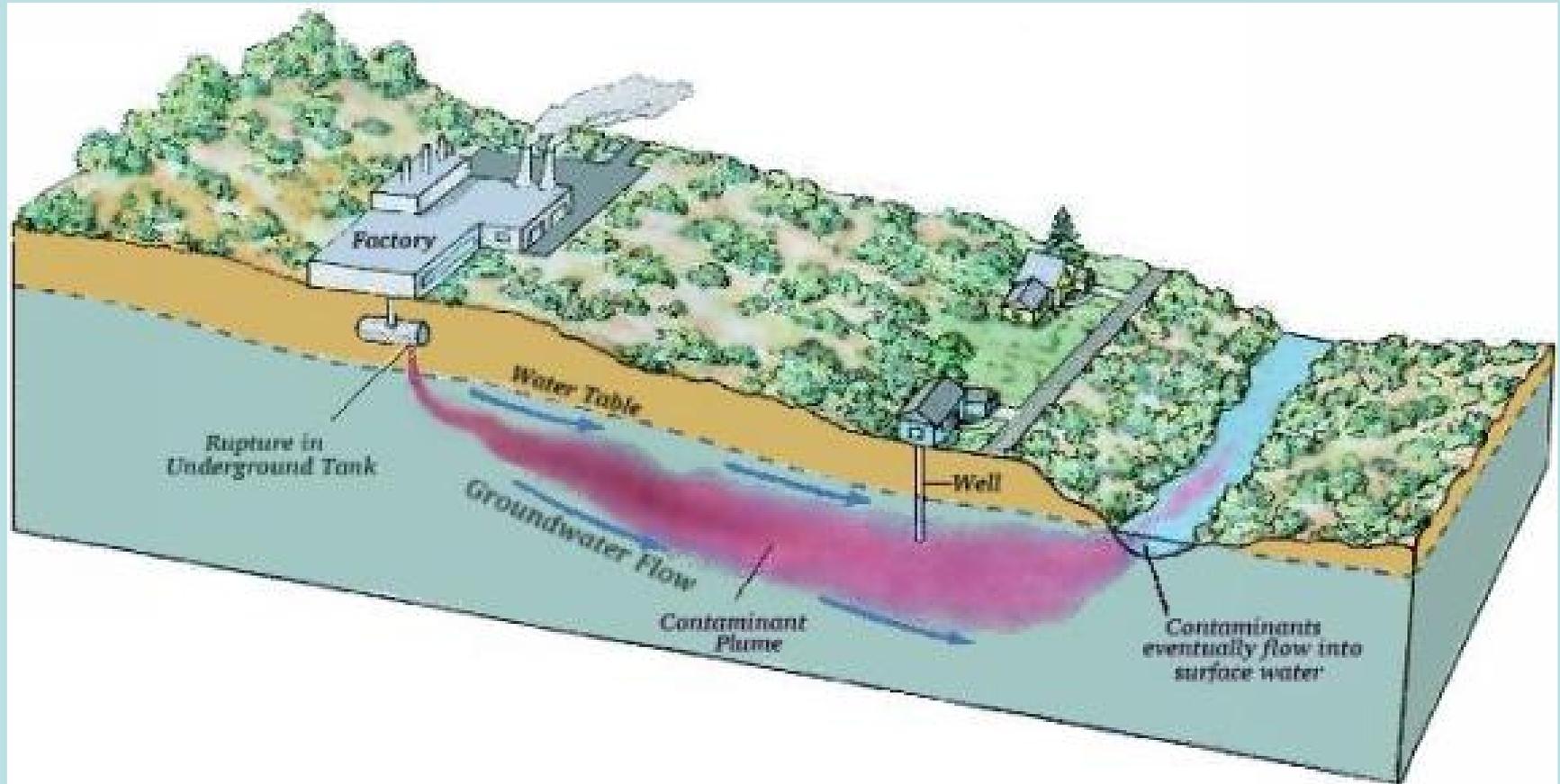


Evaluation of Plume Stability

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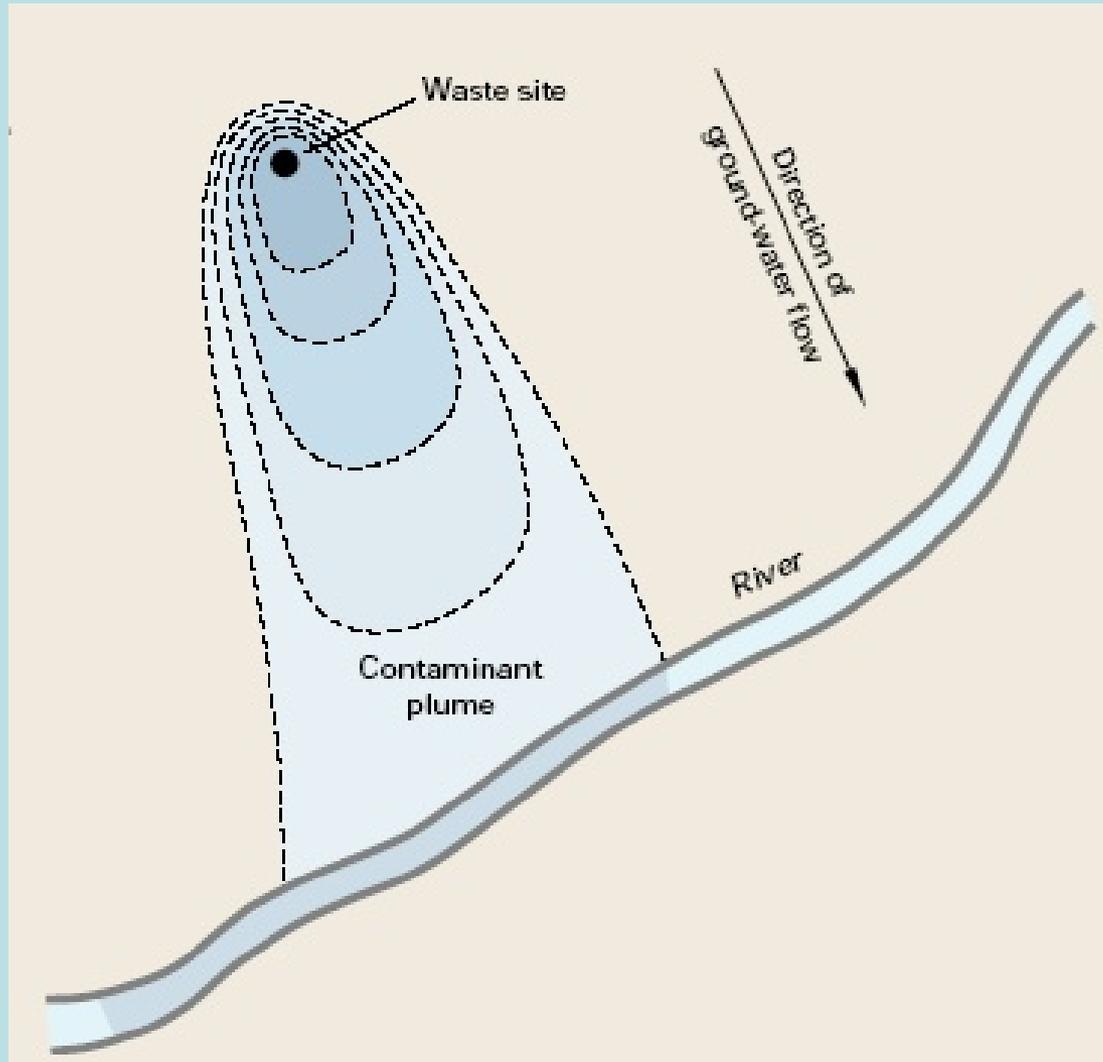
Typical Groundwater Plume



Typical Sequence of Events

- Characterize, delineate impacts
- Identify receptors, pathways
- Risk assessment
- Source removal
- Groundwater Monitoring
 - Today's Issue: Ways to Evaluate plume stability

Groundwater Plume Map View



Plume Stability Assessment

- **Objectives:**

- **Demonstrate plume is not migrating**
 - No future risk to downgradient receptors
- **Demonstrate that COCs are attenuating**
 - Reduction in risk to receptors over time
- **COC fluctuations do not create unacceptable risk to receptors**
- **Closure of R-file and issuance of NFRA**

Assessment Methodologies

- **Variety of statistical & graphical methods**
 - **Individual Wells Methods**
 - **Linear regression analysis**
 - Evaluates COC concentrations vs. time
 - How closely does trend line match data?
 - Correlation coefficient (R^2) - “goodness of fit”
 - **Mann Kendall Analysis**
 - Measure of stability of COCs vs. time
 - Stable, unstable, decreasing, increasing

Assessment Methodologies

- **Whole Plume Evaluation Methods**
 - **Ricker Method**
 - Graphical 3D Analysis using “Surfer” software
 - **Average COC concentration linear regression**
 - Average COC concentrations for all wells vs. time (proportional to plume mass vs. time)
 - **Cross Sectional Analysis**
 - 2D presentation of data across plume (area under curve proportional to plume mass)

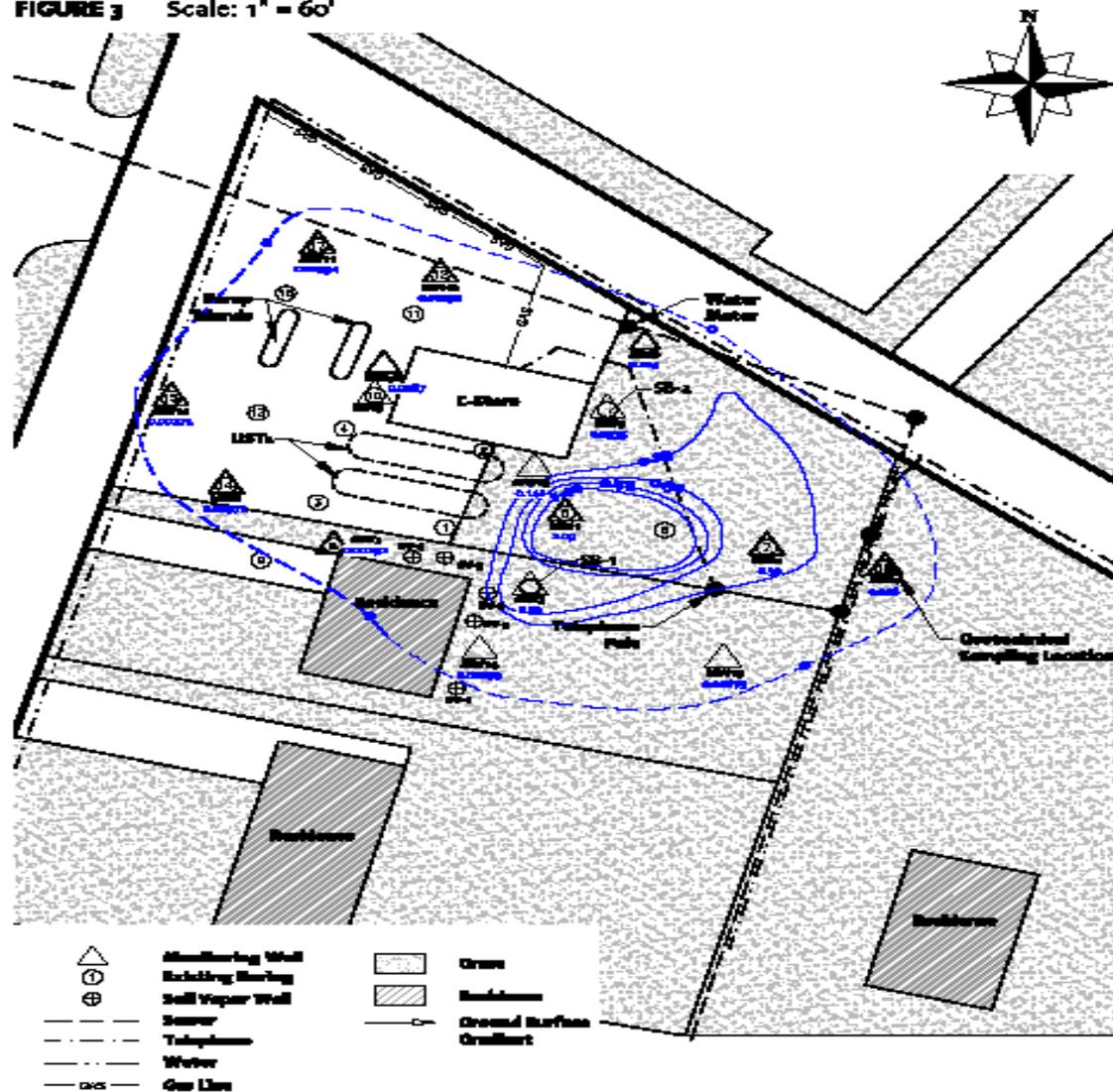
Assessment Methodologies

- **Combination of methods**
 - Can make a more convincing case for plume stability
- **Individual well + whole plume techniques**
 - Puts individual well fluctuations at heart of plume area in a big picture context
 - Make more convincing case for plume stability

Example Site Using Multiple Methods

- **Site located in western Missouri**
 - Active convenience store
 - USTs replaced 1991
 - Residual impacts in tank pit continue to feed groundwater plume
 - Groundwater data from 2004 to 2010

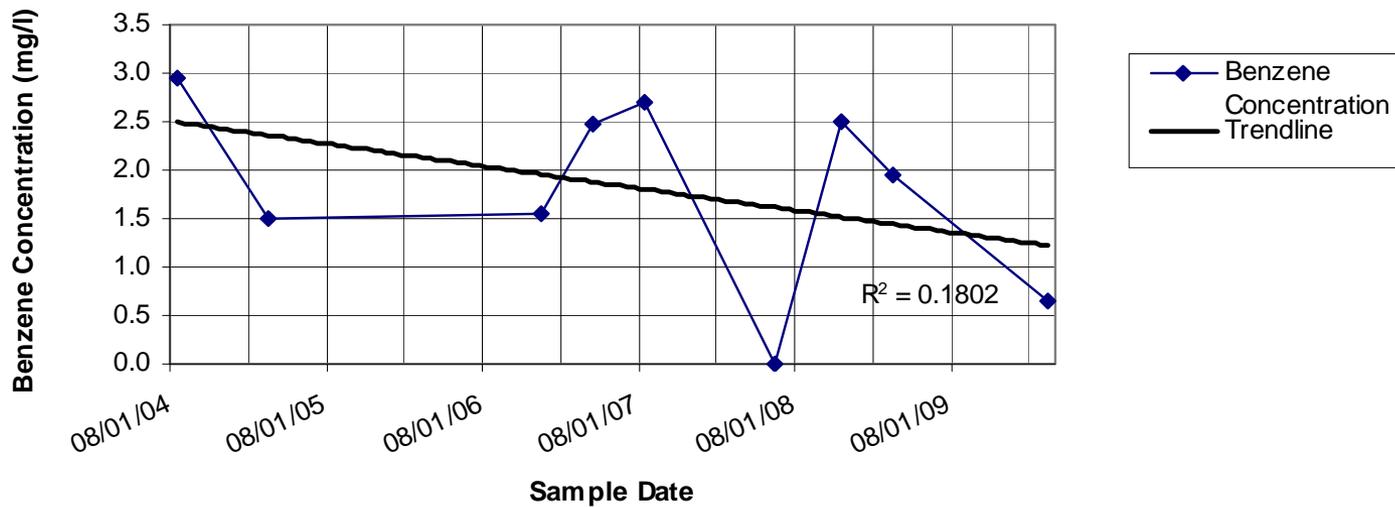
FIGURE 3 Scale: 1" = 60'



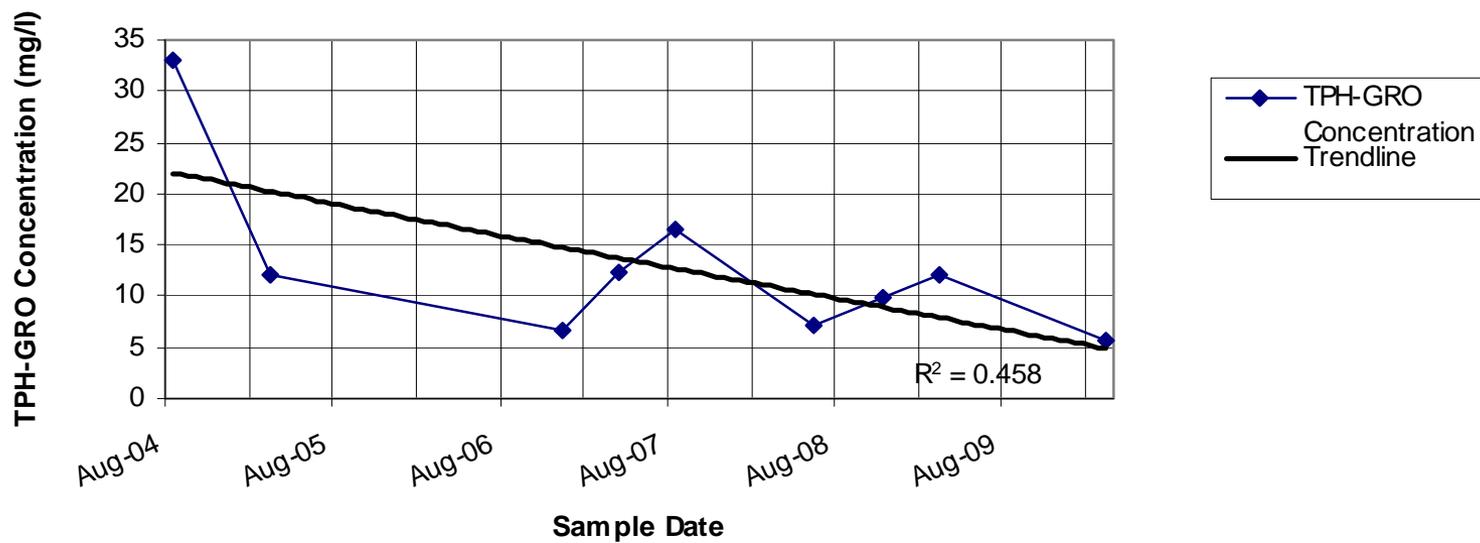
Assessment of Individual Wells

- **Good News:**
 - Individual well - concentration vs. time plots
 - Generally show attenuating trend
 - COC's decreasing
- **Bad News:**
 - Individual wells with seasonal COC fluctuations
 - Linear regression R^2 values <0.5

Benzene Concentration Vs. Time Monitoring Well MW-7



TPH-GRO Concentration Vs. Time Monitoring Well MW-7



Assessment of Individual Wells

- **Are the fluctuations in individual source area wells really indicative of unstable plume?**

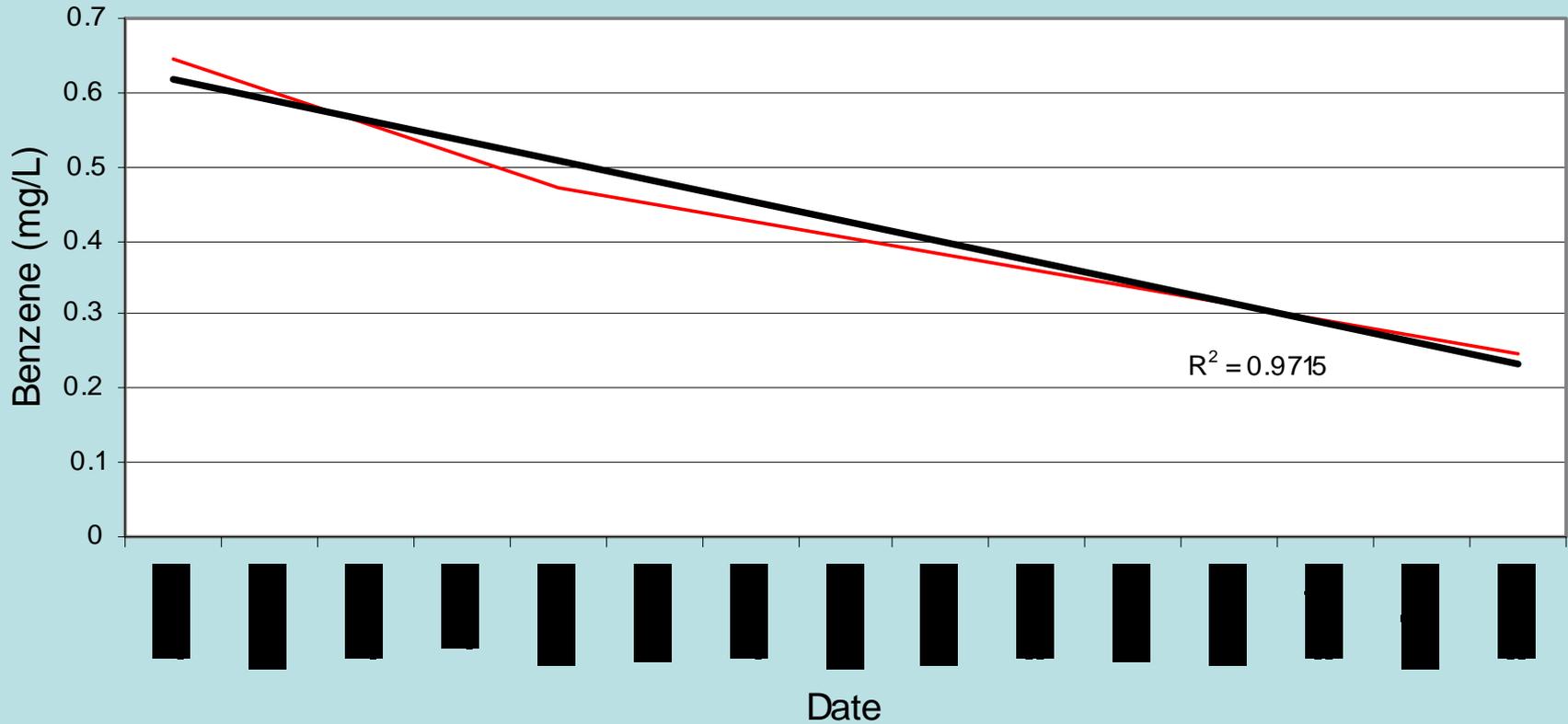
Stability Assessment Alternatives

- **My subjective assessment of the data:**
- **Despite source area fluctuations:**
 - Wells away from residual source consistently < DTLs
 - Perimeter wells - no evidence of expanding plume
- **Need alternate way to quantify my subjective assessment**

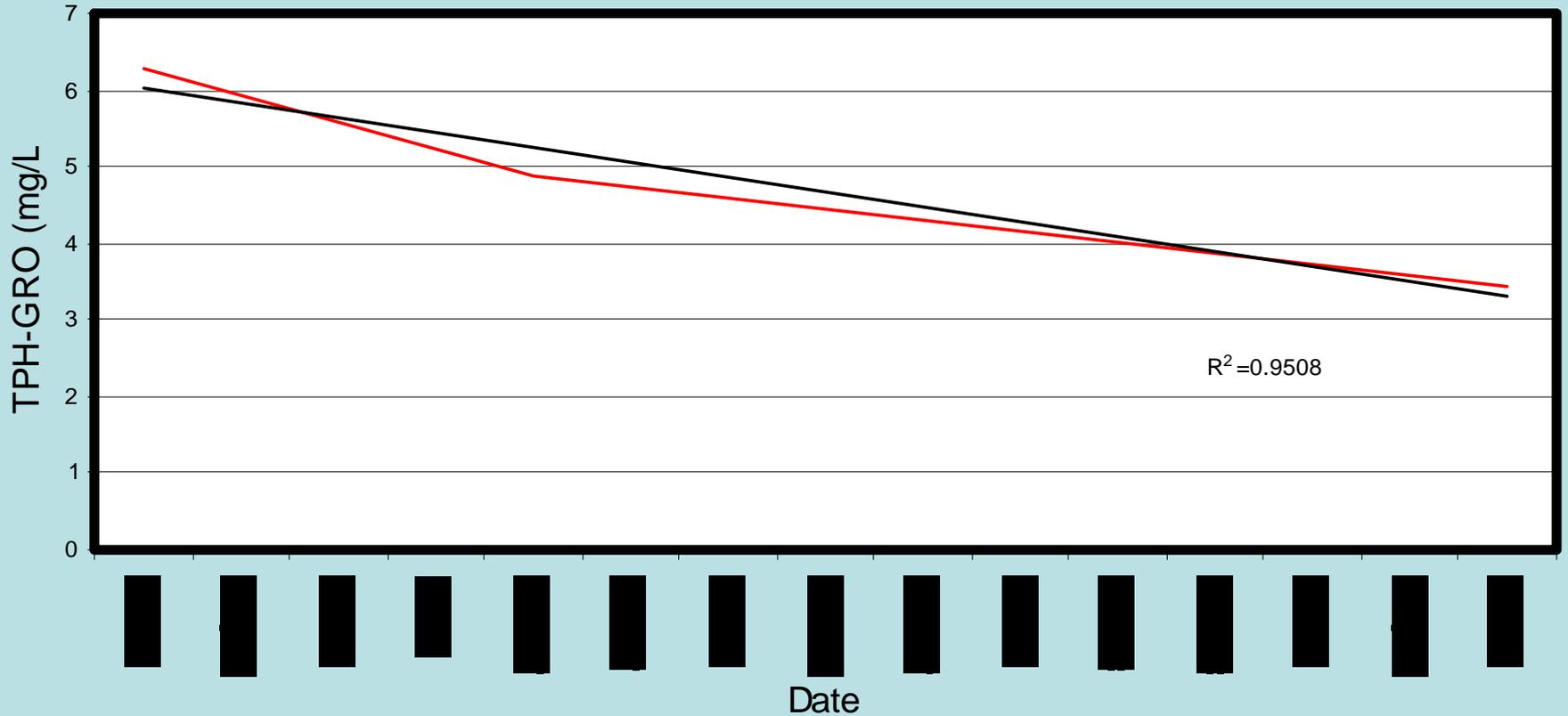
Stability Assessment Alternatives

- **Option 1: Average COC concentrations vs. time**
 - Average for individual COCs vs. time
 - Average is proportional to total plume mass
 - Linear Regression of average vs. time
 - more indicative of behavior of total plume
 - generally yields higher correlation coefficients

Average Benzene Concentration Vs. Time



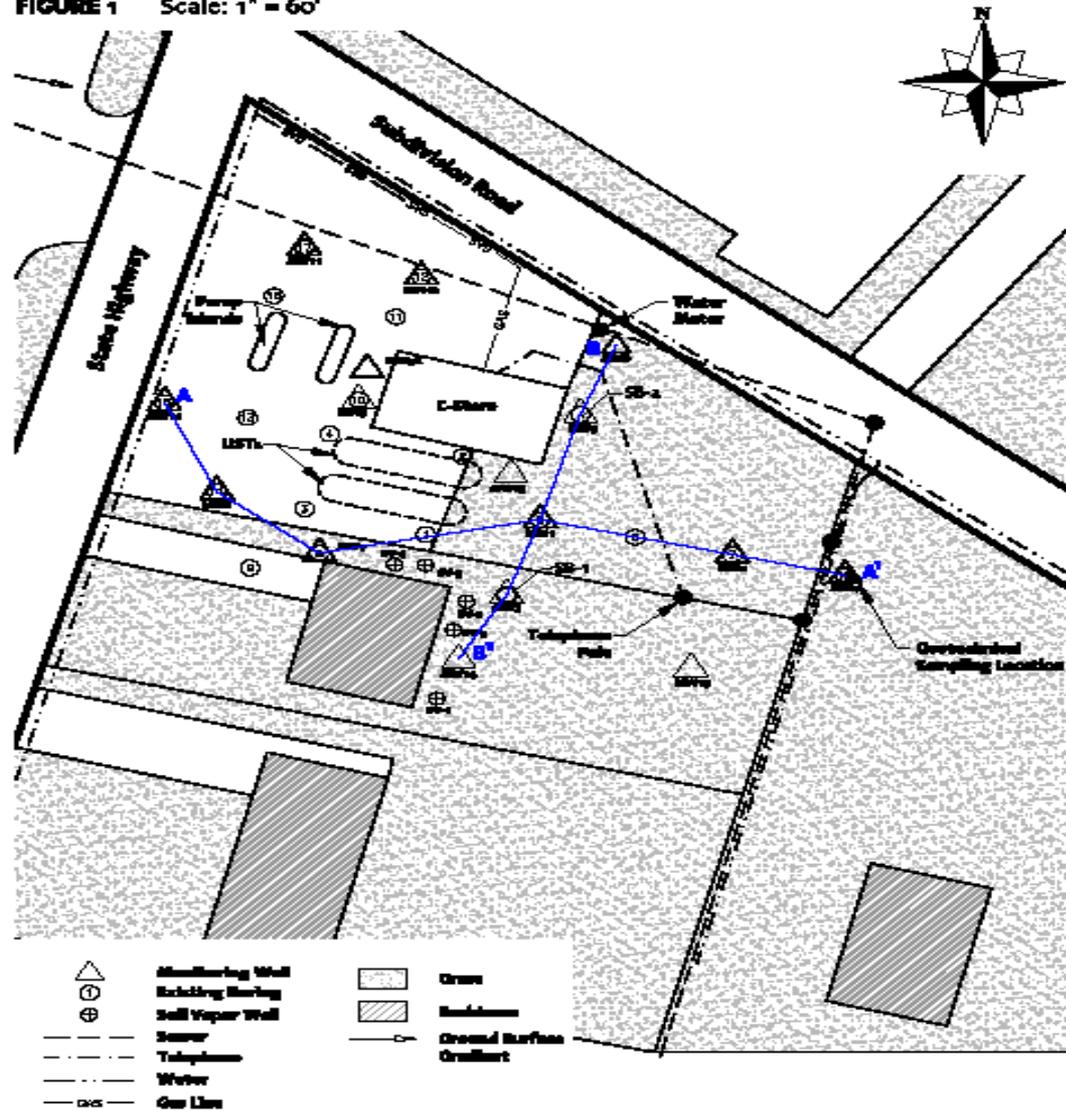
Average TPH-GRO Concentration Vs. Time



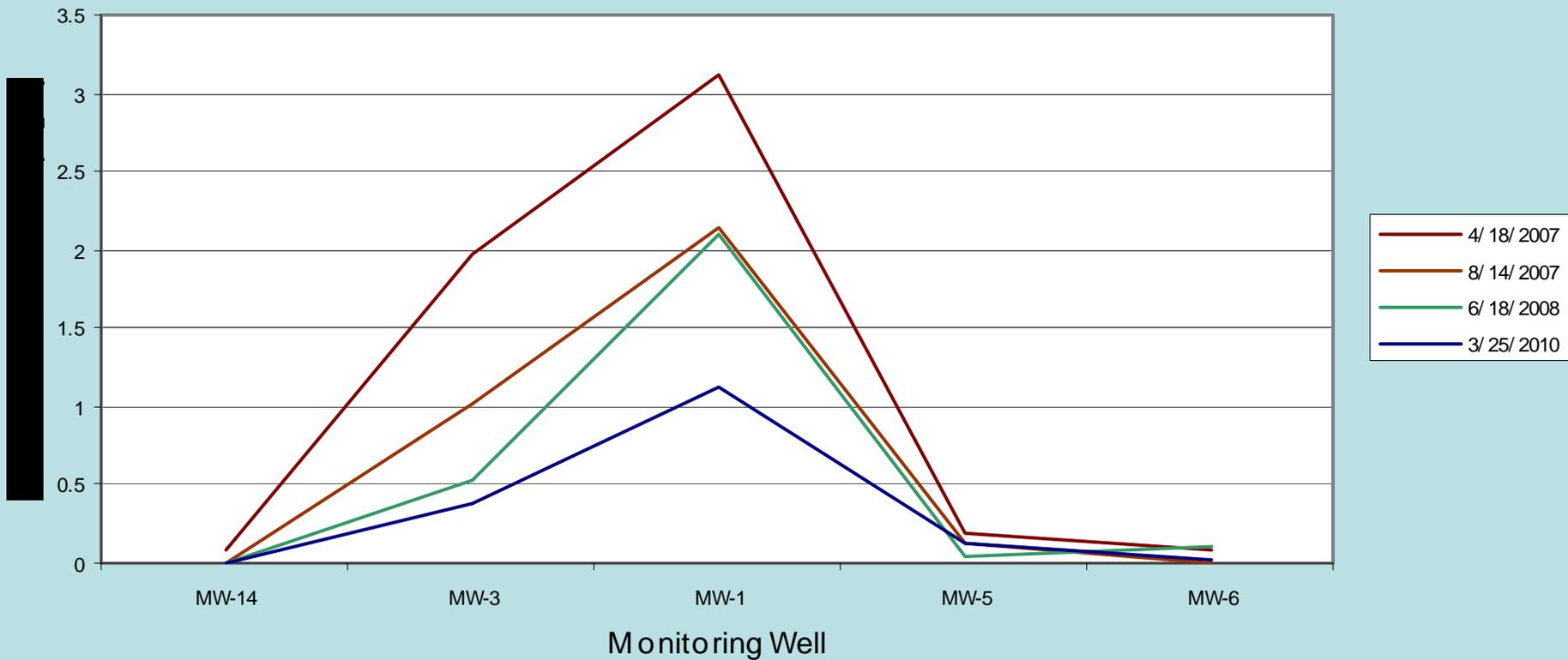
Stability Assessment Alternatives

- **Option 2: Plume centerline cross sections**
 - **Published USEPA method (Dupont, et al, 1998)**
 - Use cross sections through plume center
 - Plot data from individual monitoring events (separate line for each sampling event)
 - Area under curve proportional to total plume mass
 - For attenuating plume, area under the curve should decrease with time

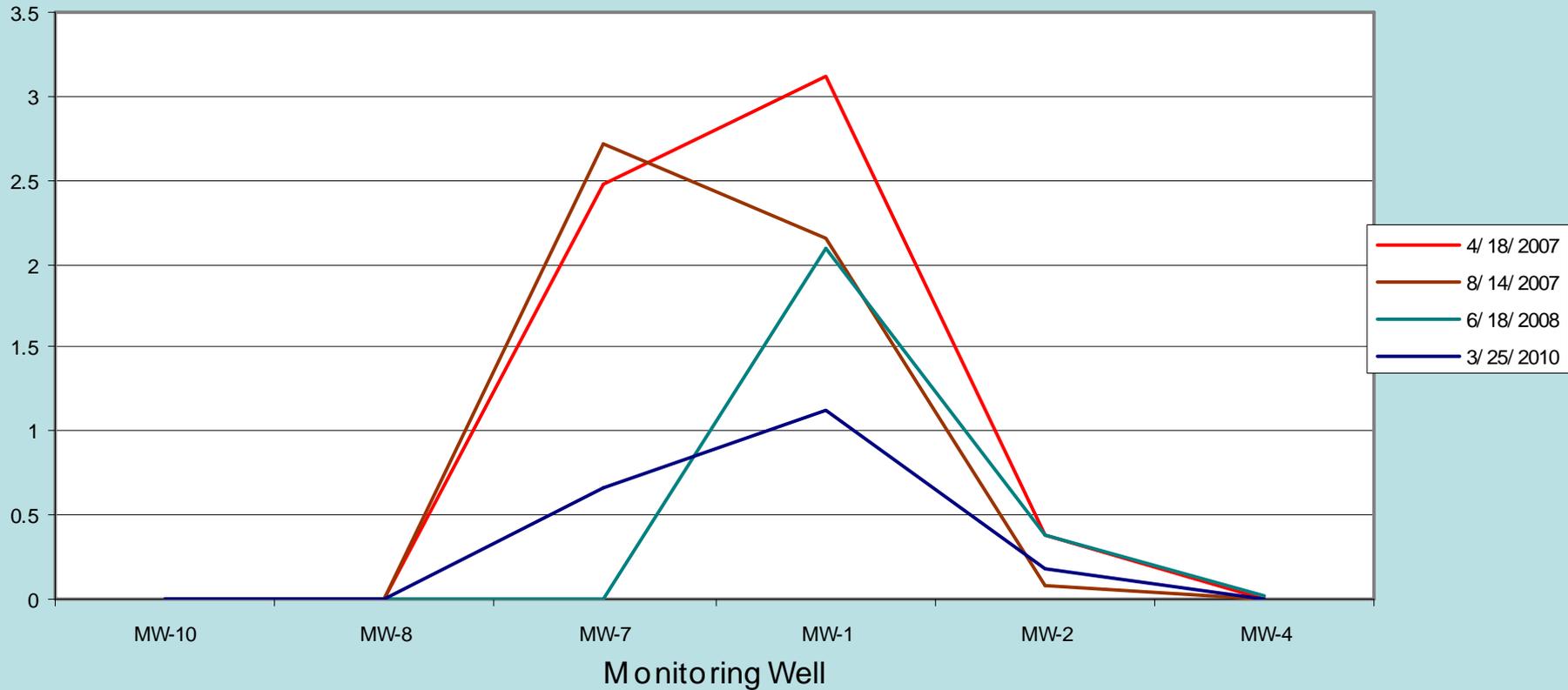
FIGURE 1 Scale: 1" = 60'



Benzene Cross Section A - A¹ vs. Time



Benzene Cross Section B - B¹ vs Time



Summary

- **Statistical evaluation of Individual wells can sometimes be misleading**
- **Plume centerline cross sections & average COC vs. time plots can provide better assessment of plume attenuation**
- **Looking at the forest rather than the trees**

Summary

- **Additional options to evaluate plume stability**
 - Additional tools in your tool box
- **Can combine with individual well or 3D analysis to make a more convincing case for plume stability**

Plume Stability Evaluation

- Thank You
- Questions?