Web-Based App to Support Transition from Active Remedies to Monitored Natural Attenuation

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FRTR Meeting

21 May 2024

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AGENDA / PROJECT TEAM

- What problem are we trying to address?
- What is a Transition Assessment?
- Project objective - development of a decision support tool
- Description of key tool modules
- Wrap-up

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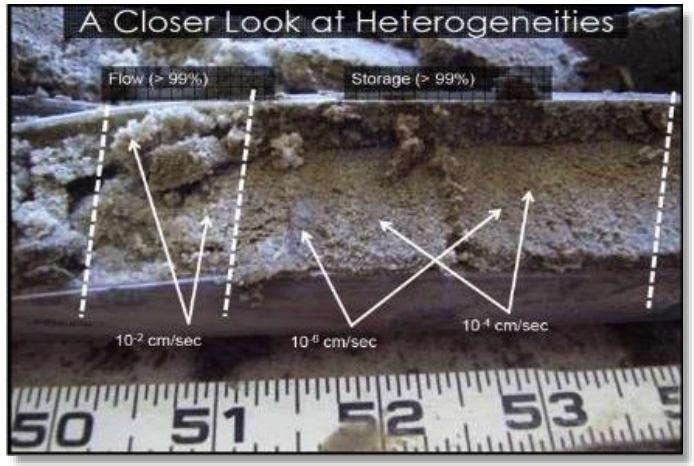
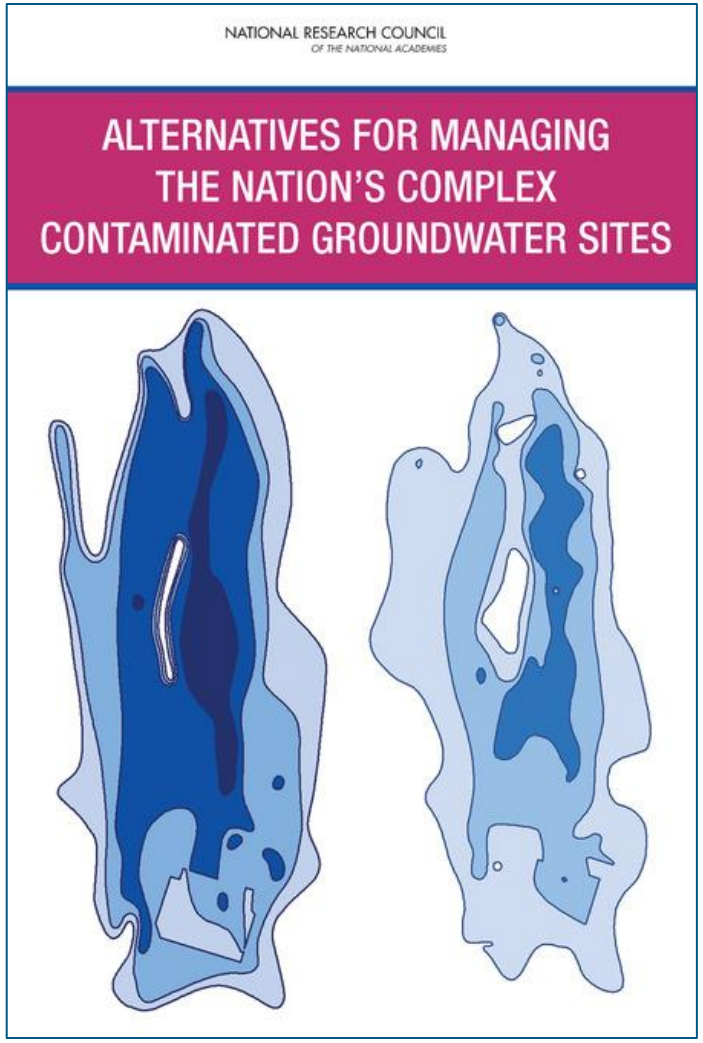
SERDP ER20-1429

Problem Statement

1. Remediation technologies for contaminated groundwater sites are expensive and imperfect
2. Matrix diffusion at heterogeneous sites can enhance contaminant persistence
3. Many sites has often appear to ***"hit a wall"*** because remaining mass is hard to treat



Critical Elements of a Transition Assessment



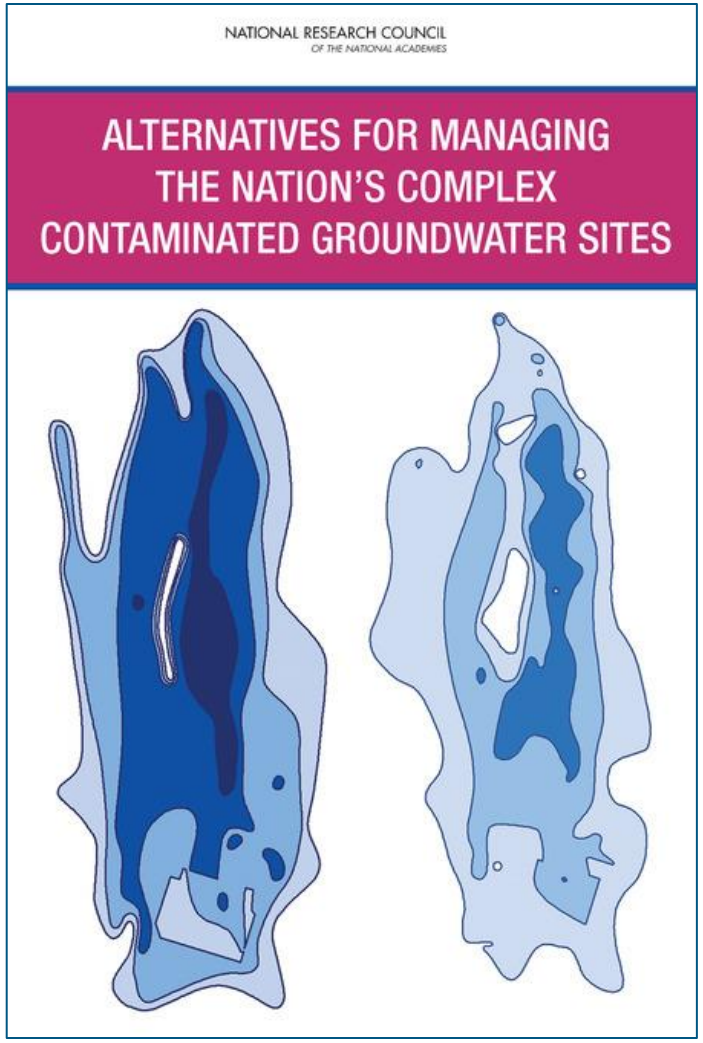
"At many complex sites, contaminant concentrations in the plume remain stalled at levels above cleanup goals despite continued operation of remedial systems."

"There is no clear path forward…"

"If the effectiveness of site remediation reaches a point of diminishing returns…the transition to monitored natural attenuation or some other active or passive management should be considered using a formal evaluation."

NRC, 2013

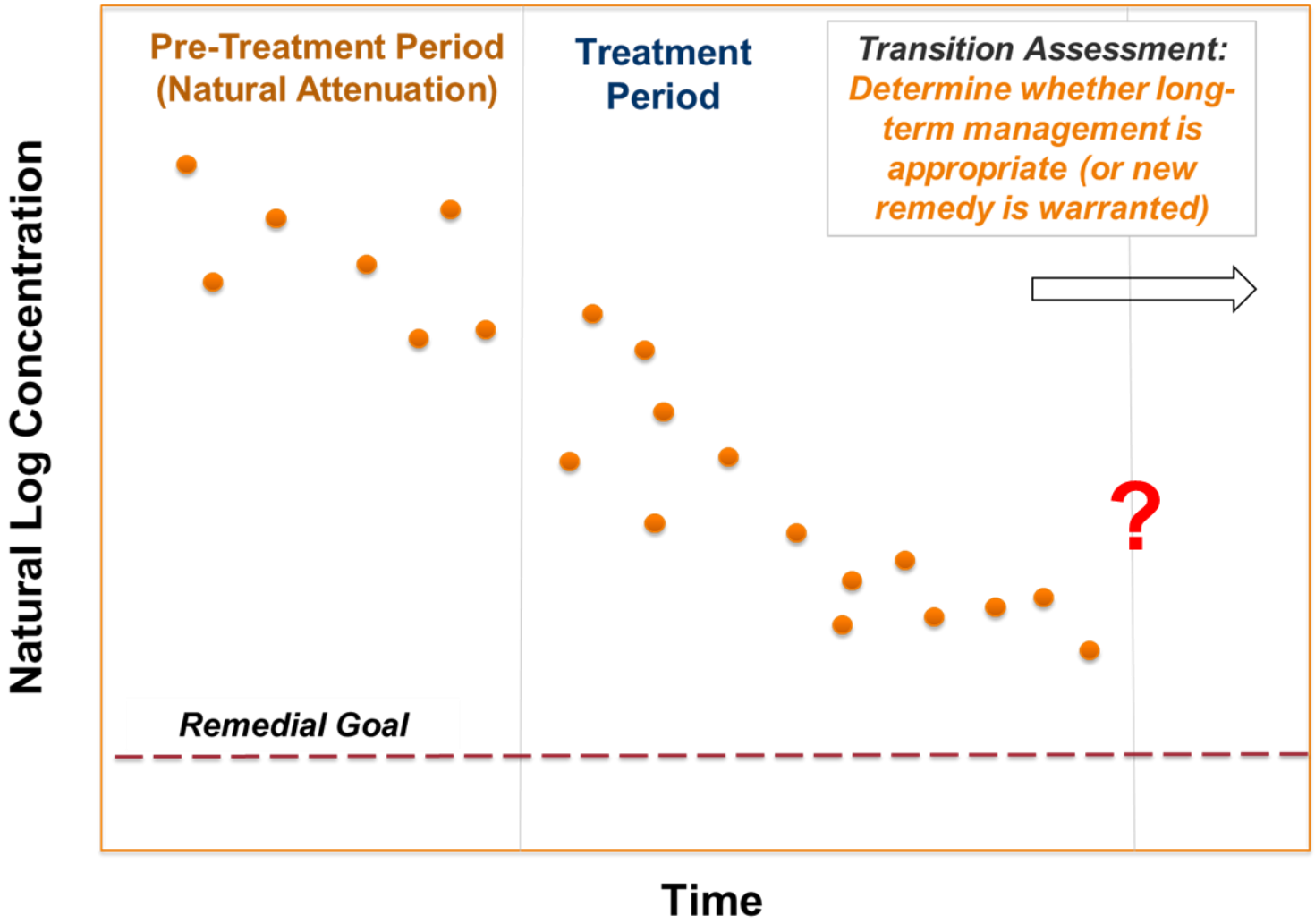
Critical Elements of a Transition Assessment



1. Describe site complexities and implications for achieving cleanup goals
2. Quantitative assessment of temporal concentration trends
3. Identification of alternative approaches for managing the site (e.g., **MNA**)

KEY POINT: **NRC emphasizes importance of transition assessment but is not prescriptive in how it should be done.**

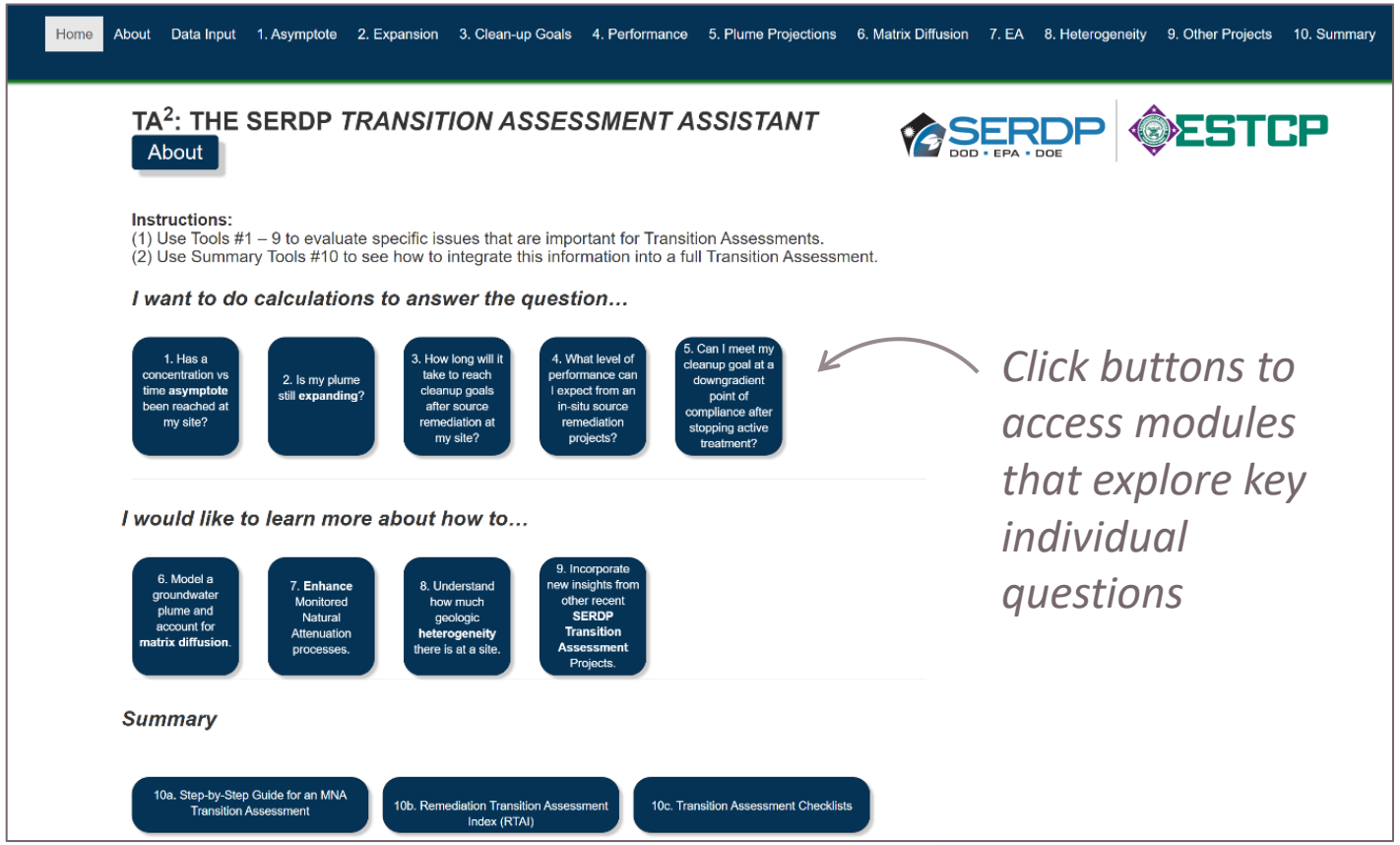
Project Objective



Develop a quantitative, research-driven **web-based tool** that provides stakeholders with reliable and transparent way to decide when to transition from active treatment to **MNA** and other alternative approaches

Web-Based Tool: *Concept and Structure*

Homepage for the working version of this app



Click buttons to access modules that explore key individual questions

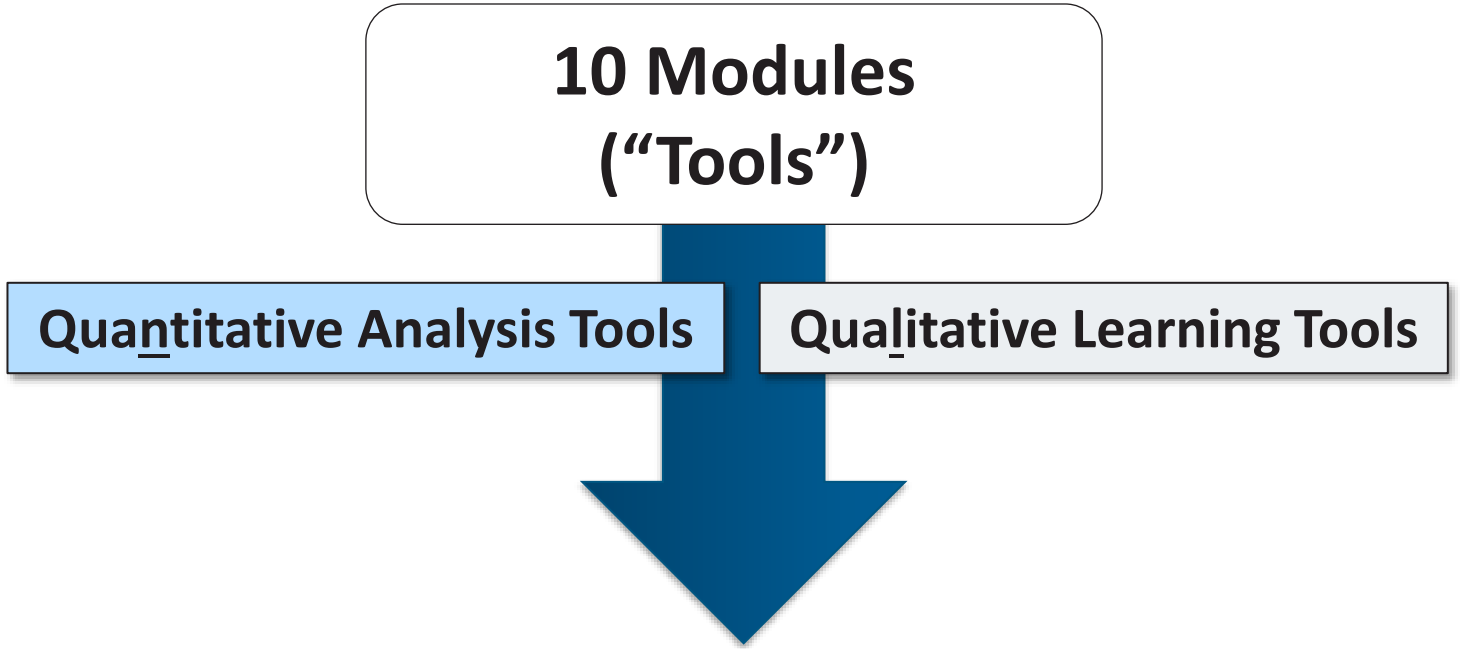
Shiny from RStudio

TA^2:

***T**eaching **A**ssistant for **T**ransition **A**ssessments*

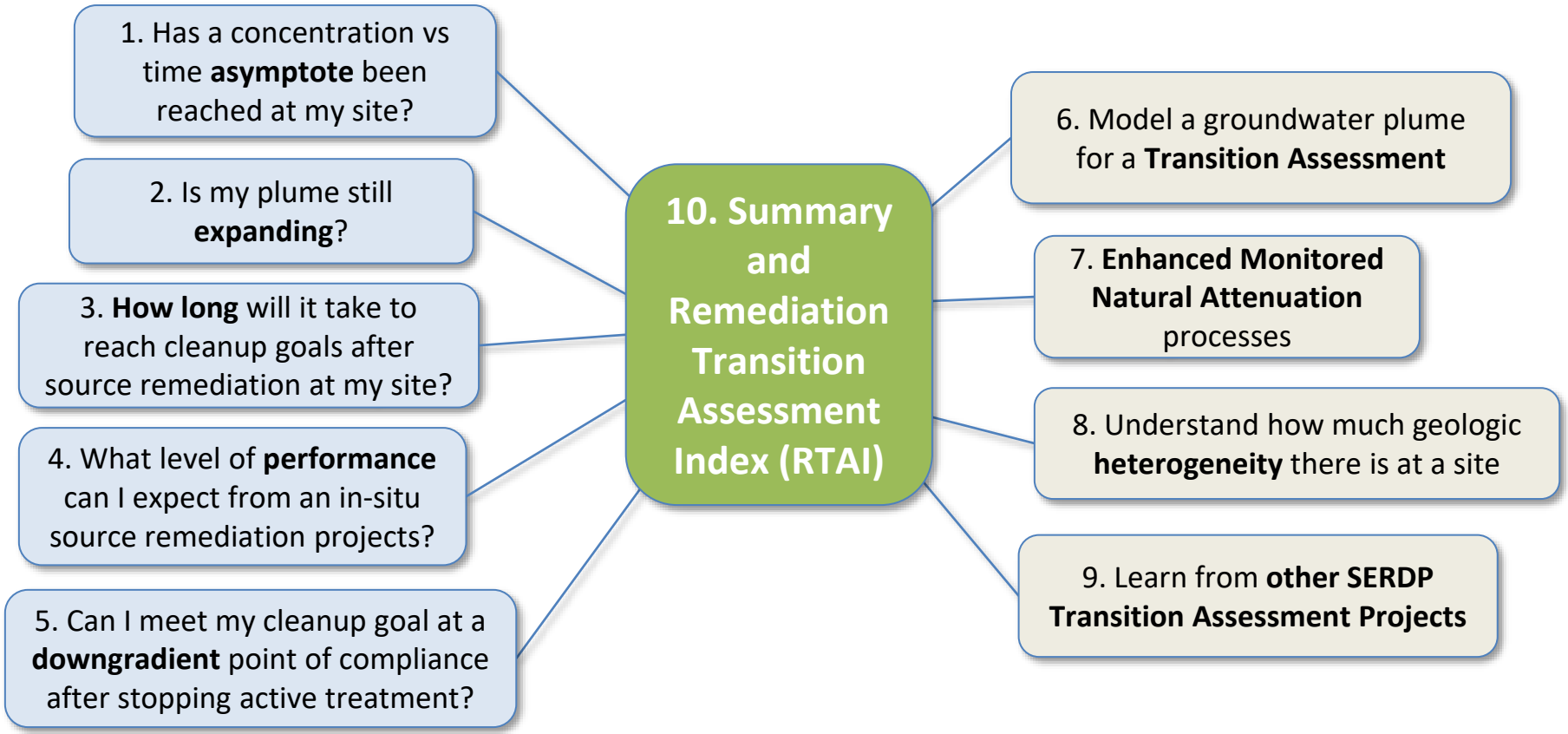
- Web-based app
- Runs in a web browser
- No downloading requirements
- Free
- Anticipated release in late 2023

Web-Based Tool: *Concept and Structure*



User can go through a single module
(to answer specific question(s))
or multiple modules
(for more comprehensive TA)

Web-Based Tool: *Concept and Structure*



Quantitative Analysis Tools

Qualitative Learning Tools

Web-Based Tool: *Data Input*

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1. Concentration and Time Data | 2. Monitoring Well Information

Event	Date	COC	Units	MW-1	MW-2	MW-3	MW-4	MW-5	MW-6	MW-7	MW-8	MW-9
1	03/02/2012	TCE	ug/L	37.10	37.10	37.10	37.10	7.00			37.10	37.10
2	08/31/2012	TCE	ug/L	41.90	41.90	41.90	41.90	8.49			41.90	41.90
3	03/02/2013	TCE	ug/L	13.00	13.00	13.00	13.00	10.70			13.00	13.00
4	08/31/2013	TCE	ug/L	5.10	5.10	5.10	5.10	11.20			5.10	5.10
5	03/02/2014	TCE	ug/L	11.50	11.50	11.50	11.50				11.50	11.50
6	08/31/2014	TCE	ug/L	5.00	5.00	5.00	5.00	12.00			5.00	5.00
7	03/02/2015	TCE	ug/L					15.00		7.00		
8	08/31/2015	TCE	ug/L	4.60	4.60	4.60	4.60	9.40	7.00	8.49	4.60	4.60
9	03/01/2016	TCE	ug/L	1.85	1.85	1.85	1.85		8.49	10.70	1.85	1.85
10	08/30/2016	TCE	ug/L					11.60	10.70	11.20		
11	03/01/2017	TCE	ug/L	1.80	1.80	1.80	1.80	14.30	11.20		37.10	1.80
12	08/30/2017	TCE	ug/L	1.20	1.20	1.20	1.20			12.00	41.90	1.20
13	03/01/2018	TCE	ug/L	1.00	1.00	1.00	1.00		12.00	15.00	13.00	1.00
14	08/30/2018	TCE	ug/L	1.20	1.20	1.20	1.20		15.00	9.40	5.10	1.20
15	03/01/2019	TCE	ug/L	1.00	1.00	1.00	1.00		9.40		11.50	1.00
16	08/30/2019	TCE	ug/L	0.80	0.80	0.80	0.80			11.60	5.00	0.80

KEY POINTS:

- Site-specific monitoring data is pasted or uploaded into the tool
- No data is stored in the cloud - users save data on their computers.

Tool 1 - Asymptotes: *Are you approaching a concentration vs. time asymptote?*

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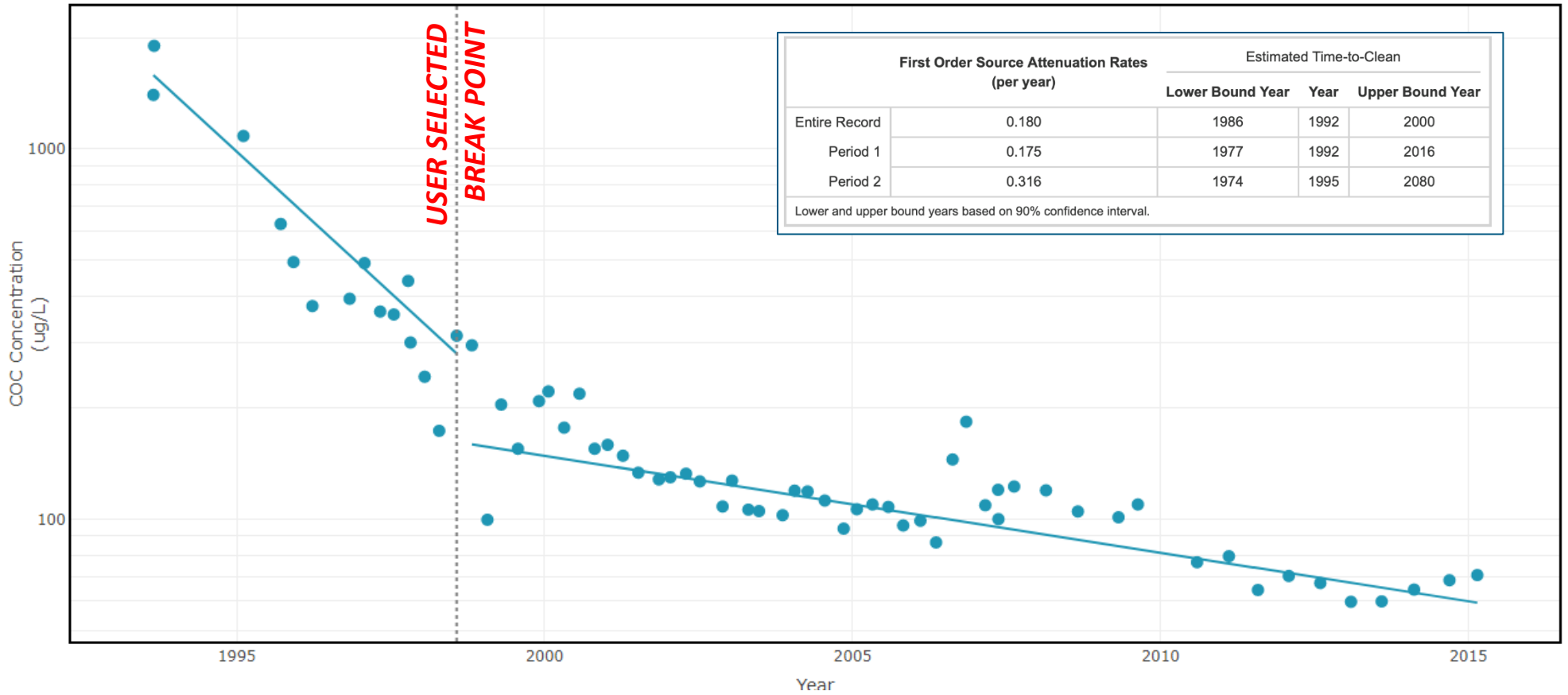
Results | Data

Average Concentration of COC in Selected Wells Over Time



	First Order Source Attenuation Rates (per year)	Estimated Time-to-Clean		
		Lower Bound Year	Year	Upper Bound Year
Entire Record	0.180	1986	1992	2000
Period 1	0.175	1977	1992	2016
Period 2	0.316	1974	1995	2080

Lower and upper bound years based on 90% confidence interval.

Tool 1 - Asymptotes: *Five asymptote tests*

Possible Asymptotic Conditions	Is the Condition Met?
1. Are the two slopes for the two periods significantly different?	YES
2. Is the rate for period 2 significantly different then 0?	YES
3. Is the rate of the first period more than two times the second rate?	YES
4. Is the concentration difference of the last points on the regression lines shown in the graph greater than one order of magnitude?	YES
5. Is the period 2 rate less than 0.0693 per year (10 year half-life)?	YES

5 of the **5** possible asymptotic conditions are present.

KEY POINT: Site-specific data are processed to develop simple Lines of Evidence (LOE)

Tool 2 – Plume Stability:

Spatial and temporal analysis

OVERALL MANN-KENDALL TEST RESULTS

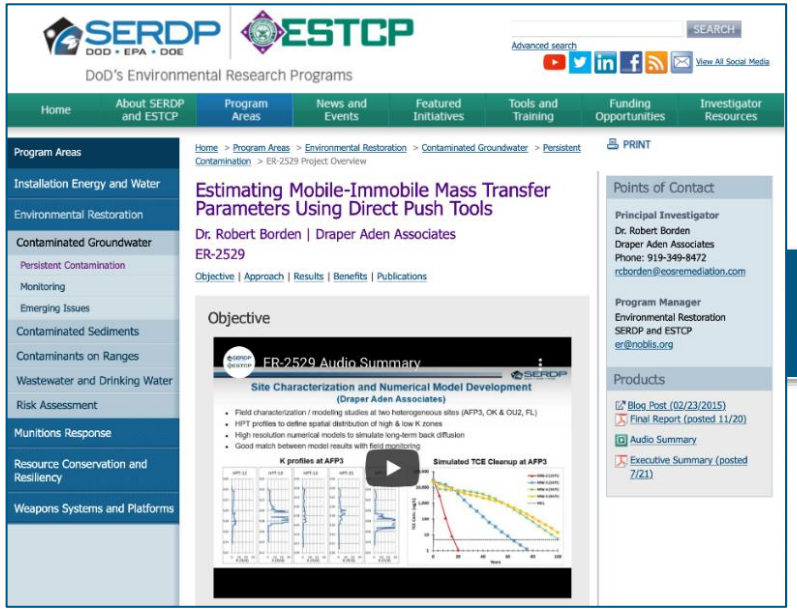
Groups of Wells	Trend	*S Statistic*	*p-Value*	*Coefficient of Variation*	*Sen's Slope*
All Monitoring Wells	Decreasing	−104	0.000832	3.11	−0.507

MANN-KENDALL TEST RESULTS BY WELL

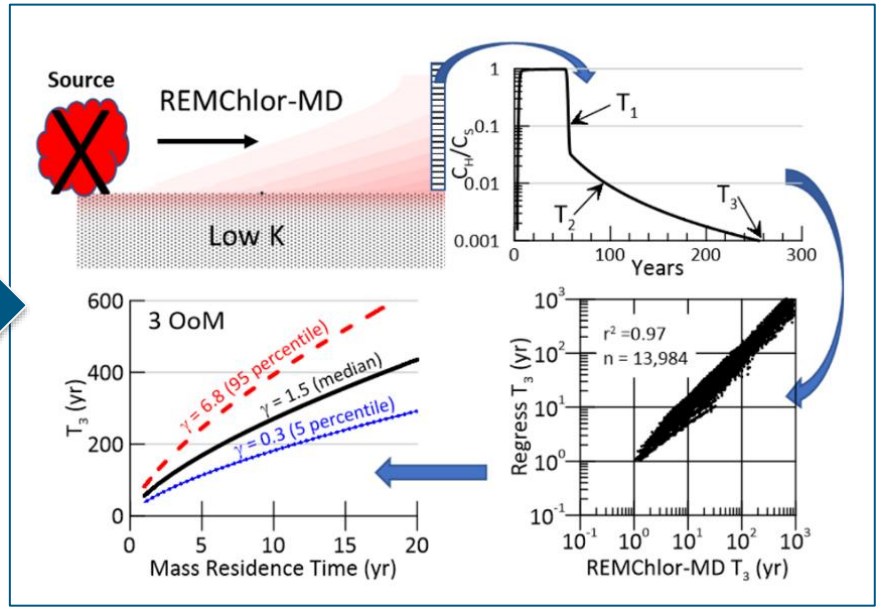
Monitoring Well	Trend	*S Statistic*	*p-Value*	*Coefficient of Variation*	*Sen's Slope*
MW-1	Decreasing	−96	0.0000886	3.53	−0.579
MW-2	Decreasing	−96	0.0000886	2.85	−0.579
MW-3	Decreasing	−96	0.0000886	3.46	−0.579
MW-4	Decreasing	−96	0.0000886	3.46	−0.579
MW-5	Probably Increasing	23	0.0868	2.71	0.800
MW-6	Probably Increasing	23	0.0868	2.10	0.800
MW-7	Probably Increasing	23	0.0868	2.80	0.800
MW-8	No Trend	−32	0.199	1.26	−0.400
MW-9	Decreasing	−96	0.0000886	2.70	−0.579

	Is the plume still expanding?
All Monitoring Wells	*No*

Tool 3 – Remediation Timeframe Estimates: *How long will it take to reach cleanup goals after source remediation?*

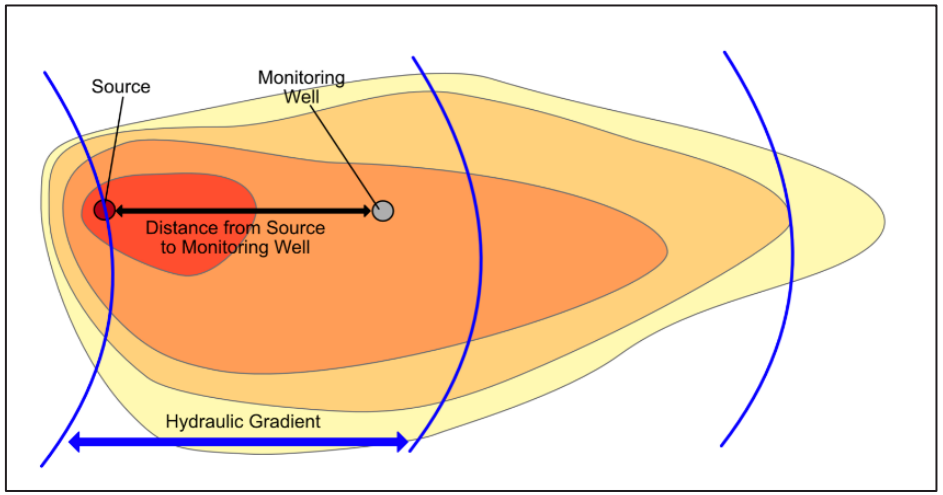


SERDP Project ER-2529
(PI: Dr. Bob Borden)
28,000 REMChlor-MD Simulations



Borden and Cha Paper
(*Science of the Total Environment*, 2021)

Tool 3 – Remediation Timeframe Estimates



Input Data

1. Site/Temporal Settings & COC | 2. Select Scenario & Hydrologic Setting | 3. Site-Specific Parameters (Optional)

4. Uncertainty Analysis (Optional)

Enter specific parameters below or use buttons to upload data (requires use of template file):

Choose Input File

Browse... | No file selecte

Update Input Values from Input File

Will reset all input values.

Distance from Source to Monitoring Well (meters):	50	?
Hydraulic Gradient (-):	0.0001	?
Constituent of Concern:	TCE	?
Year Source Started:	1970	?
Year Source Removed:	2020	?
Concentration of COC Before Source Removed (ug/L):	10000	?

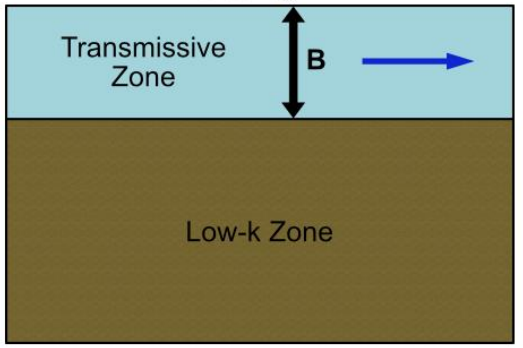
Tool 3 – Remediation Timeframe Estimates

Select the hydrogeologic setting that best matches your site.

?

- (●) Setting 1: Aquifer with aquitard (either below, above, or both)
- ( ) Setting 2: Aquifer with no aquitard but layers/lenses
- ( ) Setting 3: Aquifer with both aquitard and layers/lenses

Setting 1

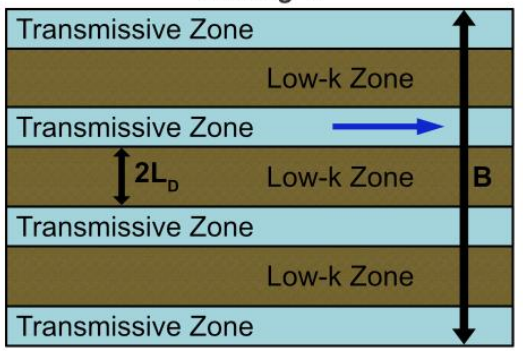


Describe Layers and Lenses

For All Scenarios:

Aquifer Thickness (meters):	1	?
Transmissive Zone Soil Type:	Gravel	?
Low-k Soil Type:	Clay	?

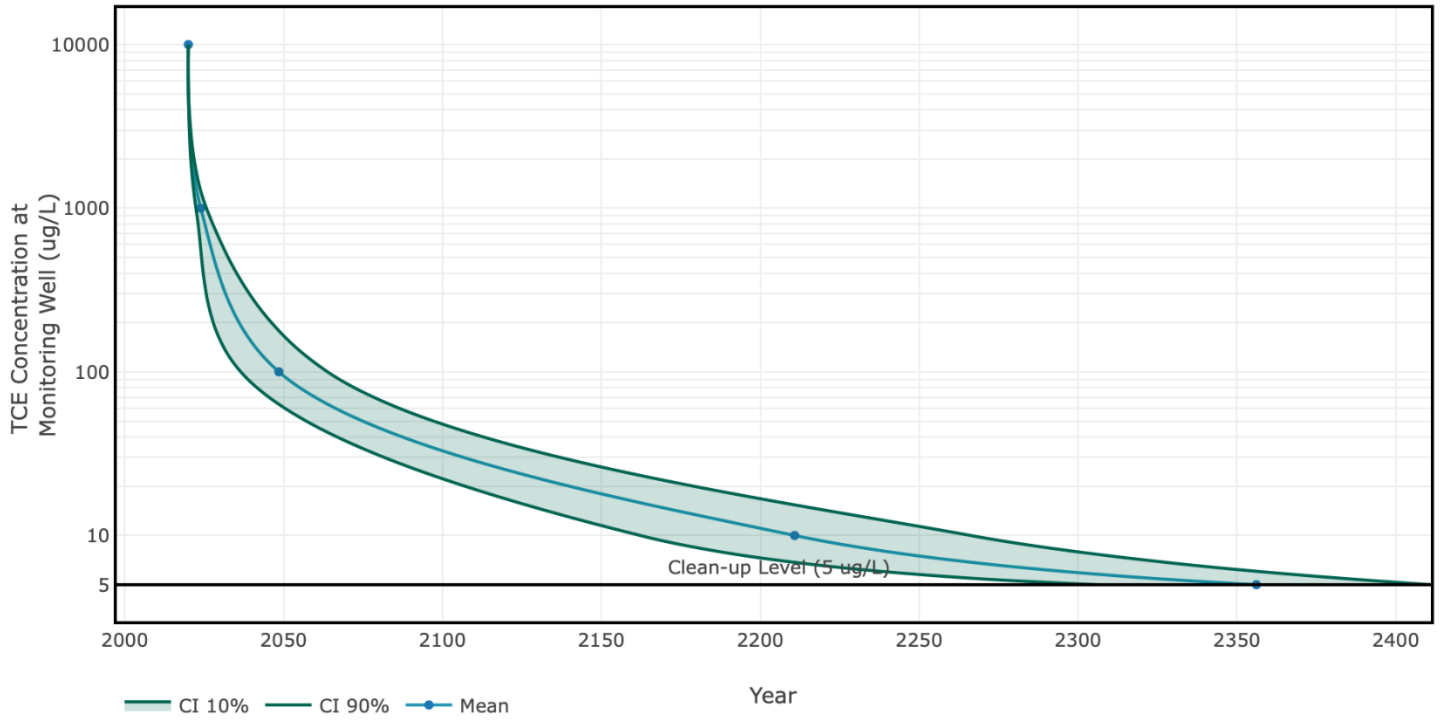
Setting 2



Tool 3 – Remediation Timeframe Estimates

1. See Timeframe to Reduce Plume Concentrations by 90%, 99%, and 99.9%

Concentration Reduction	Concentration (ug/L)	Year Achieved	Years From Now (2022)	Deviation of Years from Mean
90% (1 OoM)	1000	**2024**	**2**	1 - 2
99% (2 OoMs)	100	**2049**	**27**	12 - 15
99.9% (3 OoMs)	10	**2211**	**189**	49 - 55

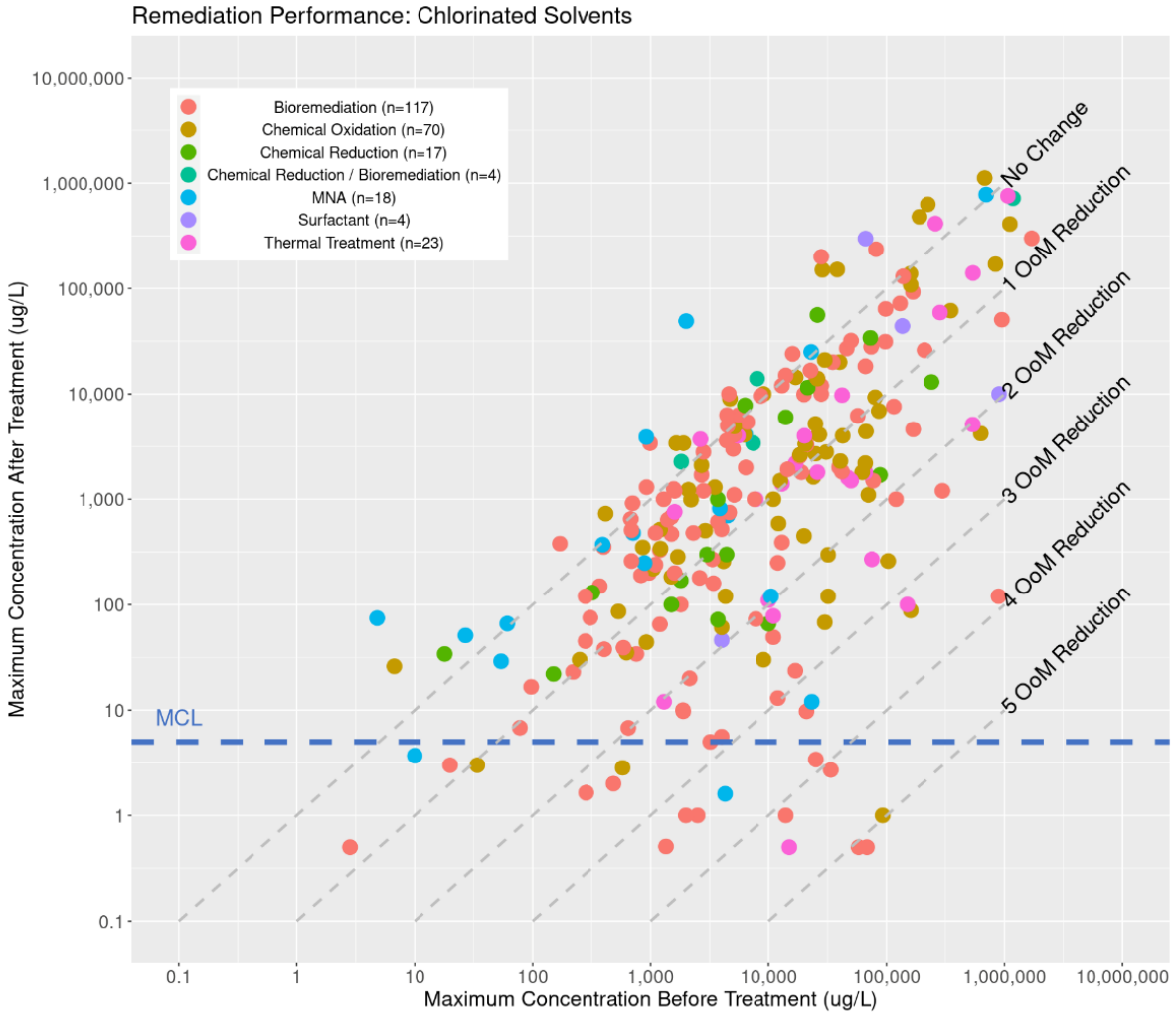


KEY POINT:

Estimates remediation timeframe after active source treatment (with uncertainty) to compare to MNA-based approaches.

Tool 4 – Remediation Performance:

What performance can I expect from in situ remediation?



Number of Remediation Projects: **253**

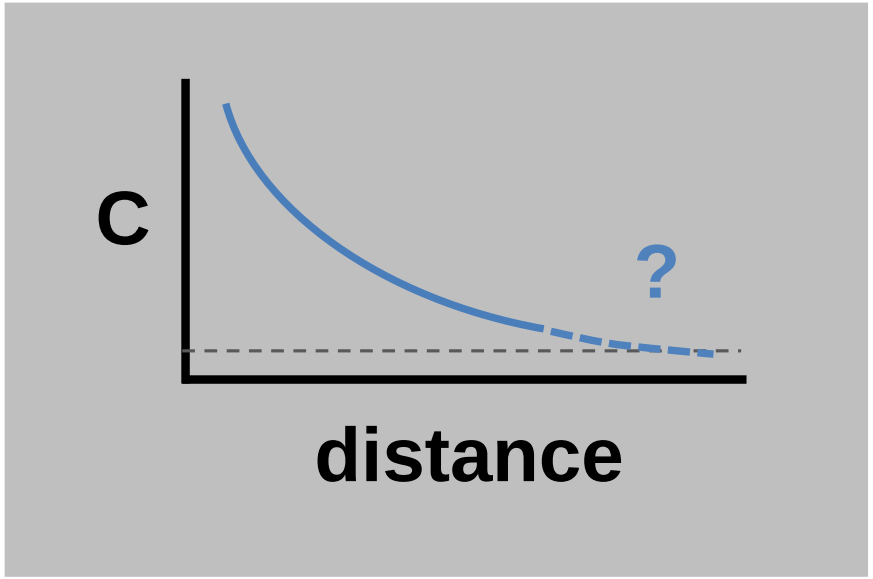
	Middle Range	Low Range	High Range
Empirical Remediation Performance Stats			
% reduction	82	Increasing	100
OoM reduction	0.75	-1.4	5.1

KEY POINT:

Tool provides access to empirical performance data for benchmarking purposes

Tool 5 – Plume Attenuation Rates: *Can I meet a downgradient cleanup goal after transitioning to MNA?*

1. Estimate the plume attenuation rate using **field data** (concentration vs. distance) or **lab-based data**
2. Use this rate to forecast the future plume extent downgradient of source area (e.g., after shutting off a P&T well)
3. If forecasted concentrations at point-of-compliance are below the goal, then this supports transitioning to MNA as risk management strategy



Tool 5 – Plume Attenuation Rates:
Use Pre-Remediation rate constants

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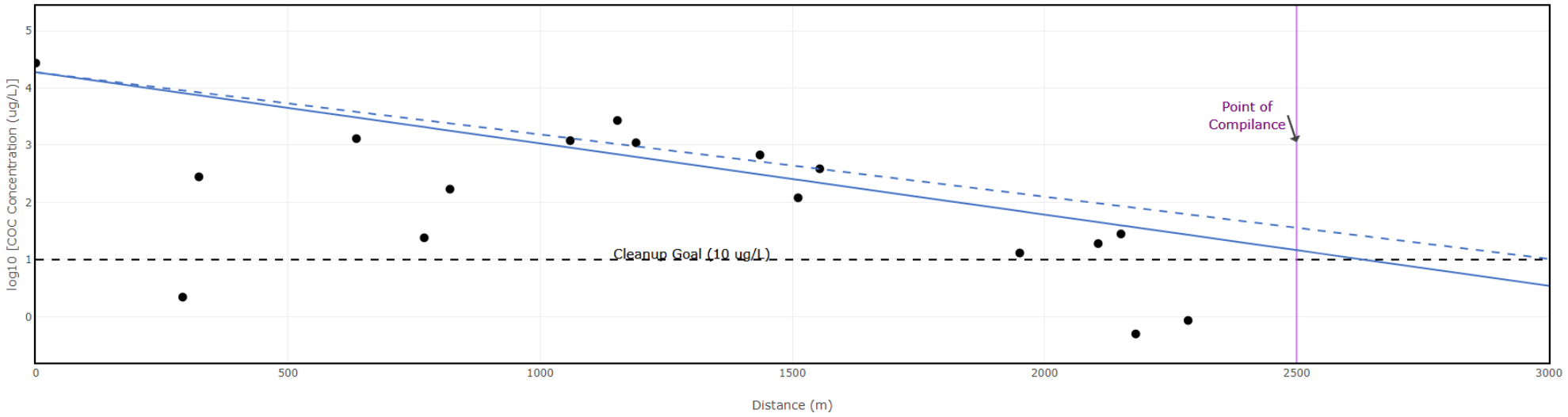
Results

1. Pre-Remediation Period (actual)

Mean Concentration of COC in Selected Wells Over Distance



Natural attenuation rate used for future plume projections

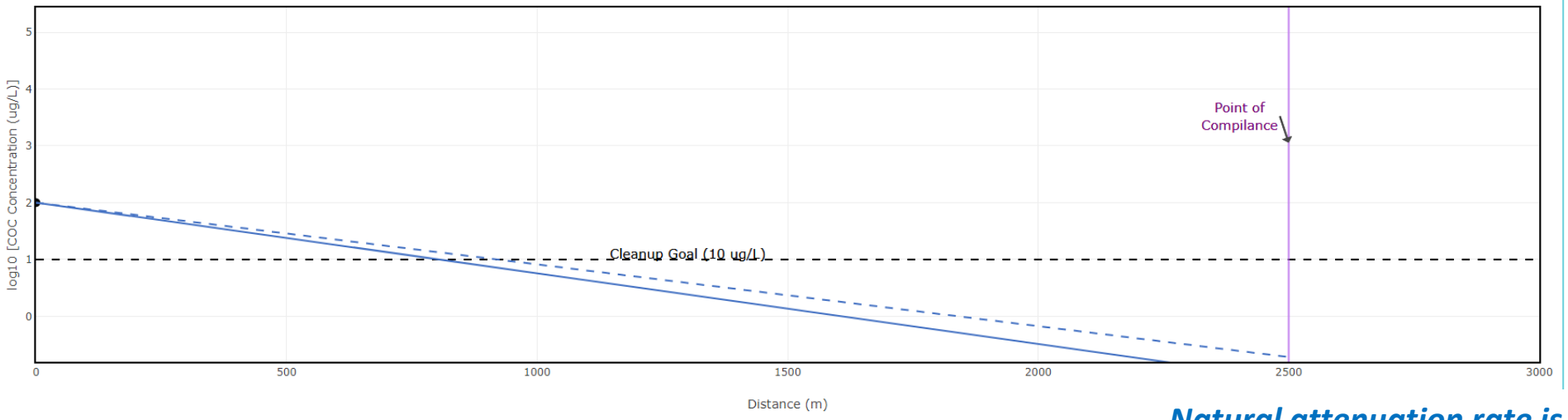
Estimated Attenuation Rate Constant (per meter)

Without Confidence Limit	With Confidence Limit
-0.0012	-0.0011

Tool 5 – Plume Attenuation Rates:
Use Pre-Remediation rate constants

2. Post-Remediation Period (projected)

Mean Concentration of COC in Selected Wells Over Distance



Natural attenuation rate is sufficient to achieve cleanup goal

	Without Confidence Limit	With Confidence Limit
Estimated Concentration at Point of Compliance (ug/L)	0.078	0.19
Cleanup Goal Achieved at Point of Compliance?	Yes	Yes

Tools 6 – 9
The Four Qualitative Modules

Tool 6 - Understanding and Modeling Matrix Diffusion

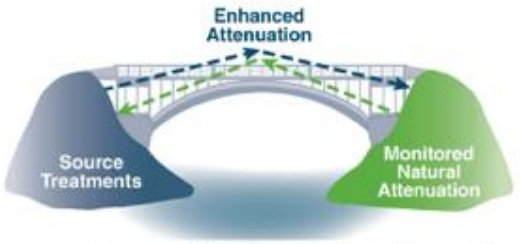
5a History of TA | 5b MD Case Study | 5c Models for TA | 5d REMChlor-MD

Tool 5d. How can I model a groundwater plume to support a Transition Assessment (TA)?

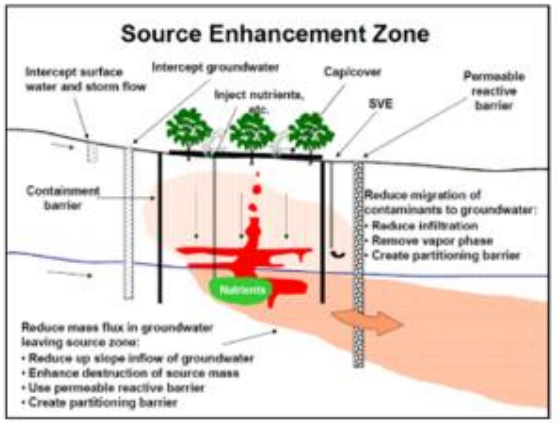
- REMCHLOR-MD MODEL OVERVIEW
- HOW TO USE REMChlor-MD FOR TRANSITION ASSESSMENTS
- KEY PARAMETERS FOR REMChlor-MD
- HOW TO CALIBRATE REMChlor-MD
- REMCHLOR-MD ASSUMPTIONS AND LIMITATIONS
- REFERENCES

Tool 7 – Enhanced Attenuation Approaches for:

- Chlorinateds
- Inorganics-radionuclides
- PFAS



Conceptual Position of Enhance Attenuation vs. Source Treatment and MNA (ITRC, 2008)



Tools 6 – 9
The Four Qualitative Modules

Tool 8 – Geologic Heterogeneity Calculator

*Tool 7 indicates the relative impact of **matrix diffusion** on remediation*

User describes aquitards and enters boring log data

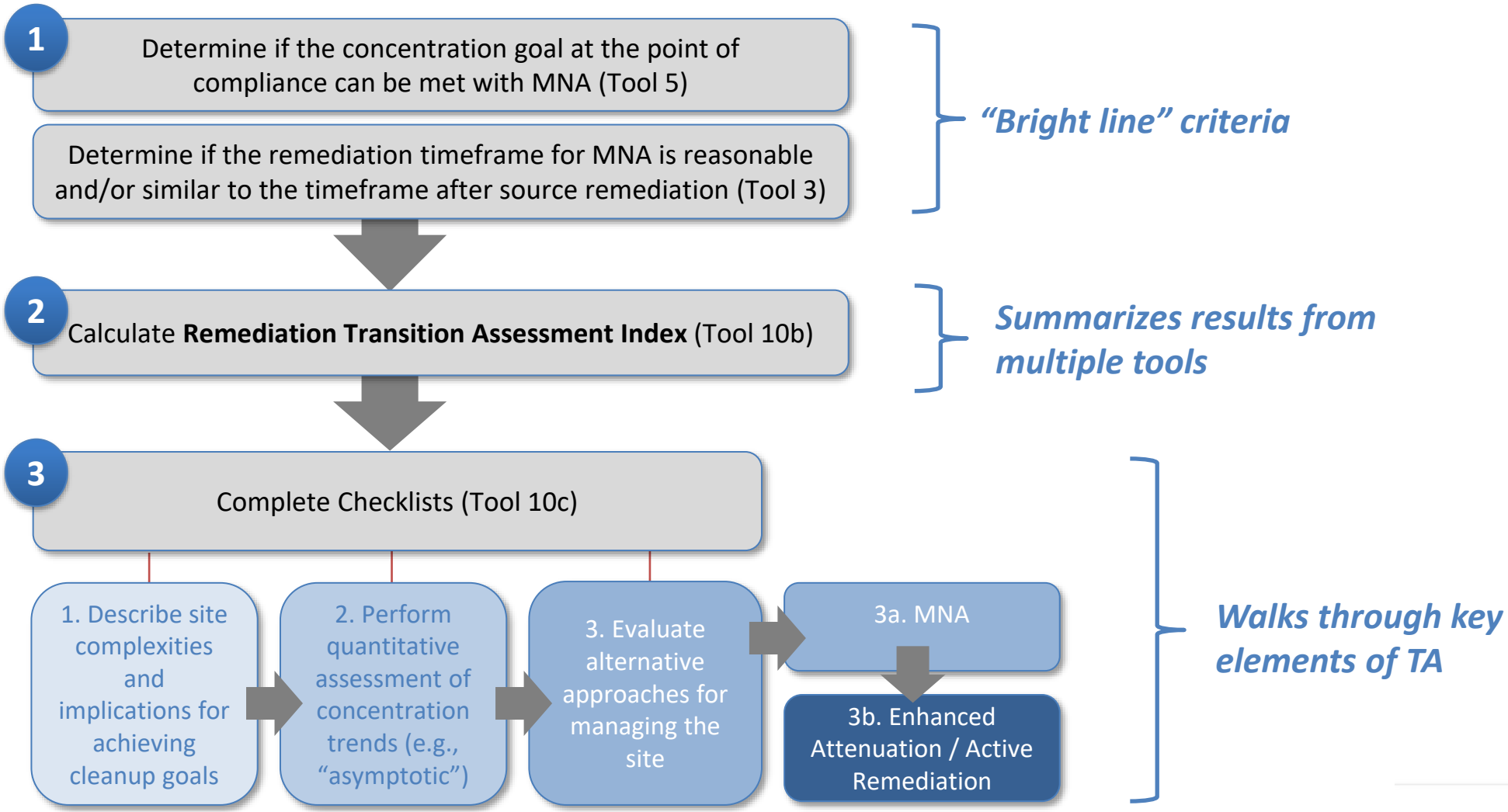
Example Result: *"Combining values from all steps, the overall impact of heterogeneity on matrix diffusion is expected to be **High**."*

Tool 9 – Learn from Other SERDP Transition Assessment Projects

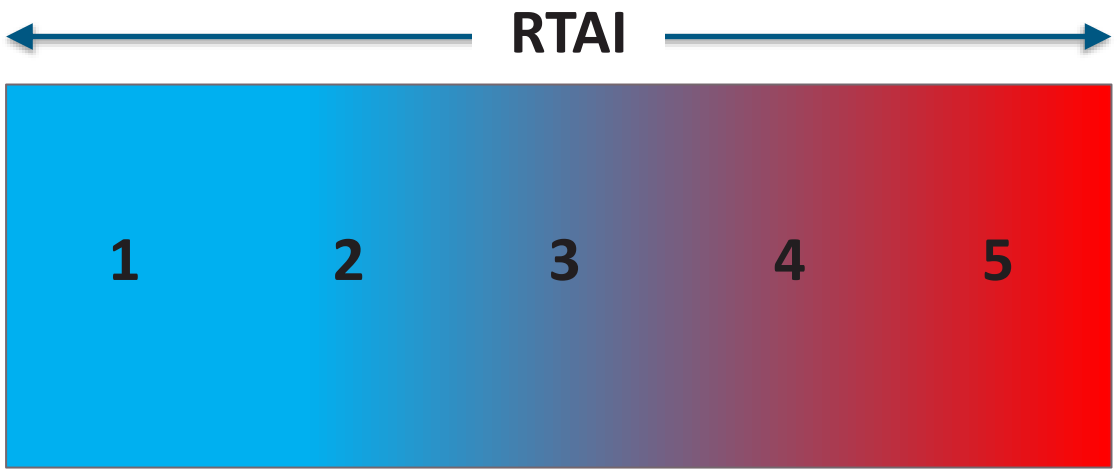
SERDP Project Number	Title
ER20-1079	Development of Predictive Tools for Assessment of Natural Attenuation Capacity and Treatment Transition at Chlorinated Solvent Sites
ER20-1203	Quantifying the Distribution of Biotic and Abiotic Transformation Rate Constants in Low Permeability Clay Zones for Improved Assessment of TCE Impacts to Groundwater at DoD Field Sites
ER20-1270	Quantitative Assessment of Long-term Abiotic Transformation Rates of Chlorinated Solvents

SERDP Project Number	Title
ER20-1357	Developing a Quantitative Framework for Predicting Abiotic Attenuation under Natural and Transitional Site Management Scenarios
ER20-1368	Development of Protocols to Quantify Abiotic Transformation Rates and Mechanisms for Chlorinated Ethenes in Water Supply Aquifers
ER20-1374	Field Deployable ORP Kit for Quantitative Assessment of Abiotic Monitored Natural Attenuation Rates

Tool 10 – Summary of Site-Specific Transition Assessment (TA)



Tool 10 – Summary of Site-Specific TA:
Remediation Transition Assessment Index (RTAI)



RTAI = 1
Site is poor candidate for transition

RTAI = 5
Site is strong candidate for transition

- Remediation Transition Assessment Index (**RTAI**) is a simple metric that reflects the relative persistence of contamination at a site due to matrix diffusion and other site-specific considerations
- Summarizes the results from relevant modules within the TA^2 Tool, assigning an RTAI value to each result

Tool 10 – Summary of Site-Specific TA:
Remediation Transition Assessment Index (RTAI)

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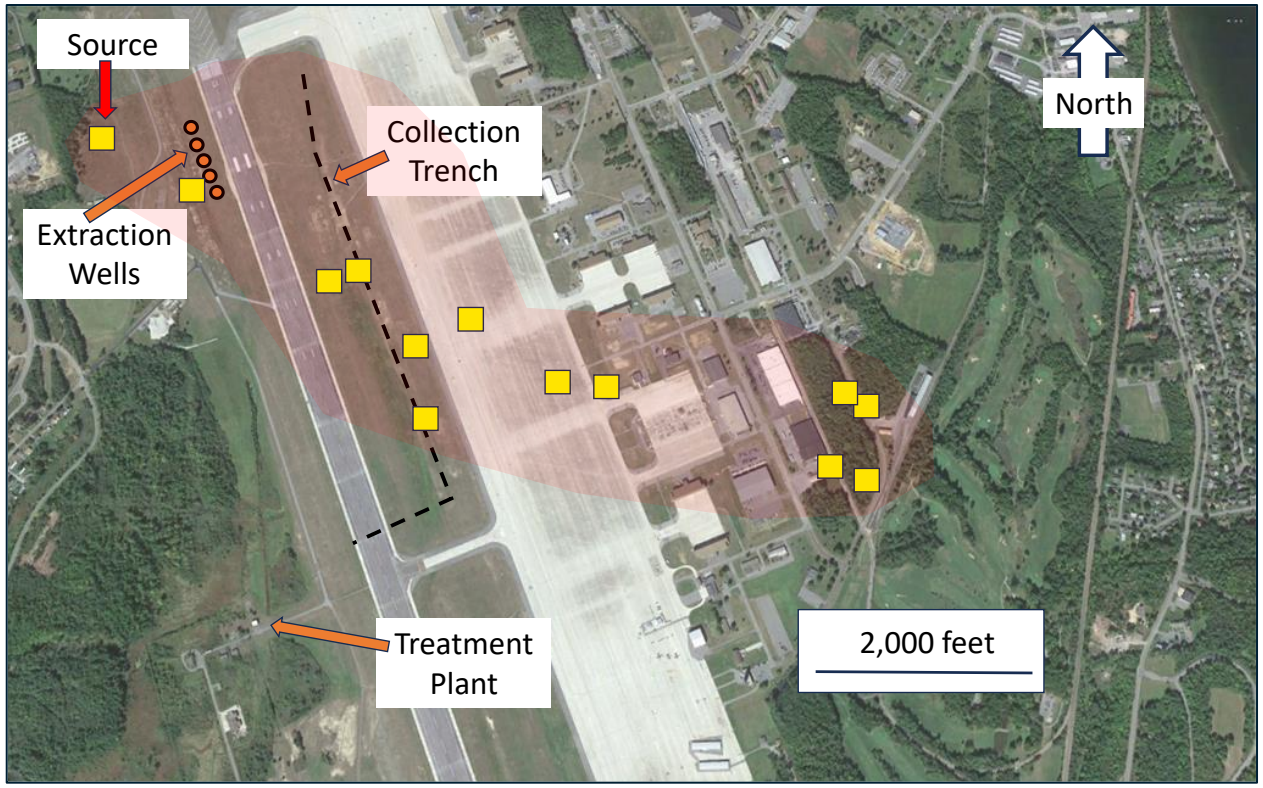
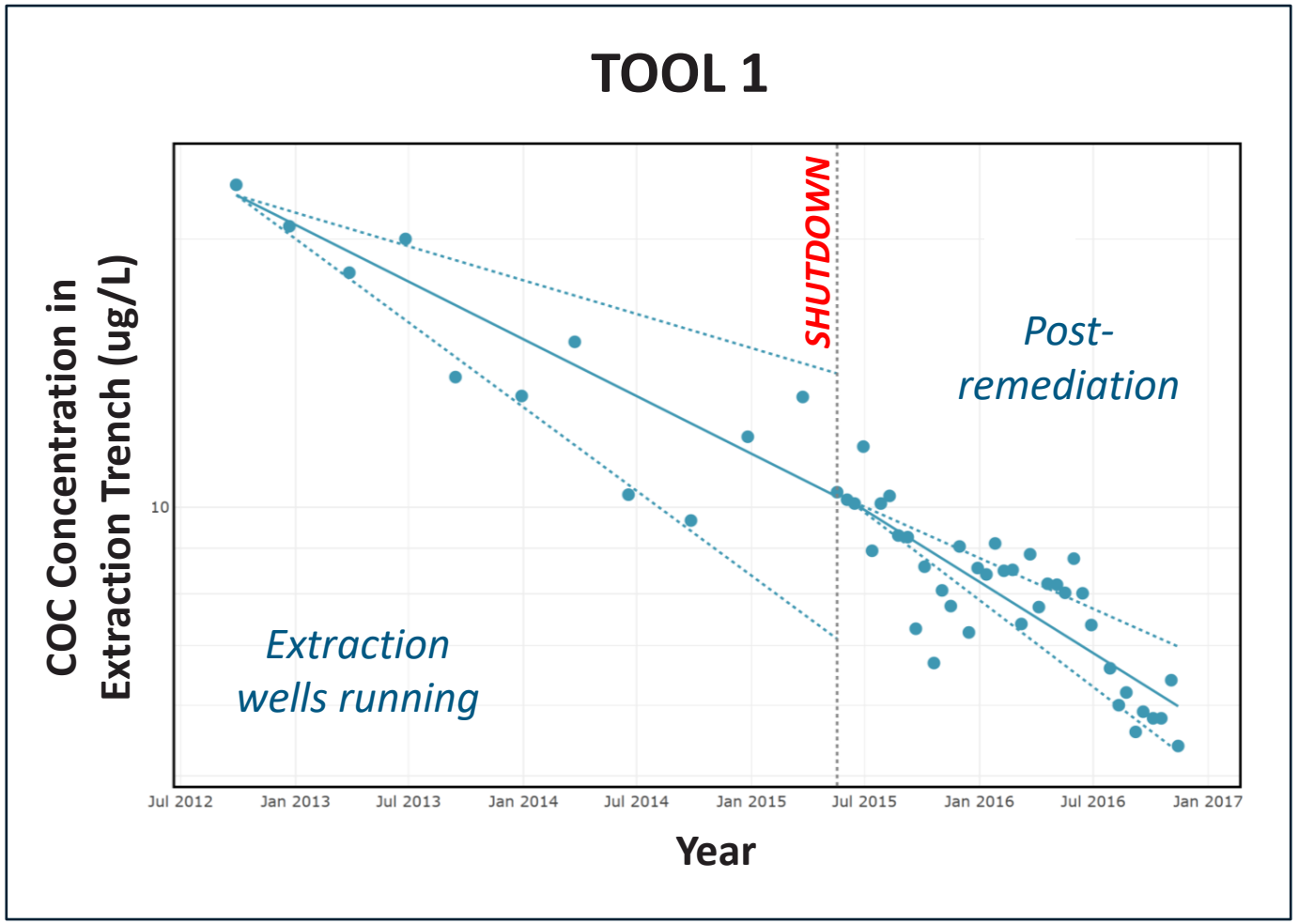
Tool	Remediation Transition Assessment Index					Rationale
	POOR Candidate RTAI = 1	FAIR Candidate RTAI = 2	TYPICAL Candidate RTAI = 3	GOOD Candidate RTAI = 4	STRONG Candidate RTAI = 5	
Asymptote? Tool 1	1	2	3	**4**	5	The RTAI is higher is there are more Lines of Evidence that concentrations at the site are asymptotic.
Expanding? Tool 2	I	PI	ST	PD	**D**	The RTAI is higher is key downgradient/sentinel well(s) exhibit stable or declining concentration trends.
Performance? Tool 4	<0.5	0.5 to <0.75	0.75 to <1.25	**1.25 to <2**	≥2	The RTAI is higher for sites where a higher concentration reduction is needed and may not be achievable based on the expected performance of remediation technologies.
ITRC Potential? Tool 4	High	High-Mod	Moderate	Mod-Low	**Low**	The RTAI is higher for sites with challenging cleanup goals and difficult conditions based on a methodology developed by ITRC.
Timeframe? Tool 3	<5	5 to <10	10 to <25	25 to <50	**≥50**	The RTAI is higher for sites where additional source remediation does not result on short remediation timeframes. It is based on the estimated number of years to reach the cleanup goal after remediation.
Enhance? Tool 7	NA	NA	NA	NA	NA	The RTAI is higher for sites where EA technologies or approaches can by easily implemented. It is based on the depth and width of the area being targeted, which are used as proxies for cost and ease of installation.
METRIC VALUE	**0**	**0**	**0**	**2**	**3**	

Case Study Snapshot



- Chlorinated solvent plume (TCE) was being managed by extraction system (including collection trench) for ~10 years
- Sandy aquifer with high seepage velocity overlaying low-k clay till
- Decision was made to transition from pump-and-treat to MNA starting in 2015

Case Study Snapshot



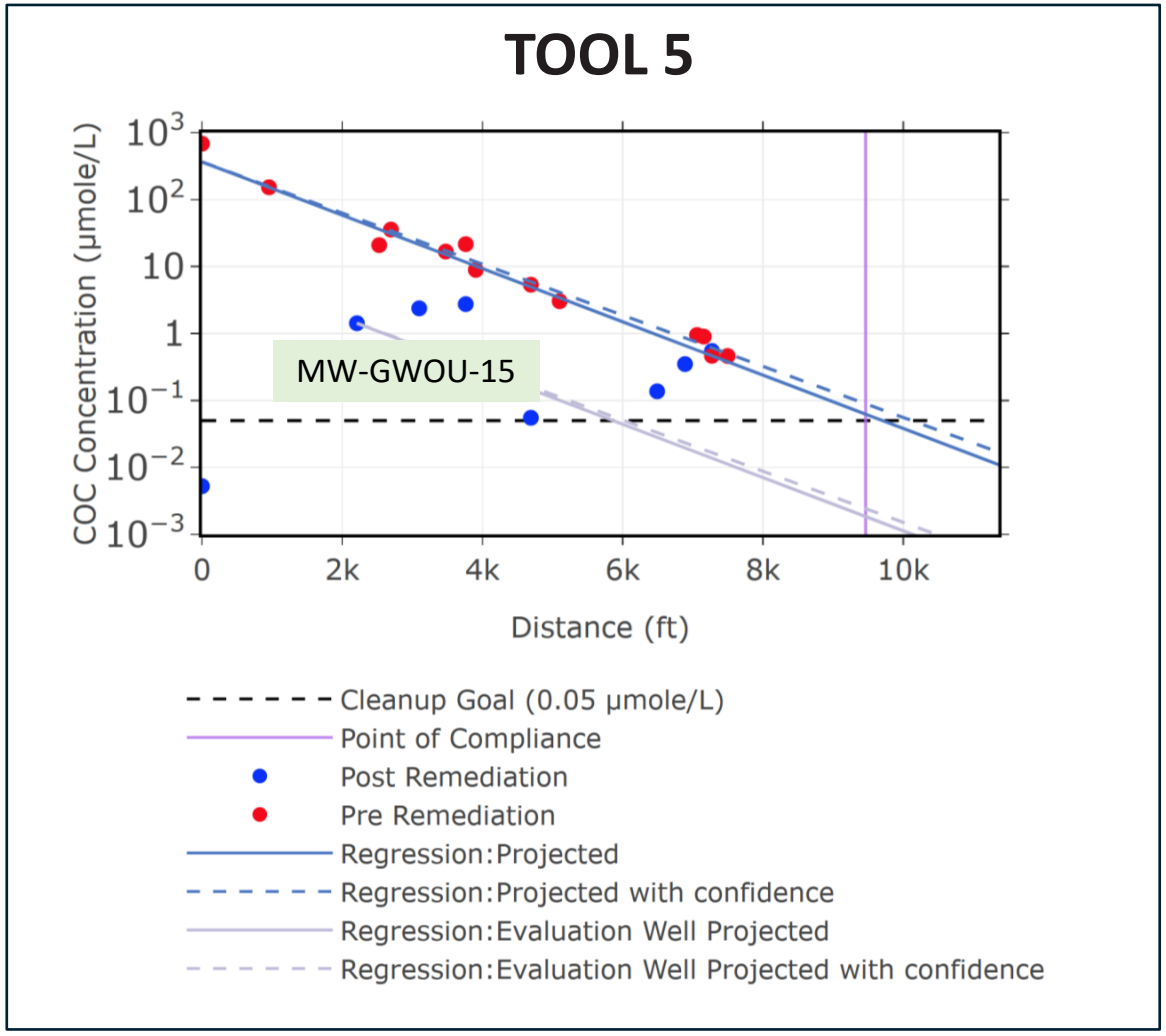
- Site would have been considered a good candidate for TA based on some metrics, but not others
  - No asymptote
  - Performance of additional remediation not strongly influenced by site geology

RTAI = 1 or 2

  - Decreasing concentration trends and favorable plume stability

RTAI = 5

Case Study Snapshot



- Natural attenuation rate was estimated based on pre-remediation data (**red symbols**)
- During the post-remediation period (**blue symbols**), the natural attenuation rate was sufficient to achieve cleanup goal
  - Tool was used to project concentrations from multiple downgradient wells
- Field-based rate was consistent with lab-based rate showing that abiotic processes were responsible

Conclusions

- Transitioning to MNA requires a clear path with strong technical basis
- Project deliverable is a software app that makes transition assessments easier
  - **Free, web-based, and fully compatible**
- Supports evaluation of passive, less-intensive approaches
- Case studies provide site-specific examples of app's utility
- Additional training webinar and short course are planned

TA^2 Tool

Available mid-2024

Will be available for download at the SERDP ER20-1429 project page: https://serdp-estcp.org/projects/details/350cbc0b-893a-43a6-8a0c-c9c057bacac0