



**PREDICTIVE MODELING OF DOWNGRADIENT
CONCENTRATIONS AND OVERALL CLOSURE TIMEFRAME
RESULTING FROM BIOREMEDIATION**

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Project Overview

- Industrial facility since 1975
- RCRA program / TCEQ oversight / TRRP
- Groundwater impacts 10-25 ft
 - PCE + degrad. products
 - TCA + degrad. products
 - Chlorinated benzenes (CBs)
- Impacts from 1970s era former stormwater pond



Conceptual Site Model

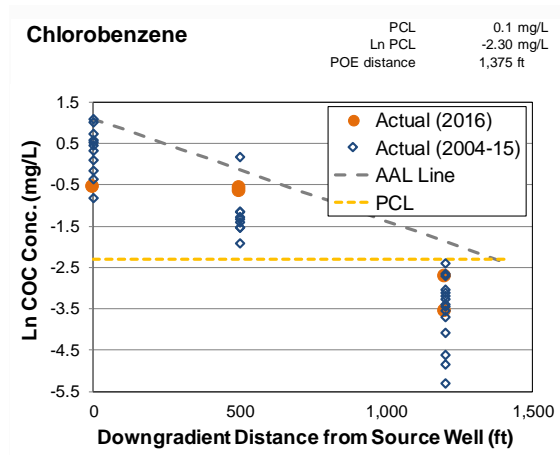
- Large, dilute plume
- Cis-DCE and vinyl chloride indicate reductive dechlorination
- Thin fine sand bounded above and below by fine-grained strata



Site Strategy



PLUME MANAGEMENT ZONE (PMZ)



MONITORED NATURAL ATTENUATION (MNA)



ACTIVE REMEDIATION

On-Site

PCE, TCA, CBs (ACLs)

TCA, CBs (AALs)

PCE (ACLs/MCLs)

Off-Site

na

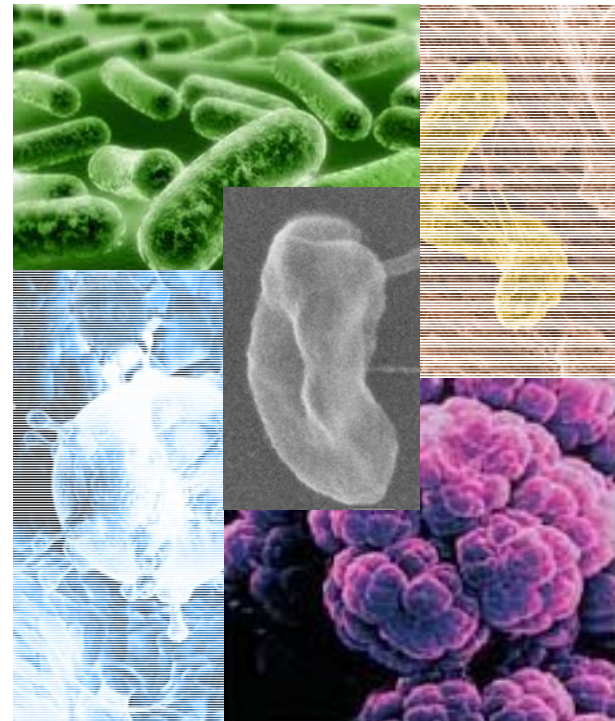
PCE (MCLs)

PCE (MCLs)

Remediation Technology Selection

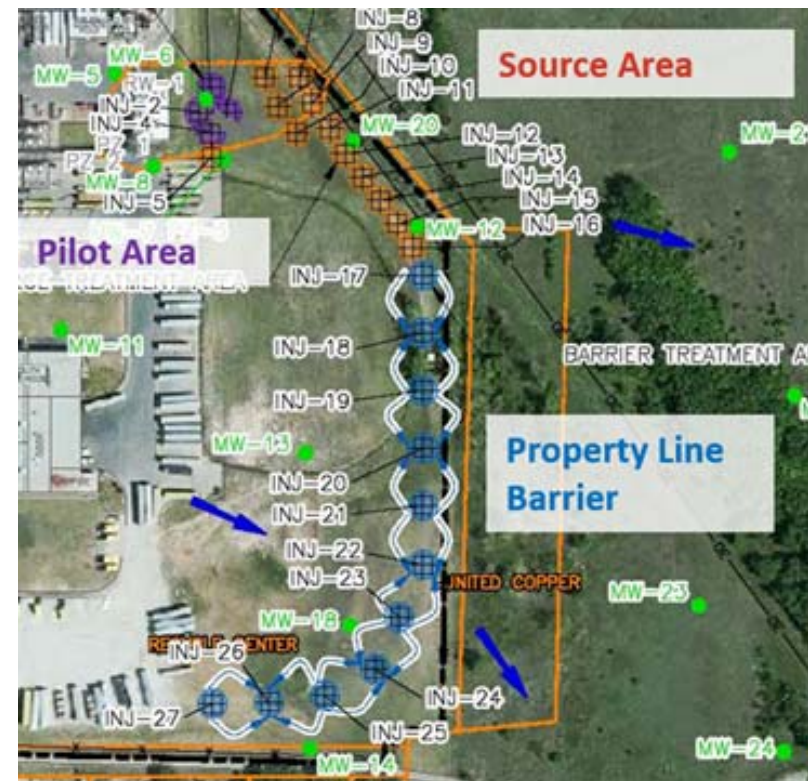
- Economical reagents required for large plume
- Expanding footprint of treatment needed for large plume with access restrictions
- Persistent process needed for middle/late stage plume
- Cis-DCE and vinyl chloride indicated reductive dechlorination ongoing

In-Situ Bioremediation (ISB) most compatible with above criteria



Modeling and ISB Design

- Response Action Plan (RAP) submitted to TCEQ
- Conceptual design
 - Source area treatment
 - Client property line treatment
- Per TCEQ: State proposed 'reasonable time frame' and provide justification
- *Use model to assess when ISB attains MCLs off-site*



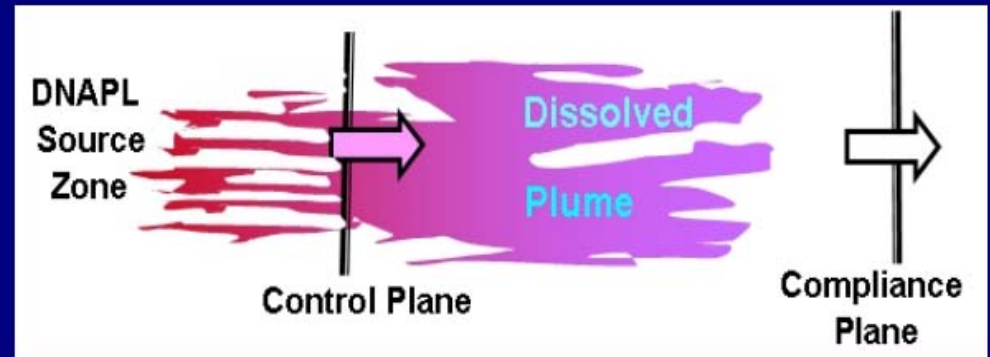
Step 1: Model Selection

- Remediation
- EPA-vetted
- Biodegradation
- Back-diffusion
- Analytical model

REMChlor

Remediation Evaluation Model for Chlorinated Solvents

Version 1.0



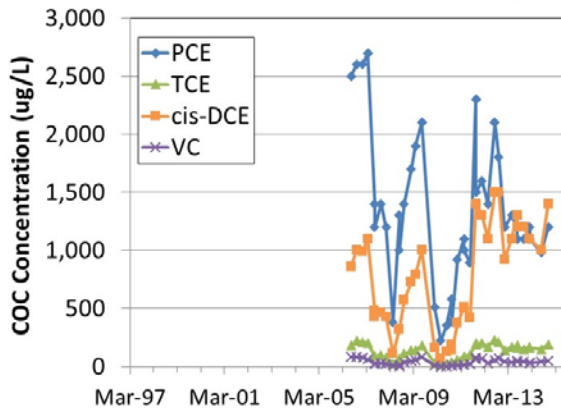
Step 2: Model Calibration

- Calibrate to historical data
 - Multiple time points
 - Multiple locations
- Capture plume-scale behavior
 - Rapid concentration increase upon plume arrival
 - $\text{PCE} \geq \text{cis-DCE} > \text{TCE} > \text{VC}$

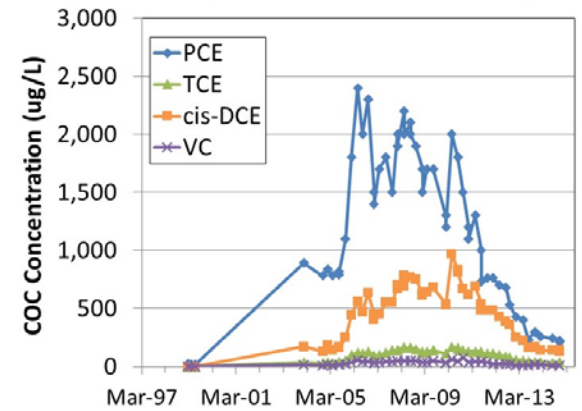


Model Calibration: Historical Data

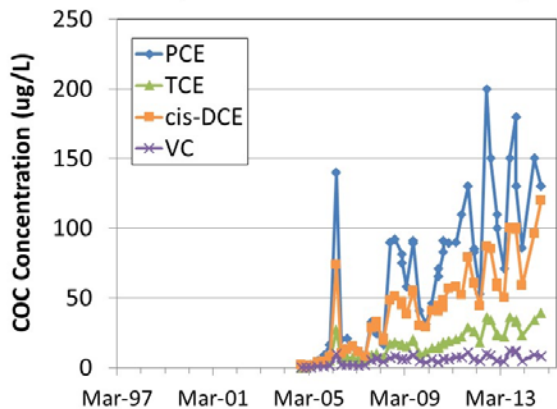
MW-20 (200 ft from source area)



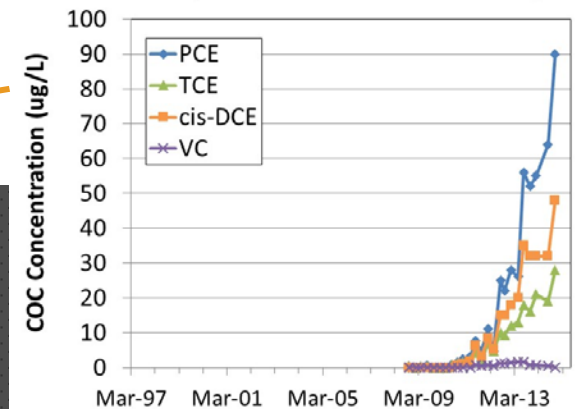
MW-12 (300 ft from source area)



MW-16 (1,450 ft from source area)



MW-27 (2,150 ft from source area)



6 time points 2005 to 2014

Model Calibration: Parameters

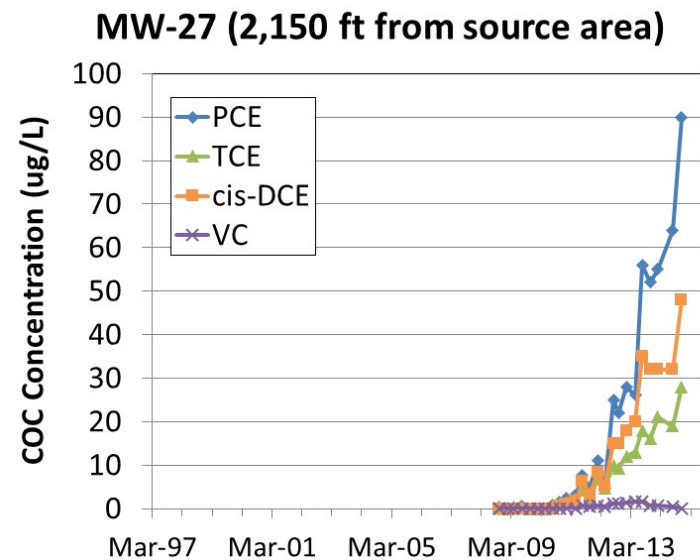
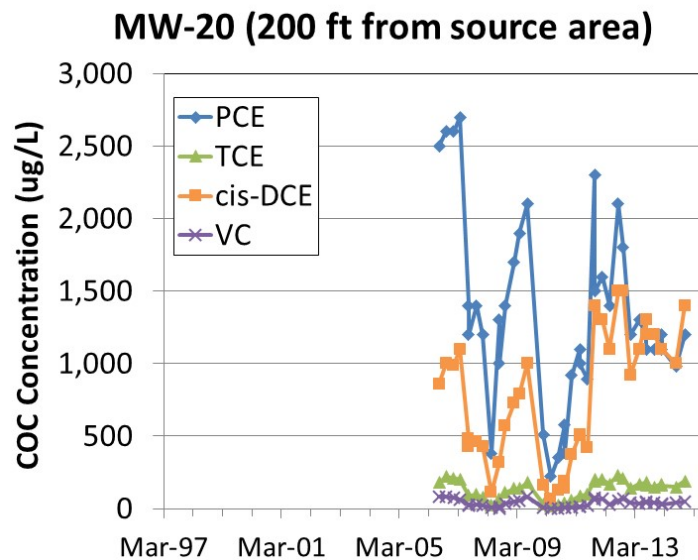
- 54 parameters
 - 11 source
 - 7 groundwater
 - 36 decay
- Constrain number of options
 - Direct measurements
 - Plume-scale behavior
 - Fitting parameters

Source Zone Parameters																															
Source Parameters																															
Initial Source																															
Concentration (g/L)	0.015																														
Mass (Kg)	500																														
Gamma	1																														
Source Dimensions																															
Source Width (m)	20																														
Source Depth (m)	5																														
Darcy Velocity (m/yr)	13																														
Porosity	0.3																														
Source Remediation																															
Fraction Removed	0																														
Remediation Time																															
	30 (Years)	30																													
Start Time (T1)	End Time (T2)																														
Source Decay (1/yr)	0.005																														
Transport Parameters																															
Retardation Factor	1.8																														
Velocity																															
	0.1	0	1.5																												
Sigmav	vMin	vMax																													
Number of Stream Tube	300																														
	0.001	0.001																													
alphay (m)	alphaz (m)																														
Simulation Parameters																															
	Intervals	Min Value	Max Value																												
X - Direction	51	1E-05	1200																												
Y - Direction	1	0	0																												
Z - Direction	1	0	0																												
Time	100	0	100																												
			Units																												
			Meter																												
			Meter																												
			Meter																												
			Year																												
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Component Name PCE																															
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Cancer Risk																															
Lifetime Oral Cancer Risk		Lifetime Inhalation Cancer Risk																													
Component 1	Component 2	Component 3	Component 4																												
0.54	0.013	0	0.27																												

Model Calibration: Plume-Scale Behavior

Decreasing concentrations in source area ->
Source concentration and decay

Fast breakthrough ->
Low dispersion velocity profile



Model Calibration: Fitting Parameters

- Retardation
 - One value for 4 constituents
- Decay rates
 - Highest in source area
 - Highest for TCE

Source Zone Parameters

Source Parameters

Initial Source

Concentration (g/L)

Mass (Kg)

Gamma

Source Dimensions

Source Width (m)

Source Depth (m)

Darcy Velocity (m/yr)

Porosity

Source Remediation

Fraction Removed

Remediation Time

(Years)

Start Time (T1) End Time (T2)

Source Decay (1/yr)

Transport Parameters

Retardation Factor

velocity

Sigmav vMin vMax

Number of Stream Tube

alphay (m) alphaz (m)

Cancer Risk

Lifetime Oral Cancer Risk | Lifetime Inhalation Cancer Risk

Component 1 Component 2 Component 3 Component 4

Simulation Parameters

	Intervals	Min Value	Max Value	Units
X - Direction	51	1E-05	1200	Meter
Y - Direction	1	0	0	Meter
Z - Direction	1	0	0	Meter
Time	100	0	100	Year

Yield

	Yield 1 From 1	Yield 2 From 1	Yield 3 From 2	Yield 4 From 3
Component 1	<input type="text" value="0.795"/>	<input type="text" value="0.737"/>	<input type="text" value="0.64"/>	<input type="text"/>
Component 2	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Component 3	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Component 4	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

Component Name PCE

	Zone 1	Zone 2	Zone 3
Decay Rate (1,3)	<input type="text" value="2.2"/>	<input type="text" value="0.27"/>	<input type="text" value="0.27"/>
Decay Rate (2,3)	<input type="text" value="2.2"/>	<input type="text" value="0.27"/>	<input type="text" value="0.27"/>
Decay Rate (3,3)	<input type="text" value="2.2"/>	<input type="text" value="0.27"/>	<input type="text" value="0.27"/>
Decay Rate (1,2)	<input type="text" value="2.2"/>	<input type="text" value="0.27"/>	<input type="text" value="0.27"/>
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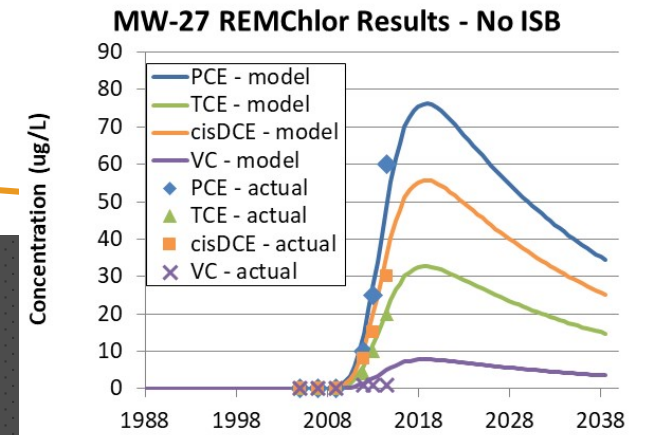
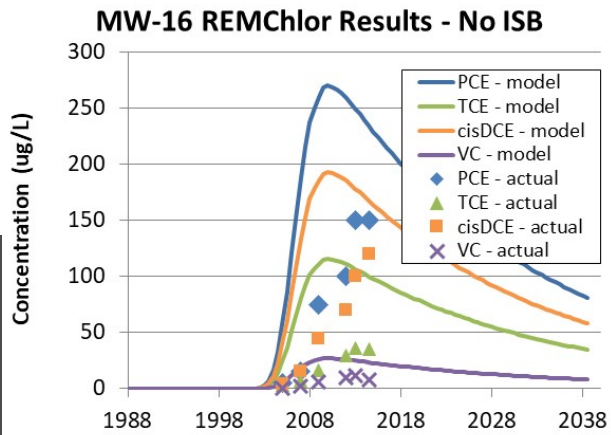
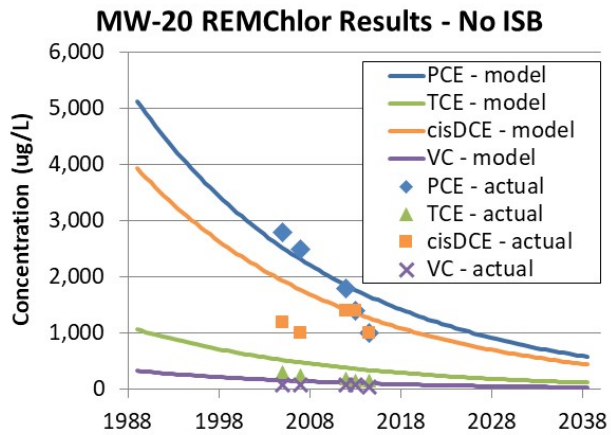
X1 X2

Distance From Source, Meters

Simulation Parameters

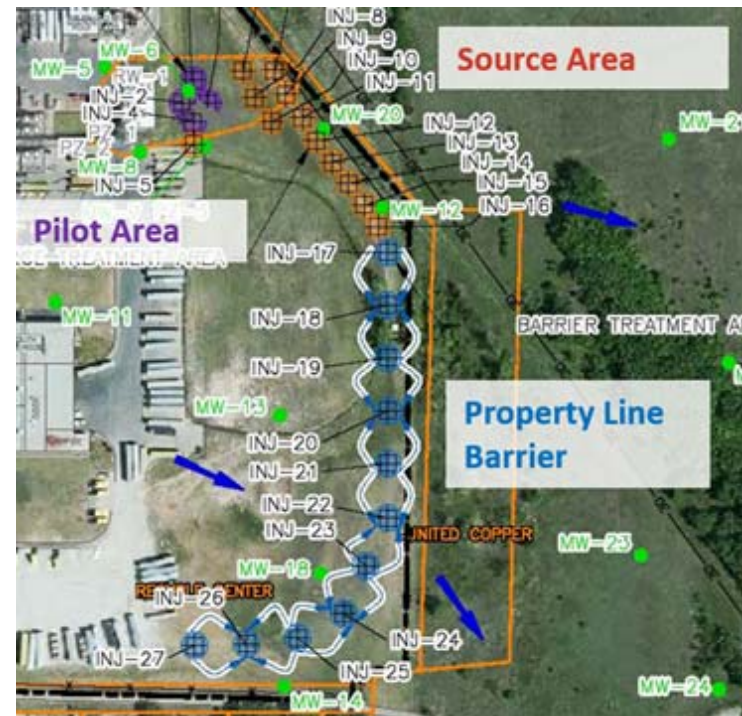
DNAPL Source Zone → Dissolved Plume

Model Calibration: Results

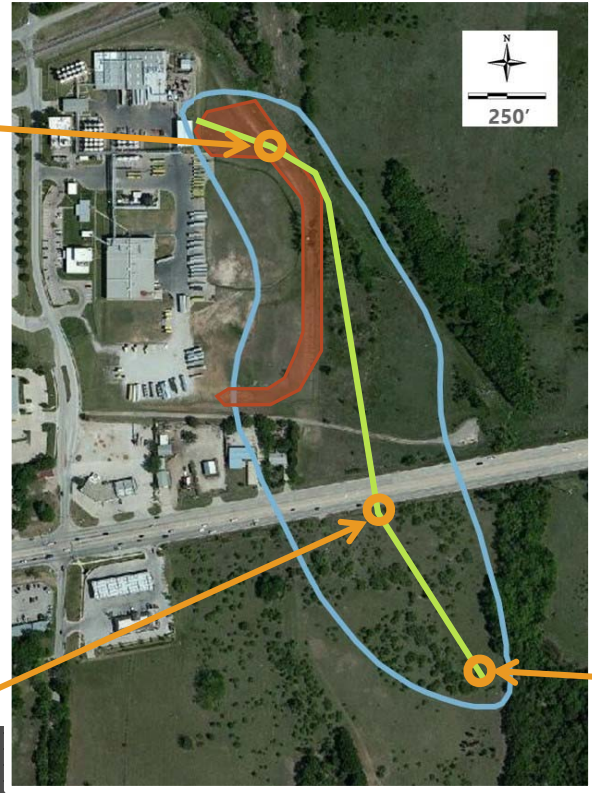
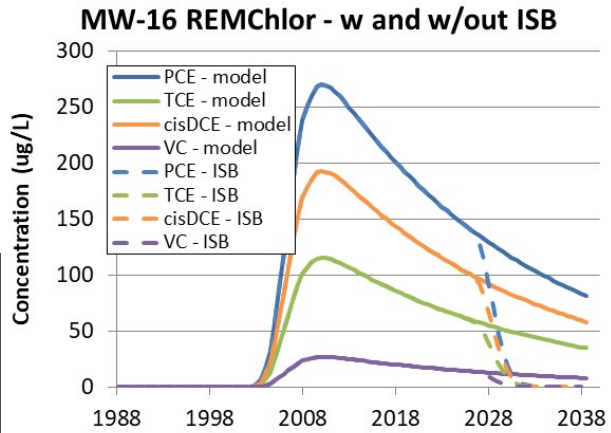
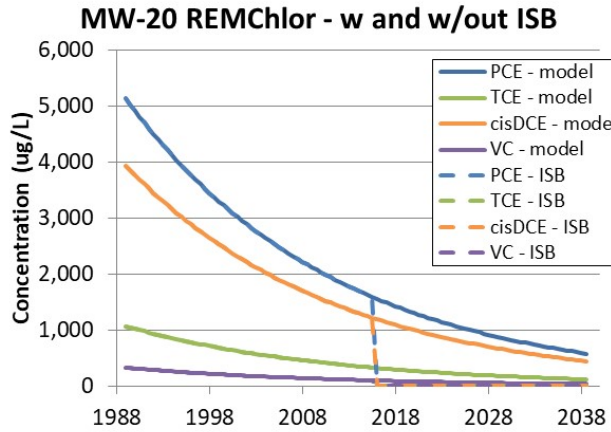


Predictions from Model: Methods

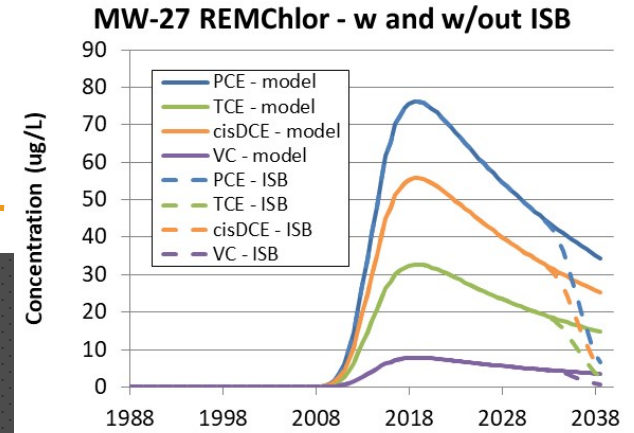
- Goal = Simulate ISB in REMChlor
- Increase degradation rates in on-site ISB footprint
 - 30 /yr for each COC
 - Source to 150m downgradient
 - Starting in 2015
 - Other model inputs constant
- Examine future concentrations downgradient in model



Predictions from Model: Results



Solid lines = model w/out ISB
Dashed lines = model w/ ISB



Predictions from Model: Conclusions

Model Results

- Model predicts that ISB on client property results in MCLs
 - 2031 at mid-point (MW-16)
 - 2039 at leading edge (MW-27)
- Longer than acceptable
- 80% longer than GW velocity calculations predict

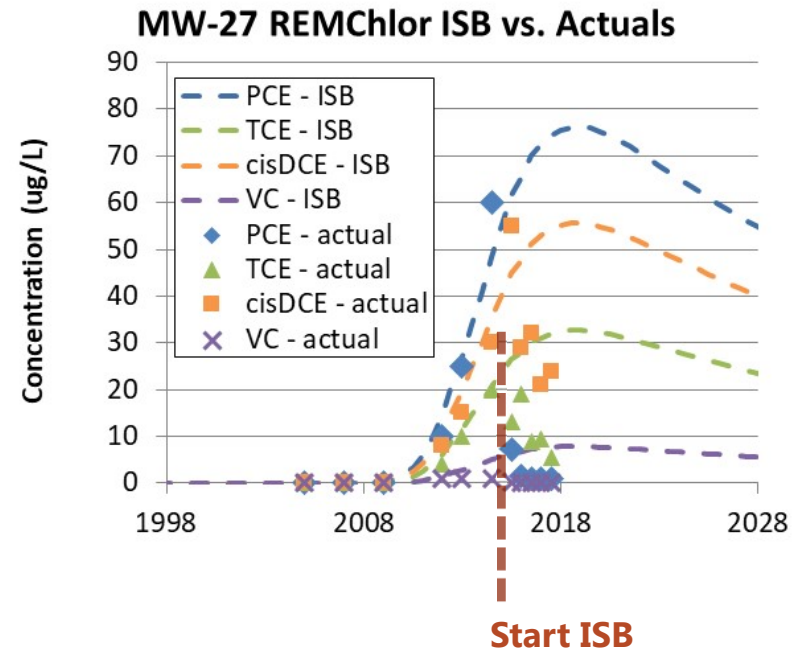
Resulting Actions

- ISB program expanded to off-site area



Post Script: What's New Since 2015

- ISB implemented full-scale in 2015
- Additional injection event 2017
- Analytical data generally supports model results



Summary and Conclusions

- Model assessed predictive results of ISB during design
- Model outcome resulted in expanded ISB footprint
- Remedy timeframe incorporated in decision documents
- ISB program ongoing





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QUESTIONS?

