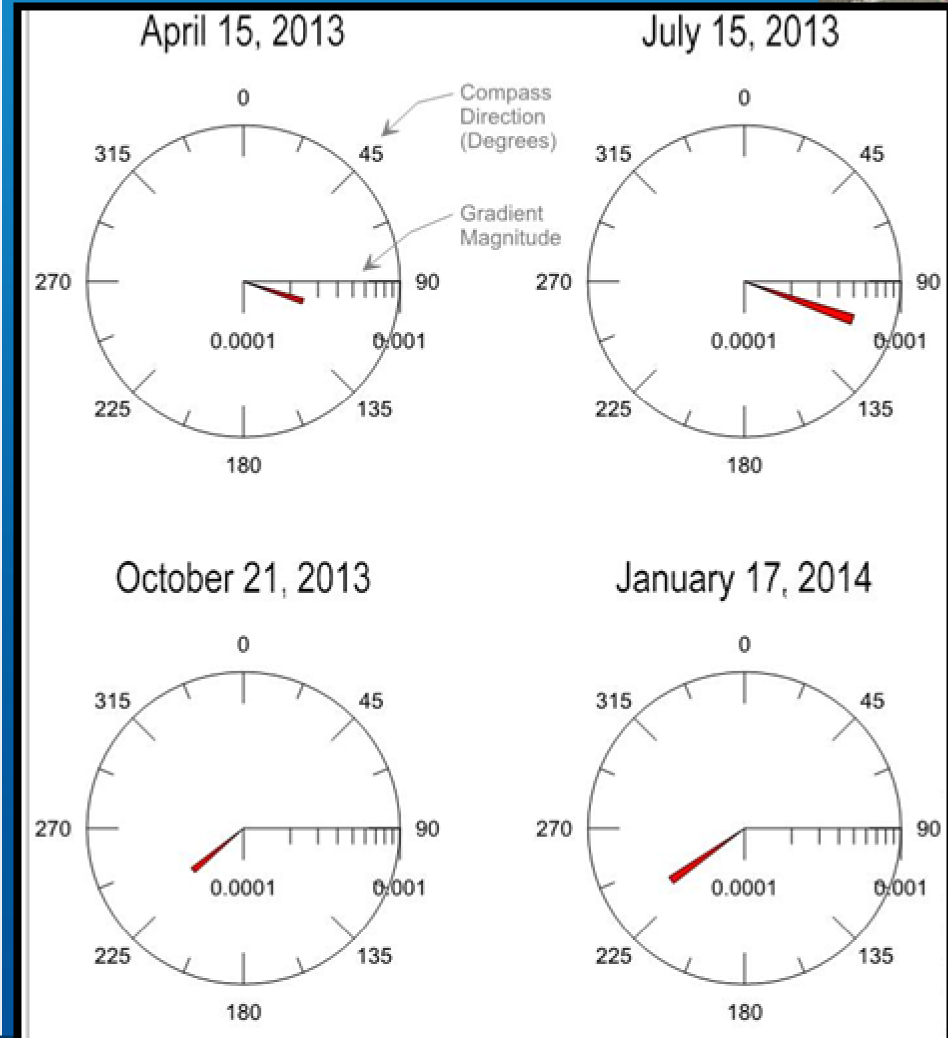
# Cross Section of Contaminant Plume

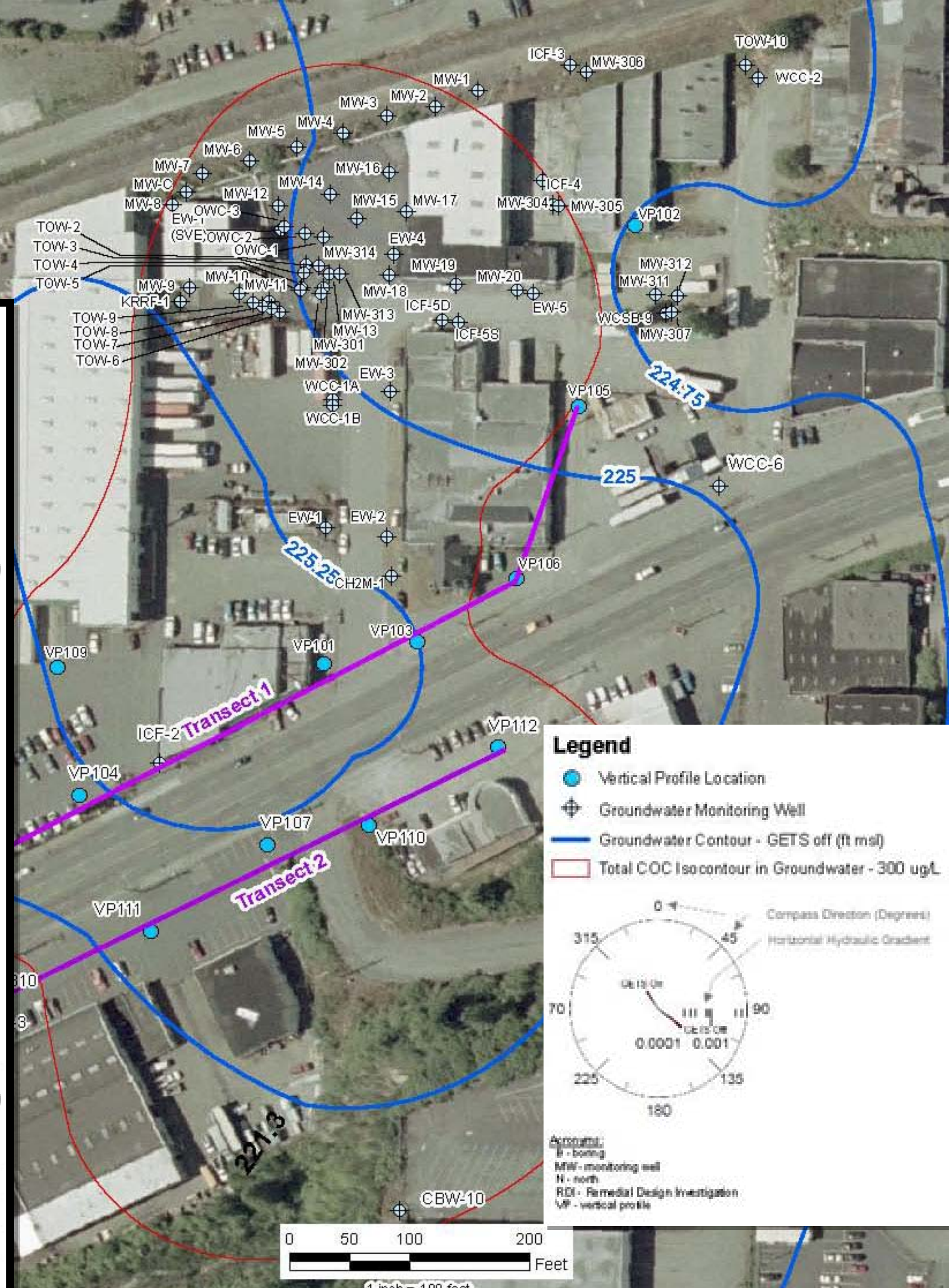
Total VOC



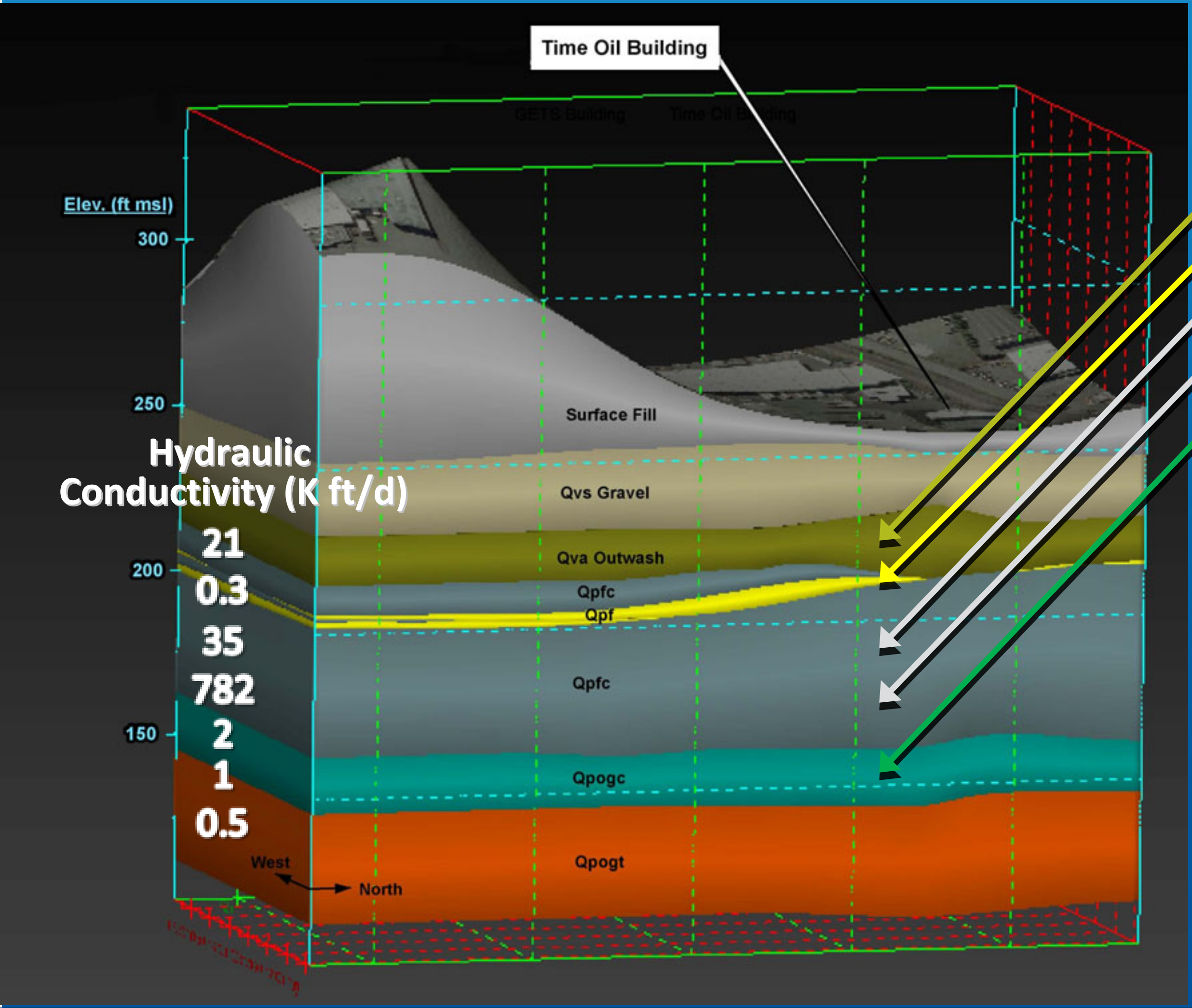



# Site Gradient



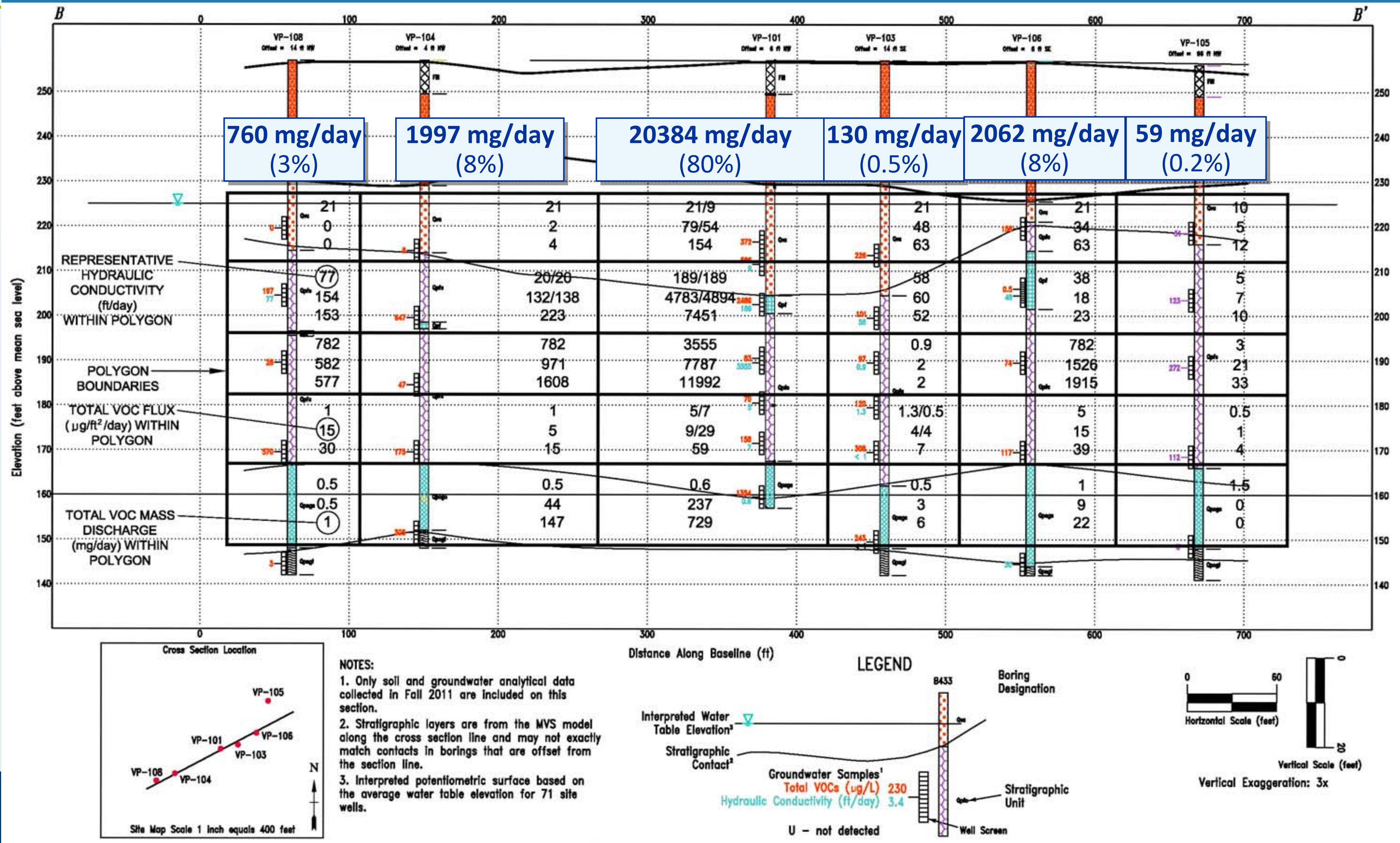



# Mass Discharge Across Transects




| | Total VOC MD (kg/yr) | | % of Total MD |
|---|---|---|---|
| **Transect 1** | | | |
| Qva | 0.1 | | 1% |
| Qpfc1/Qpf | 2.9 | | 31% |
| Qpfc2 | 5.9 | 96% | 64% |
| Qpfc3 | 0.06 | | 1% |
| Qpogc | 0.3 | | 4% |
| Total | 9.3 | | |
| % of Total | | | |
| **Transect 2** | | | |
| Qva | 0.01 | | 0.4% |
| Qpfc1/Qpf | 0.2 | | 7% |
| Qpfc2 | 1.7 | | 57% |
| Qpfc3 | 0.1 | | 3% |
| Qpogc | 1.0 | | 33% |
| Total | 3.0 | | |

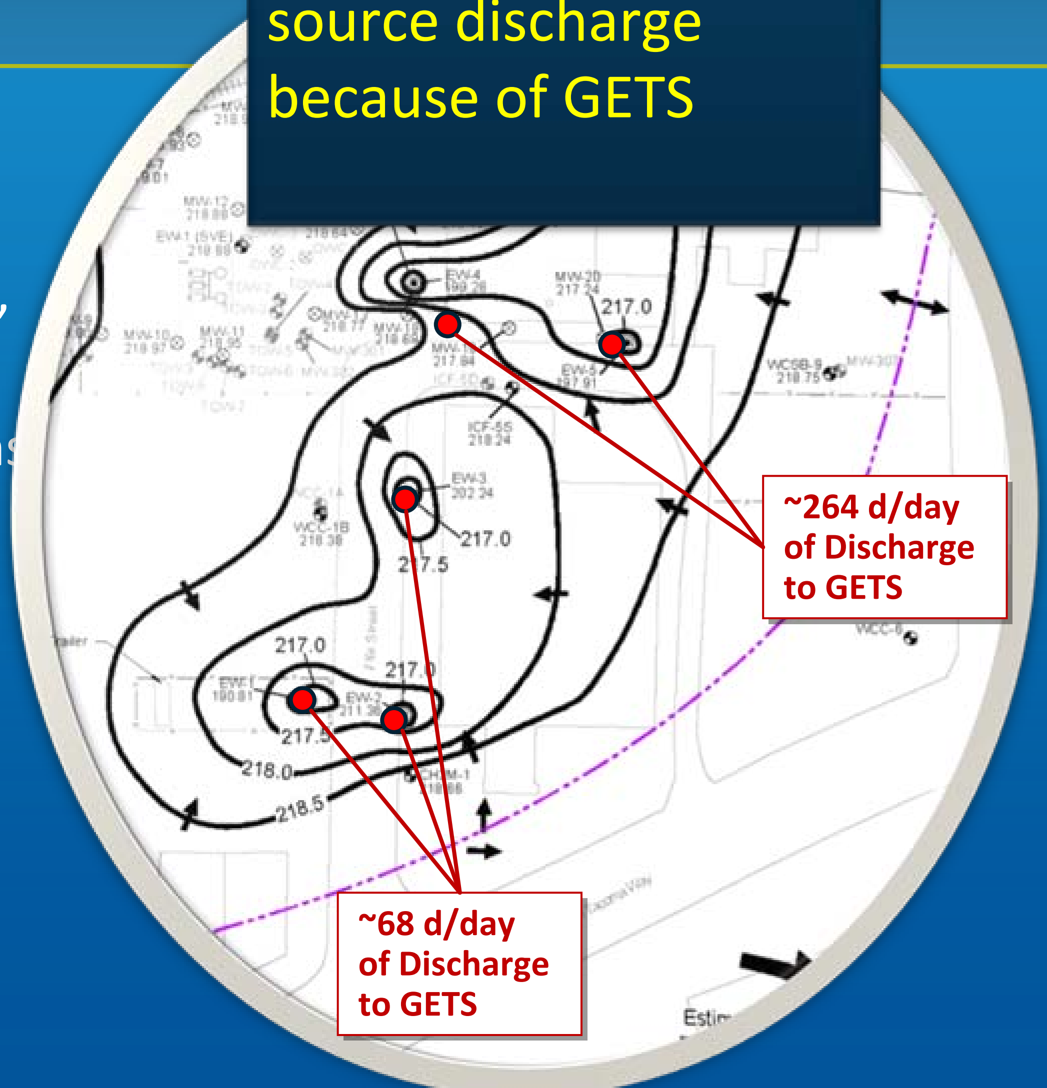
# Transect 1 TOTAL DISCHARGE: 25 G/DAY



# Initial Mass Discharge Evaluation with GETS

- Groundwater extraction and treatment system (GETS) constructed in 1988 with EW-1, in 1995 system was expanded.
- 1988 – 2011: 860 million gallons of groundwater and 18,625 lbs VOCs extracted/treated
  - EW-1, 40 gpm
  - EW-2, 8-16 gpm
  - EW-3, 7-9 gpm
  - EW-4, 6-15 gpm
  - EW-5, 6-12 gpm

Transect not representative of source discharge because of GETS



# Well Capture Mass Discharge Calculation

Nichols and Roth, 2004

**Measure Q, $C_{well}$ from well**

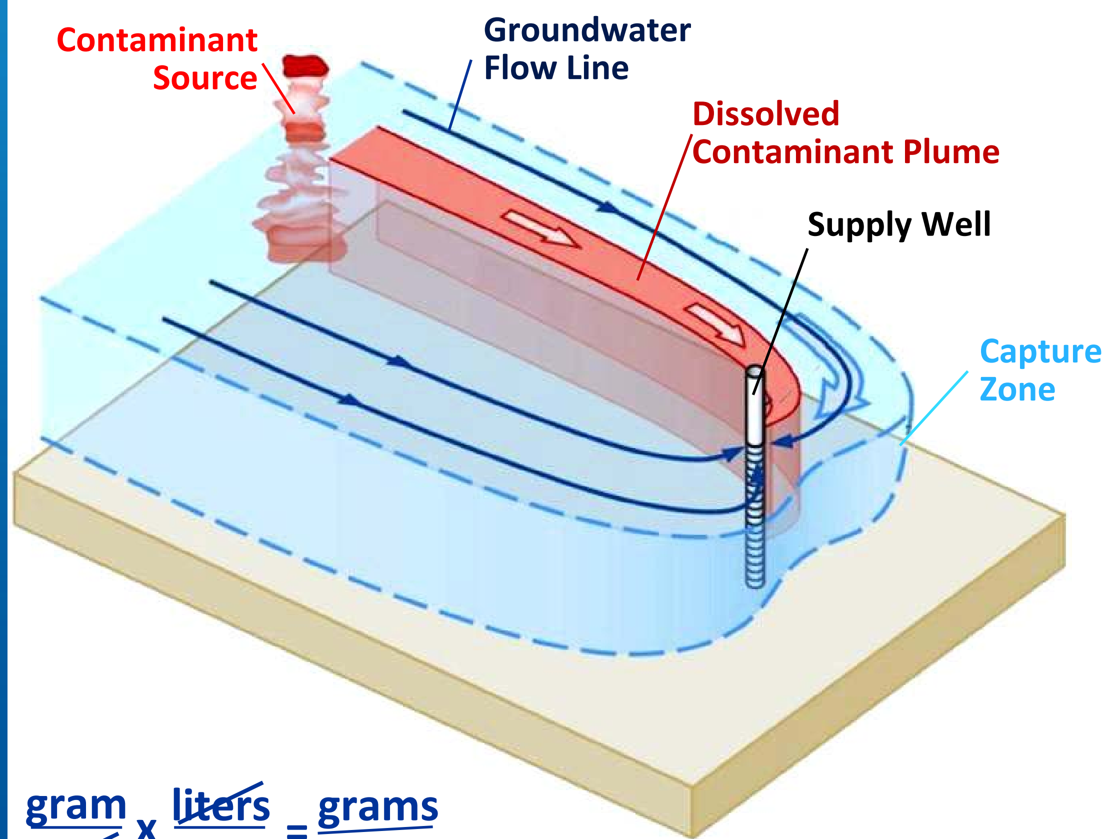
Calculate mass discharge based on total capture of plume by pumping system

$$M_d = Q \times C_{well}$$

$M_d$ = Mass discharge (grams per day)

$C_{well}$ = concentration in recovery well effluent (grams per liter)

Q = Well pumping rate (liters per day)




$$\frac{\text{gram}}{\cancel{\text{liter}}} \times \frac{\cancel{\text{liters}}}{\text{day}} = \frac{\text{grams}}{\text{day}}$$

# Developing a Strategy for Determining Baseline Mass Discharge using GETS Pumping Test

## *Goals:*

- Determine when adequate data has been collected to support a conclusion that mass discharge are stable and a baseline measurement can be agreed to.
- Once baseline conditions are stable within an ***acceptable degree of uncertainty***, propose a baseline mass discharge measurement and appropriate uncertainty boundary for consideration and approval by the team.

# Strategy for Determining When GETS is Stable

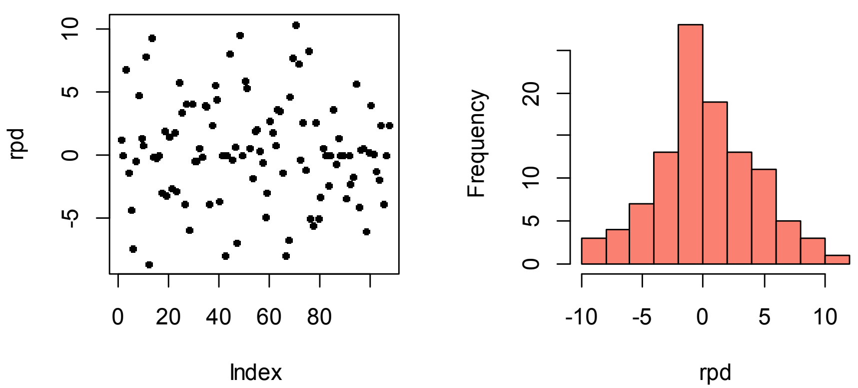
1. Define what the analytical variability in the measurements,
2. Define what the intrinsic variability is in collecting GETS samples (variability in sampling and analysis),
3. Determine tolerance for the variability in the data,
4. Define when the data has reached a point where the mass discharge measurements are stable, i.e. measurements are within the acceptable range of variability.

# Step 1: Relative Percent Difference Analysis

- Metric for establishing attainment of steady-state conditions is the relative percent difference (RPD) between successive measurements (*a*, *b*):

$$RPD = \frac{a-b}{(a+b)/2} \times 100$$

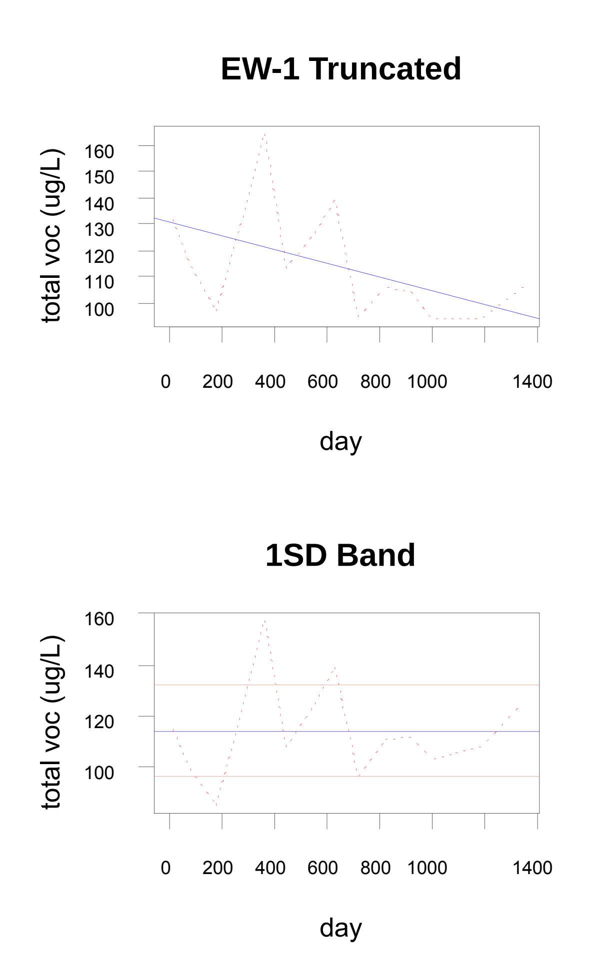
- Measured RPD may be compared with a threshold RPD. Used replicate data available for SP-2.
- An analysis of the *n* = 107 paired SP-2 and SP-2 duplicate dataset, after removal of two outliers.




- ***Resulted in RPD ±10 for total VOC concentrations***

# Step 2 cont: Variability in Sampling the GETS

| Well | Total VOC Mean (ug/L) | 1 SD | RPD |
|---|---|---|---|
| **SP-1** | 792.8 | 146.8 | **16.9** |
| **EW-1** | 114.2 | 17.8 | **14.5** |
| **EW-2** | 423.0 | 66.5 | **14.6** |
| **EW-3** | 843.6 | 111.4 | **12.4** |
| **EW-4** | 3449.5 | 805.0 | **20.9** |
| **EW-5** | **3672.8** | **799.0** | **19.6** |



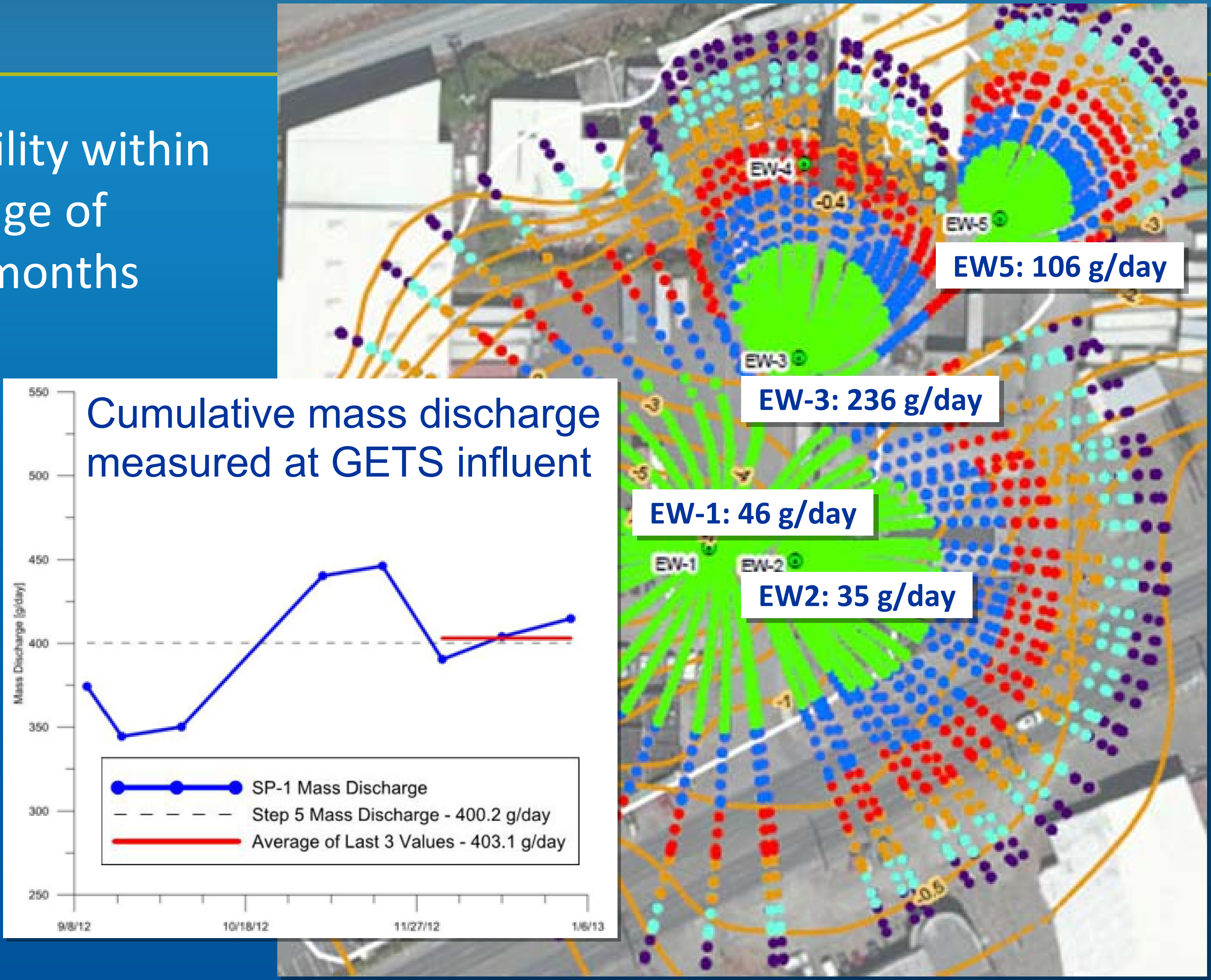
# Step 3: Determine tolerance for variability in the data.

- Variability in analysis of replicate samples: RPD: 10%
- Variability in sampling and analysis of the GETS:
  - SP1 RPD: ~17%
  - Extraction wells EW-1, -2, -3, -5 RPD: ~12-20%
- Also Variability in Pumping Rates:
  - Define acceptable range of pumping rates outside target (pumping must occur within 10% of target flow rate over interval).
  - Use target rates to actually calculate mass discharge.

# Mass Discharge Measurement for Source Area

Data reached stability within the acceptable range of variability after 3 months of pumping

- EW-1, 80 gpm
- EW-2, 22 gpm
- EW-3, 12 gpm
- EW-5, 7 gpm



# Mass Discharge Method: Pump Test Pros

- Infrastructure is already in place and can use the existing GETS system.
- Better integrated measure of mass discharge that accounts for a larger portion of the source treatment area.
- Cost for measurements is minimal over routine GETS O&M.
- Metric will be less affected by seasonal changes and pumping at Well 12A.
- Measurements can be taken during or nearly immediately after treatment.
- Metric directly relates to timing of GETS shutdown.

# Mass Discharge Method: Pump Test Cons

- Significant changes in flow field requires equilibration period.
- Inherent variability in measurements must be accounted for in determining criteria for collecting a measurement.
- Must define specific criteria (flow and concentration) that indicate that the target zone is getting captured and the system is stable for pre- and post-RA measurements.
- GETS system may need to be operated for several months at a time to achieve stabilization, especially with significant changes in operation.

# Mass Discharge Methods: Transect Method Pros

- Relatively easy to collect measurements (just groundwater samples).
- We have quantified one of the more difficult parameters (hydraulic conductivity) with reasonable certainty.

# Mass Discharge Methods: Transect Method Cons

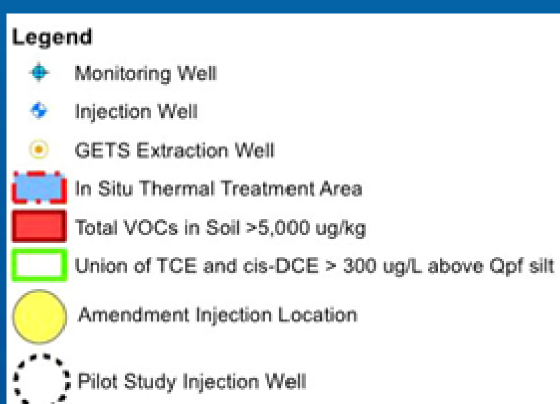
- Significant site heterogeneity requires more intensive transect and sample density to represent mass discharge.
- There is significant variability in the vertical stratification of contaminants- need to evaluate multiple depths.
- With the operation of the GETS, TM underestimates mass discharge and a significant (likely years) timeframe to achieve equilibrium.
- Significant shift in the gradient under ambient (gradient direction approximately southwest), with Well 12A operating (shift in gradient to the southeast) and with the GETS operating.
- Variability in the results of the method due to shifting gradients may be difficult to capture and precisely quantify over time, also makes placing transect difficult.

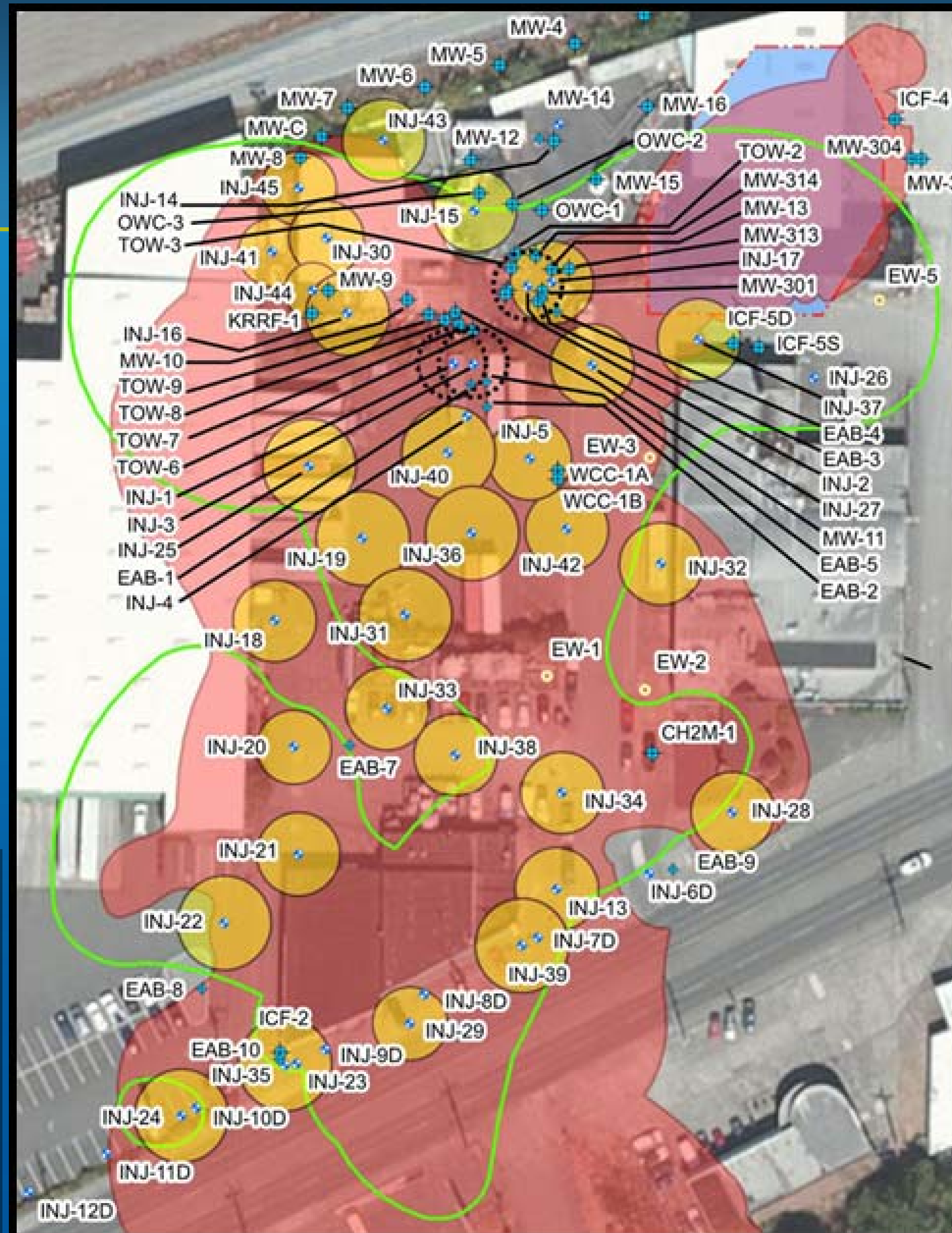
# Consensus: Pump Test Method for Compliance

- Pumping Rates:
  - Acceptable range- within 10% of target flow rate over interval.
  - Use target rates to actually calculate mass discharge.
- Use mean of last 3 sampling events to calculate mass discharge- ~403 g/d for baseline.
- Post-RA measurement: define target mass discharge value establish criteria for stable/declining trends and acceptable RPDs.
- Strategy for post-RA measurement presented in the baseline mass discharge memorandum

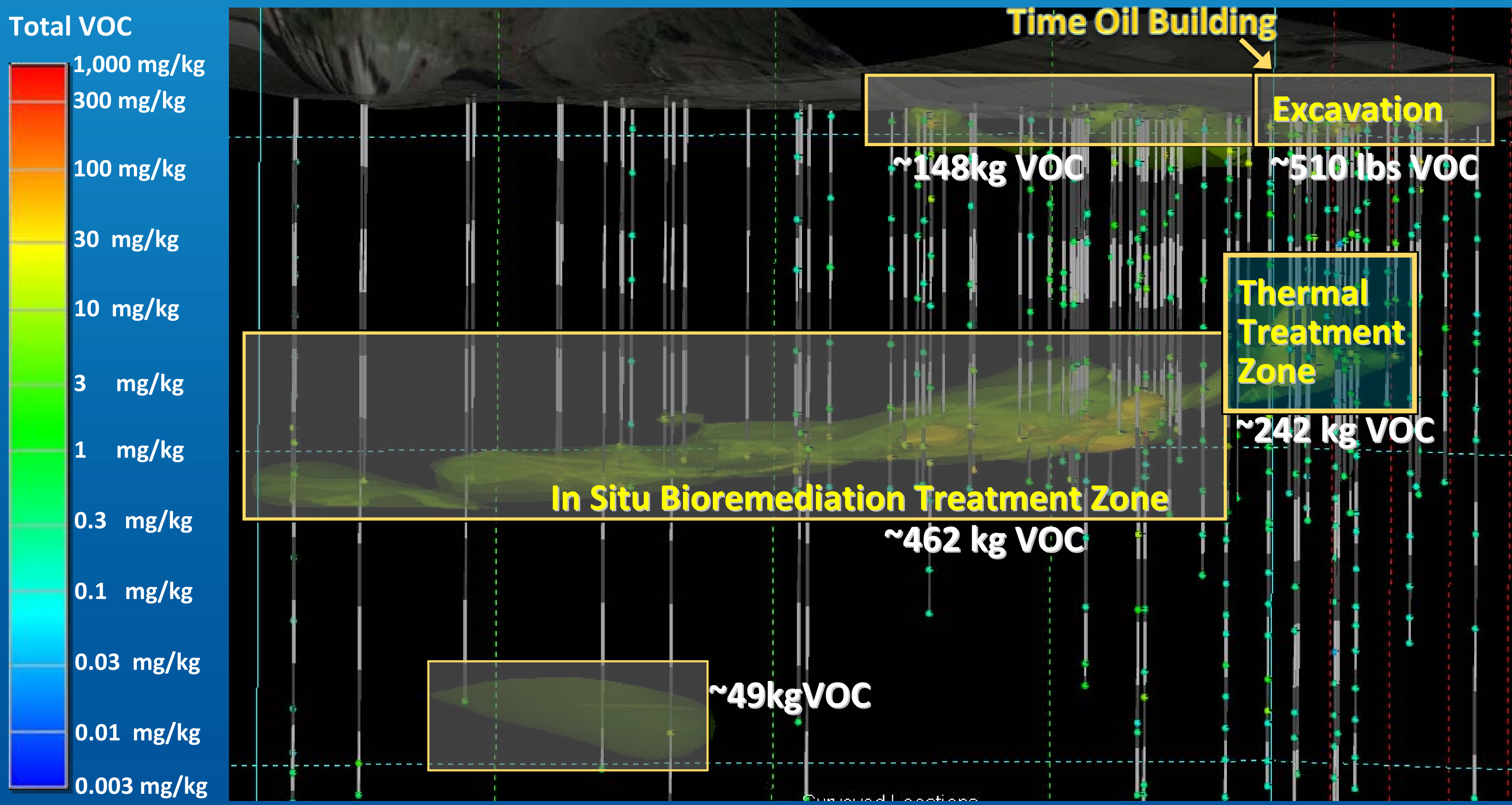
# Mapping Technologies

| Zone | Surface Area ($ft^2$) | VOC Mass (kg) | Discharge to GETS |
|---|---|---|---|
| Excavation Zone | 3819 | 510 | NA |
| Thermal Treatment Zone | 13,000 | ~242 | 224 g/day (53%) |
| *In Situ* Bioremediation Zone | 162,000 | ~462 | 199 g/day (47%) |



# Treatment Zones: Selecting Vertical Intervals



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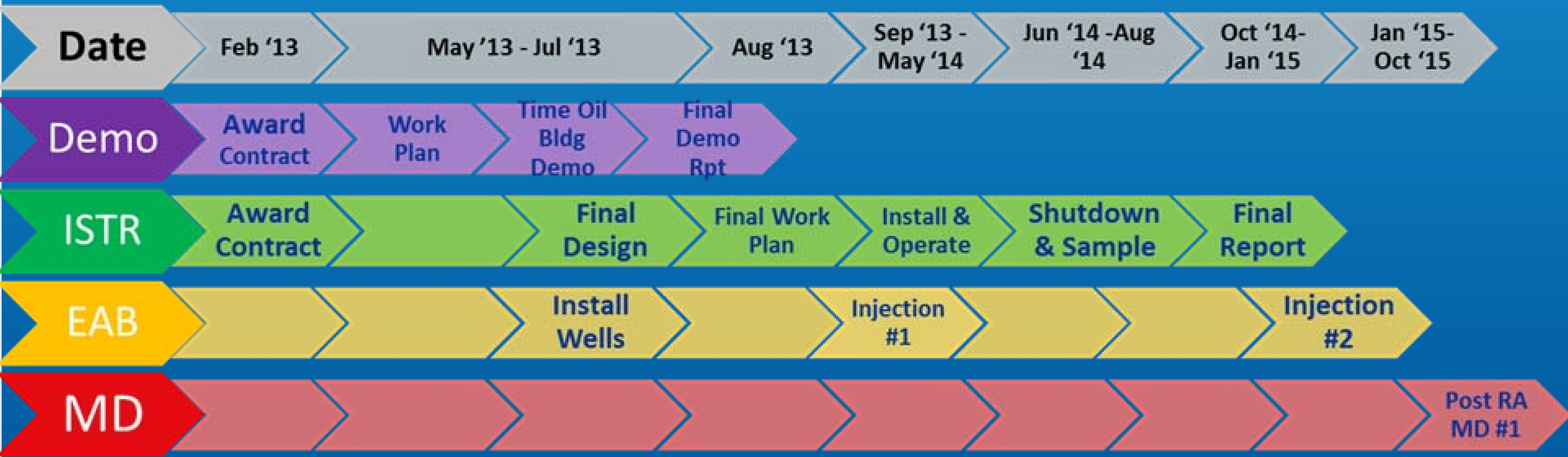
# Remedial Strategy - Schedule




Notes:

Bldg-Building

Demo- Time Oil Building Demolition

Rpt- Report

ISTR- In Situ Thermal Remediation

MD- Mass Discharge assessment for Compliance

RA- Remedial Action

EAB- Enhanced Anaerobic Bioremediation

# Acknowledgments

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