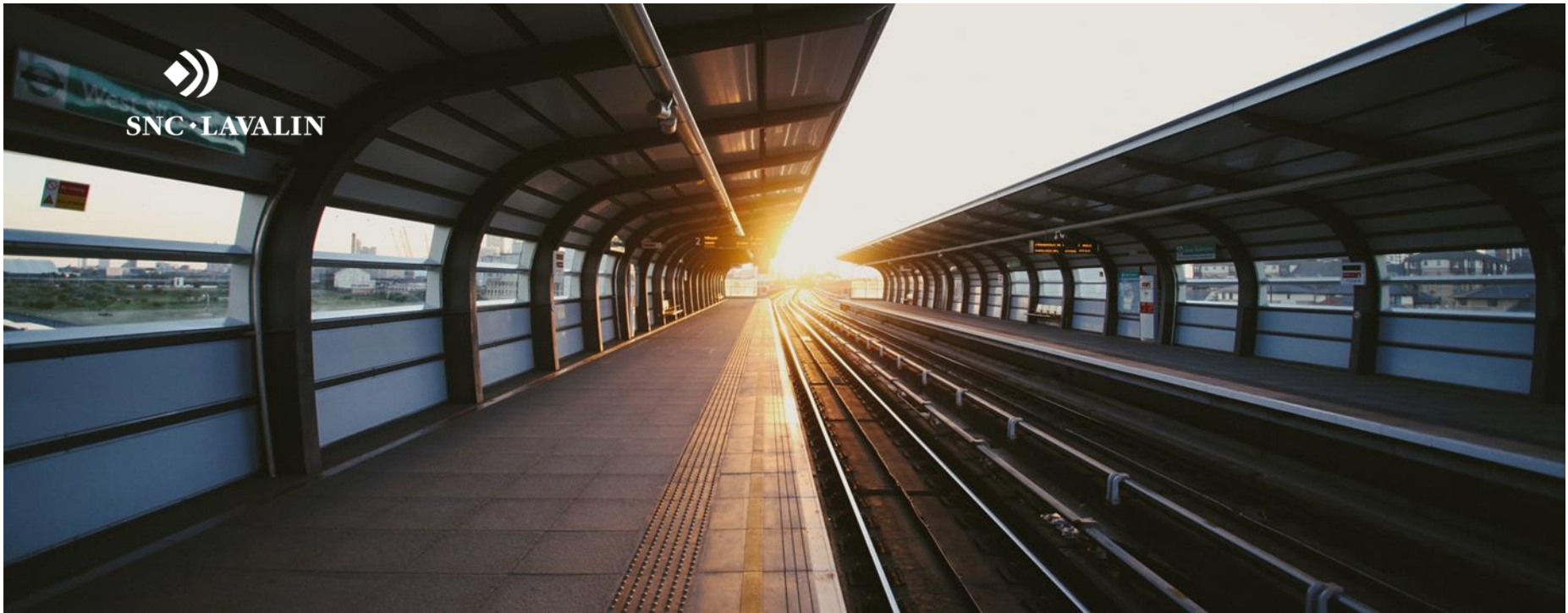




SNC · LAVALIN



## Applications of Plume Stability Analysis in Risk Assessment for Contaminated Sites

Ms. Sheila Duchek, M.Sc., P.Geol. & Ms. June Lu, M.Sc., P.Eng.

October 12, 2018



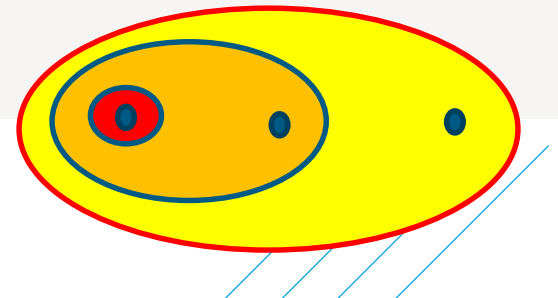
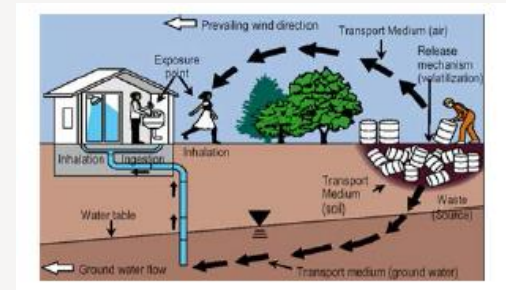
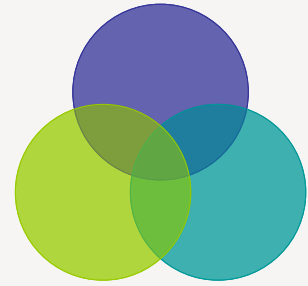
## Our vision

We strive to be the premier engineering solutions partner, committed to delivering complex projects from vision to reality for a sustainable lifespan.



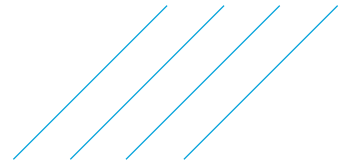
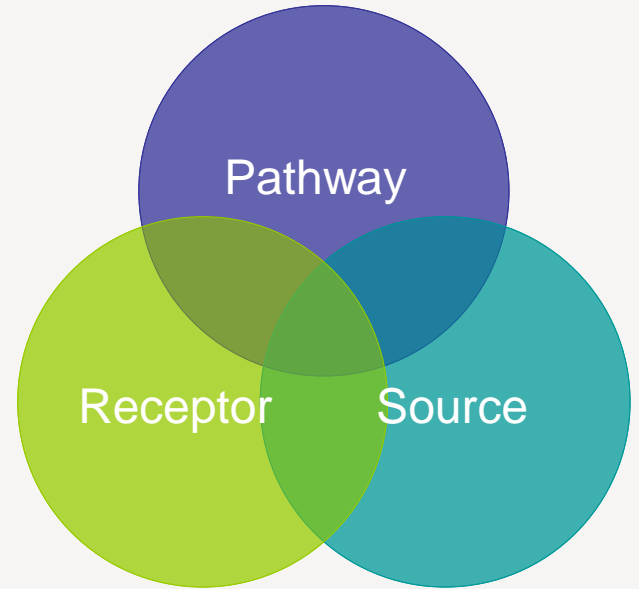
# Presentation Outline

- › Brief overview of risk assessment
- › How plume stability is used to support risk assessment
- › Plume anatomy: shrinking vs expanding plumes
- › Use of statistical analyses and trends
- › Determining plume stability
- › Examples of data and plumes and results of Plume Stability Analysis



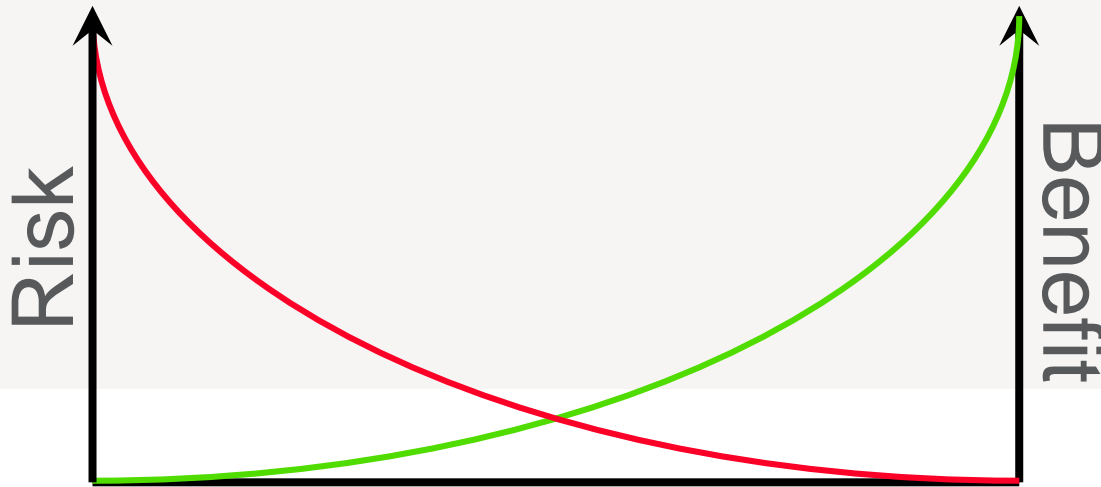
# Risk Assessment

- › Site characterization requires collecting data to develop our understanding of the site & to support future site management plans
- › Risk Assessment is understanding the three pillars: source, pathway, receptor.
- › If risk is unacceptable, risk management measures are recommended.
- › Stakeholders implement Risk Management Plans and follow up monitoring.



# Relative Risk

- › Primary Goal: to find a solution to manage risk that presents the best compromise of risk reduction / risk control and societal benefit.
- › Secondary Goal: to find a balance between the 'precautionary principle' and evidenced-based risk management decision-making.



# Risk Assessment Methods

**Problem Formulation**  
Overall Conceptual Site Model (CSM)

**Ecological Risk Assessment (ERA)**

Problem Formulation (ECSM)  
- COPCs, sources, pathways, receptors

Exposure Assessment

Toxicity Assessment - Ecological TRV

Risk Characterization

**Human Health Risk Assessment HHRA)**

Problem Formulation (HHCSM)  
- COPCs, sources, pathways, receptors

Exposure Assessment

Toxicity Assessment - Human Health TRV

Risk Characterization

if risks are unacceptable

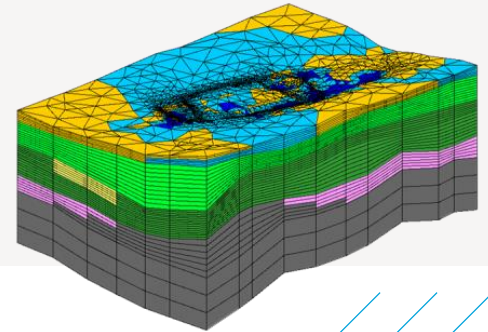
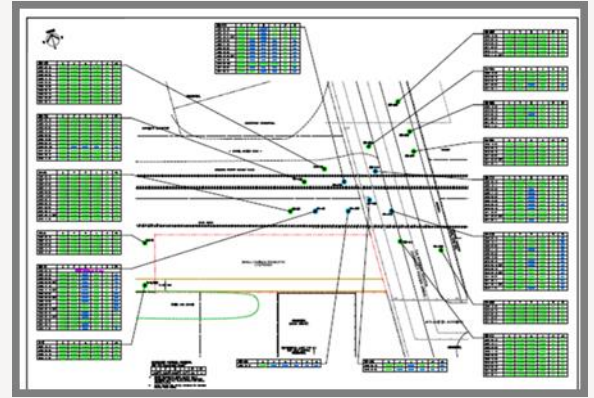
**Risk Management Plan**

# Conceptual Site Models

Developing a CSM is a step-wise approach where data (available and needed) is reviewed, organized and presented in an accessible format:

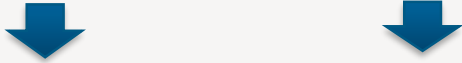
- › Establish your framework
- › Know your impact
- › Understand your receptors
- › Assess data gaps to feed your CSM

There are many acceptable formats... choose one that is most appropriate for your audience.



# Risk Assessment Methods

**Problem Formulation**  
Overall Conceptual Site Model (CSM)



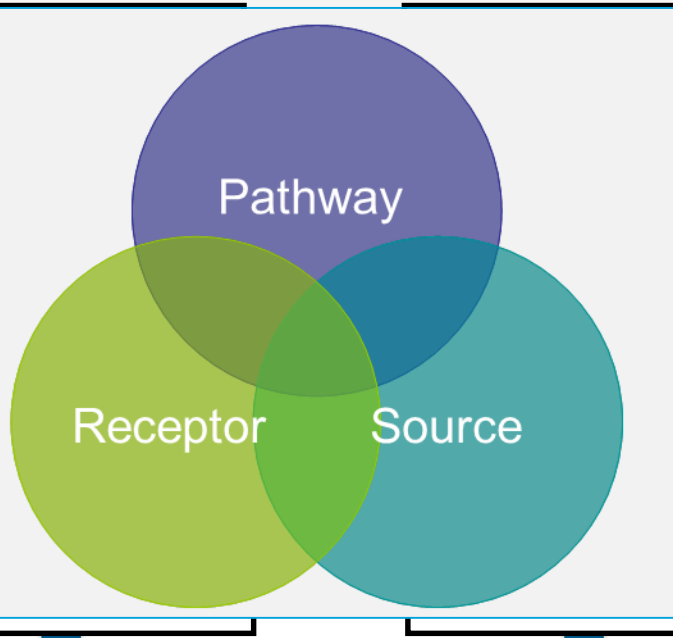
**Ecological Risk Assessment**

Problem Formulation  
- COPCs, sources, pathways

Exposure Assessment

Toxicity Assessment - Ecological

Risk Characterization



**Risk Assessment (HHRA)**

Problem Formulation (HHCSM)  
- COPCs, pathways, receptors

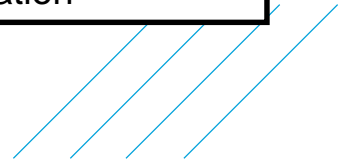
Exposure Assessment

Toxicity Assessment - Human Health TRV

Risk Characterization

if risks are unacceptable

**Risk Management Plan**



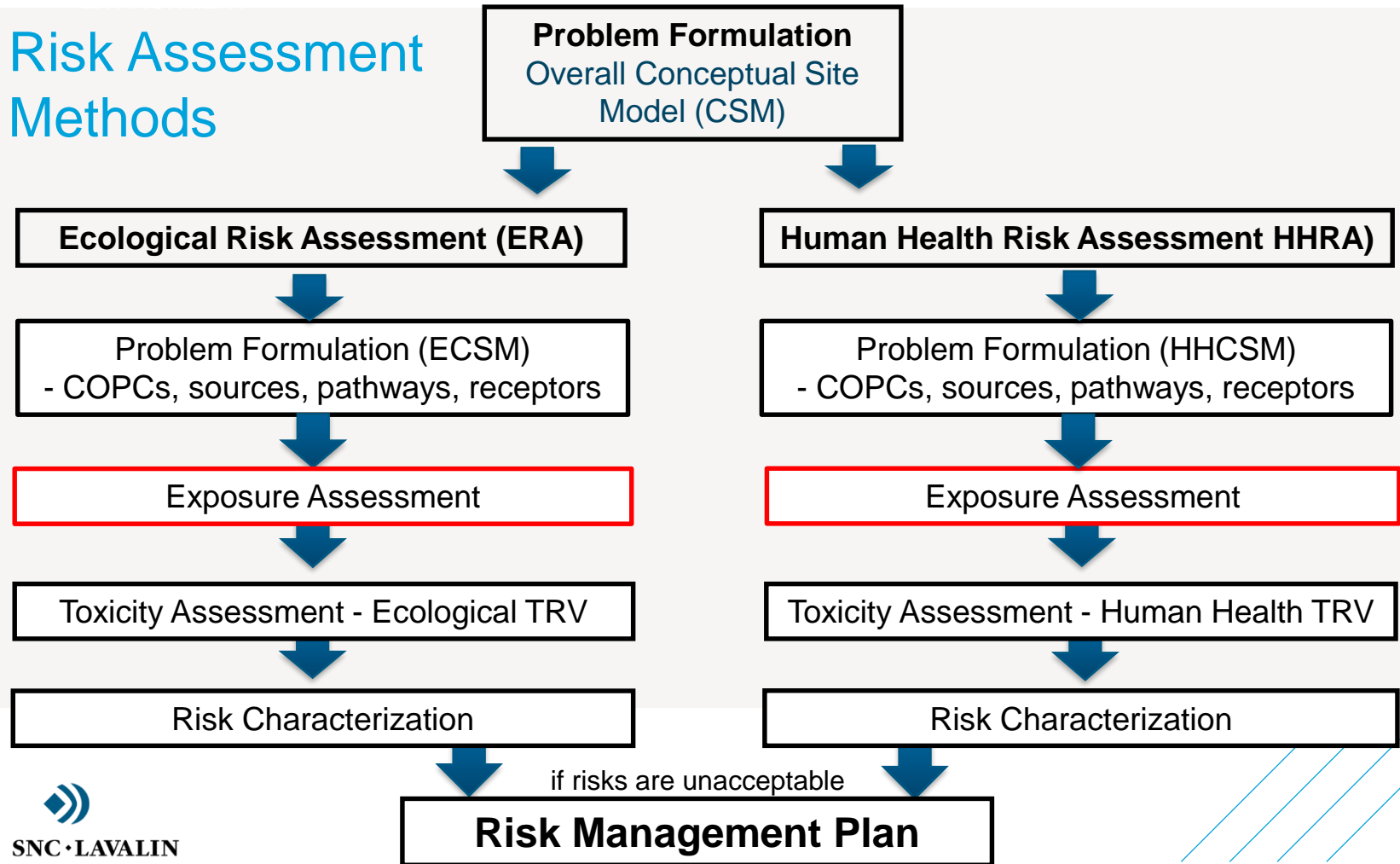


# Problem Formulation

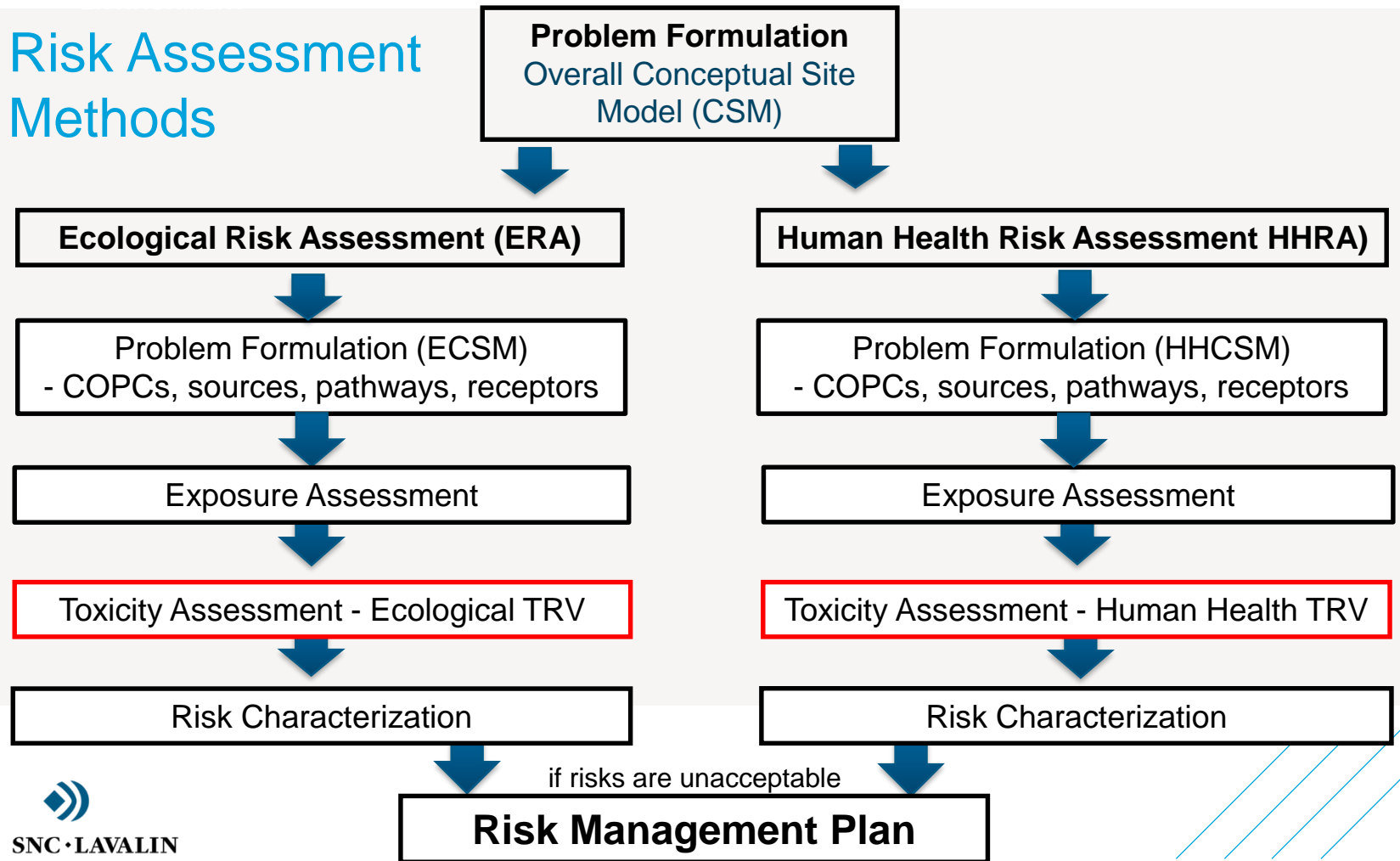
- › Identifying Chemicals of Potential Concern (COPC)
  - › *Measured in water and other media (soil, sediment, vapour, food)*
  - › *Screening identifies COPC, with guidelines specific to receptors*
- › Selection of Receptors
  - › *Identifies who may be exposed to contaminants (workers, residents, visitors)*
  - › *Identifies ecological receptors (plants, invertebrates, birds, mammals, amphibians, fish)*
  - › *Rare ecological species are also considered*
- › Exposure Pathway Analysis
  - › *Identifies exposure pathways where receptors can be exposed to site impacts*
- › Human Health and Ecological Conceptual Site Model



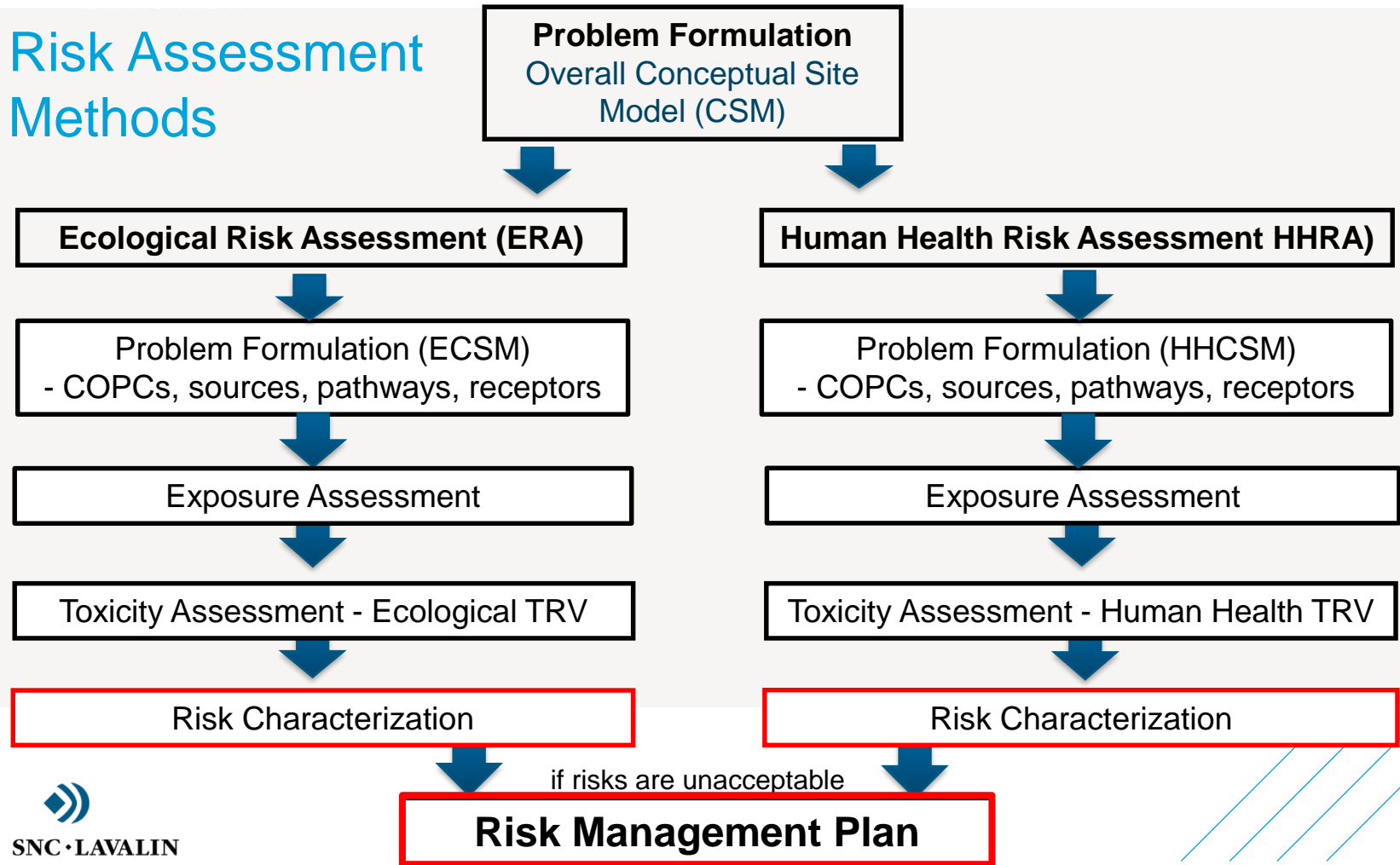
# Risk Assessment Methods



# Risk Assessment Methods



# Risk Assessment Methods

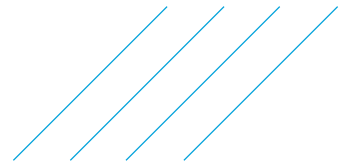
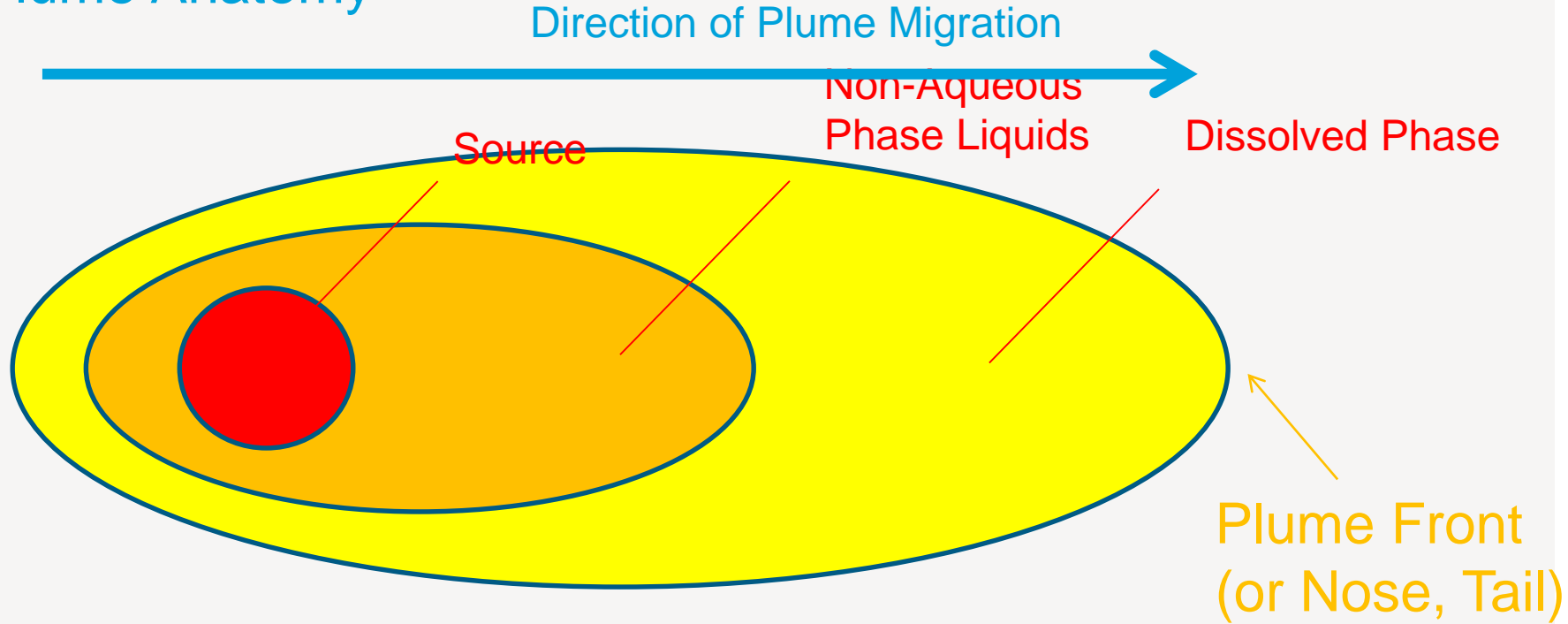


# Reasons to Conduct Plume Stability Analysis

- › Provides quantified values to characterize plumes
- › Supports risk analysis of the plume in relation to neighbouring properties
- › Identifies if there are potential risks to sensitive receptors
- › Answers key regulatory requirements of plume stabilization
- › Can be used as an indicator for remediation performance
- › Provides a line of evidence to support Monitored Natural Attenuation
- › Can visually support closure for low risk sites.

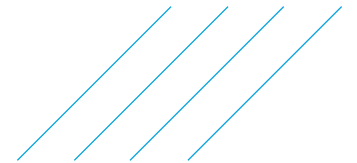
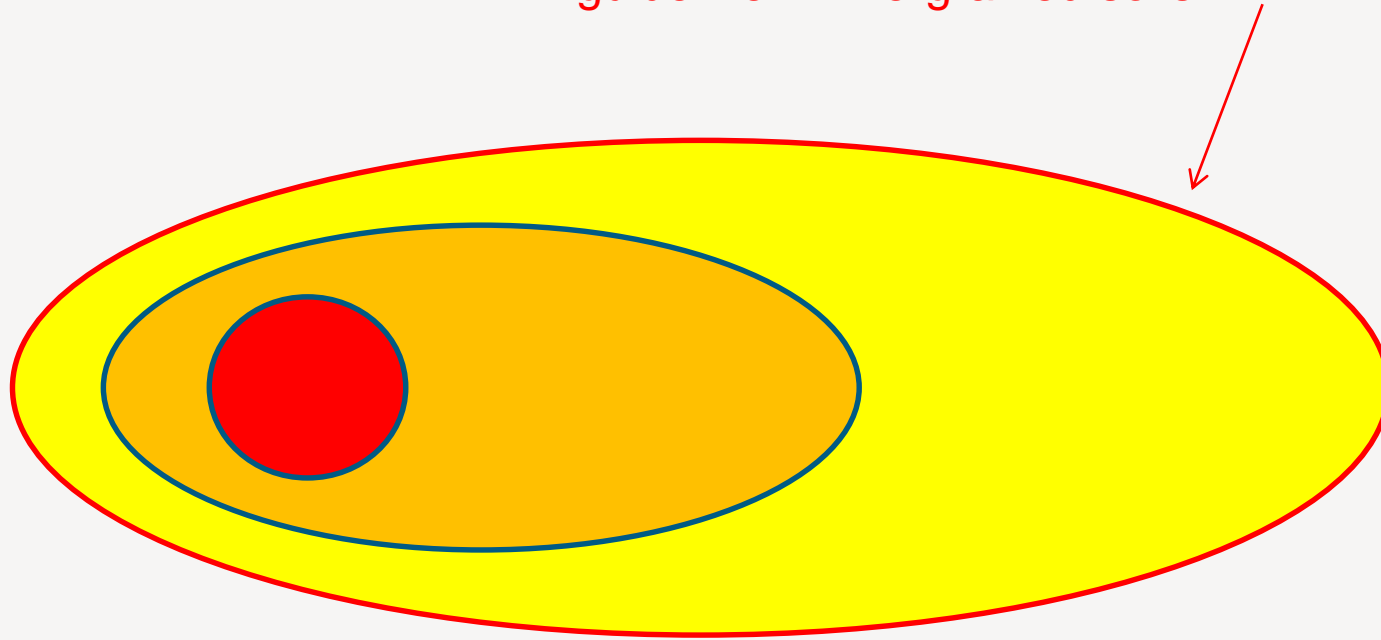


# Plume Anatomy



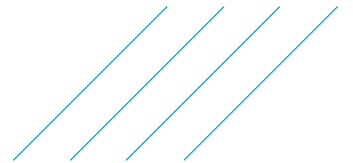
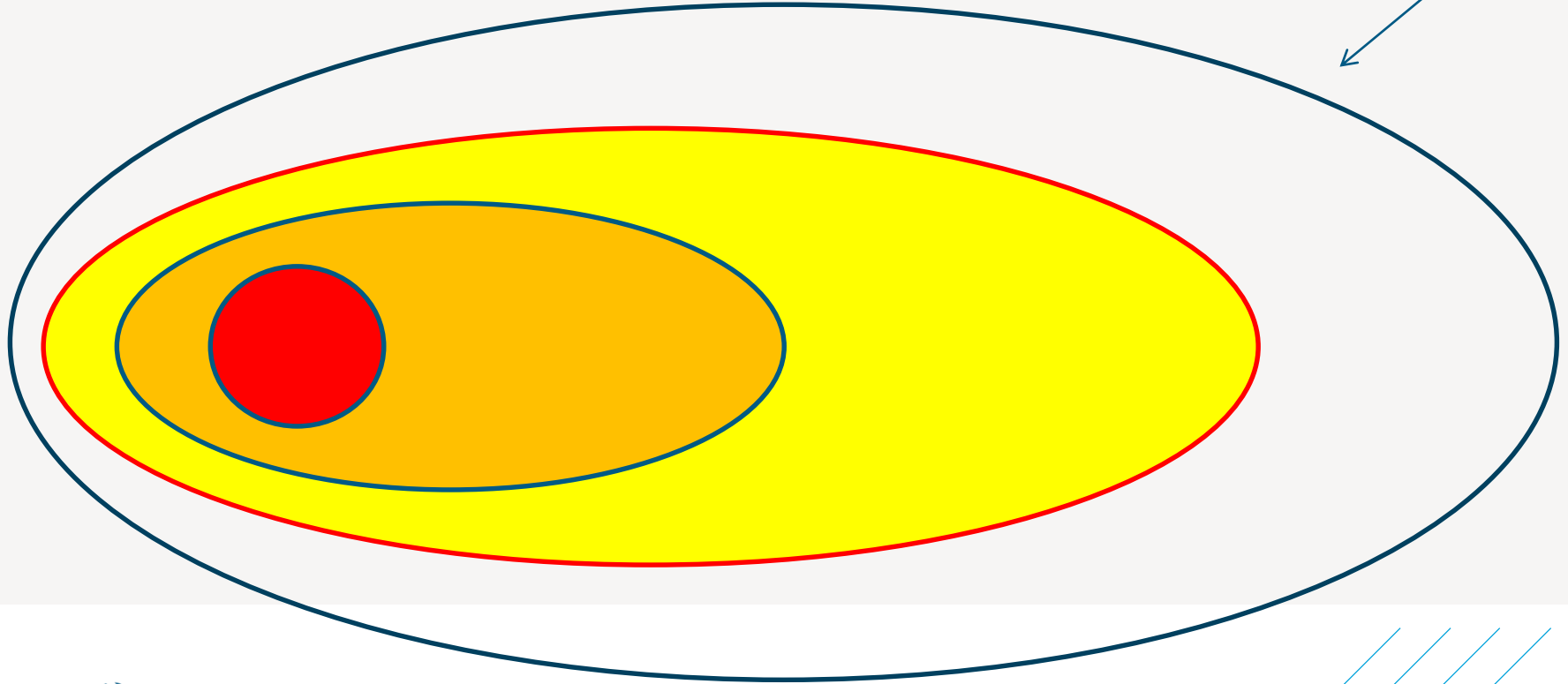
# Plume Anatomy

Benzene Concentration at 0.046 mg/L, equal to ABT1 guideline in fine-grained soils



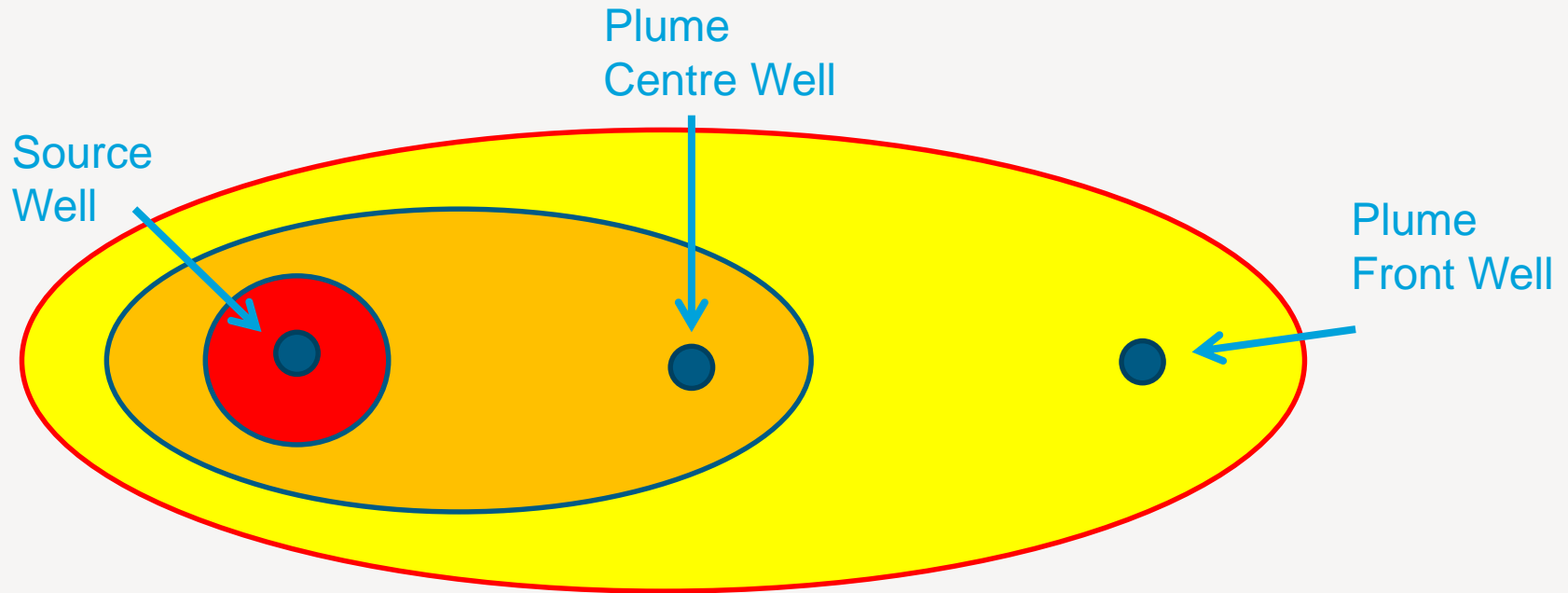
# Plume Anatomy

Detection Limit of 0.0005 mg/L





# Plume Anatomy



# Plume Stability

**Rate of Mass Gain** Chemical Added into Plume

=

**Rate Mass Loss** Chemical Loss from Plume

**The interpolated data tells you if:**

- › Plume is, or is not, expanding or shrinking in size
- › Plume footprint is, or is not, moving



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## How to Determine Plume Stability Classification

- › Mann-Kendall is a non-parametric statistical procedure that predicts trends in individual wells over time.
- › Provides confidence values for the calculated trend analysis.
- › Mann-Kendall considers historical concentration data, including non-detectable concentrations.
- › The tool also provides a basis for the modification and / or reduction of proposed risk management programs.



# Determining Plume Stability – Using Statistical Methods

## Calculation of Mann-Kendall S Statistic for Five Sampling Events

Statistic Method-Mann Kendall

Benzene (mg/L)	Event 1	Event 2	Event 3	Event 4	Event 5	TOTAL POINTS
	13.95	42.08	33.90	33.67	18.05	
Compare To Event 1		+1	+1	+1	+1	+4
Compare To Event 2			-1	-1	-1	-3
Compare To Event 3				-1	-1	-2
Compare To Event 4					-1	-1
Apparent Decreasing Trend					<b>S =</b>	<b>-2</b>

# Determining Plume Stability – Using Statistical Methods

<i>S</i> Statistic	Confidence In Trend	Trend
$S > 0$	$CF > 95\%$	Increasing
$S > 0$	$95\% \geq CF \geq 90\%$	Probably Increasing
$S > 0$	$CF < 90\%$	No Trend
$S \leq 0$	$CF < 90\%$ and $COV \geq 1$	No Trend
$S \leq 0$	$CF < 90\%$ and $COV < 1$	Stable
$S < 0$	$95\% \geq CF \geq 90\%$	Probably Decreasing
$S < 0$	$CF > 95\%$	Decreasing



# Determining Plume Stability

Evaluation Date: **12-Oct-18**  
 Facility Name: **ABC Corporation**  
 Conducted By: **Sheila Duchek**

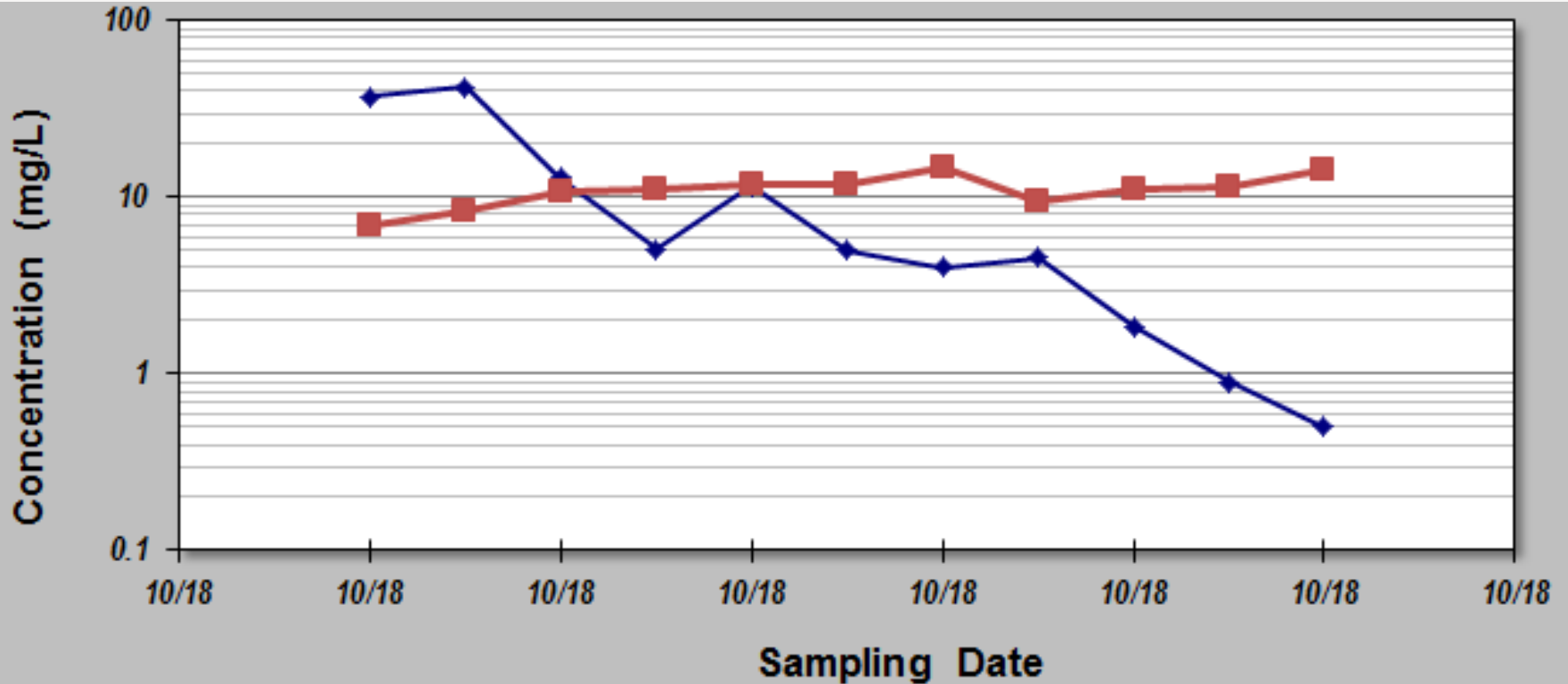
Job ID: **9999**  
 Constituent: **Contaminant of Concern**  
 Concentration Units: **mg/L**

Sampling Point ID: **MW18-1A**    **MW18-1B**

Sampling Event	Sampling Date	CONTAMINANT OF CONCERN CONCENTRATION (mg/L)					
		MW18-1A	MW18-1B				
1	11-Oct-18	37.1	7				
2	12-Oct-18	41.9	8.49				
3	13-Oct-18	13	10.7				
4	14-Oct-18	5.1	11.2				
5	15-Oct-18	11.5	11.8				
6	16-Oct-18	5	12				
7	17-Oct-18	4	15				
8	18-Oct-18	4.6	9.4				
9	19-Oct-18	1.85	11.1				
10	20-Oct-18	0.9	11.6				
11	21-Oct-18	0.5	14.3				

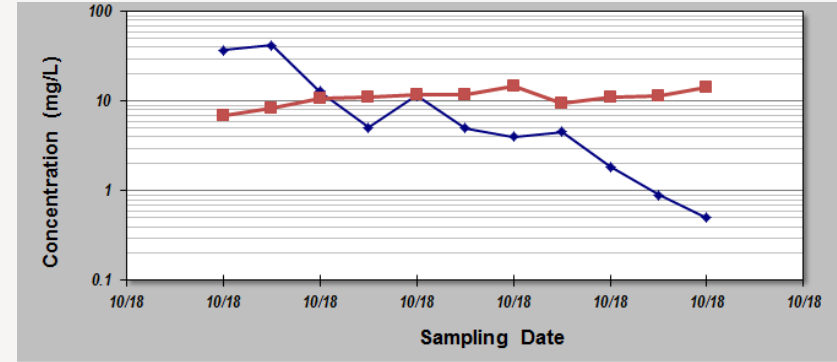


# Determining Plume Stability



# Determining Plume Stability

Evaluation Date:	12-Oct-18		Job ID:	9999
Facility Name:	ABC Corporation		Constituent:	Contaminant of Concern
Conducted By:	Sheila Duchek		Concentration Units:	mg/L
Sampling Point ID:	MW18-1A	MW18-1B		
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4	14-Oct-18	5.1	11.2	
5	15-Oct-18	11.5	11.8	
6	16-Oct-18	5	12	
7	17-Oct-18	4	15	
8	18-Oct-18	4.6	9.4	
9	19-Oct-18	1.85	11.1	
10	20-Oct-18	0.9	11.6	
11	21-Oct-18	0.5	14.3	

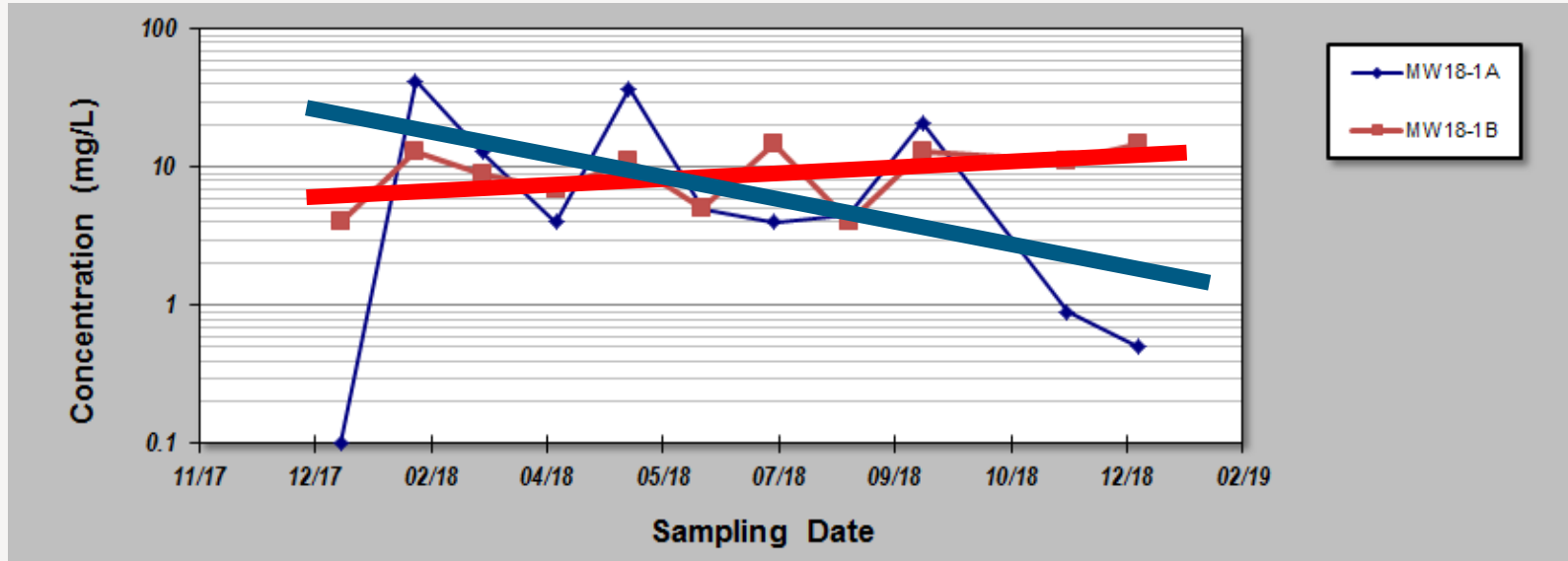


Coefficient of Variation:	1.27	0.21
Mann-Kendall Statistic (S):	-49	29
Confidence Factor:	>99.9%	98.7%
Concentration Trend:	Decreasing	Increasing





# Determining Plume Stability

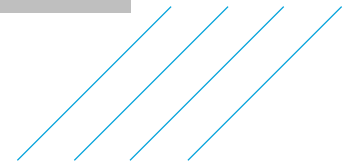
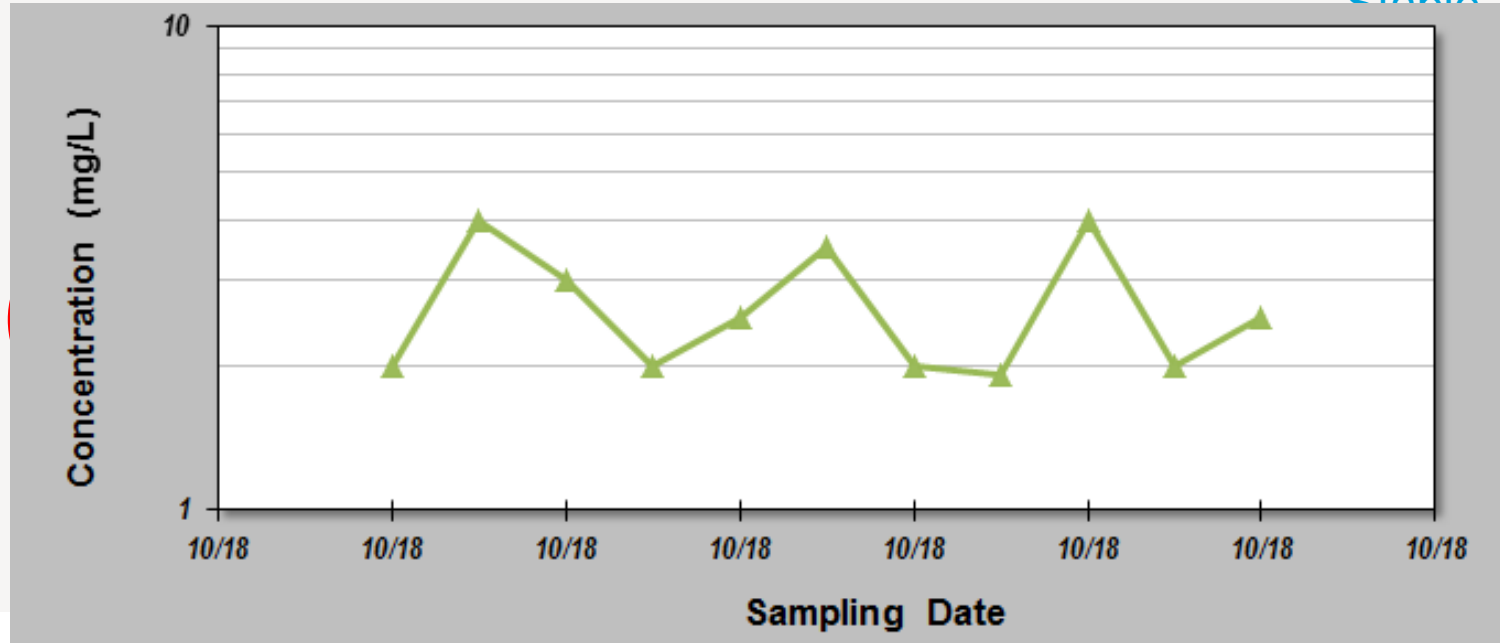


Coefficient of Variation:	1.24	0.43
Mann-Kendall Statistic (S):	-14	15
Confidence Factor:	84.0%	85.9%
Concentration Trend:	No Trend	No Trend

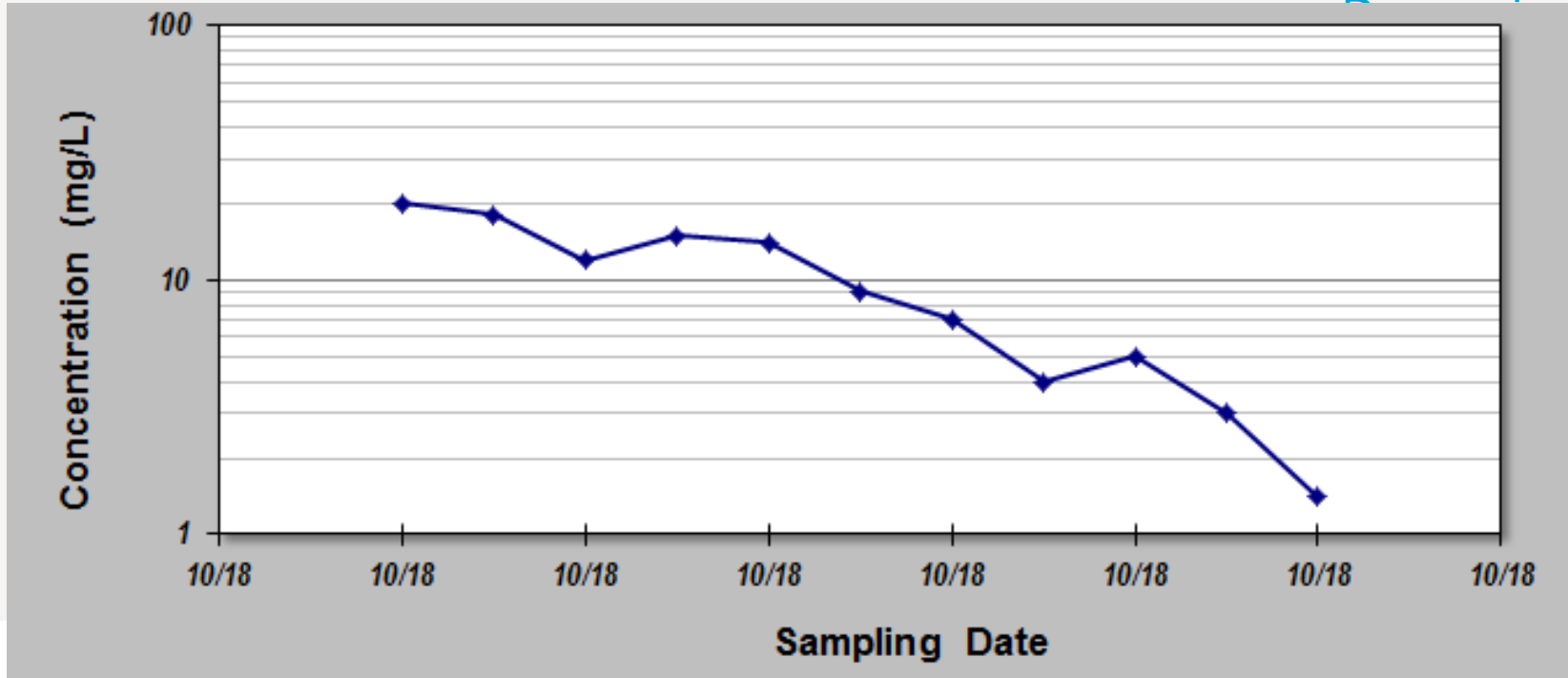


# Plume Status: Stable Plumes

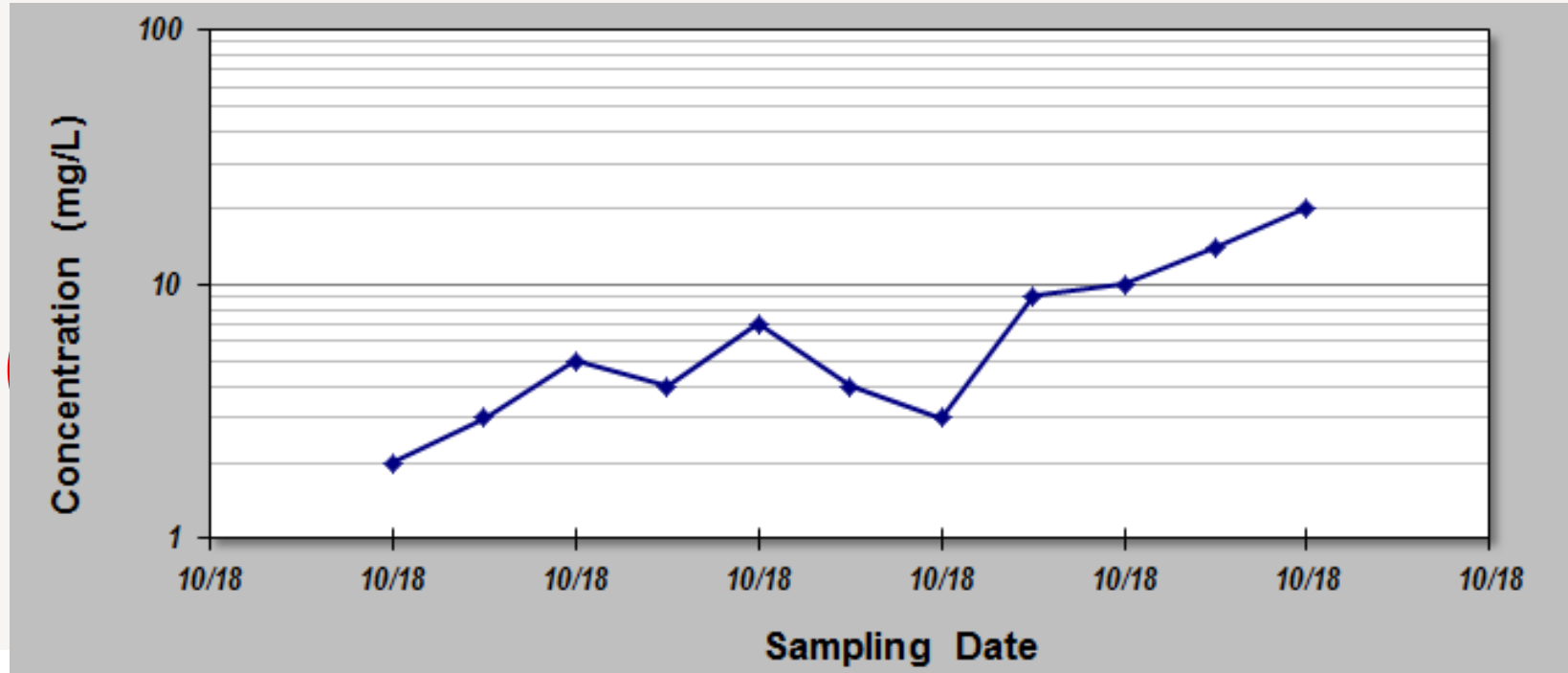
Stable Trend



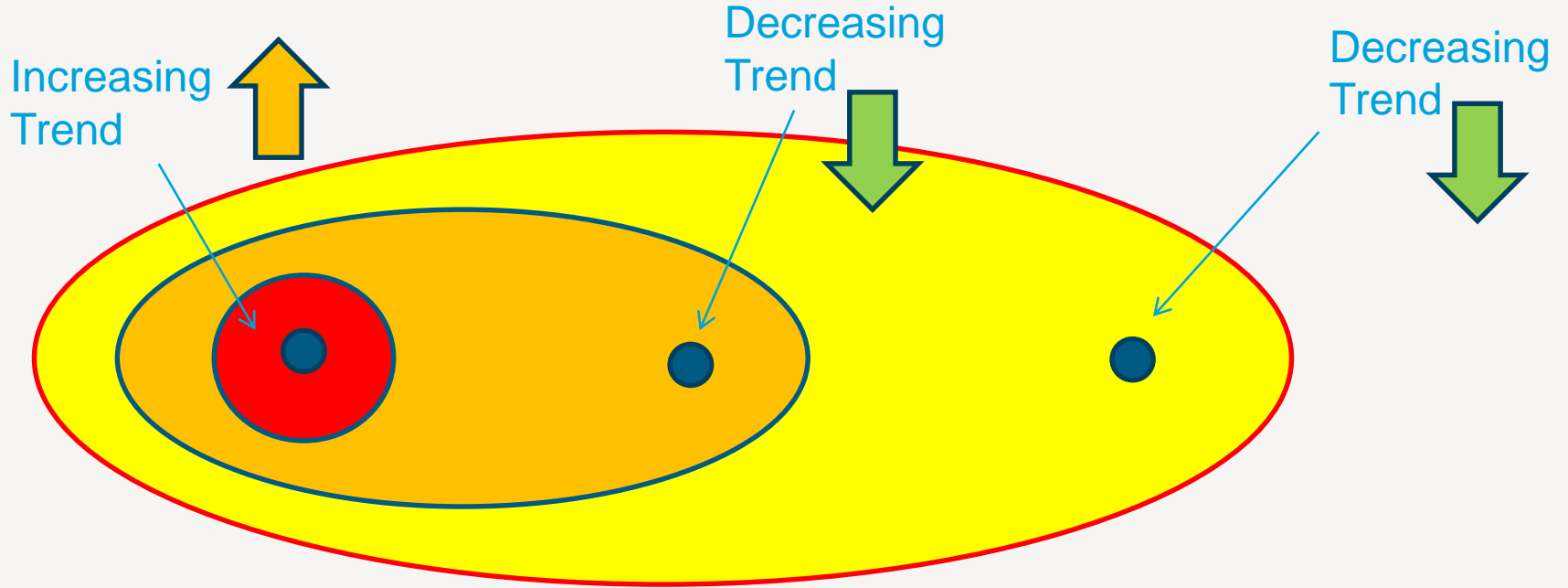
# Plume Status: Shrinking Plumes



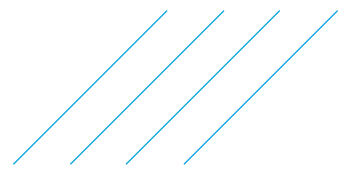
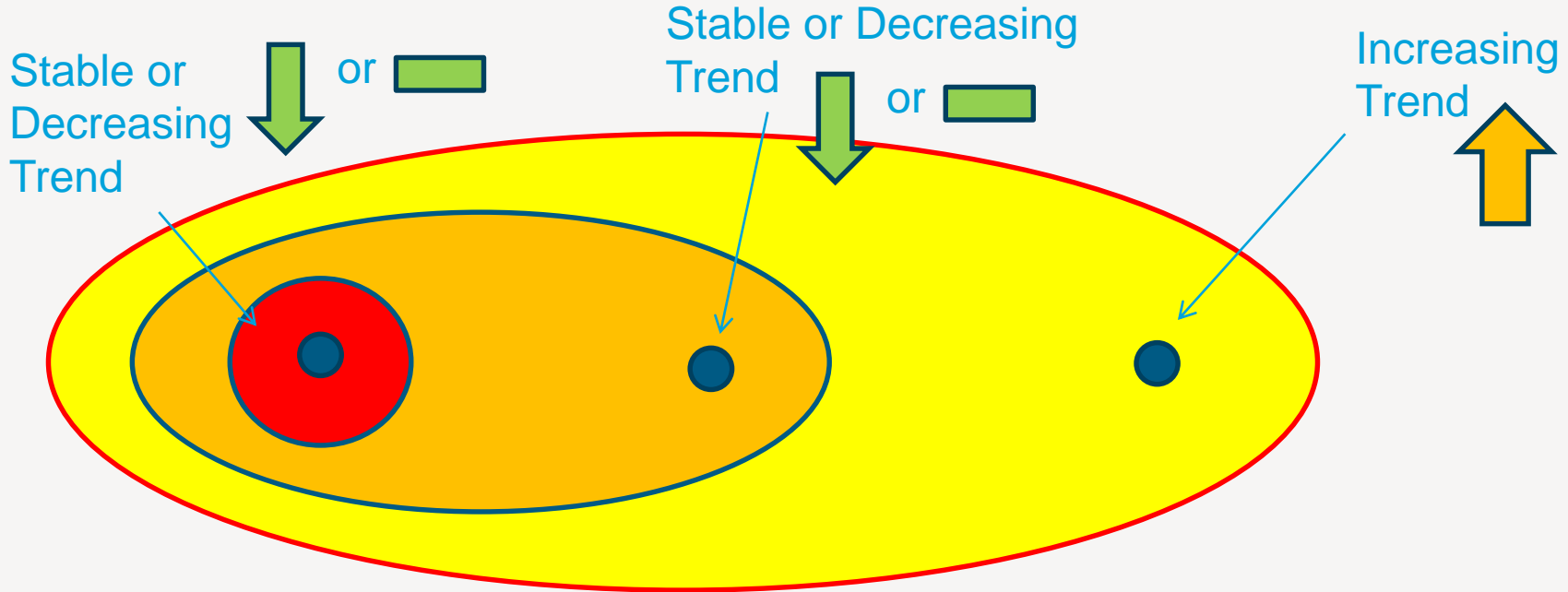
# Plume Status: Expanding Plumes



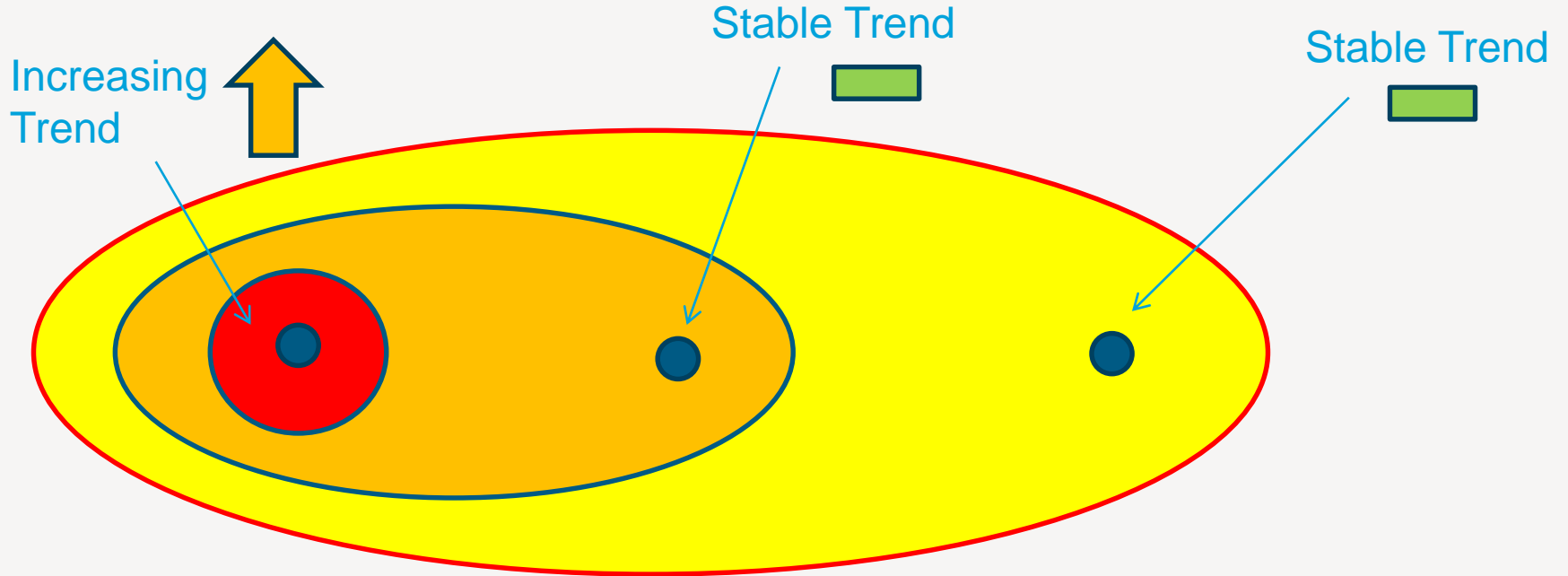
# Plume Status: Shrinking



# Plume Status: Expanding



# Plume Status: Stable



# More Methods to Determine Plume Stability

## Qualitative Methods

- › Concentration Temporal Trend Charts
- › Concentration Spatial Trend Maps
- › Concentration Isopleth Maps

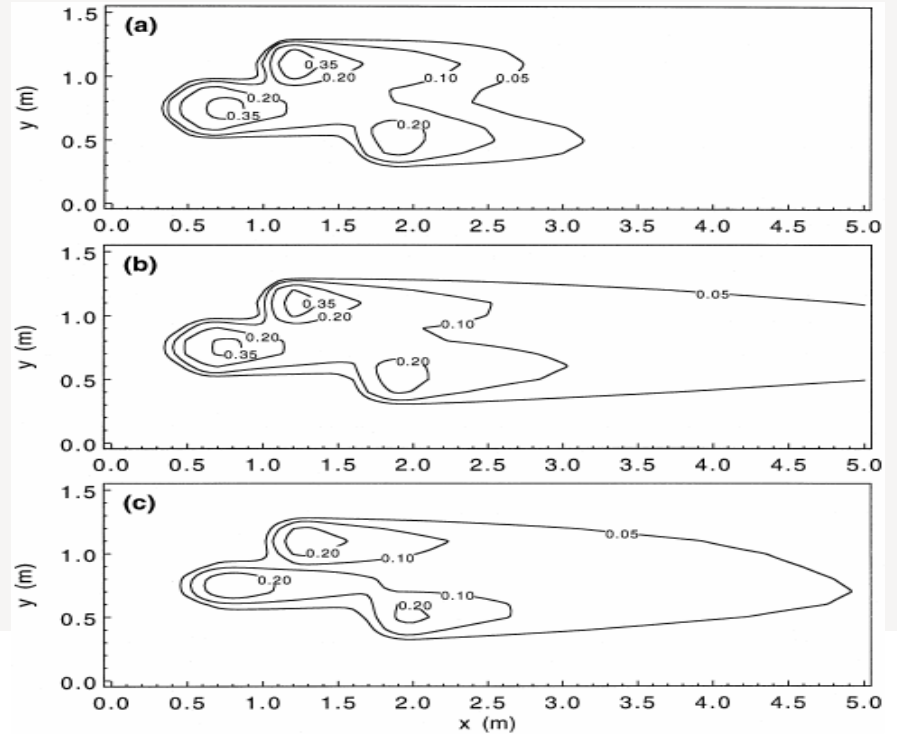
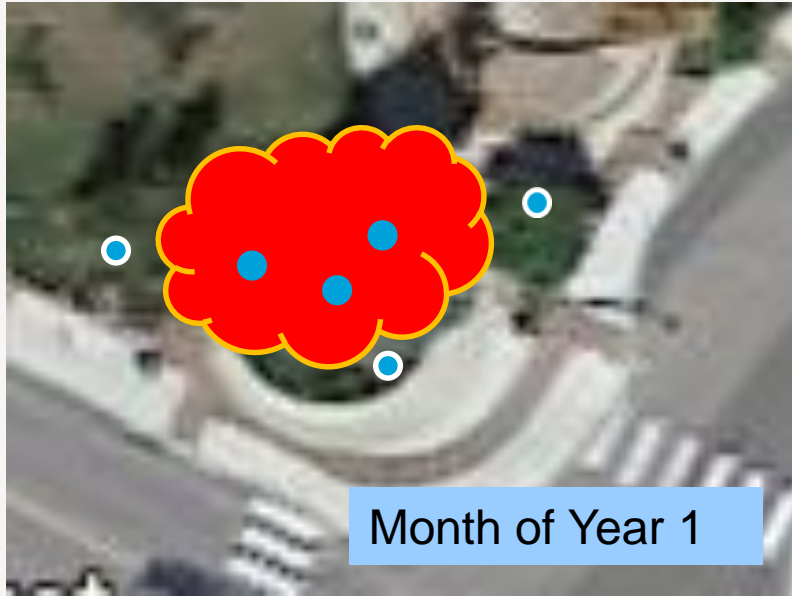
## Combined Methods

- › Analyzing concentration trends in individual monitoring wells
- › Plume characterization
- › Assessing nonparametric statistical trends in plume characteristics, including area, average concentration, total mass.

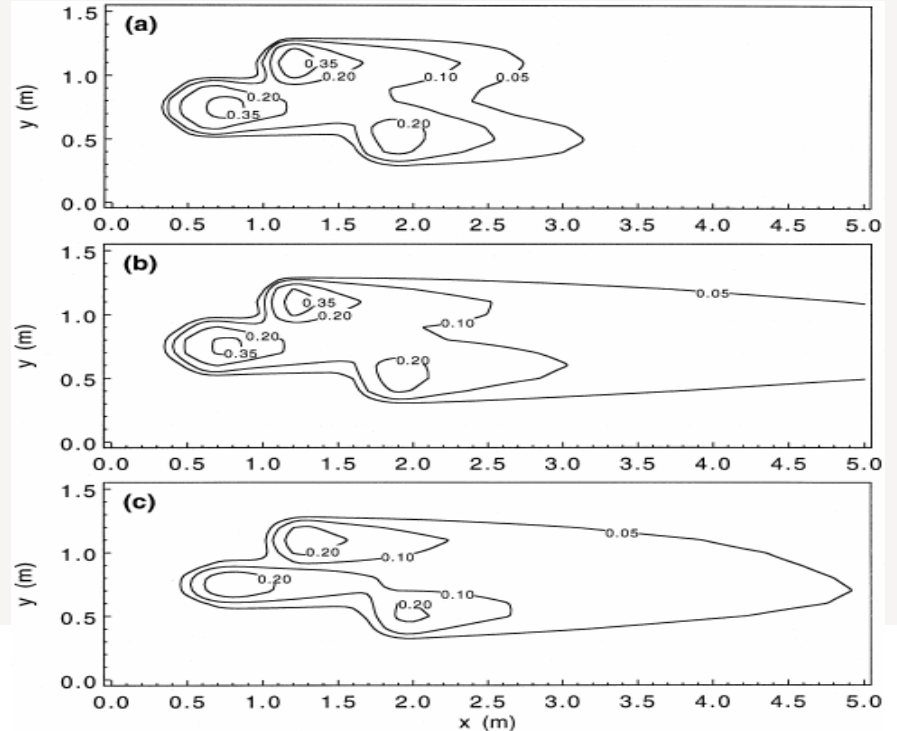
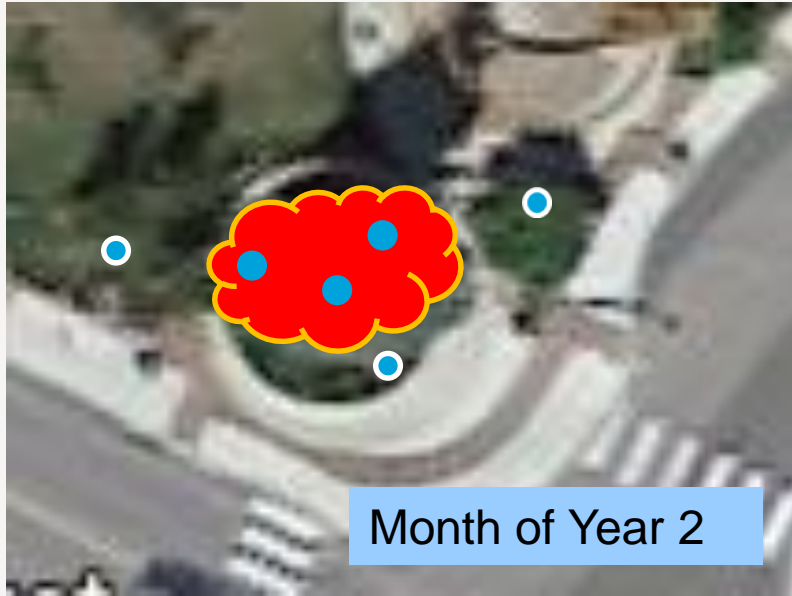




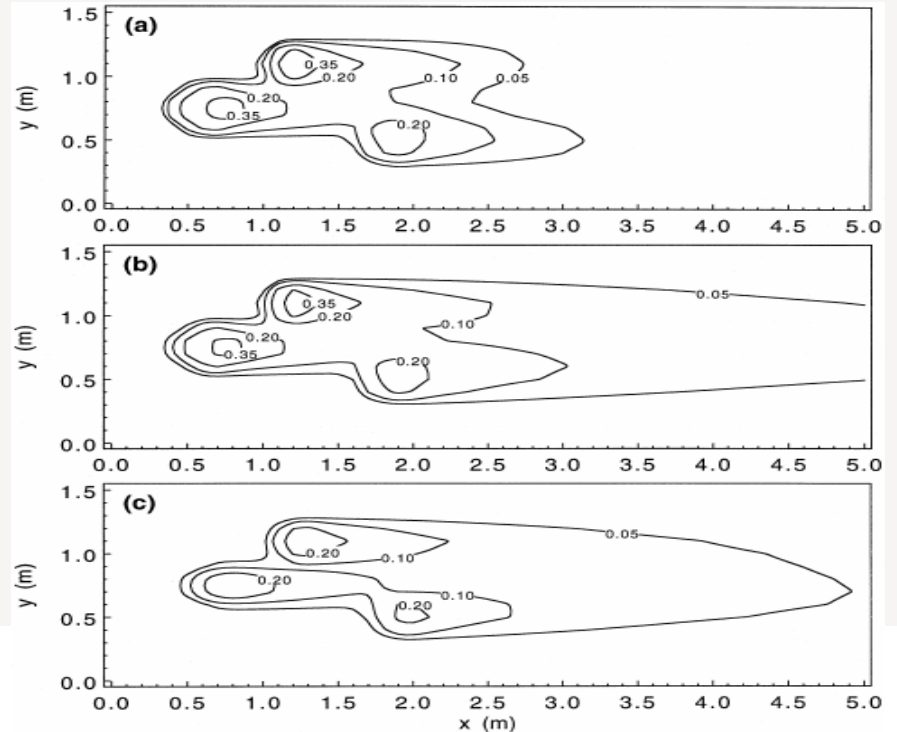
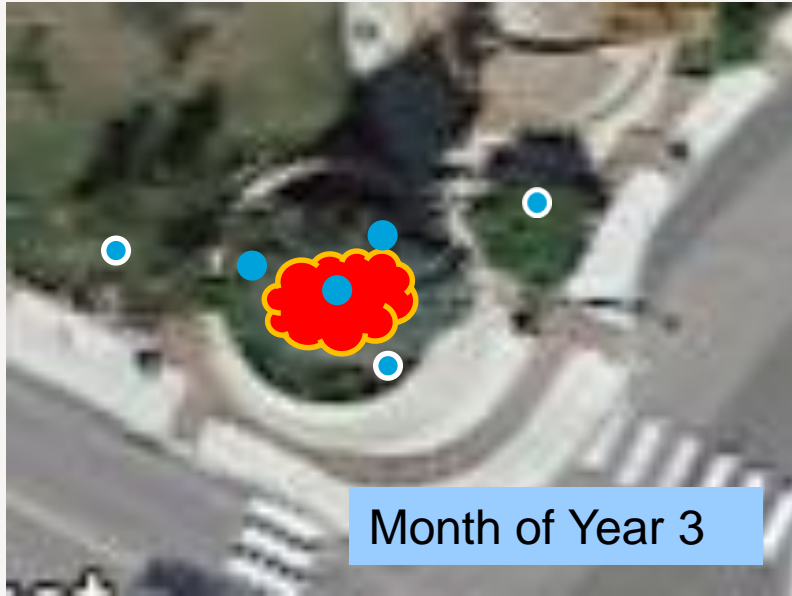
# Concentration Spatial Trend Maps & Isopleth Charts



# Concentration Spatial Trend Maps & Isoleth Charts

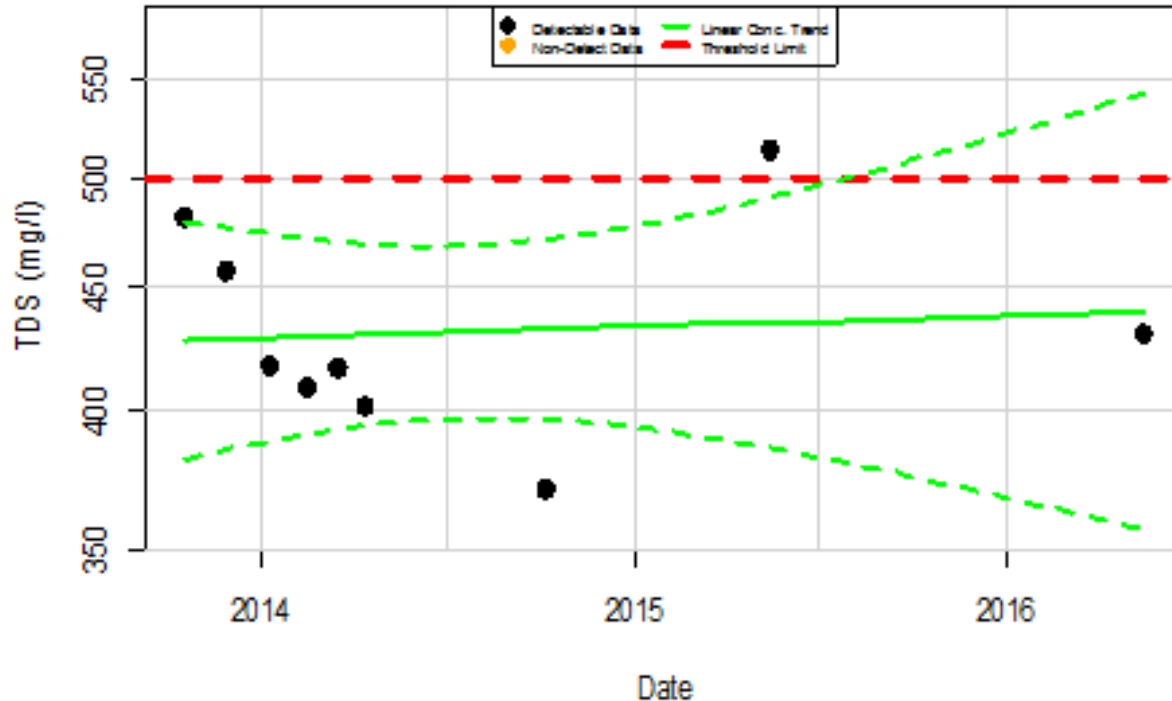


# Concentration Spatial Trend Maps & Isopleth Charts



# Concentrations Temporal Trend Charts: Total Dissolved Solids

TDS in REGMW13-01A : Aquifer-Surficial  
Mann-Kendall P.Value= 0.348; HalfLife> -5 Years



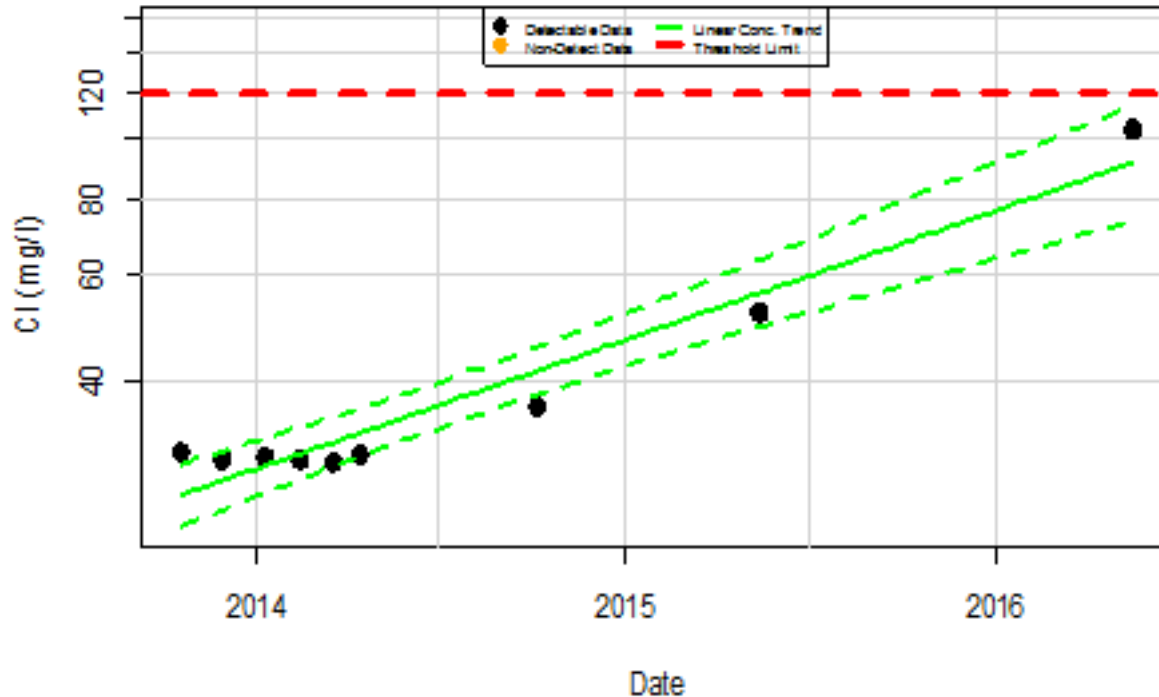
- Detectable Data
- Linear Conc. Trend
- - - Threshold Limit



# Concentrations Temporal Trend Charts: Chloride

*Cl in MW13-04A : Aquifer-Surficial*

Mann-Kendall P.Value= 0.0763; HalfLife= -511 days



- Detectable Data
- Linear Conc. Trend
- - - Threshold Limit



## Determine Plume Stability – Combining Methods

- › Plume Characterization
  - › Understand the Conceptual Site Model
  - › Understand the plume's configuration
  - › Understand the history of impact
    - › *Source removal*
    - › *On-going remediation or monitored natural attenuation*
    - › *Active operation*
- › Analyzing concentration trends in indicator wells;
- › Assessing other plume characteristics
  - › *Plume area (qualitative methods)*
  - › *Average concentration*
  - › *Plume mass*
  - › *Non parametric analysis on the above plume characteristics*



# Summary: Plume Stability as a Tool for Risk Assessment

- › Risk Assessment is understanding the three pillars: source, pathway, receptor.
- › If you can eliminate, isolate, or remove any of the three, there is no risk.
- › Finding a solution to manage risk will present the best compromise between risk control and societal benefit.
- › Plume Stability Analysis answers whether plumes are stable and / or decreasing.
- › Understand the plumes' anatomy to determine the status.
- › Combined methods will support the Plume Stability Analysis.
- › Use of statistics will support evidence-based decision-making.
- › Can include concentration trending charts, isopleth maps, spatial concentration maps to reinforce Plume Stability Analysis.



*Our values are the essence of our company's identity.  
They represent how we act, speak and behave together,  
and how we engage with our clients and stakeholders.*

*SAFETY*

*We put safety at the heart of everything we do, to safeguard people, assets and the environment.*

*INTEGRITY*

*We do the right thing, no matter what, and are accountable for our actions.*

*COLLABORATION*

*We work together and embrace each other's unique contribution to deliver amazing results for all.*

*INNOVATION*

*We redefine engineering by thinking boldly, proudly and differently.*

