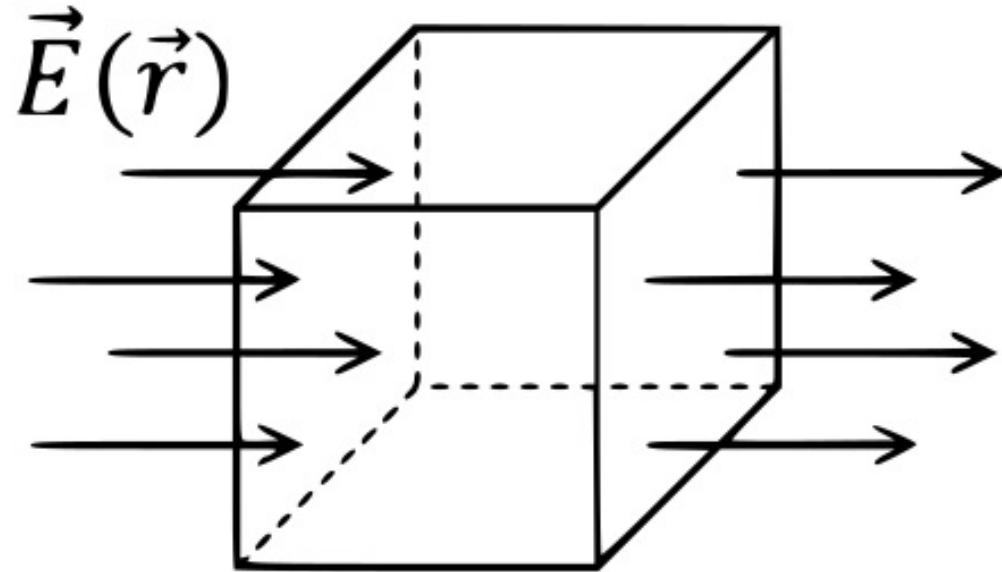


Passive Groundwater/Mass Flux Meters to Support Natural Attenuation

In Complex Geologic/Hydrogeologic
Conditions

Doug Gray

I DON'T GIVE A FLUX



$$\Phi = \oiint_{\partial V} \vec{E} \cdot d\vec{A} = 0$$

Agenda

- 01 Introduction / Background
- 02 Technology Overview
- 03 Project Summary
- 04 Results / Evaluation
- 05 Conclusions / Lessons Learned

Acknowledgements

- Scott Martin
- Lucian Manea
- Jeff Kronick
- Tom Stilley, Nancy Grosso, and Erin Mack

01

Introduction / Background

Site History

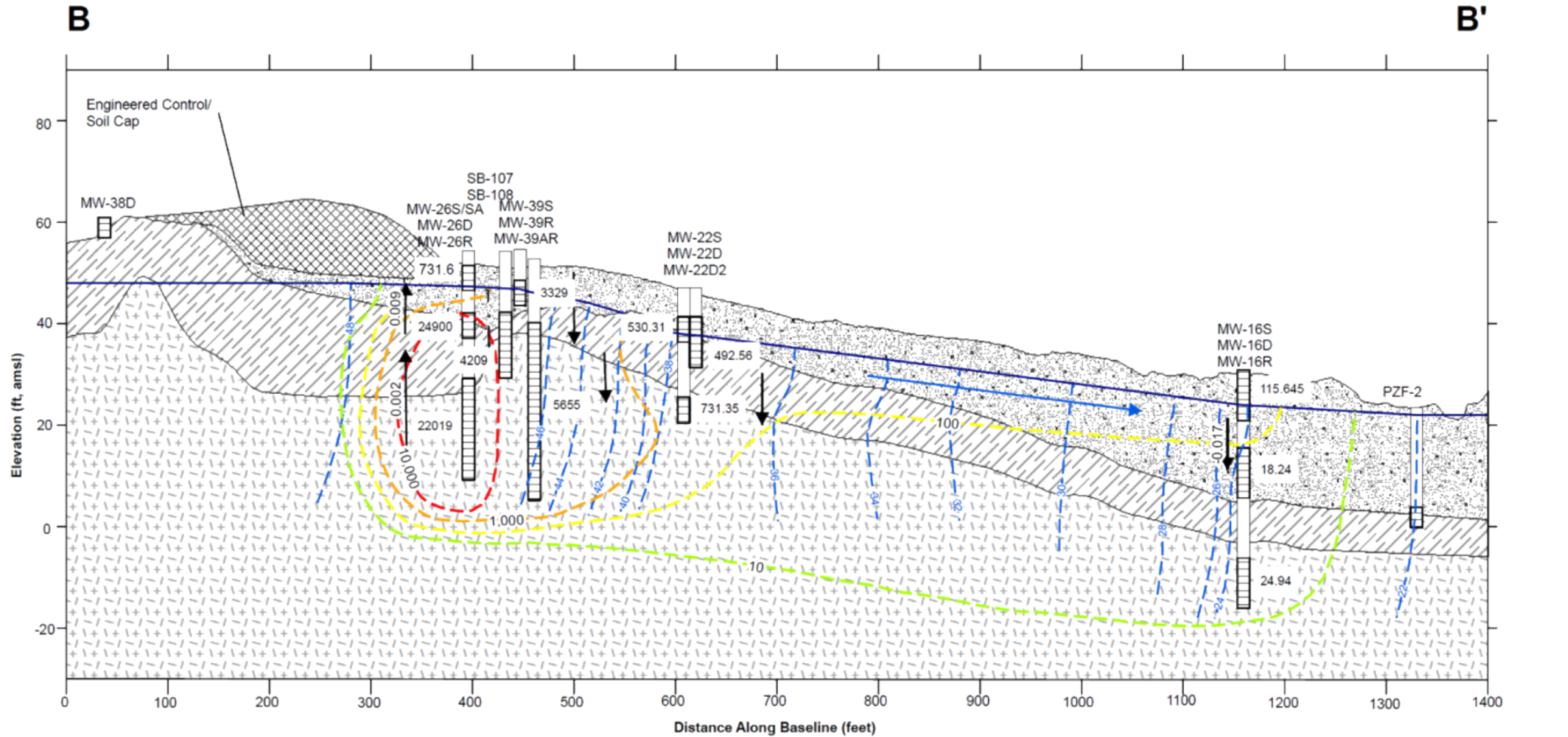


C

Area A – Cross Section

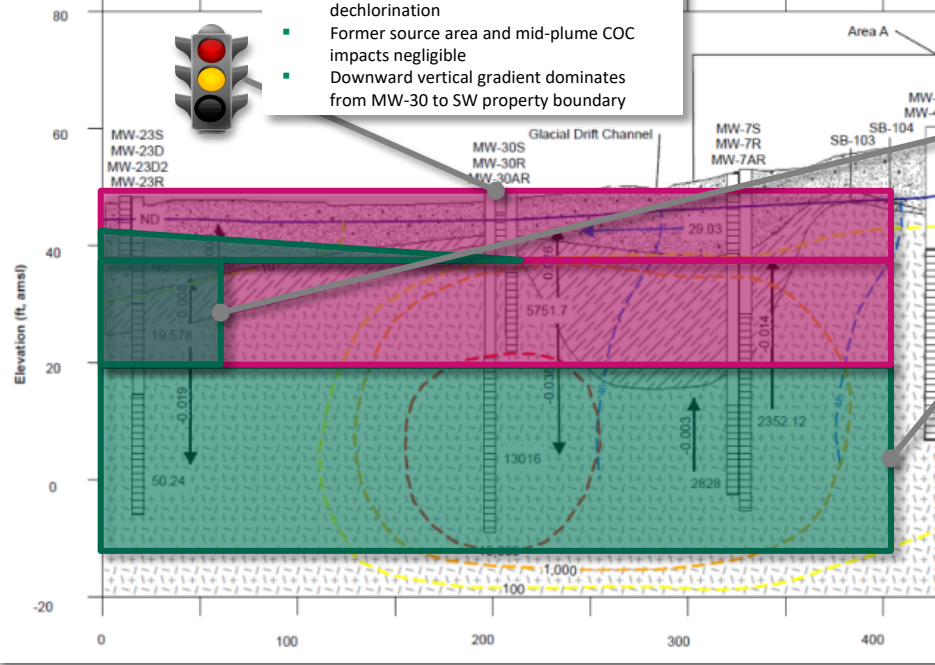
C'





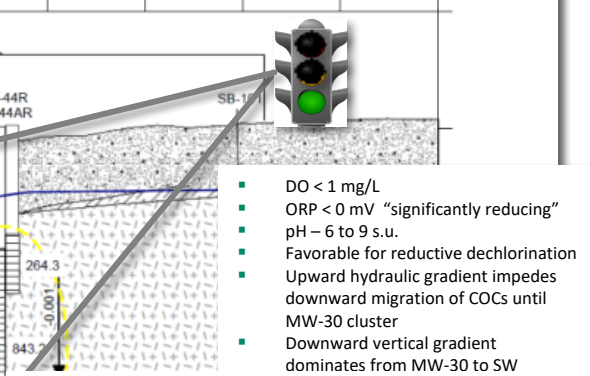
Southwest

C



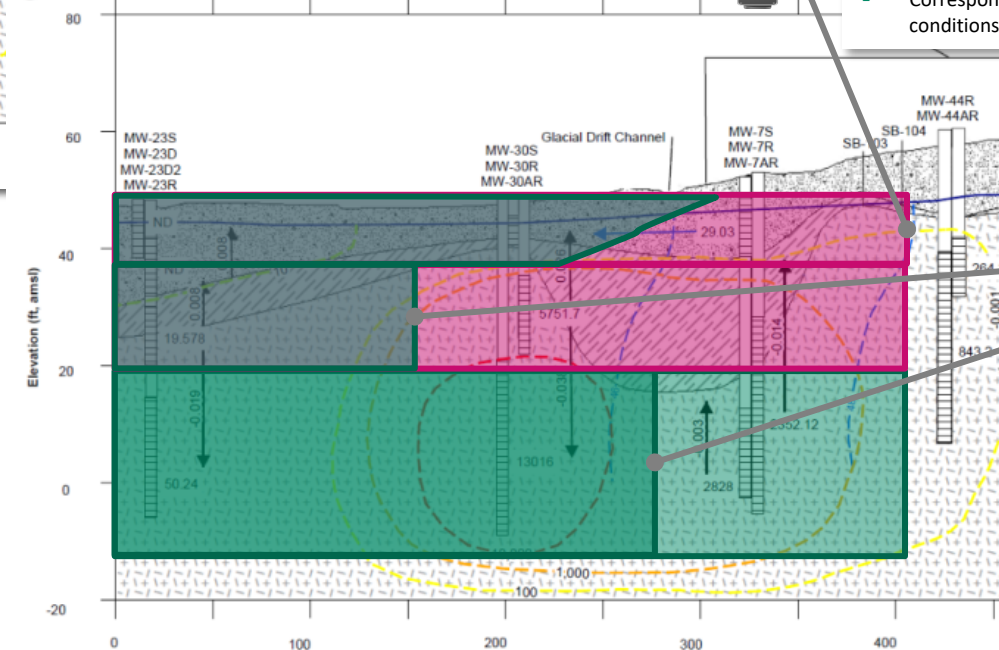
Northeast

C'



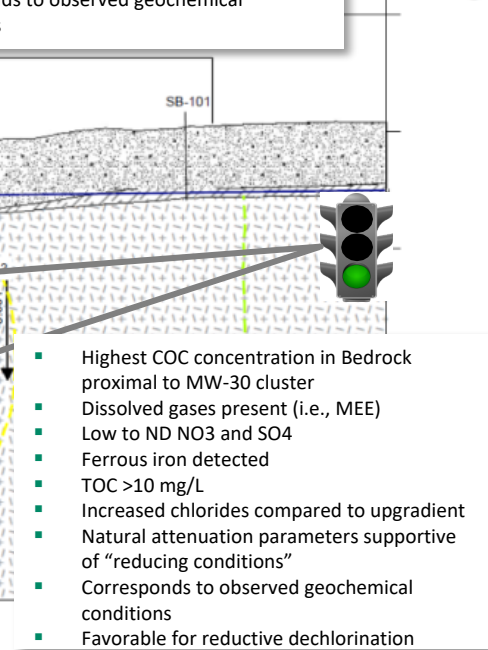
Southwest

C



Northeast

C'



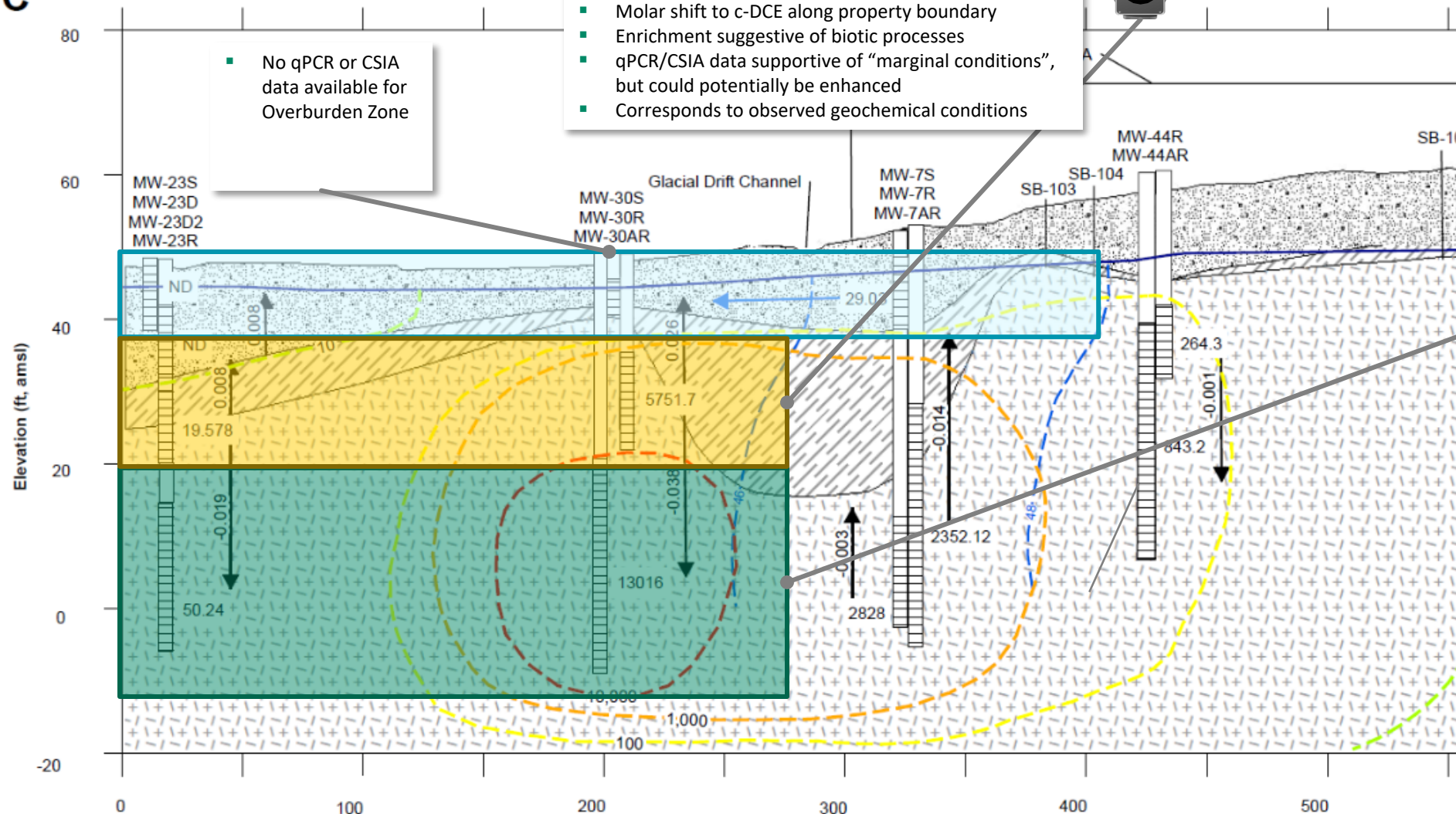
Geochemical and Natural Attenuation Conditions – Area A (Cross Sectional – All Zones)

Southwest

C

- qPCR data indicated presence of DHC and functional reductase genes @ low populations
- CSIA data indicate enrichment of PCE and TCE along property boundary
- Molar shift to c-DCE along property boundary
- Enrichment suggestive of biotic processes
- qPCR/CSIA data supportive of “marginal conditions”, but could potentially be enhanced
- Corresponds to observed geochemical conditions

No qPCR or CSIA data available for Overburden Zone



Northeast

C'

- qPCR data indicated presence of DHC and functional reductase genes @ low populations
- Additional microorganisms (DHBt, DHB, etc.) detected in reasonable population for partial reductive dechlorination
- CSIA data indicate enrichment of PCE/TCE/c-DCE @ MW-30 and downgradient
- Molar shift to TCE/c-DCE from PCE
- Enrichment suggestive of biotic processes
- qPCR/CSIA data supportive of “mostly favorable conditions”; could potentially be enhanced
- Corresponds to observed geochemical conditions

Microbial Conditions – Area A (Cross Sectional – All Zones)



**“ Please, sir,
I want some
more.”**

Charles Dickens (Oliver Twist)

02

Technology Overview

Technology Overview

The EnviroFlux Passive Flux Meter™ (PFM)

- Nylon mesh tube filled with a sorbent/tracer mixture
- Permeable sorbent retains dissolved contaminants
- Sorbent mixture is preloaded with specified amounts of resident tracers
- Activated carbon is used as the sorbent and a suite of different alcohols are used for the tracers
- After a period of exposure, PFM is removed
- Sorbent is extracted to quantify the mass of all contaminants intercepted by the PFM and the residual masses of all resident tracers
- Contaminant mass used to calculate time-averaged contaminant flux; residual resident tracer mass used to calculate cumulative groundwater flux.
- Variable depth deployment provides water/contaminant mass flux profiles from a single PFM deployment event

Technology Overview



PATENTS

EnviroFlux has the exclusive license from the University of Florida for the Passive Flux Meter™ device and method, represented by the following patent:

United States Patent 6,401,547

Device and method for measuring fluid and solute fluxes in flow systems



03

Project Summary

Project Summary

- Deployed PFMs in Areas A & B
- Targeted weathered bedrock and bedrock zones
- Twenty-two (22) PFMs deployed
 - Area A – 13 PFMs
 - Area B – 9 PFMs
- PFM sizes ranged from 2-in to 5-in, depending on the borehole/well size
- Well construction varied from cased well to open-hole completion
- PFMs allowed to soak for ~ 5 weeks prior to start of removal

04

Results / Evaluation

Results -Flux Meter Data

Well ID	Total Depth (feet bgs)	Screened Zone	Top of Screen Zone (feet bgs)	Bottom of Screen Zone (feet bgs)	Length of Screen Zone (feet)	Hole Diameter (inches)	Top of Casing Elevation (feet)
Area A							
MW-44AR	50	Bedrock (open borehole)	18	50	32	4.875	57.00
MW-7AR	58	Bedrock (open borehole)	43	58	15	2.875	55.68
MW-30R	28	Bedrock (open borehole)	14	28	14	4.875	49.61
MW-30AR	60	Bedrock (open borehole)	28	58	30	4.875	49.12
MW-23R	55	Bedrock (open borehole)	35	55	20	4	49.15
Area B							
MW-26R	47	Bedrock (open borehole)	27	47	20	2.875	55.74
MW-39AR	49	Bedrock (open borehole)	14	49	35	4.875	54.20
MW-22D2	29	Bedrock (2-in well)	24	29	5	2	57.02
MW-16R	48	Bedrock (2-in well)	38	48	10	2	31.86

Notes:

Survey datum: Connecticut State Plane Coordinate System (NAD83/NAVD88-128) in U.S. Survey feet.

bgs = below ground surface

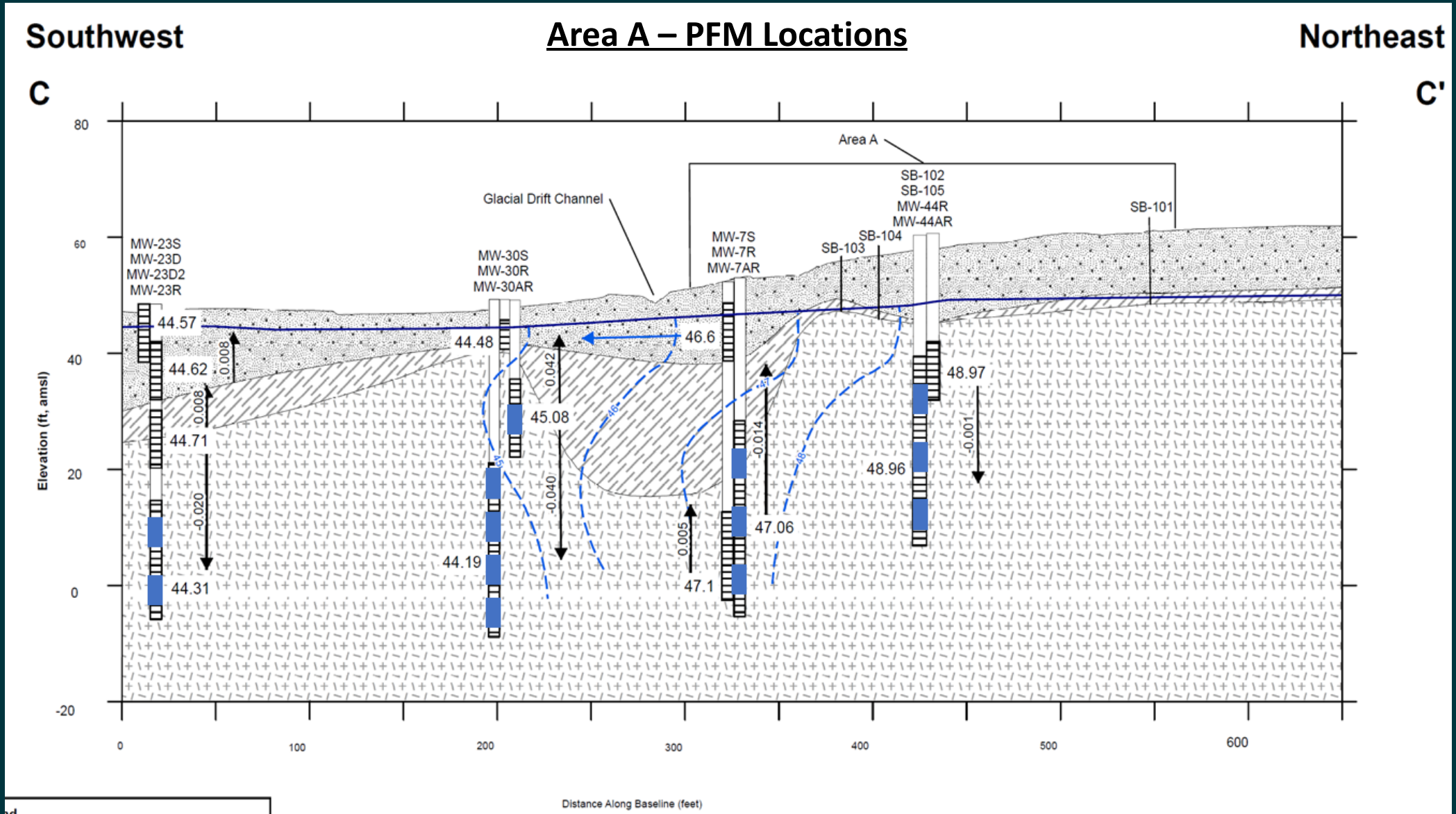
Well ID	# PFM Samplers	PFM-1 Interval [ft-bgs]	PFM-2 Interval [ft-bgs]	PFM-3 Interval [ft-bgs]	PFM-4 Interval [ft-bgs]	Total # Samples [All PFMs]
Area A						
MW-44AR	3	22-27	33-38	44-49	-	6
MW-7AR	3	43-48	48-53	53-58	-	6
MW-30R	1	20-25	-	-	-	3
MW-30AR	4	29-34	37-42	45-50	53-58	8
MW-23R	2	40-45	50-55	-	-	4
Area B						
MW-26R	3	28-33	35-40	42-47	-	6
MW-39AR	4	14-19	24-29	34-39	44-49	8
MW-22D2	1	24-29	-	-	-	2
MW-16R	1	40-45	-	-	-	3

Notes:

- approximate equal spacing within each well screen interval (see screened intervals on previous tab)

Well ID	# PFM Samplers	Total # Samples [All PFMs]	PFM-1 Interval [ft-bgs]	PFM-2 Interval [ft-bgs]	PFM-3 Interval [ft-bgs]	PFM-4 Interval [ft-bgs]
Area A						
MW-44AR	3	6	22-27	33-38	44-49	-
	Approximate Sample Intervals ➡		23-24; 25-26	34-35; 36-37	45-46; 47-48	✖
MW-7AR	3	6	43-48	48-53	53-58	-
	Approximate Sample Intervals ➡		44-45; 46-47	49-50; 51-52	54-55; 56-57	✖
MW-30R	1	3	20-25	-	-	-
	Approximate Sample Intervals ➡		21; 22.5; 24	✖	✖	✖
MW-30AR	4	8	29-34	37-42	45-50	53-58
	Approximate Sample Intervals ➡		30-31; 32-33	38-39; 40-41	46-47; 48-49	54-55; 56-57
MW-23R	2	4	40-45	50-55	-	-
	Approximate Sample Intervals ➡		41-42; 43-44	51-52; 53-54	✖	✖
Area B						
MW-26R	3	6	28-33	35-40	42-47	-
	Approximate Sample Intervals ➡		29-30; 31-32	36-37; 38-39	43-44; 45-46	✖
MW-39AR	4	8	14-19	24-29	34-39	44-49
	Approximate Sample Intervals ➡		15-16; 17-18	25-26; 27-28	35-36; 37-38	45-46; 47-48
MW-22D2	1	2	24-29	-	-	-
	Approximate Sample Intervals ➡		26-27	✖	✖	✖
MW-16R	1	3	40-45	-	-	-
	Approximate Sample Intervals ➡		41; 42.5; 44	✖	✖	✖

Project Summary

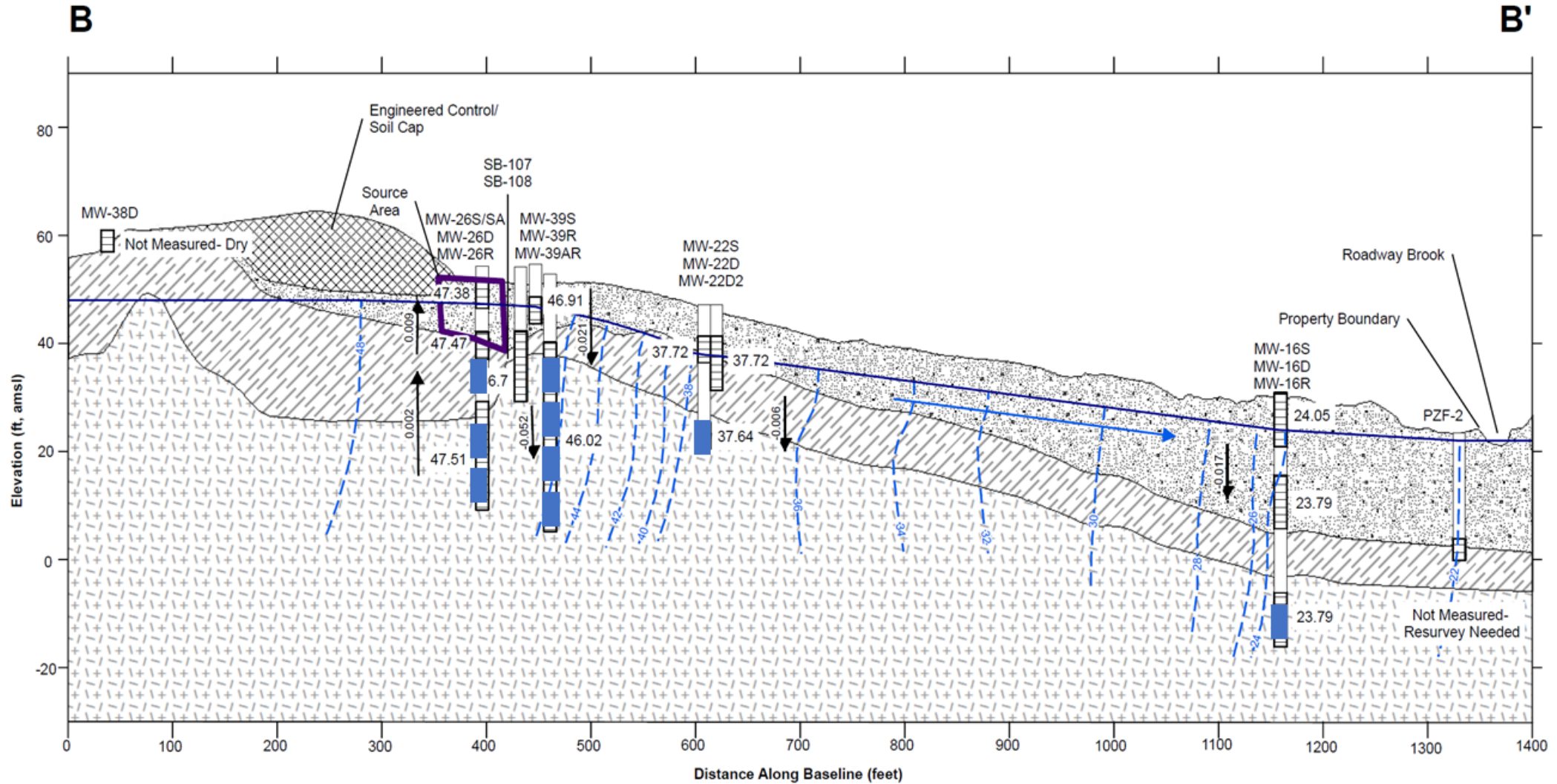


Project Summary

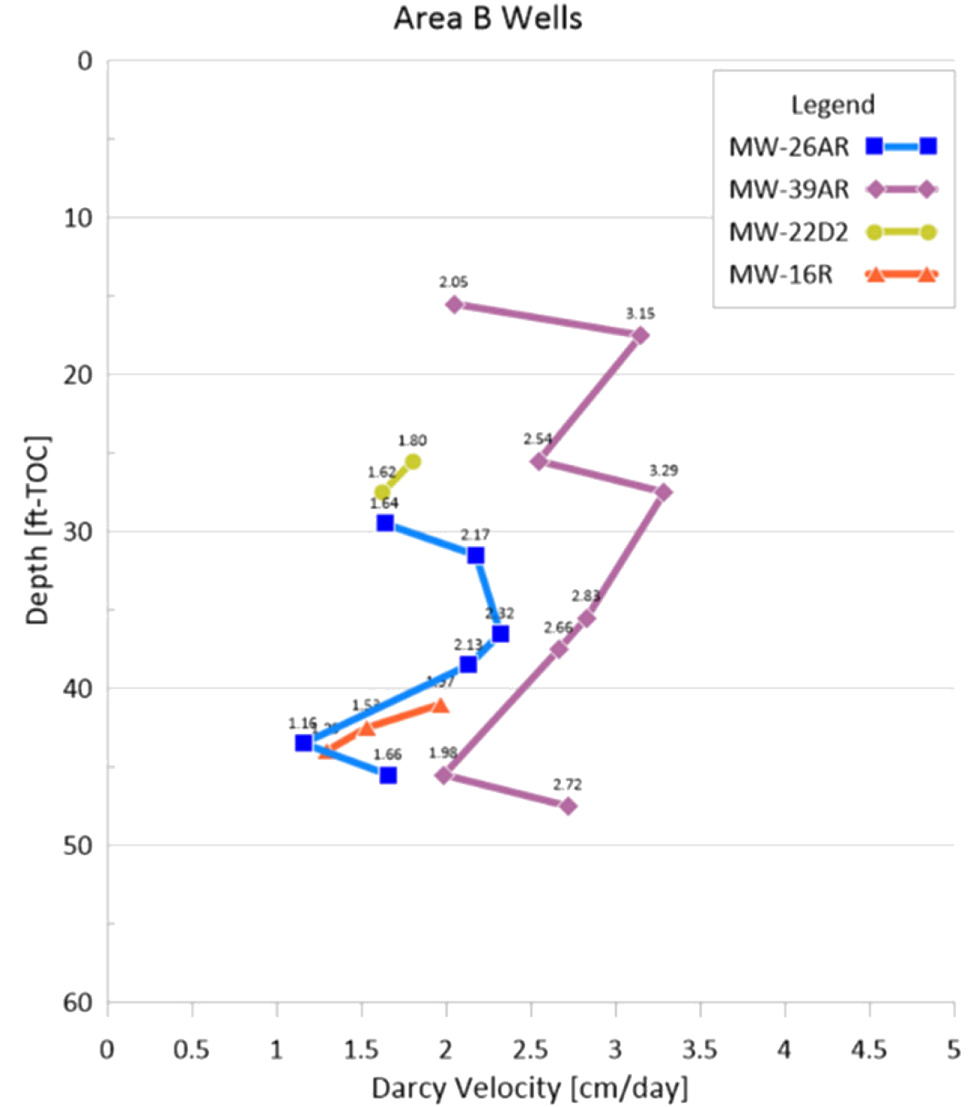
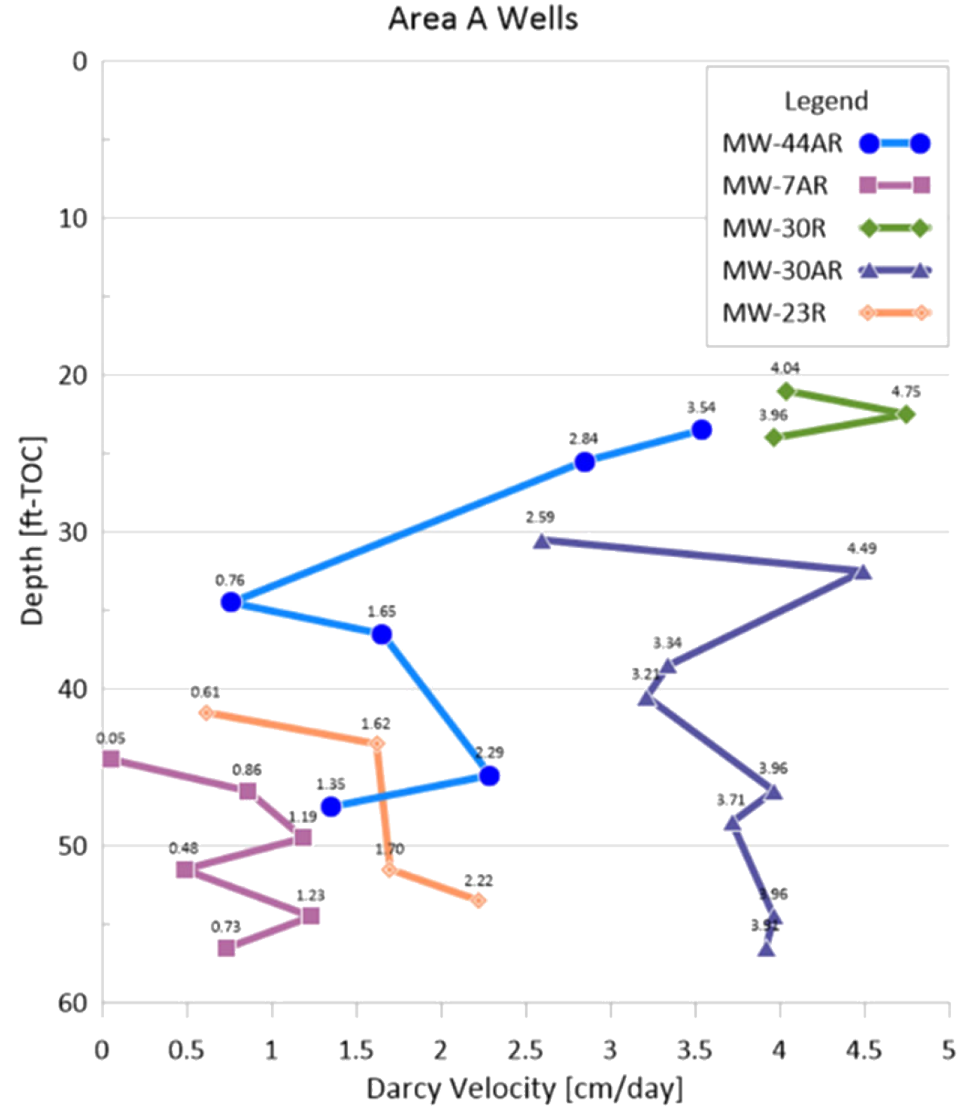
North-Northwest

Area B – PFM Locations

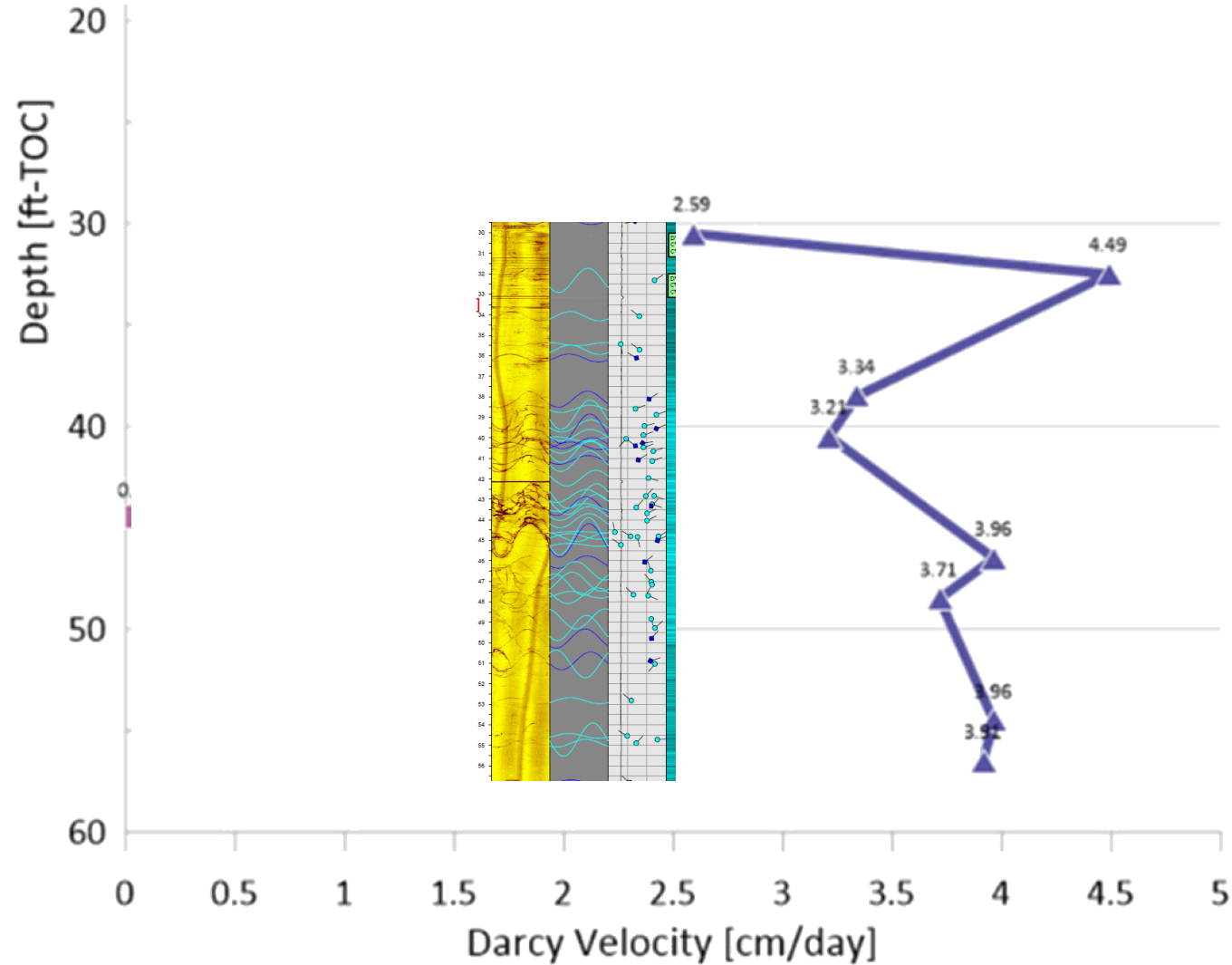
South-Southeast



Results – Areas A & B

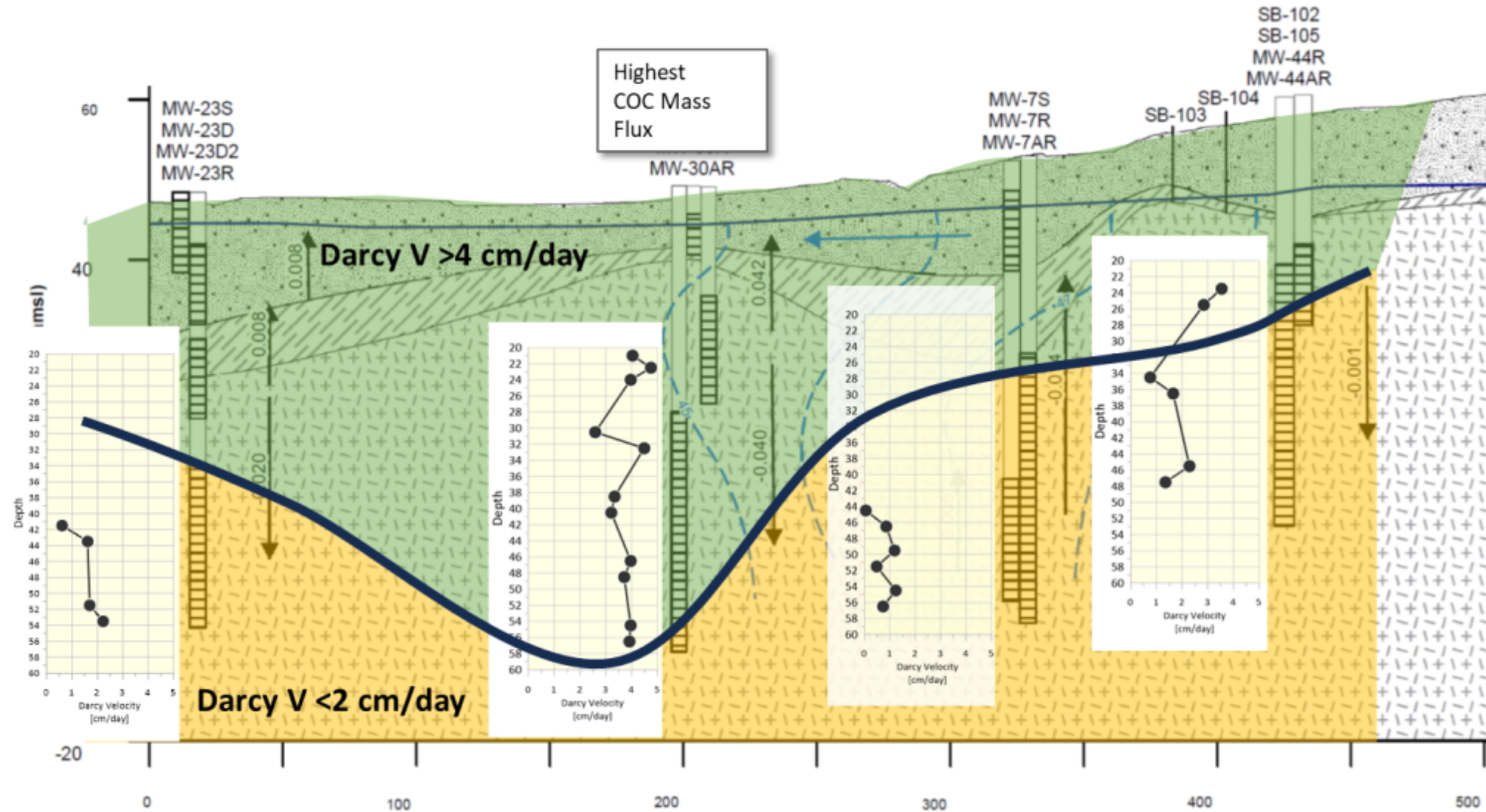


Results – Area A

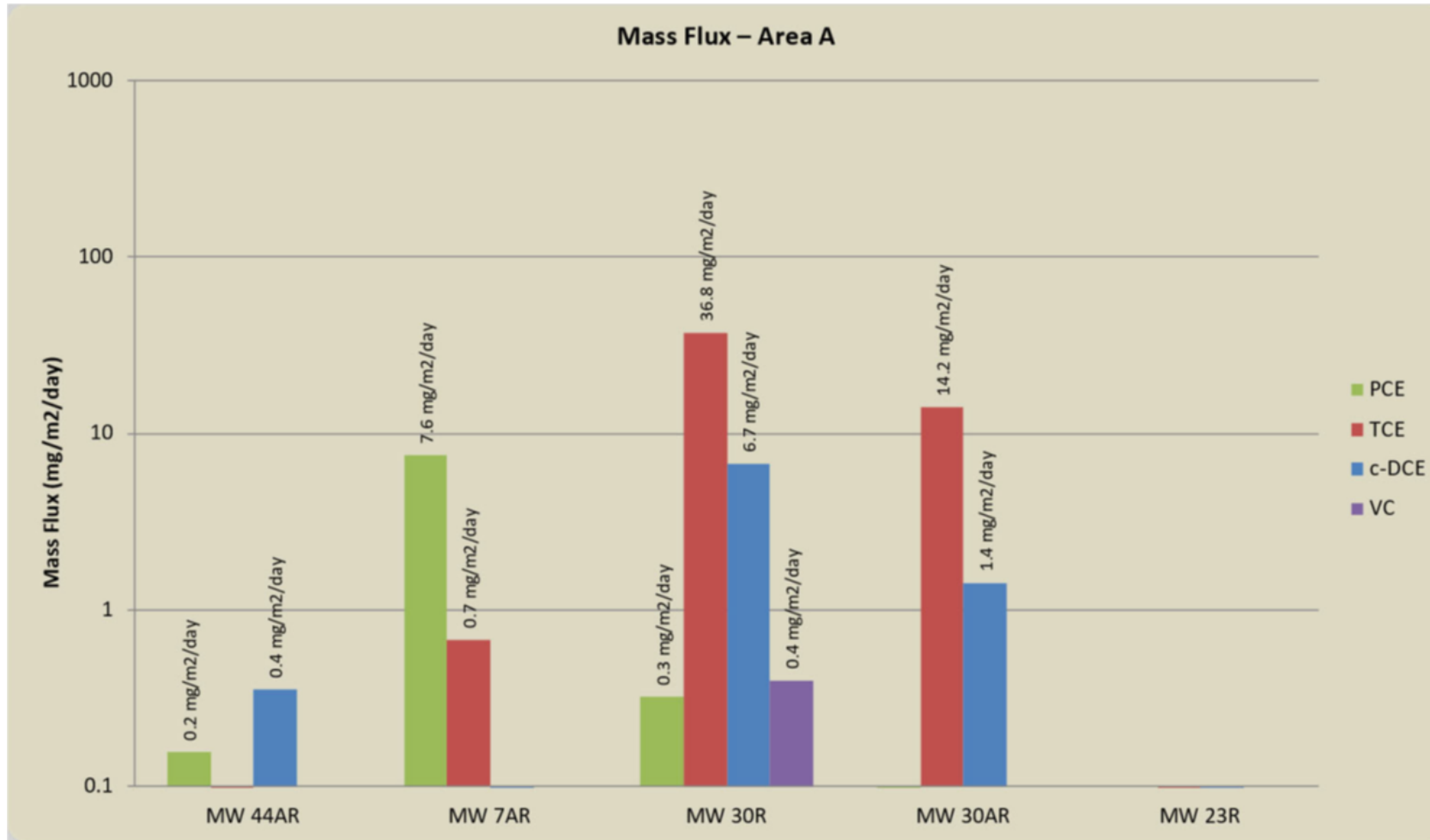


- Darcy velocities from the PFM agree well with observed fracture patterns (frequency and aperture) from the geophysical logging

Results – Area A

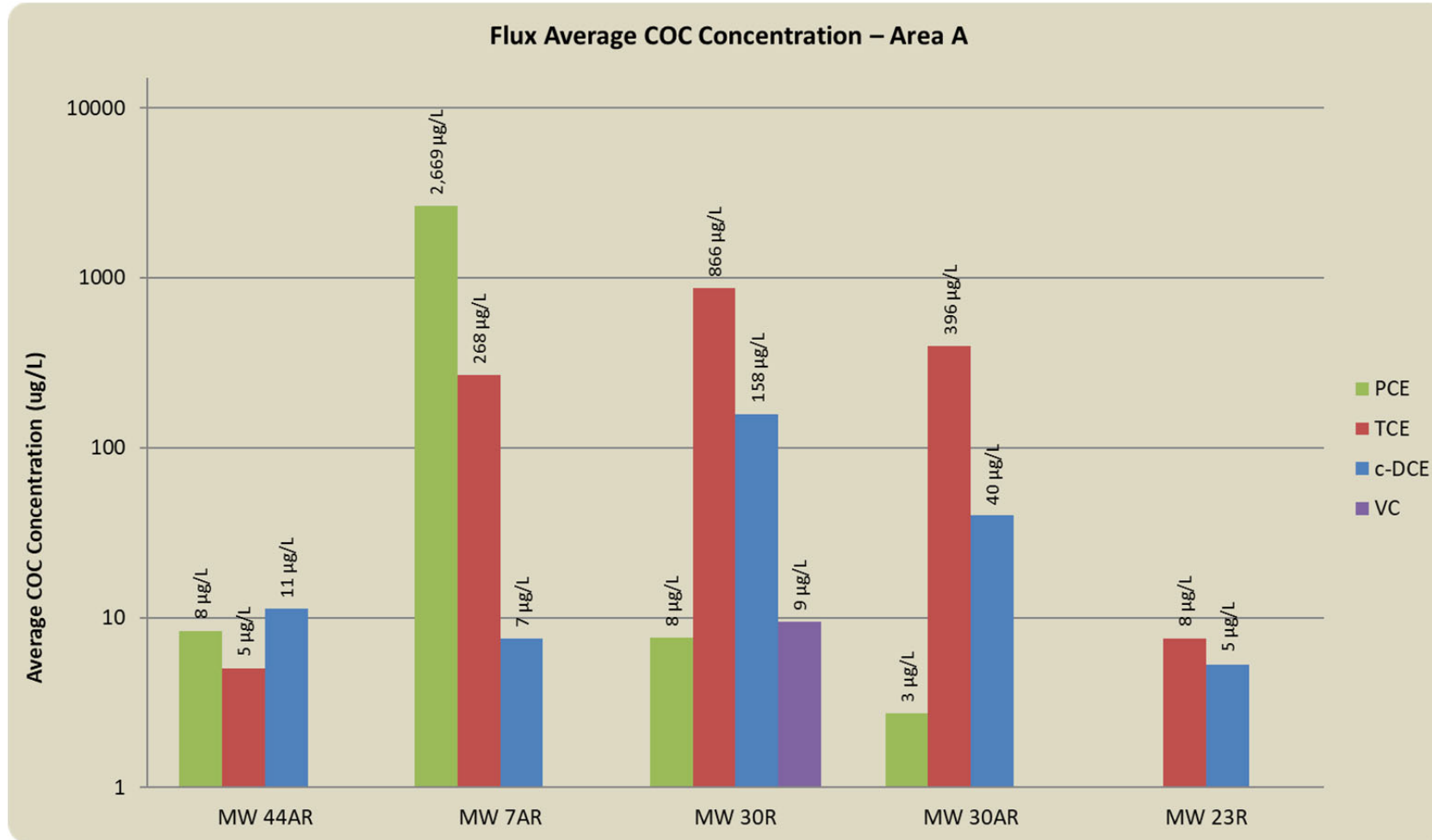


Results – Area A



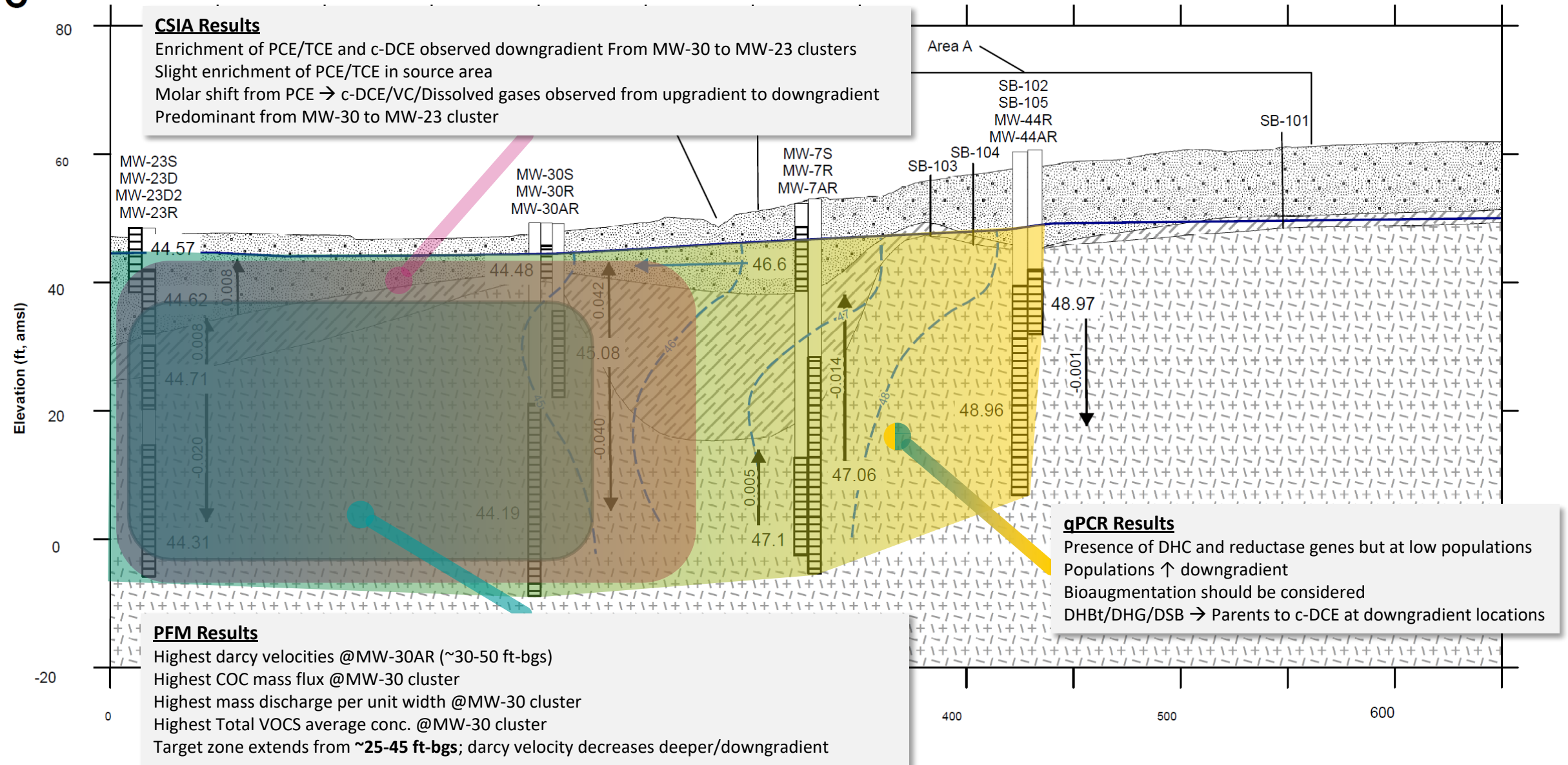
- Highest mass flux observed in and around MW-30 cluster
- Predominantly in the weathered bedrock and upper portion of the more competent bedrock
- Mass flux decreases in the downgradient direction

Results – Area A



- Highest parent product concentrations at MW-7 cluster
- Parent/degradation product observed at MW-30 cluster
 - Supportive of ongoing attenuation mechanisms
- Concentrations decrease significantly in downgradient direction
 - Further supports ongoing attenuation mechanisms

C



C'

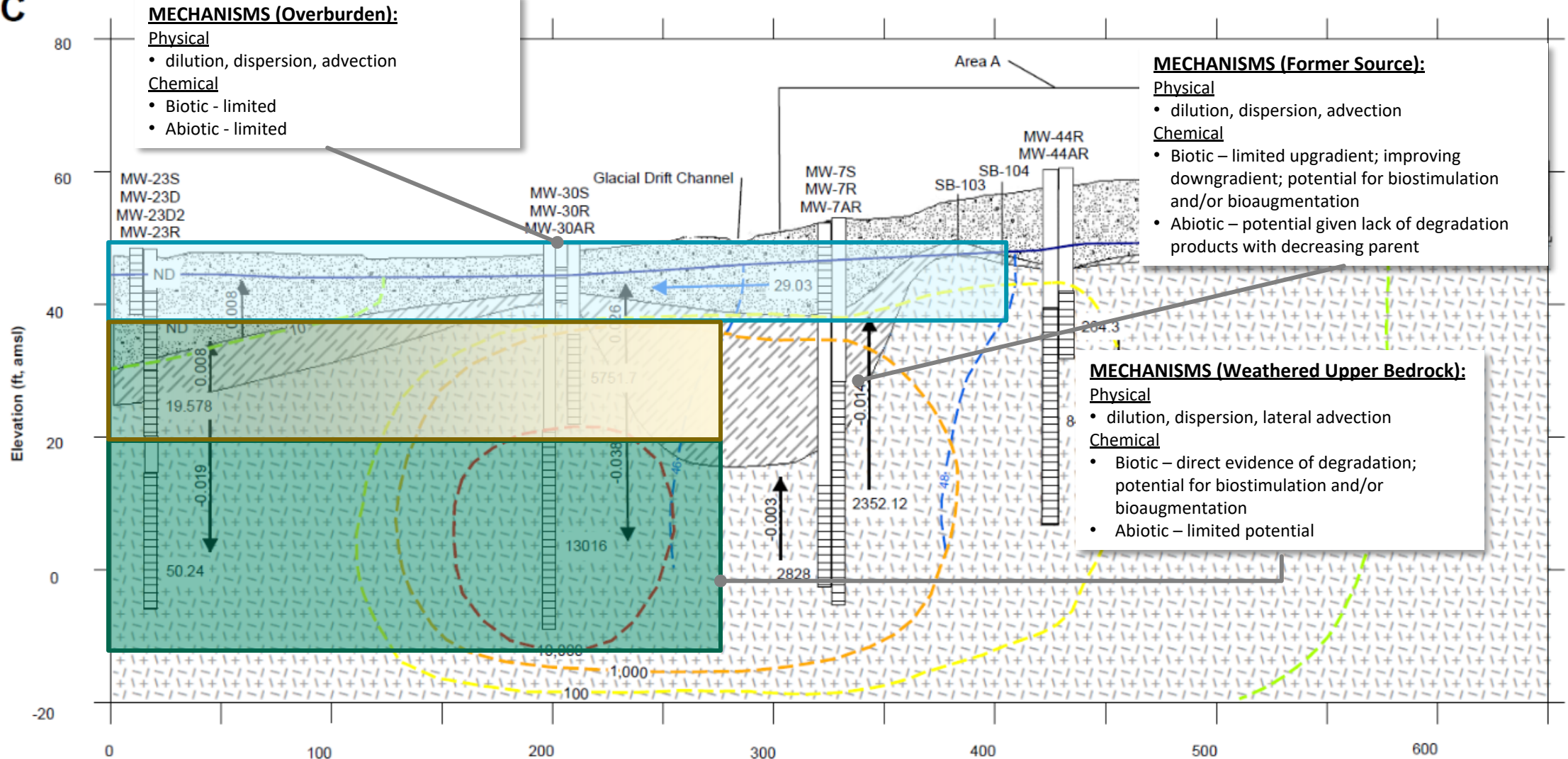
Results – Area A

Southwest

Northeast

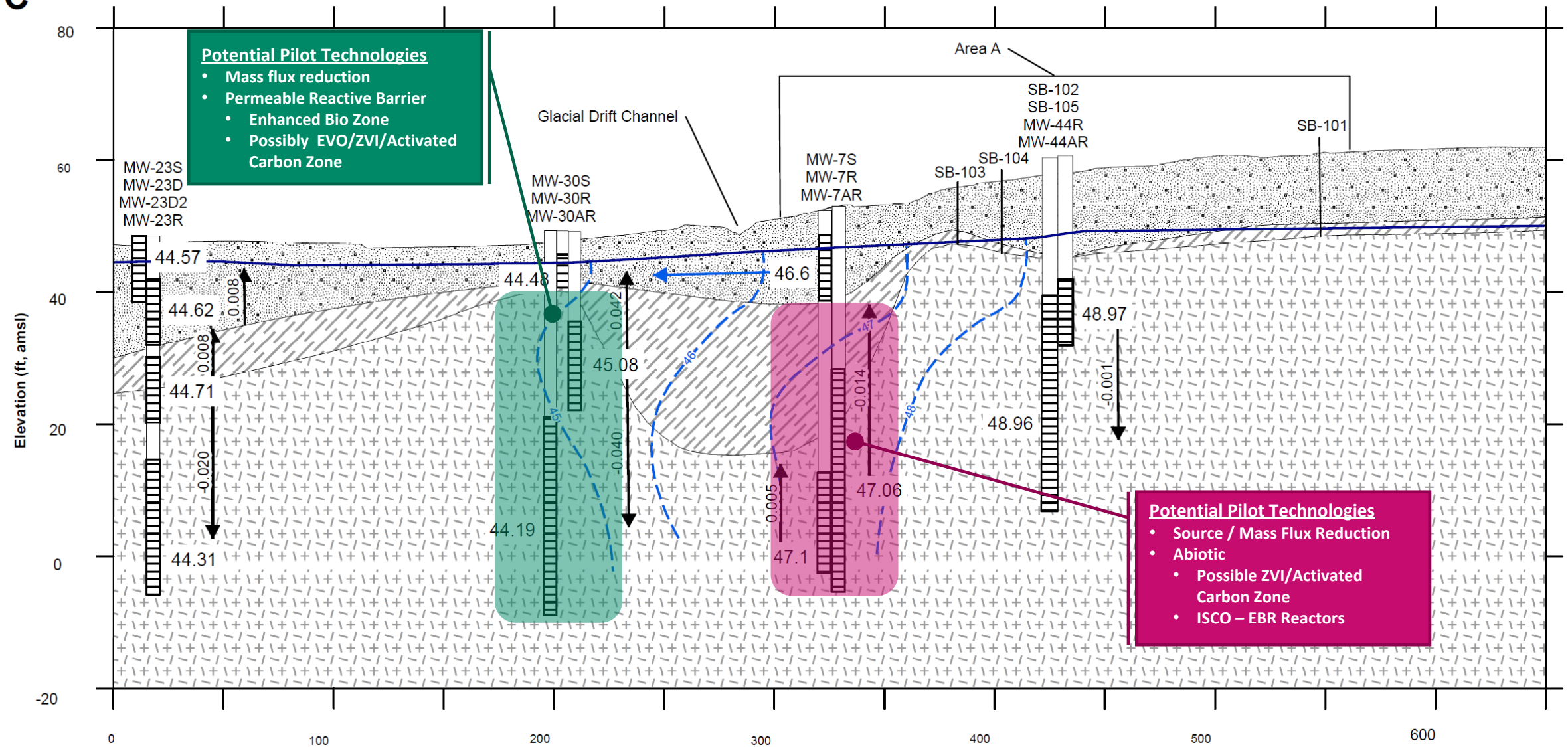
C

C'



Results – Area A

C



C'

Results – Area A

05

Conclusions Lessons Learned

Conclusions

- PFM study was successfully implemented
- Results yielded enhanced understanding of the complex flow zones in Areas A & B
- Provided for further enhancement of Geochem CSM
- Provided additional data for the development of a phased pilot study work plan
 - Phase 1 - Area A
 - Phase 2 - Area B
- Flux measurements will provide a baseline for comparison against flux measurement that will be incorporated in the planned pilot studies

Lessons Learned

- Size matters
 - 2-in PFMs easy to handle, deploy and retrieve, even if multiple intervals are daisy-chained
 - 5-in PFMs cumbersome/difficult to handle, deploy and retrieve, especially when multiple intervals are daisy-chained
- Along the same lines, for larger diameter PFMs mechanical assistance in retrieval should be considered
- Processing retrieved PFMs in the field is straightforward
- Turnaround time from the vendor for the analyses was reasonable with results in hand in 2-3 weeks following retrieval
- Results were used to enhanced CSM understanding and in the development of planned field-scale pilot demonstrations

THANK YOU!



Doug Gray
Innovative Remedial Technologies
Group Leader



AECOM