Automated Visual Tool For Source Distinction, Commingled Plume Differentiation, and Attenuation Assessment For Complex Chlorinated Compound Mixtures

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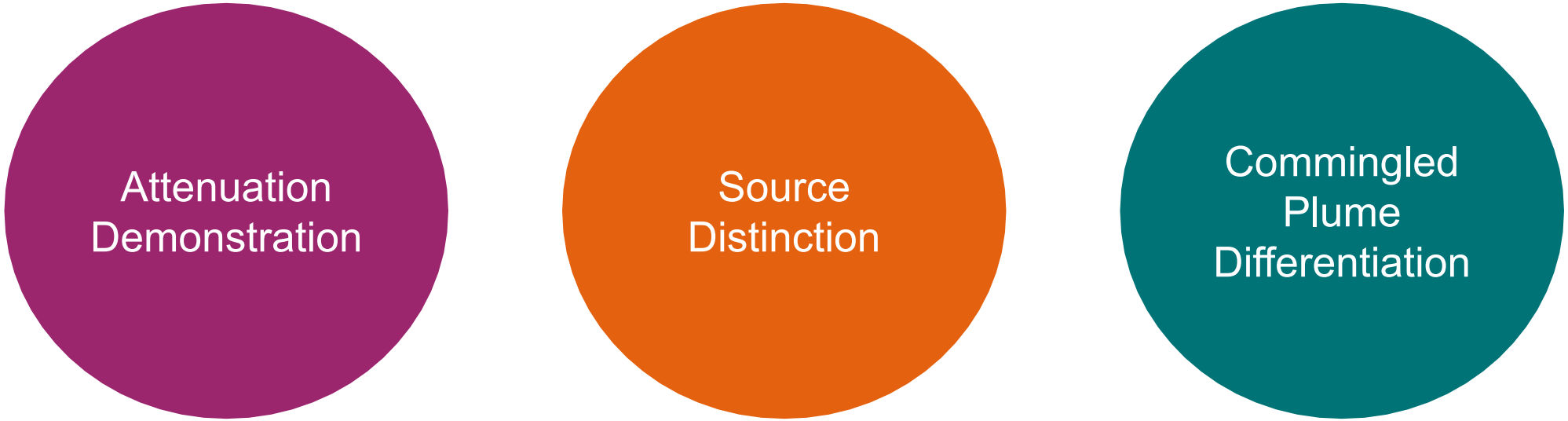
Battelle Chlorinated Conference

Denver, Colorado

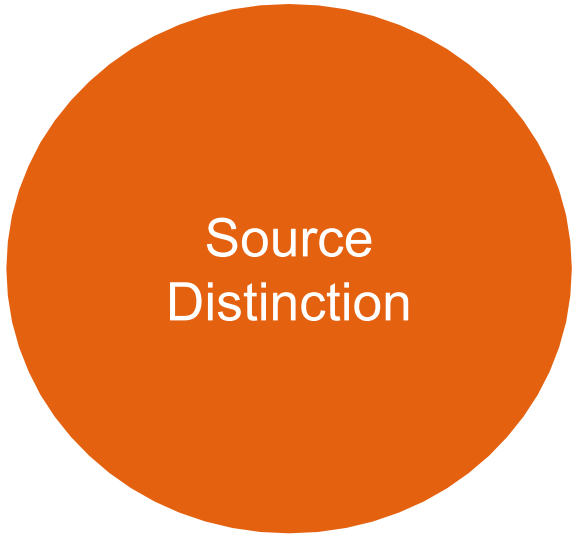
Why Evaluate CVOC Profiles?

- Forensic evaluation method that relies on readily available data from standard analytical methods
  - Chlorinated volatile organic (CVOC) concentration data have often been collected consistently over time.
- Changes in CVOC mixtures over time can demonstrate attenuation processes
  - Reductive dechlorination produces characteristic patterns
- A more detailed look at CVOC profiles may help to:
  - Distinguish sources
  - Delineate impact in commingled plumes

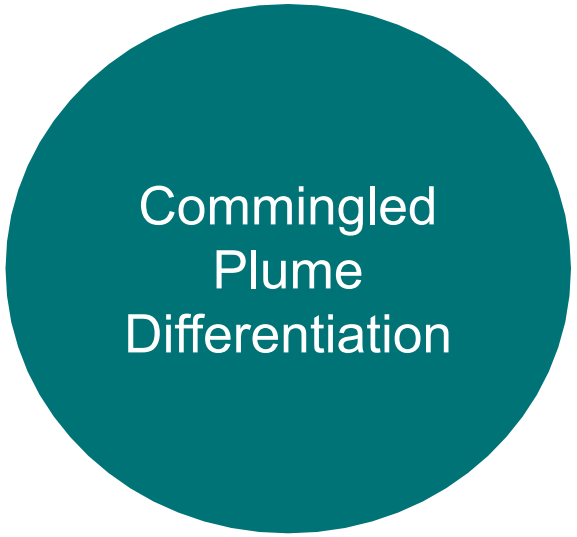


ARCADIS

Do CVOCs show a characteristic degradation pattern over time? How does that pattern correspond with total molar concentrations?

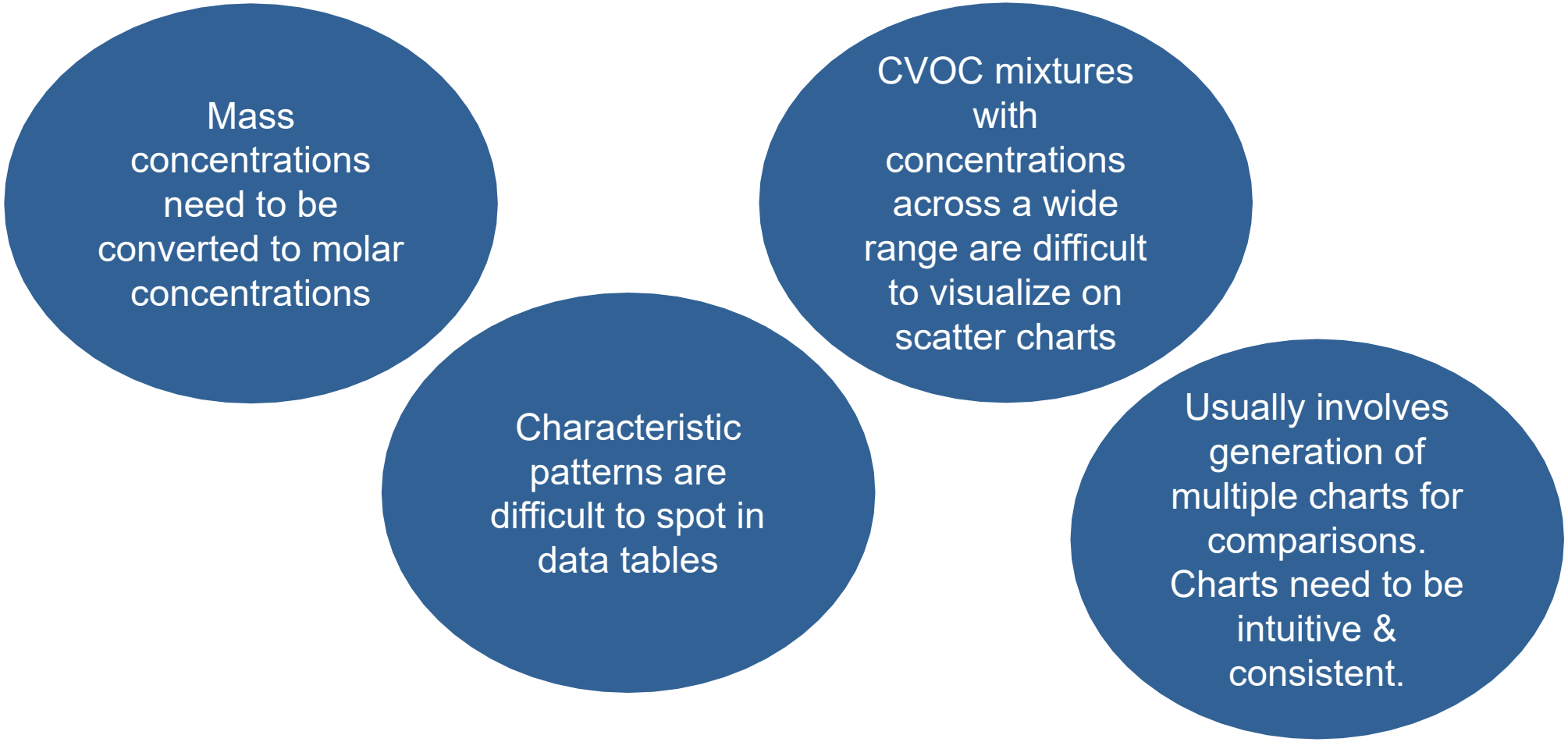


Can this plume be attributed to this source area?



Where is the boundary of responsibility?

The data are available, why isn't this considered more often?



In many cases it is a data processing and presentation challenge

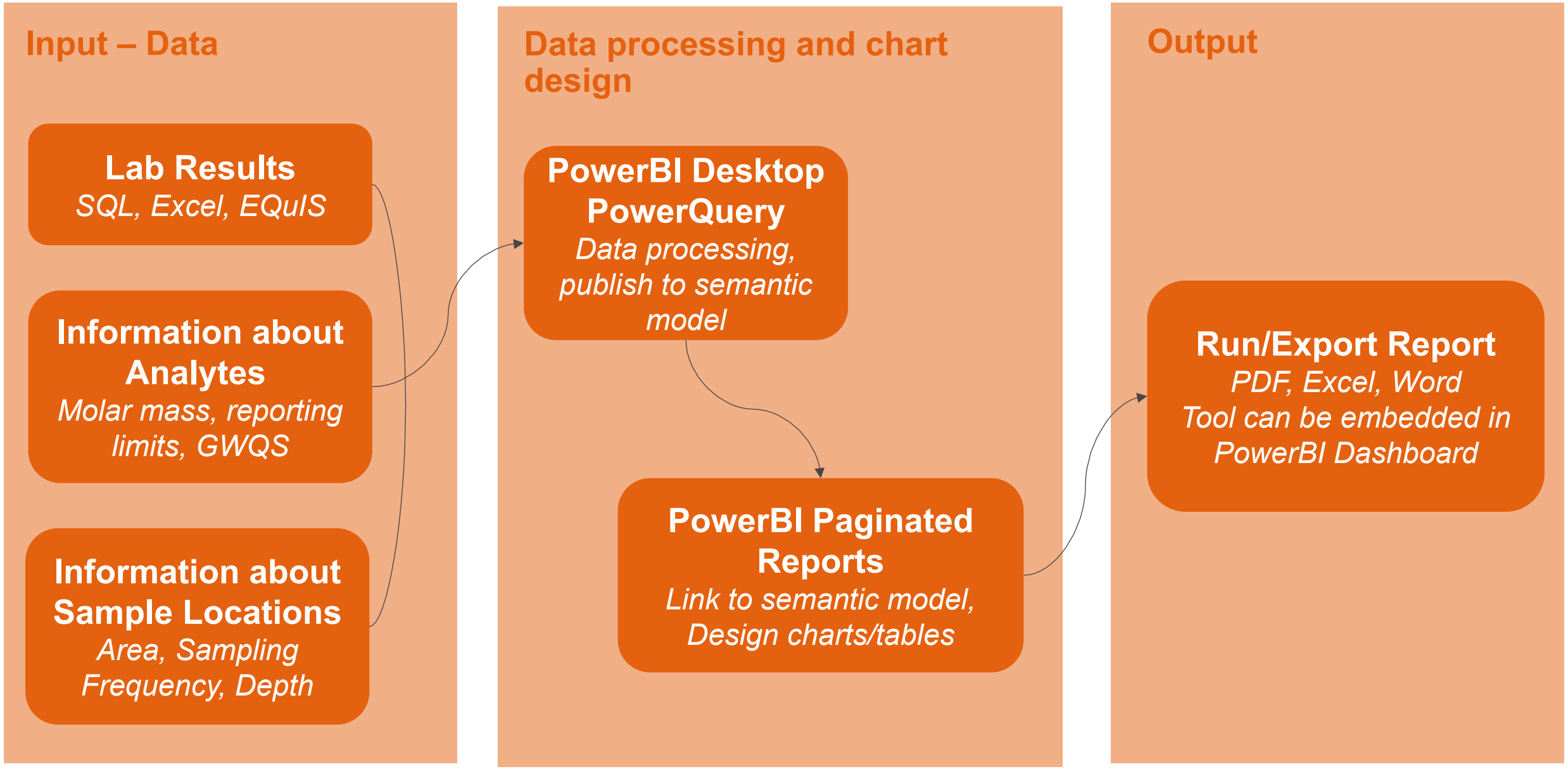
Overcoming the challenge of data processing and presentation

- Simple standardized input file
- Options for filtering data based on customizable parameters
  - Area of site
  - Depth interval
  - Constituents
  - Time period
- Standardized output
  - Easy visual comparisons

PowerBI Report Builder with option of embedding in site dashboards

Power BI Report Builder Data Flow

ARCADIS

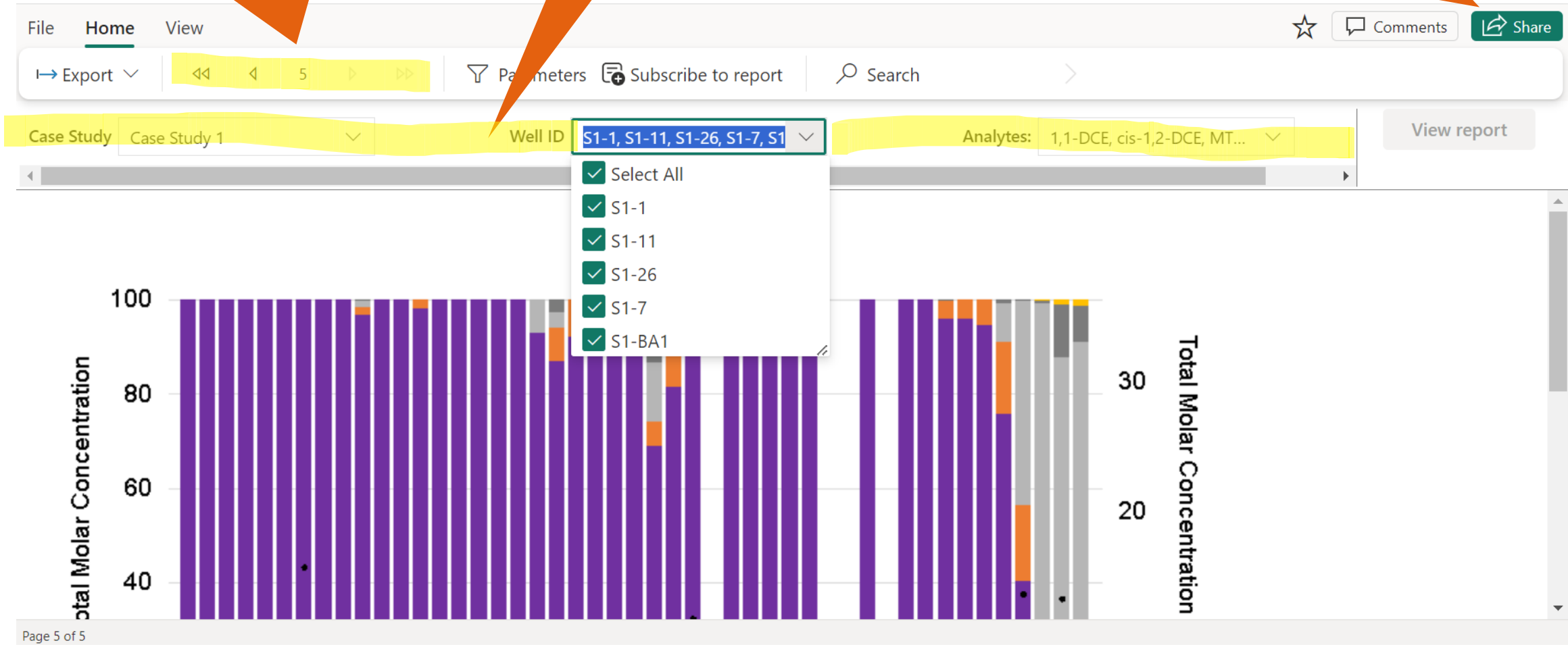


Power BI Report Builder

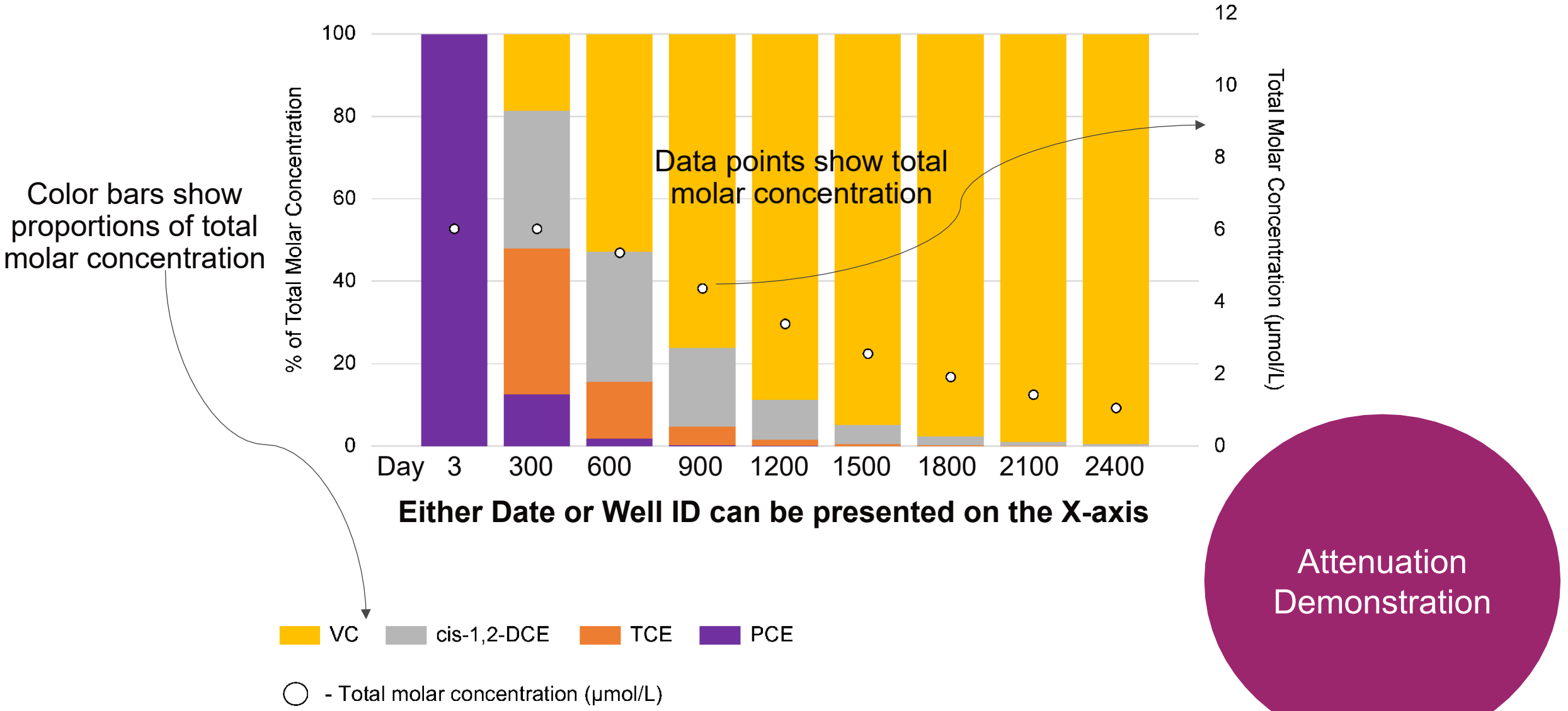
Report generates one page (one graph) for every location selected

Custom filters

Report tool can be shared or embedded in a PowerBI Dashboard



Model Reductive Dechlorination



Attenuation Demonstration

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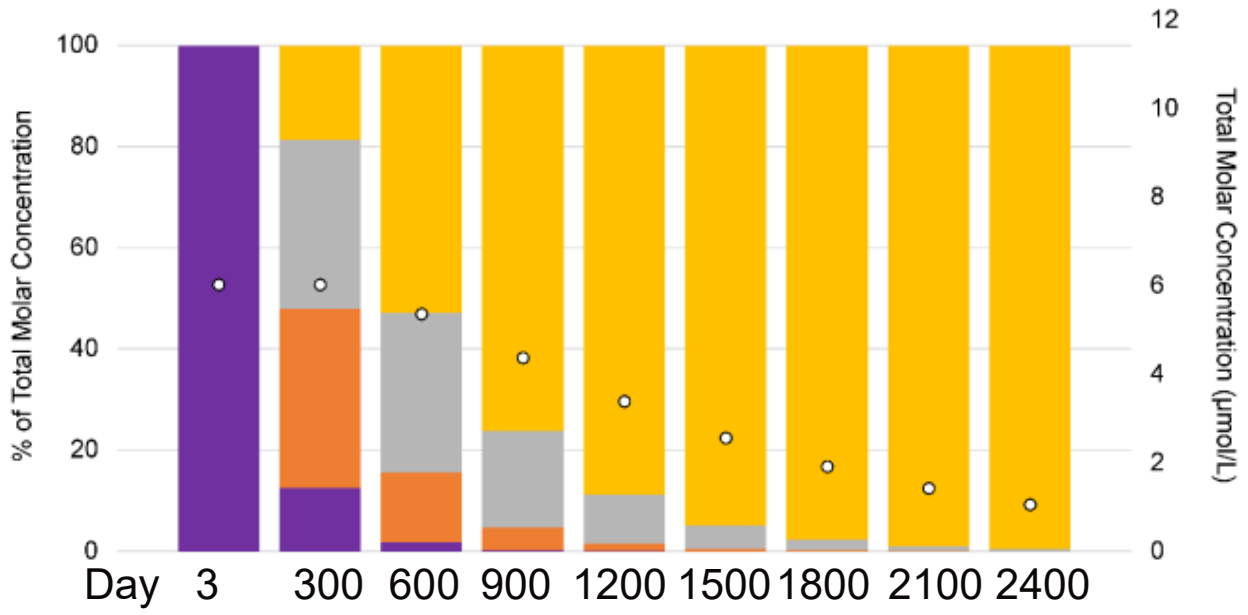
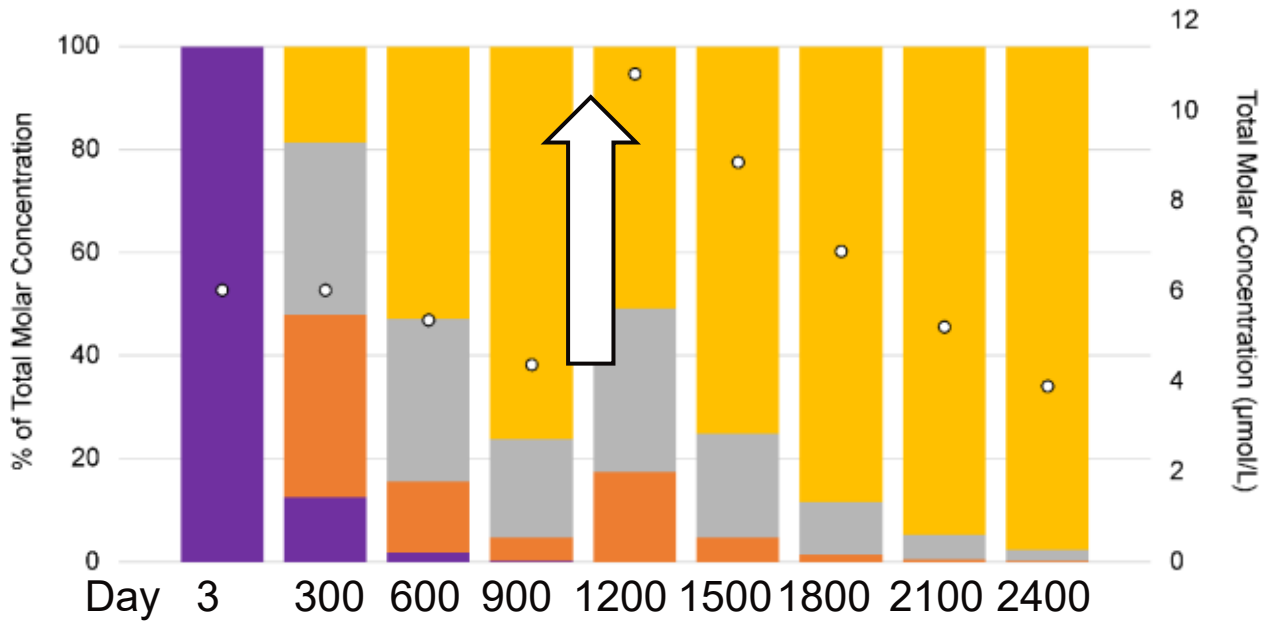
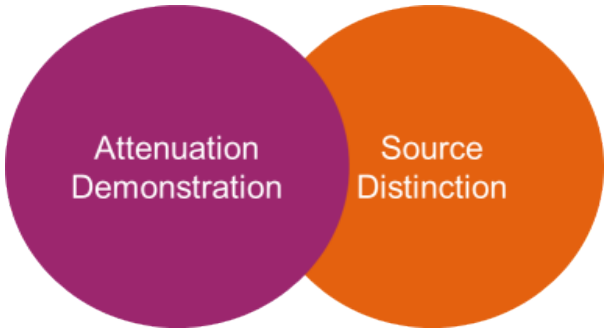
Additional TCE Source





VC cis-1,2-DCE TCE PCE

○ - Total molar concentration (µmol/L)



Total molar concentration provides persistent evidence of an additional source, even where appearance of parent product is limited and excess concentrations of degradation intermediates are not easily discernable.

100 µg/L TCE added for ~1 month ~900 days after initial PCE source degradation started

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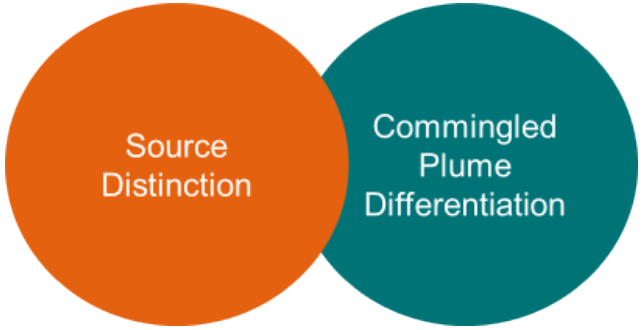
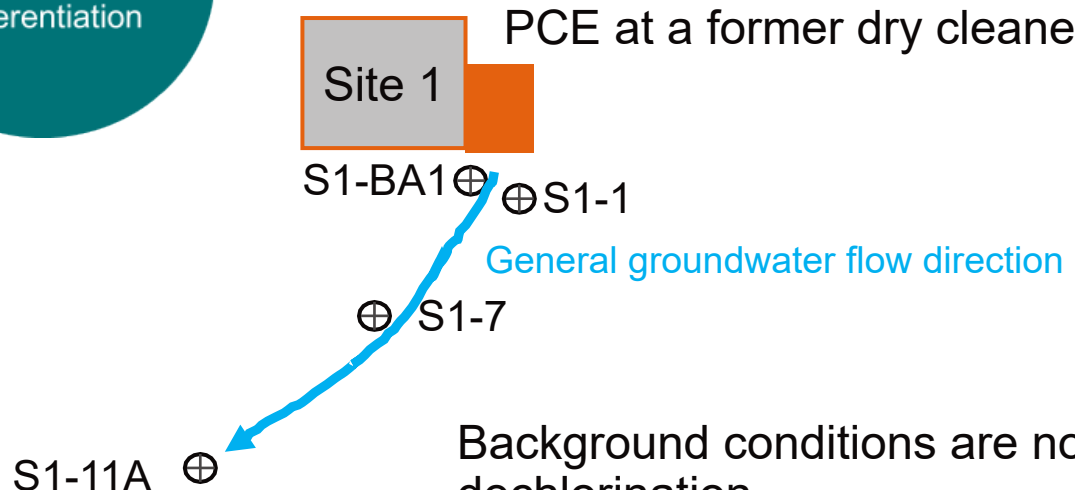
Case Study 1



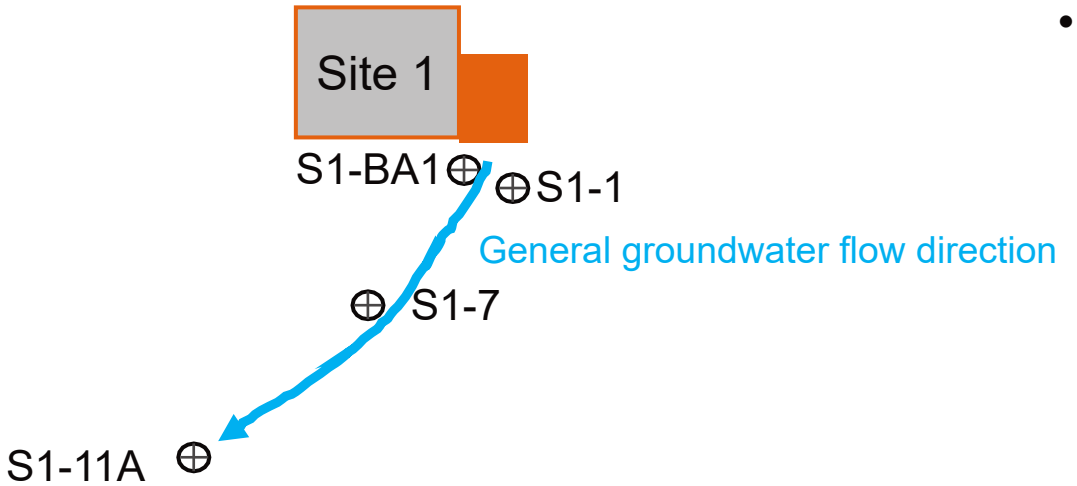


Background conditions are not conducive to reductive dechlorination.

- Geochemistry
- Historically, limited concentrations of dechlorination products

**Simplified and anonymized depiction

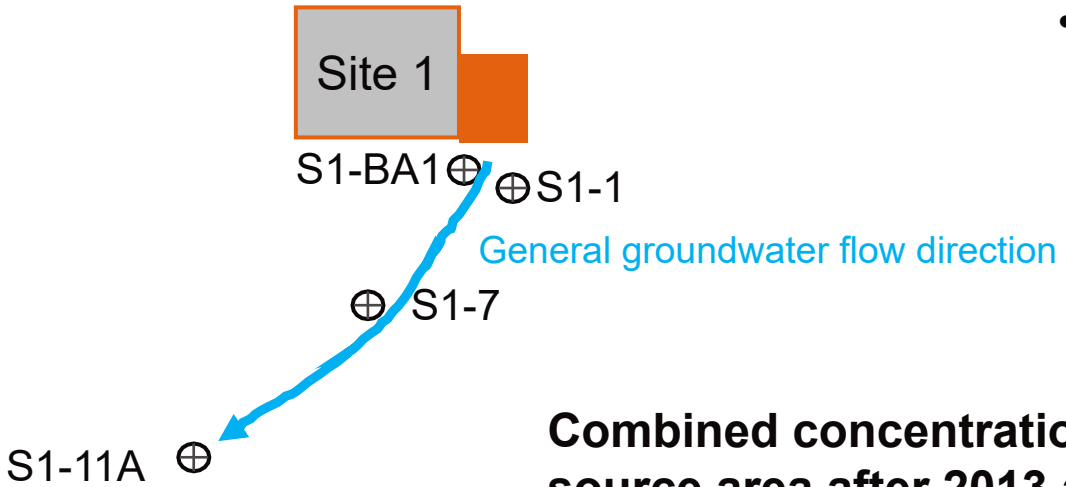
Case Study 1



Remediation History

- 1998 Targeted Excavation
- 1999-2004 Soil Vapor Extraction
- 2005 and 2007 ISCO
- 2013 Excavation with reductive dechlorination treatment media in backfill
  - Historical PCE soil exceedances removed
  - Confirmation samples demonstrate efficacy

Case Study 1



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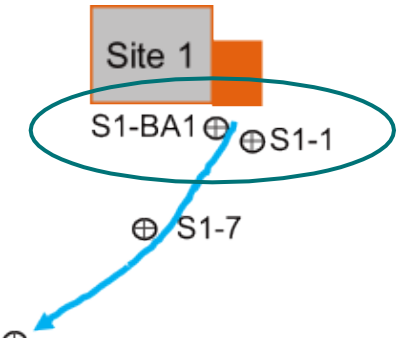
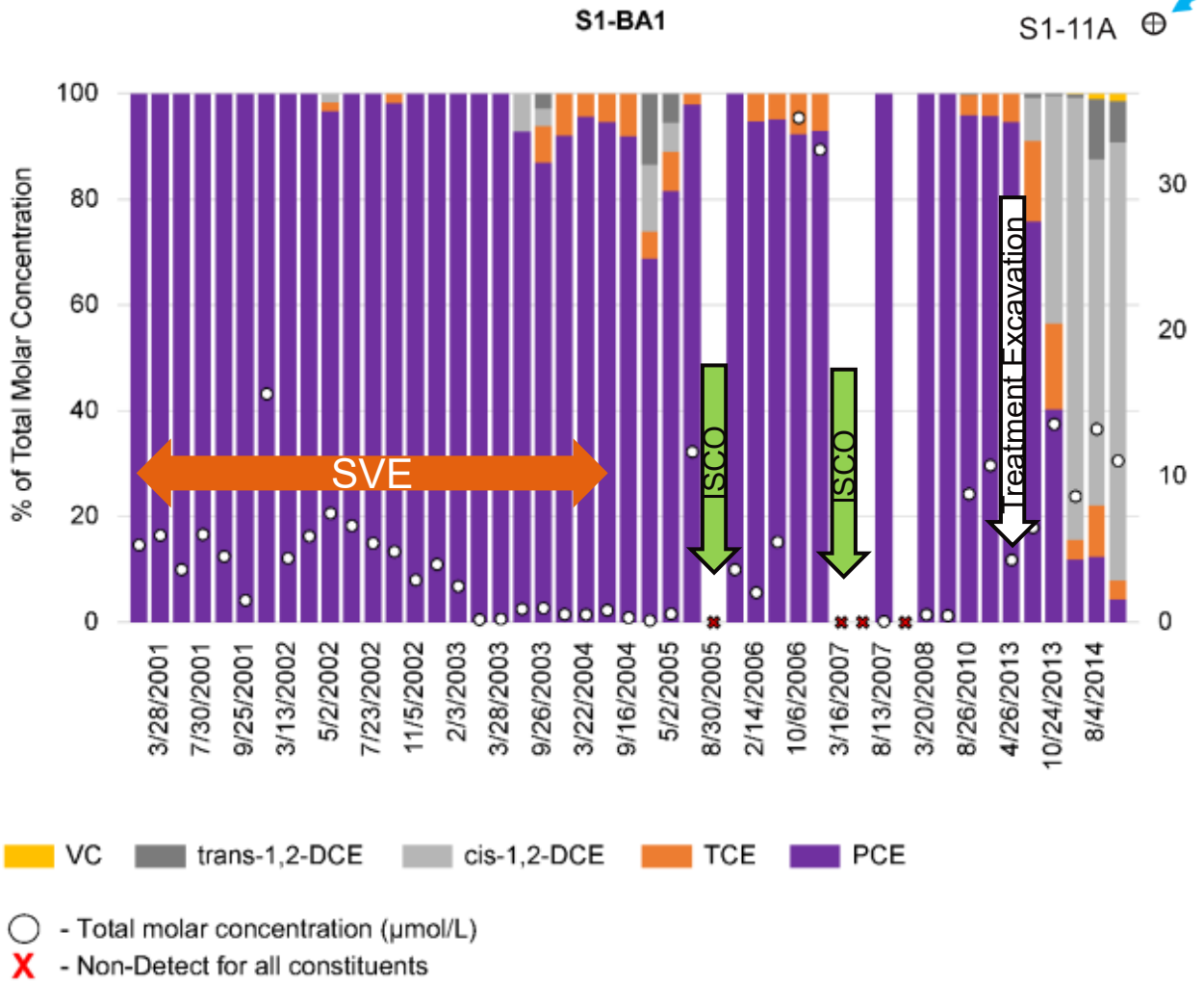
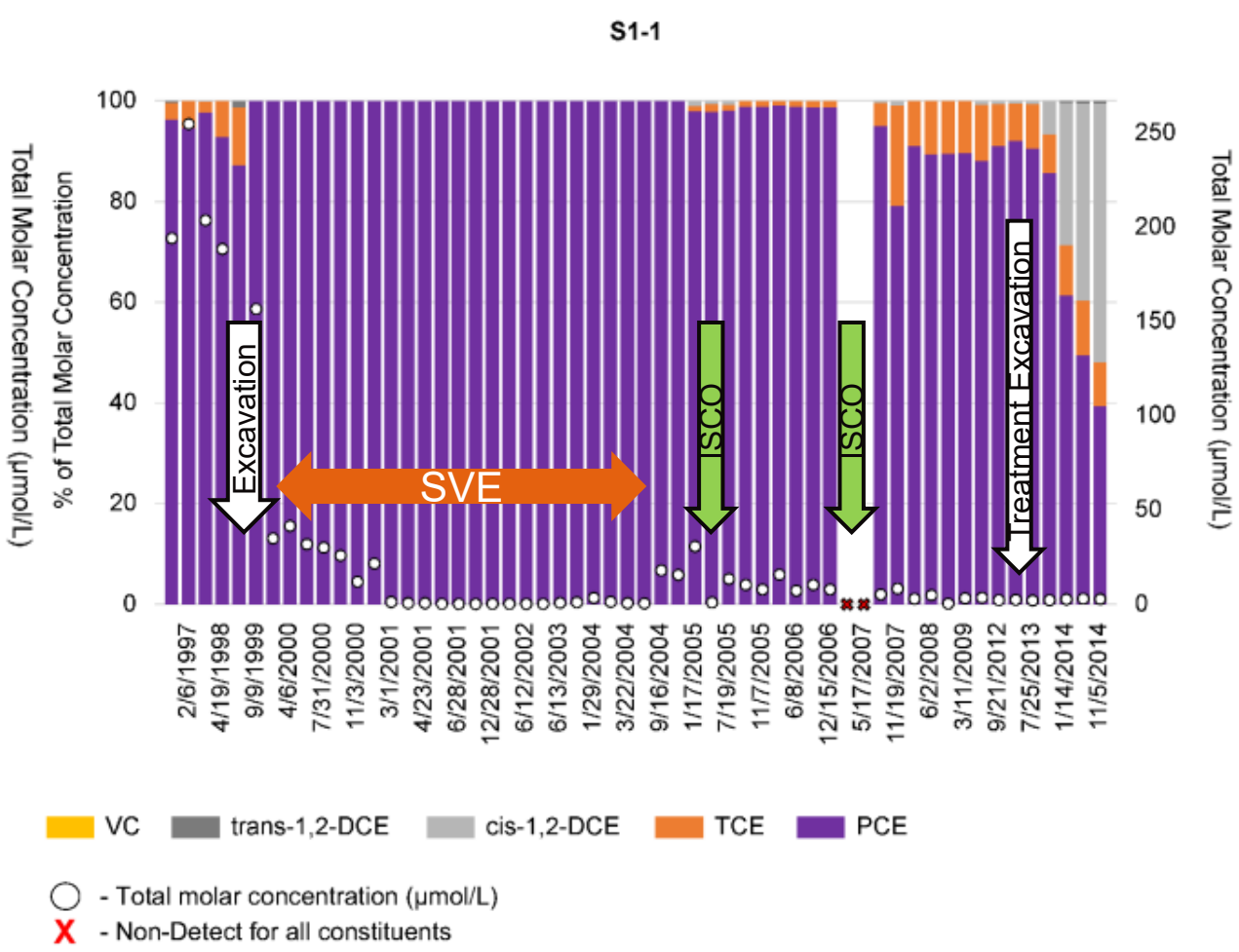
Combined concentrations of PCE and its degradation products leaving the source area after 2013 are interpreted to be substantially lower than historical concentrations measured in the site source area monitoring well network.

Case Study 1


Site 1
S1-BA1
S1-1
S1-7
S1-11A


S1-BA1
% of Total Molar Concentration
Total Molar Concentration (µmol/L)
SVE
ISCO
ISCO
Treatment Excavation
VC
trans-1,2-DCE
cis-1,2-DCE
TCE
PCE
- Total molar concentration (µmol/L)
- Non-Detect for all constituents


S1-1
% of Total Molar Concentration
Total Molar Concentration (µmol/L)
Excavation
SVE
ISCO
ISCO
Treatment Excavation
VC
trans-1,2-DCE
cis-1,2-DCE
TCE
PCE
- Total molar concentration (µmol/L)
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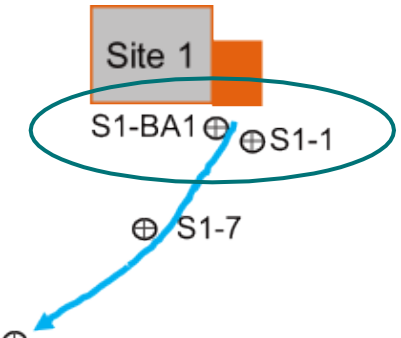
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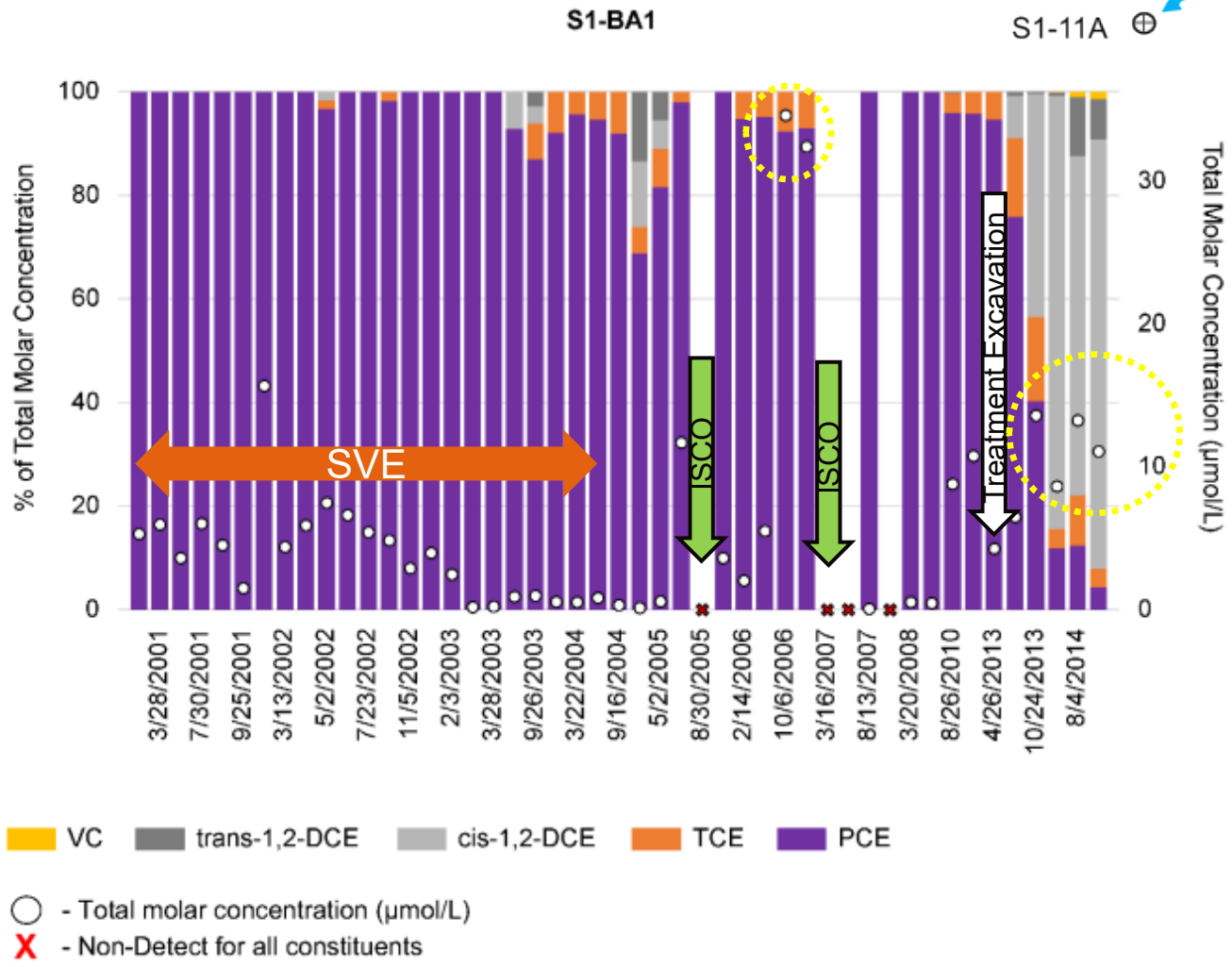
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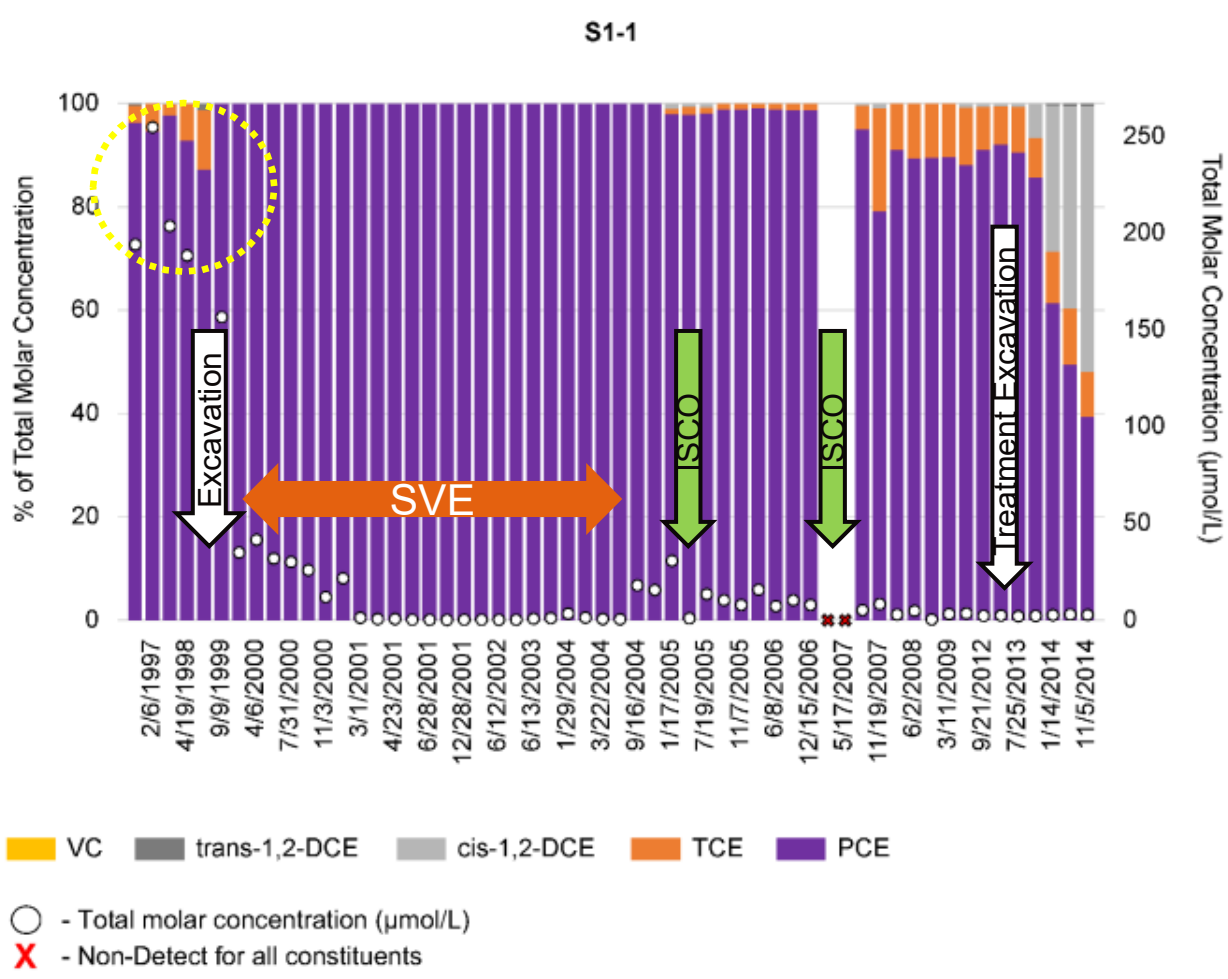
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Total Molar Concentration (µmol/L)
Excavation
SVE
ISCO
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Treatment Excavation
VC
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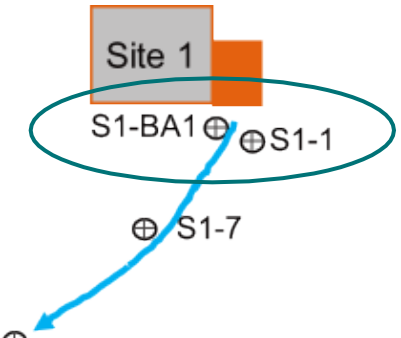
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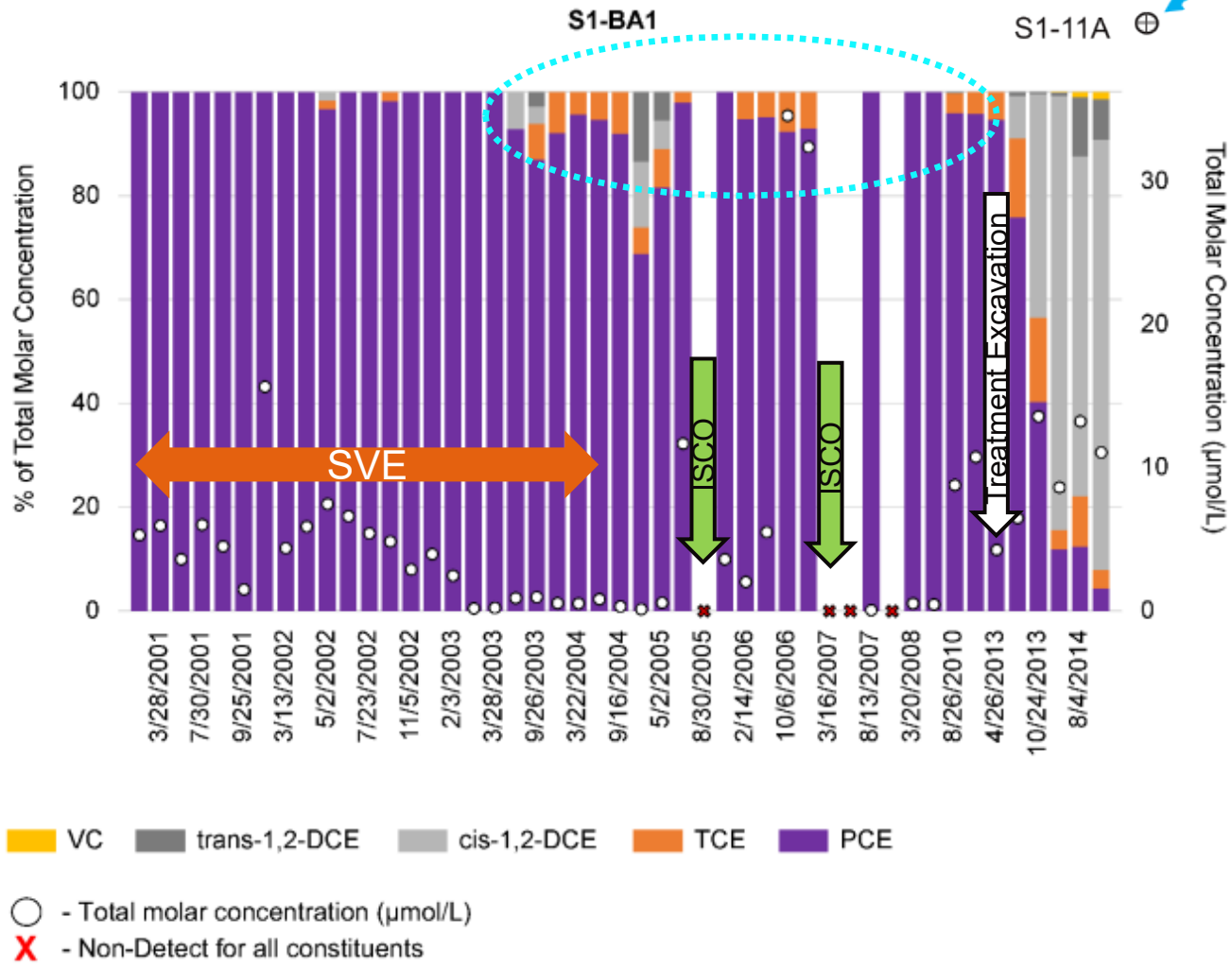
S1-BA1
% of Total Molar Concentration
Total Molar Concentration (µmol/L)
SVE
ISCO
ISCO
Treatment Excavation
3/28/2001
7/30/2001
9/25/2001
3/13/2002
5/2/2002
7/23/2002
11/5/2002
2/3/2003
3/28/2003
9/26/2003
3/22/2004
9/16/2004
5/2/2005
8/30/2005
2/14/2006
10/6/2006
3/16/2007
8/13/2007
3/20/2008
8/26/2010
4/26/2013
10/24/2013
8/4/2014
VC
trans-1,2-DCE
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TCE
PCE
- Total molar concentration (µmol/L)
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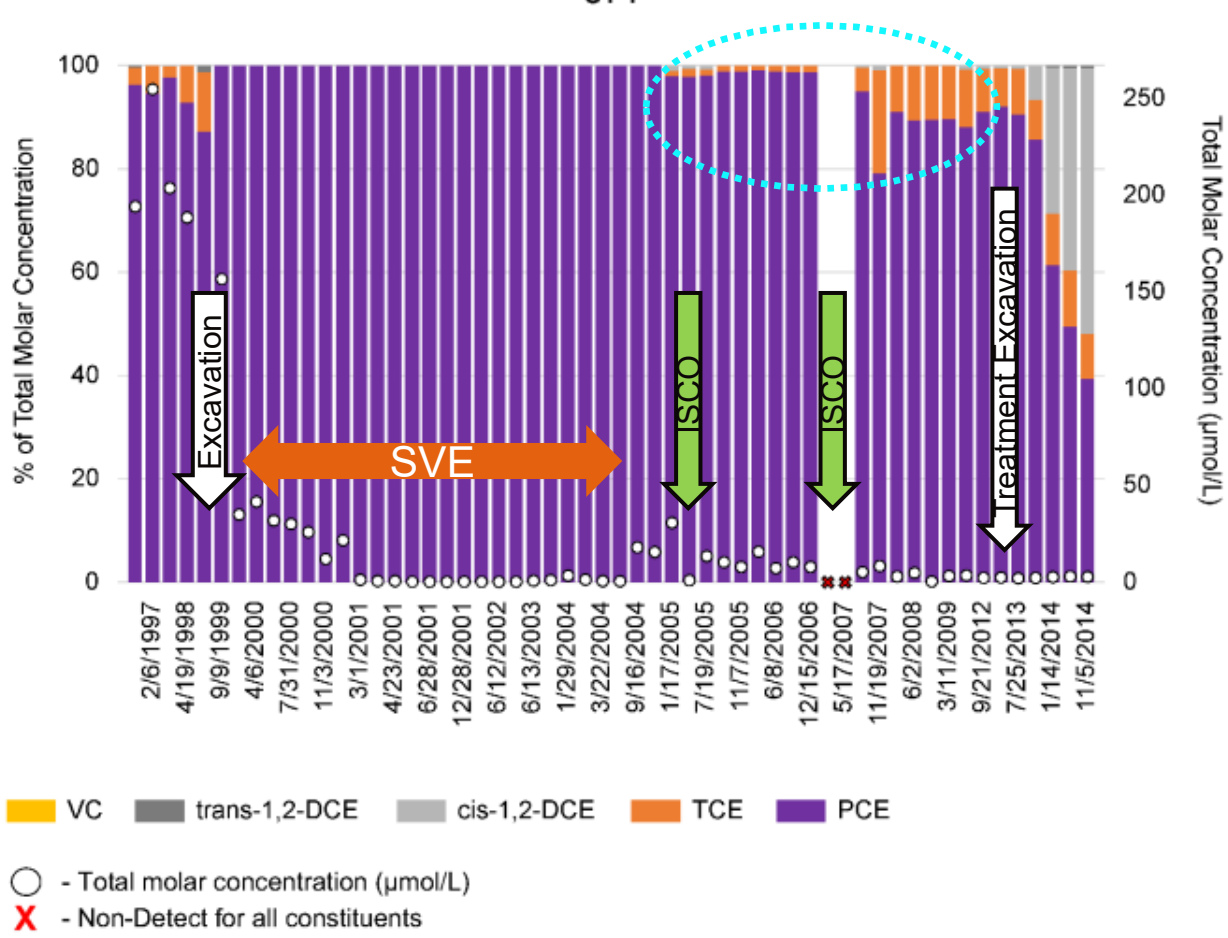
S1-1
% of Total Molar Concentration
Total Molar Concentration (µmol/L)
Excavation
SVE
ISCO
ISCO
Treatment Excavation
2/6/1997
4/19/1998
9/9/1999
4/6/2000
7/31/2000
11/3/2000
3/1/2001
4/23/2001
6/28/2001
12/28/2001
6/12/2002
6/13/2003
1/29/2004
3/22/2004
9/16/2004
1/17/2005
7/19/2005
11/7/2005
6/8/2006
12/15/2006
5/17/2007
11/19/2007
6/2/2008
3/11/2009
9/21/2012
7/25/2013
1/14/2014
11/5/2014
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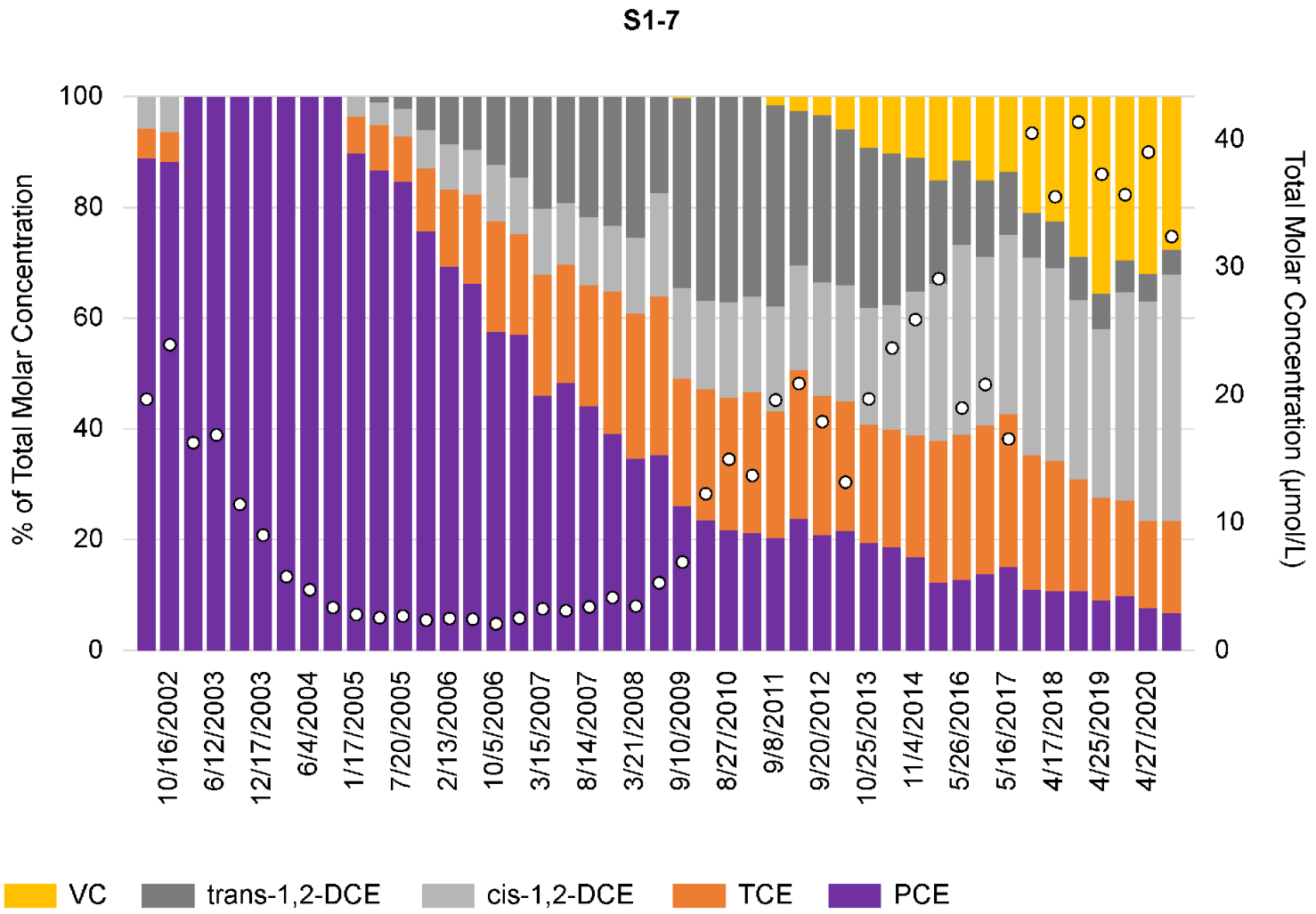

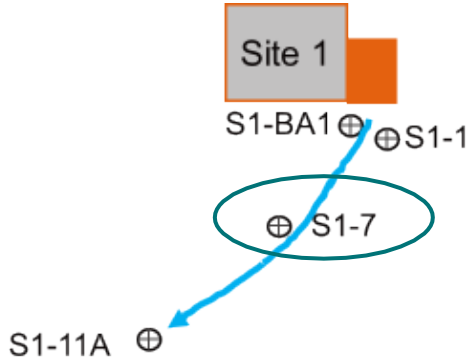

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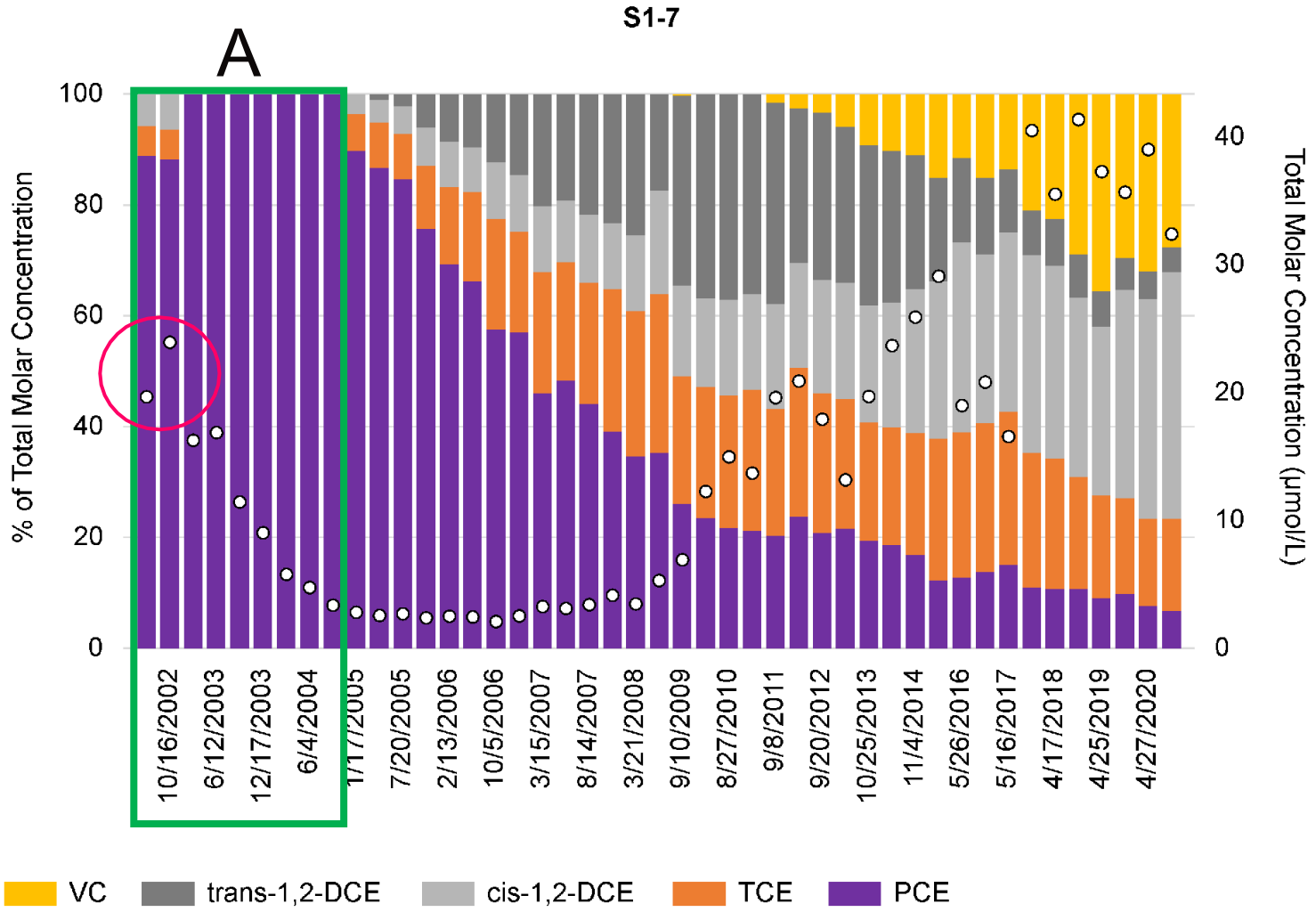
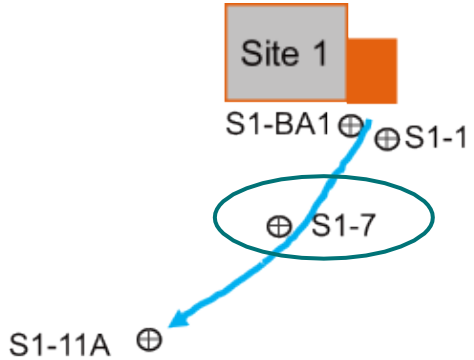
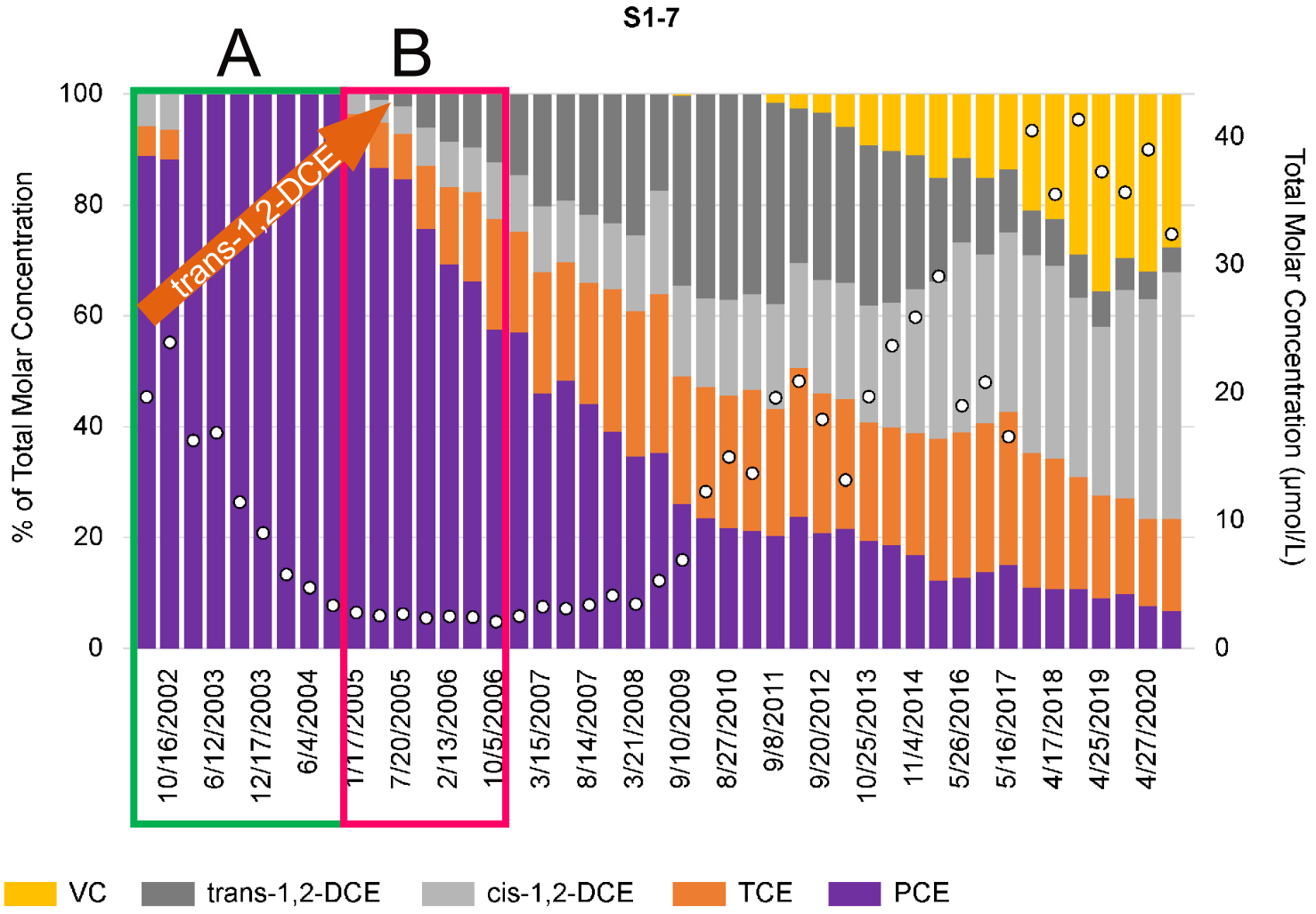
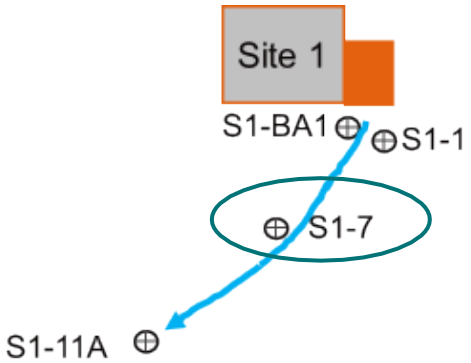




A: Reflects decrease in site-related PCE during onsite SVE period

Case Study 1

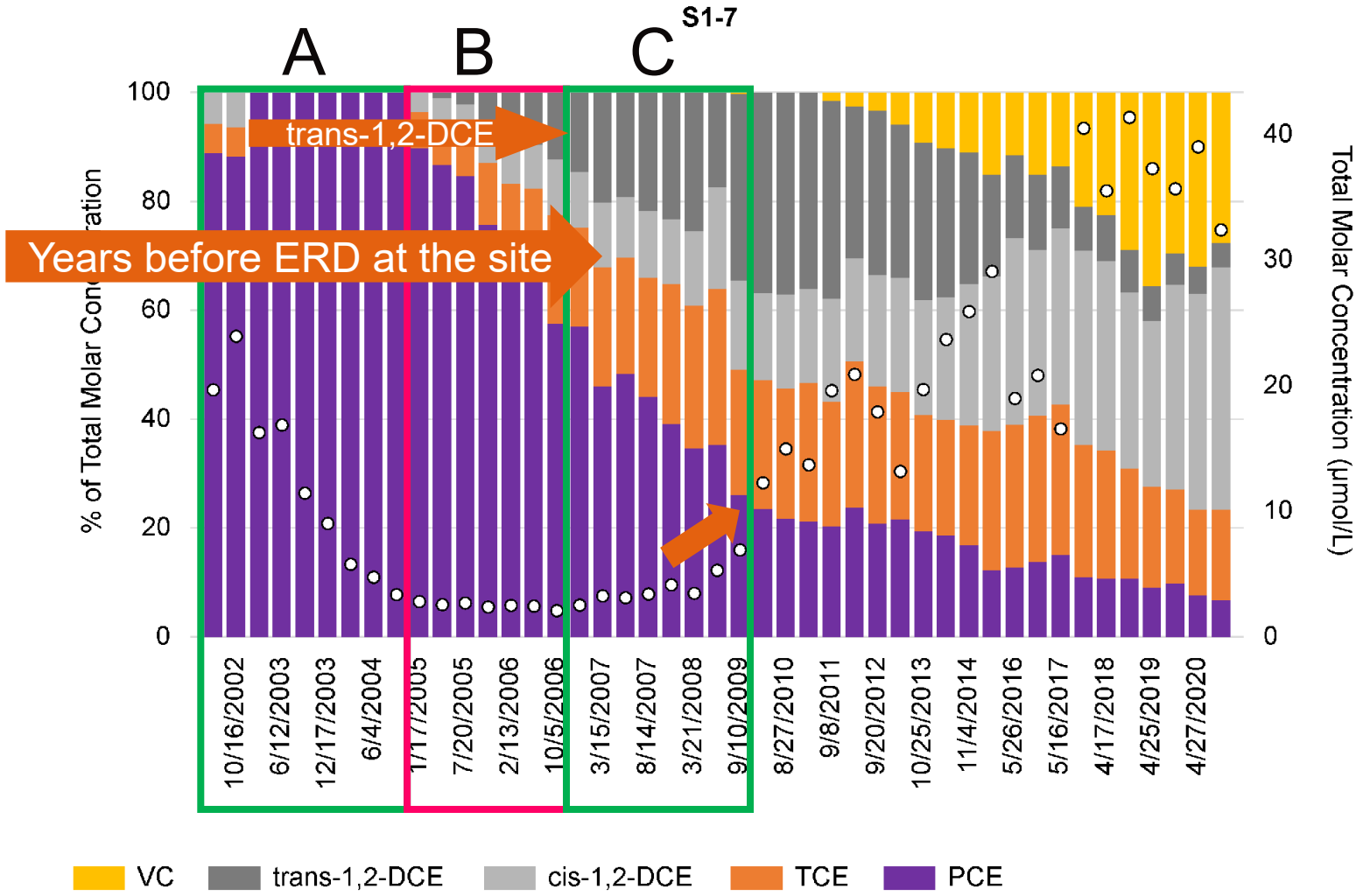


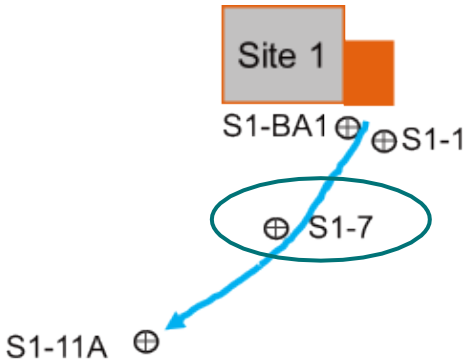


A: Reflects decrease in site-related PCE during onsite SVE period

B: Stable TMC with increasing proportions of degradation products. Reflects the arrival of 1st trailing plume

Case Study 1



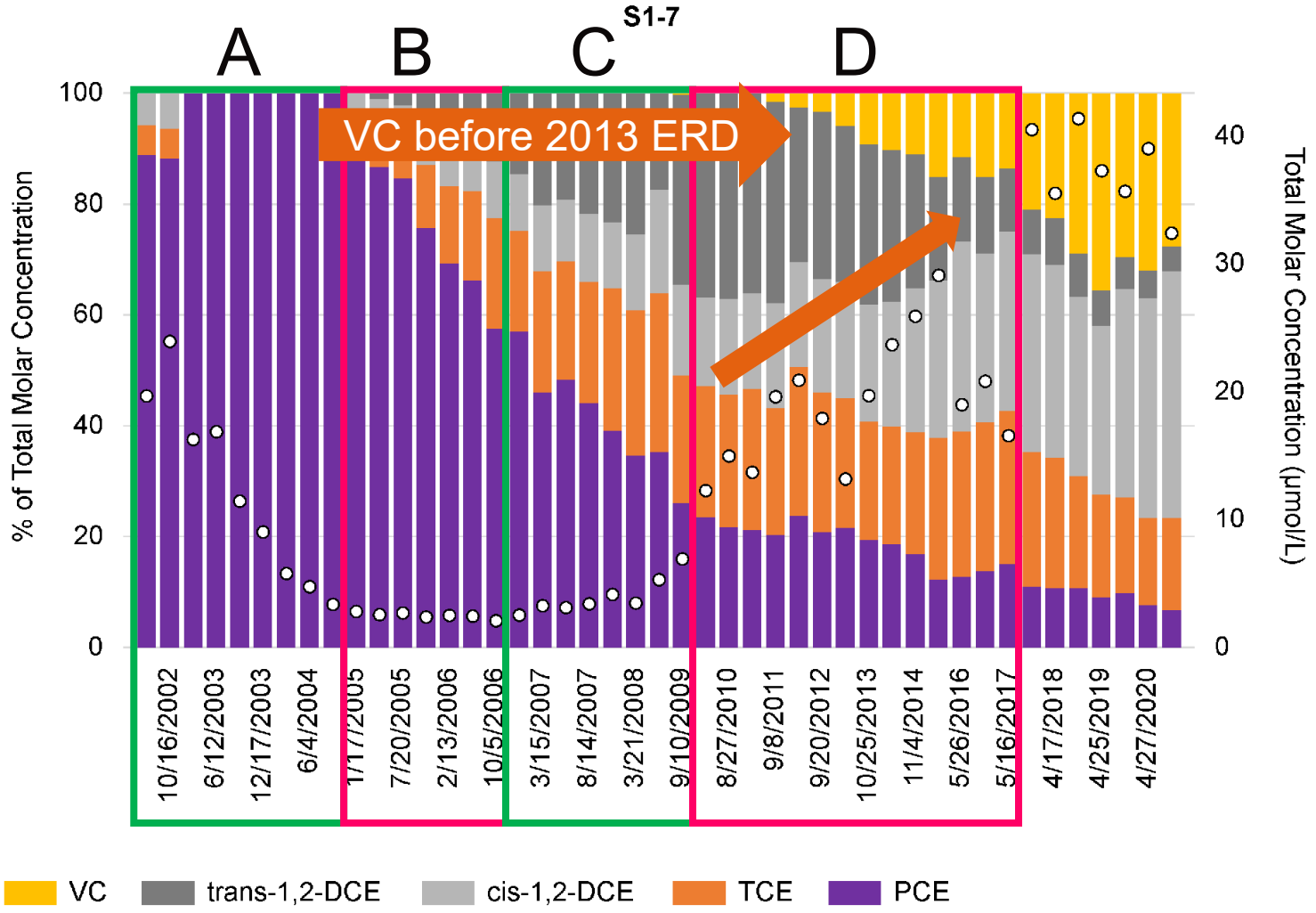


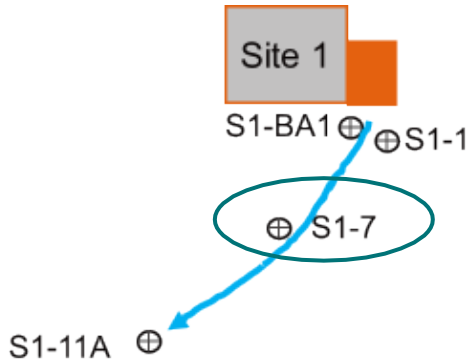
A: Reflects decrease in site-related PCE during onsite SVE period

B: Stable TMC with increasing proportions of degradation products. Reflects the arrival of 1st trailing plume.

C: Increasing influence of 1st trailing plume

Case Study 1





A: Reflects decrease in site-related PCE during onsite SVE period.

B: Stable TMC with increasing proportions of degradation products. Reflects the arrival of 1st trailing plume.

C: Increasing influence of 1st trailing plume.

D: Increasing TMC with increasing proportions of degradation product. Appearance of VC before ERD at the site.

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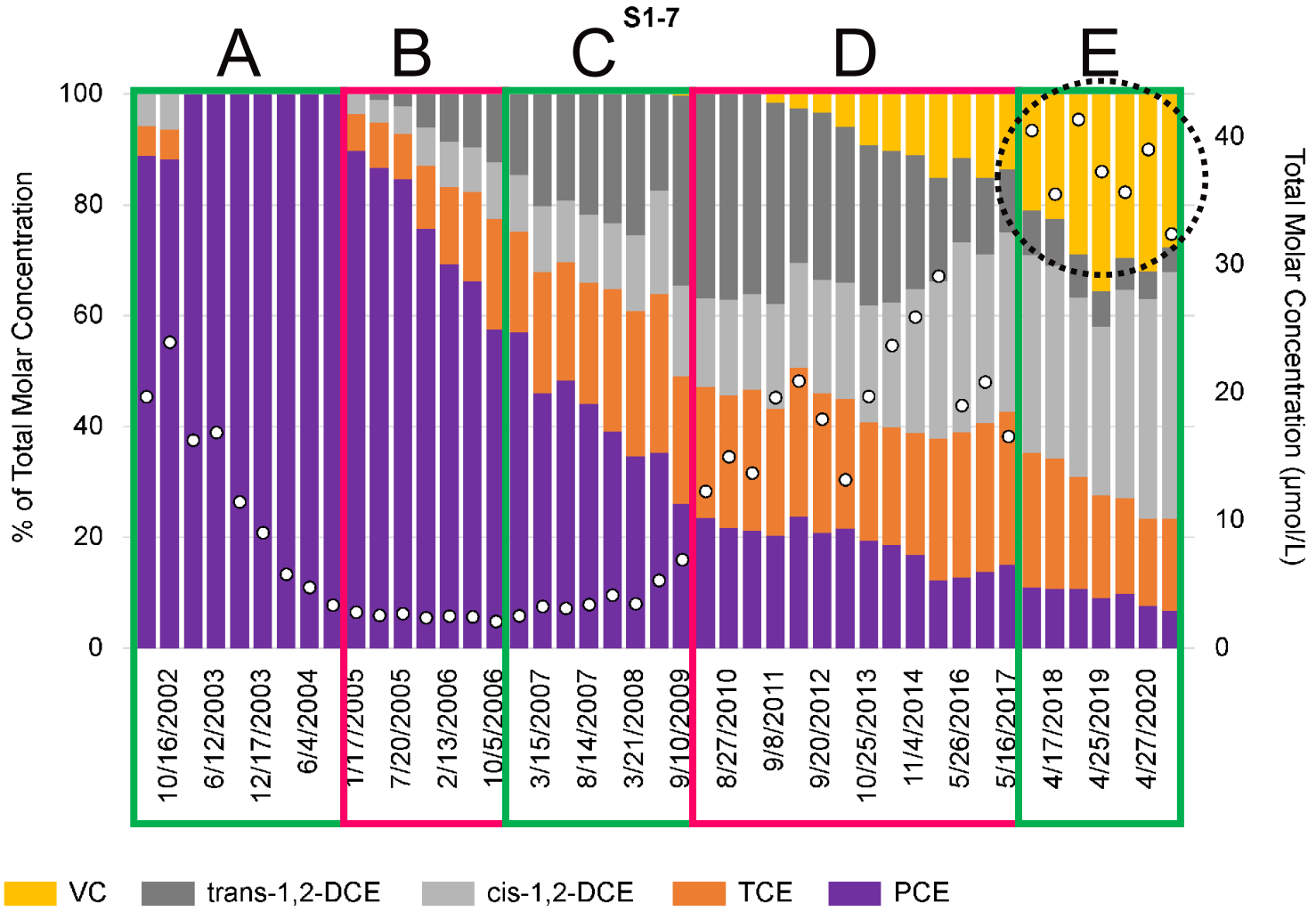
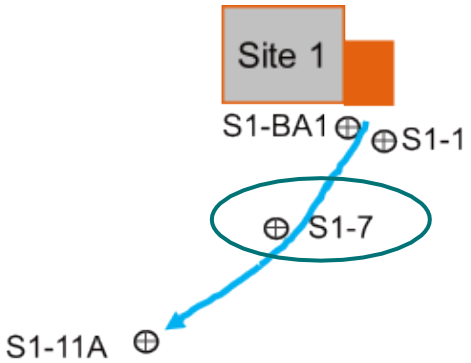




A: Reflects decrease in site-related PCE during onsite SVE period.

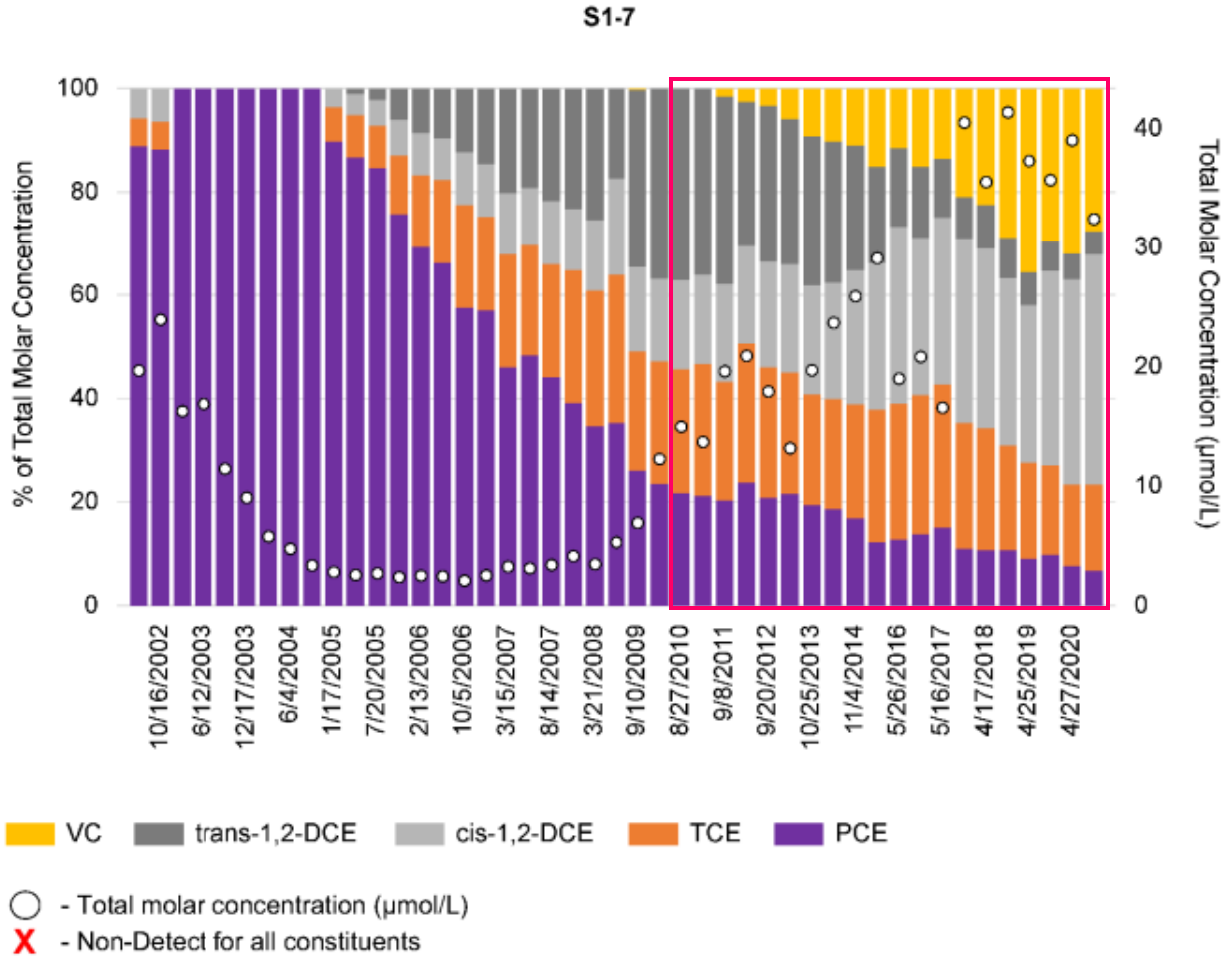
B: Stable TMC with increasing proportions of degradation products. Reflects the arrival of 1st trailing plume.

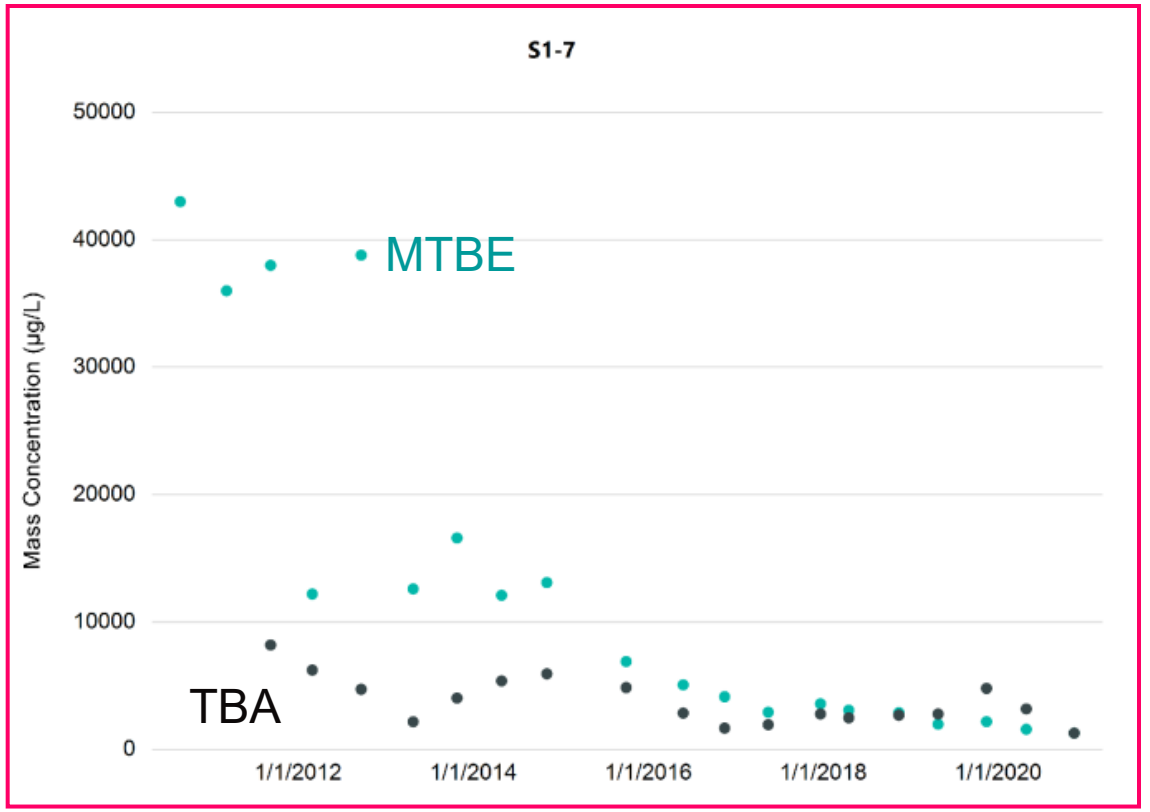
C: Increasing influence of 1st trailing plume.

D: Increasing TMC with increasing proportions of degradation products. Appearance of VC before ERD at the site. Higher TMC than onsite. Reflects 2nd trailing plume.

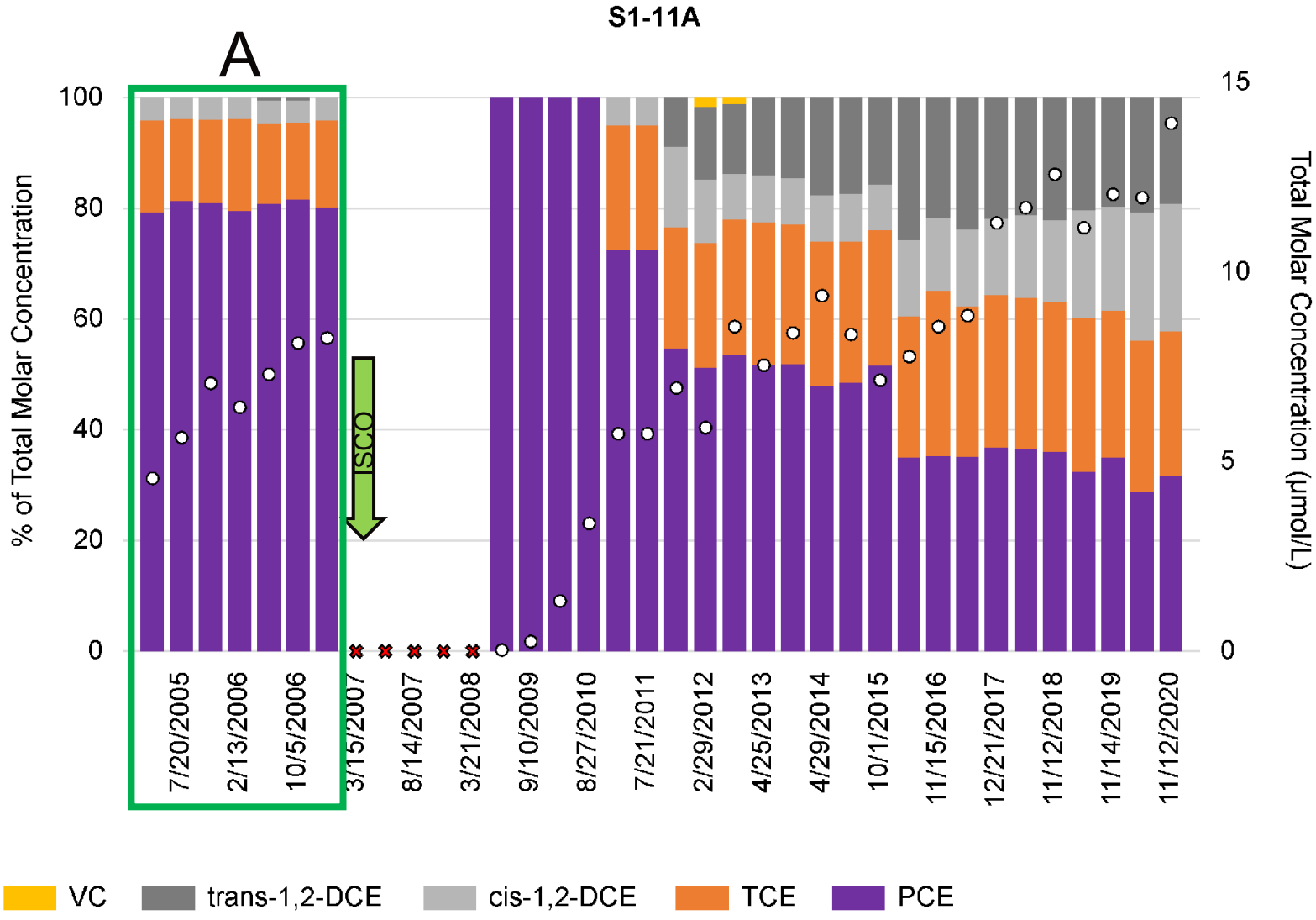
E: Substantial increase in TMC and increased VC. TMC is greater than measured onsite post-remediation.

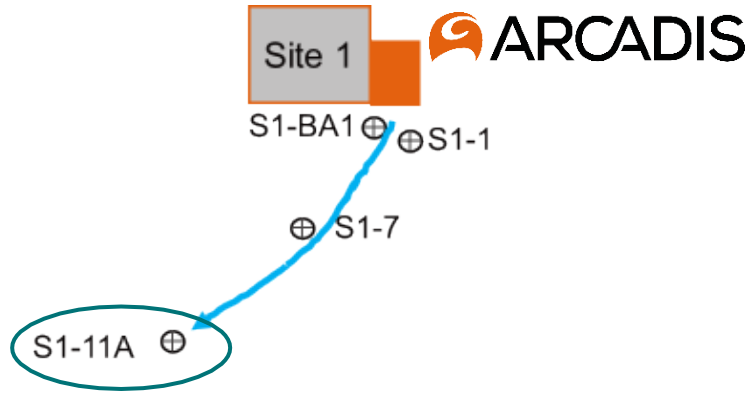
Case Study 1



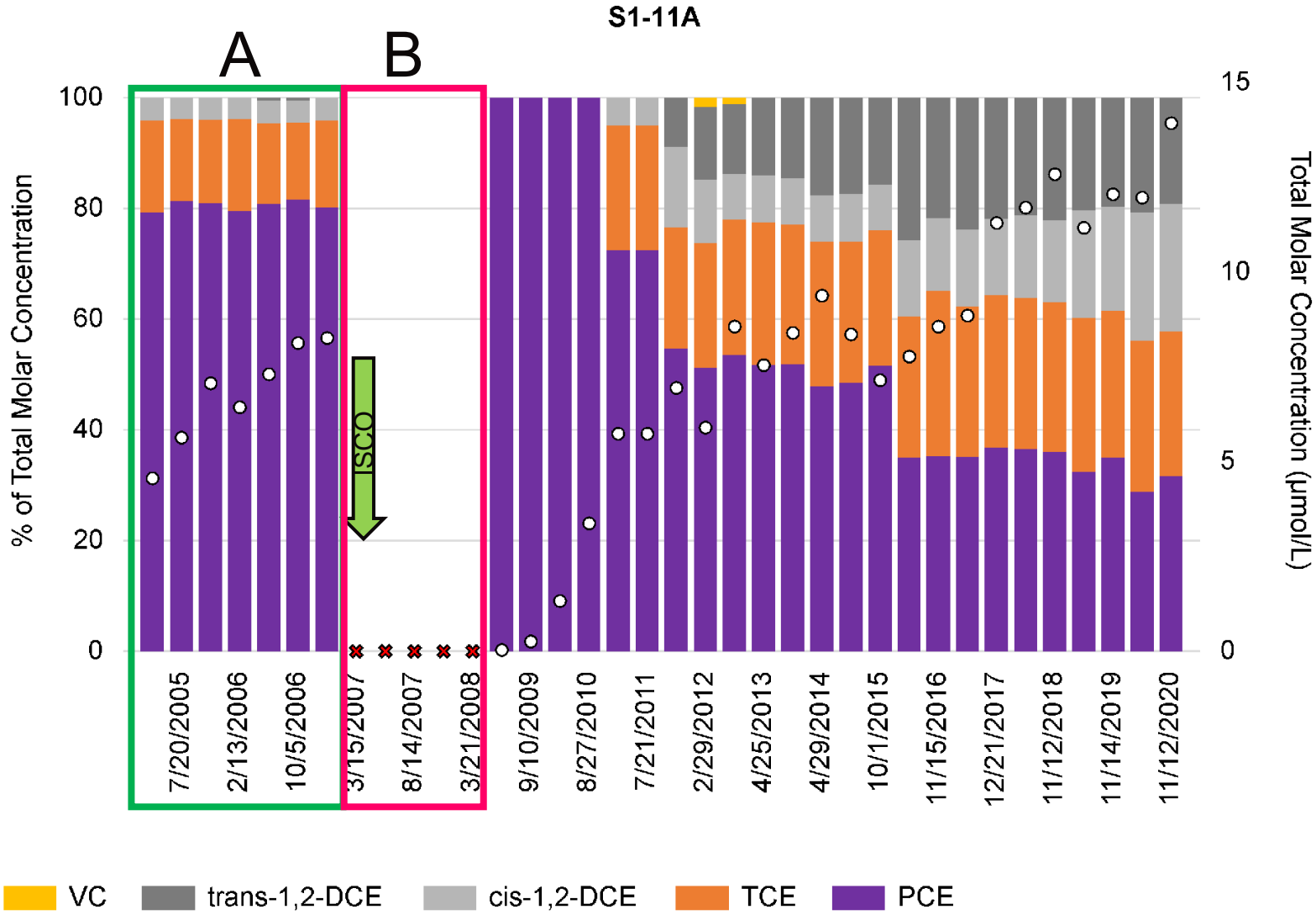


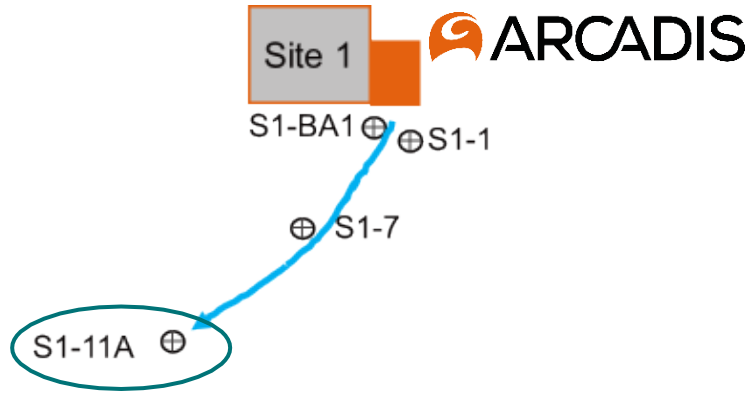
Concentrations during the highlighted period are interpreted as commingled CVOC and service station plumes sourced upgradient of the site.





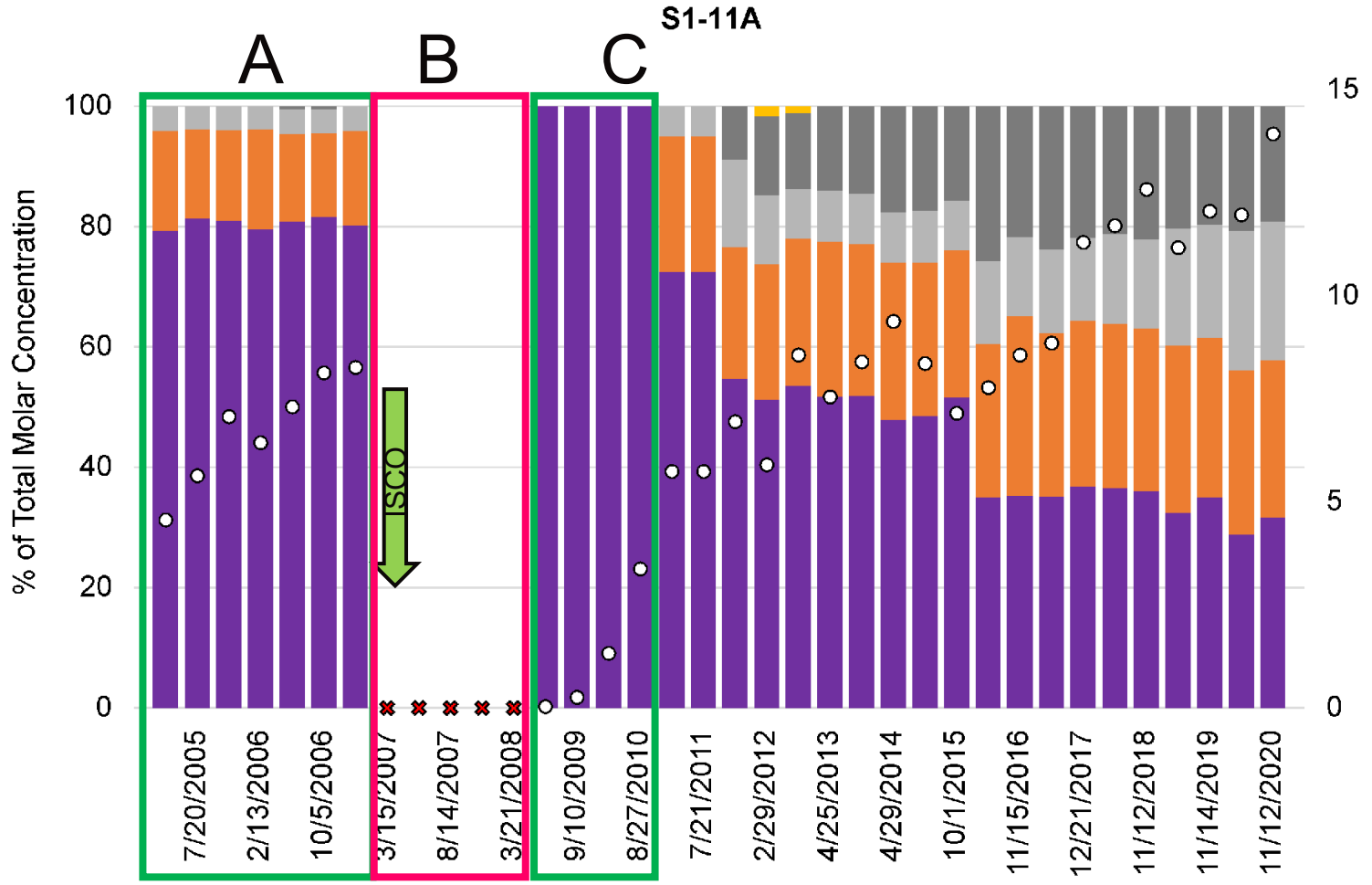
A: Potential historical site influence

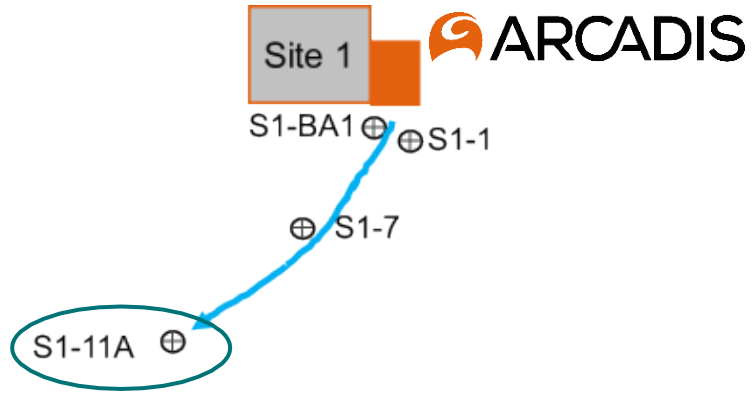




A: Potential historical site influence

B: Period of effective remediation

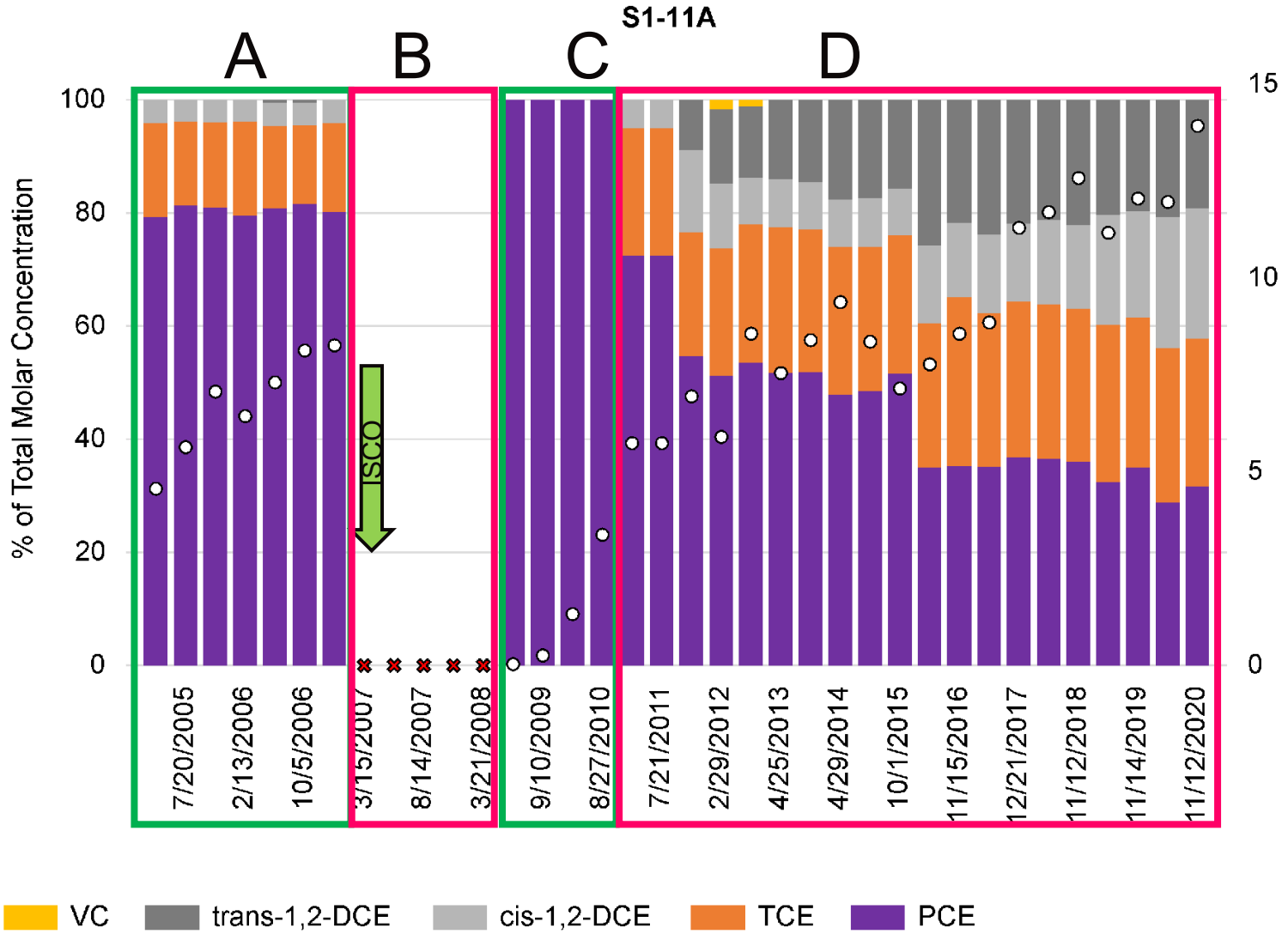


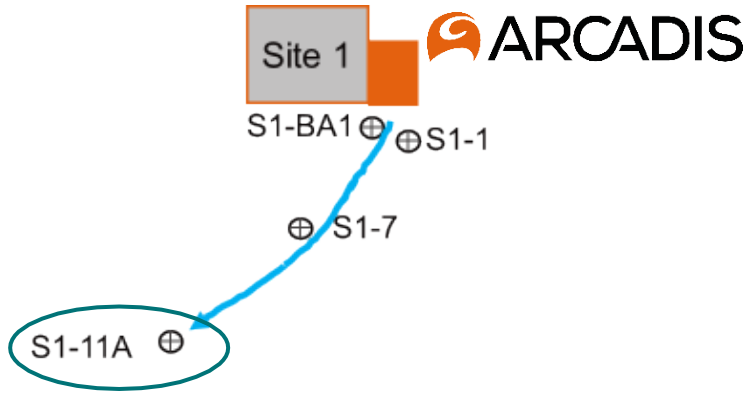


A: Potential historical site influence

B: Period of effective remediation

C: Limited PCE rebound



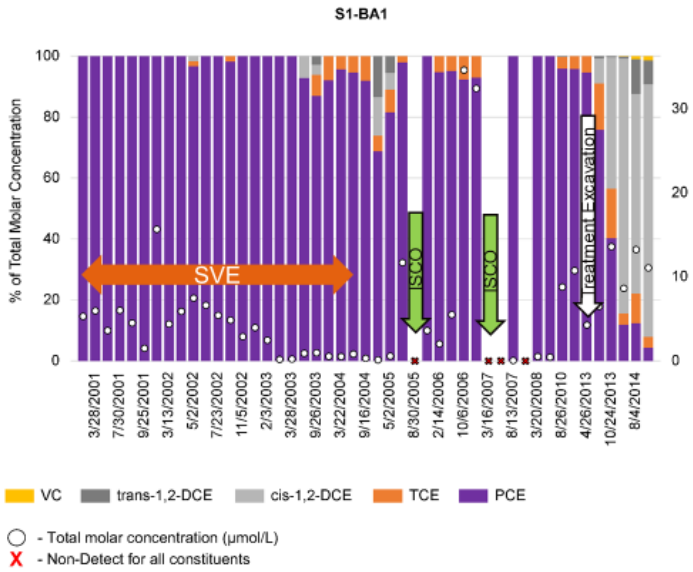


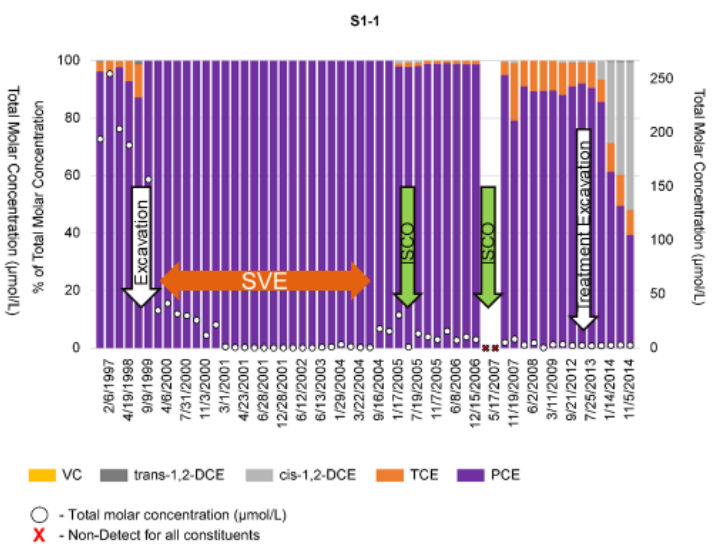
A: Potential historical site influence

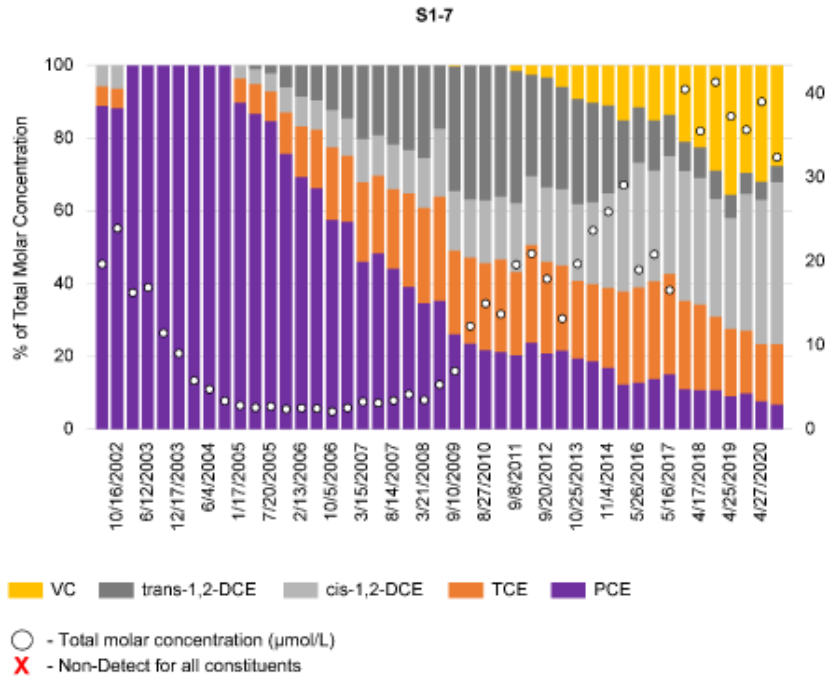
B: Period of effective remediation

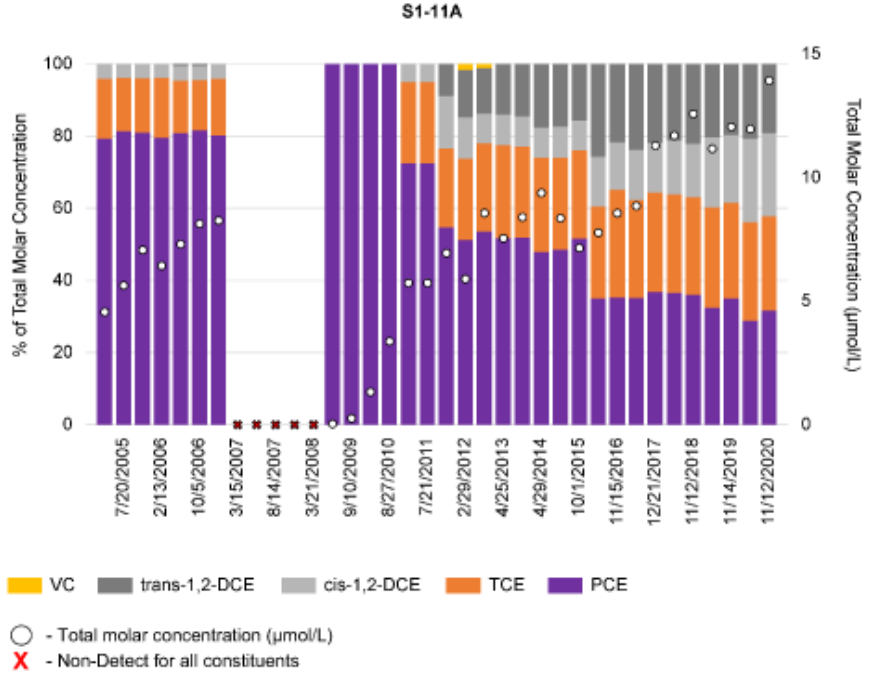
C: Limited PCE rebound

D: 1st trailing plume, characterized by increasing concentrations and proportion of trans-1,2-DCE



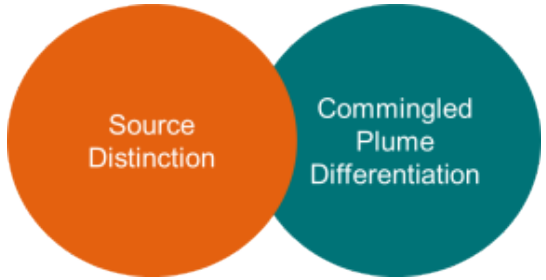




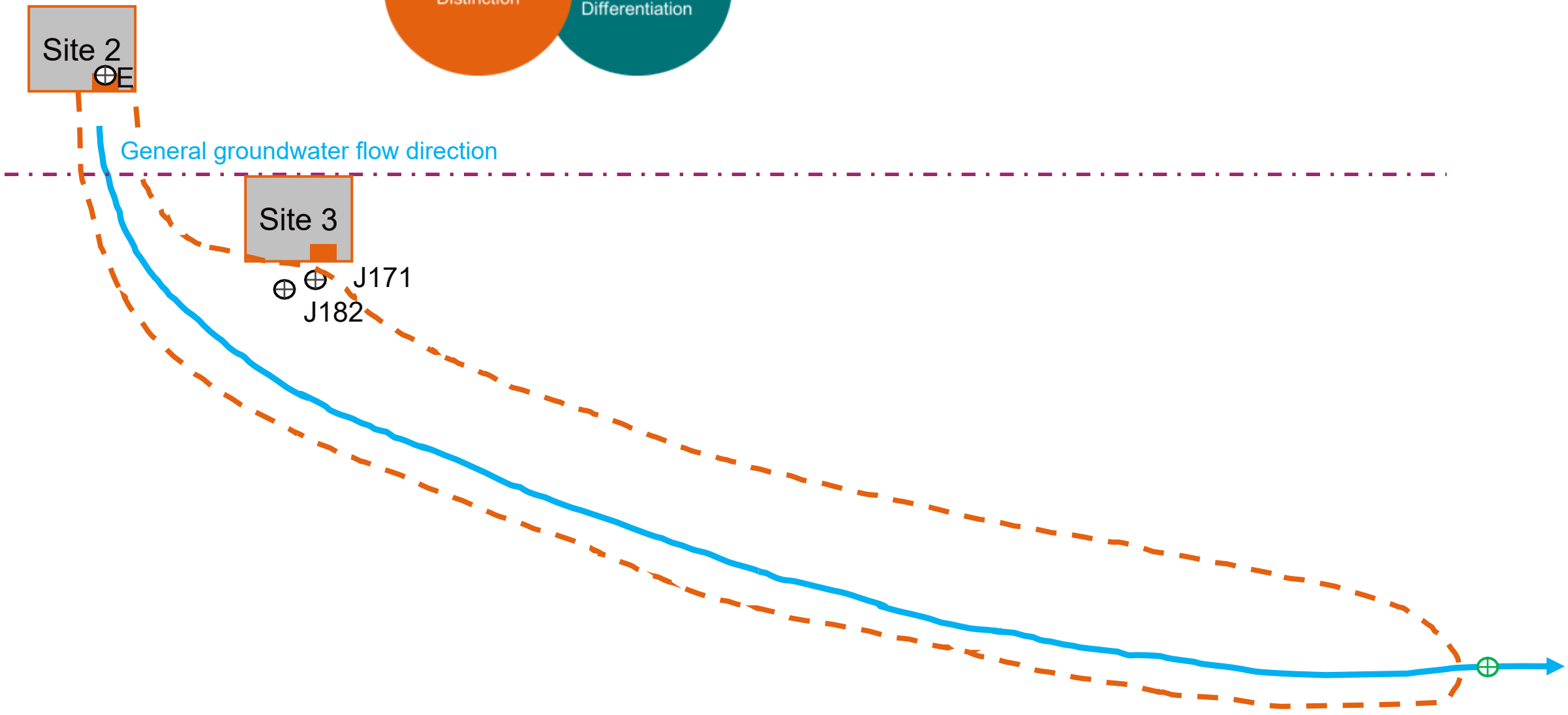


Increasing concentrations of CVOC mixtures in the downgradient site well network are not attributable to PCE from the site.

Case Study 2

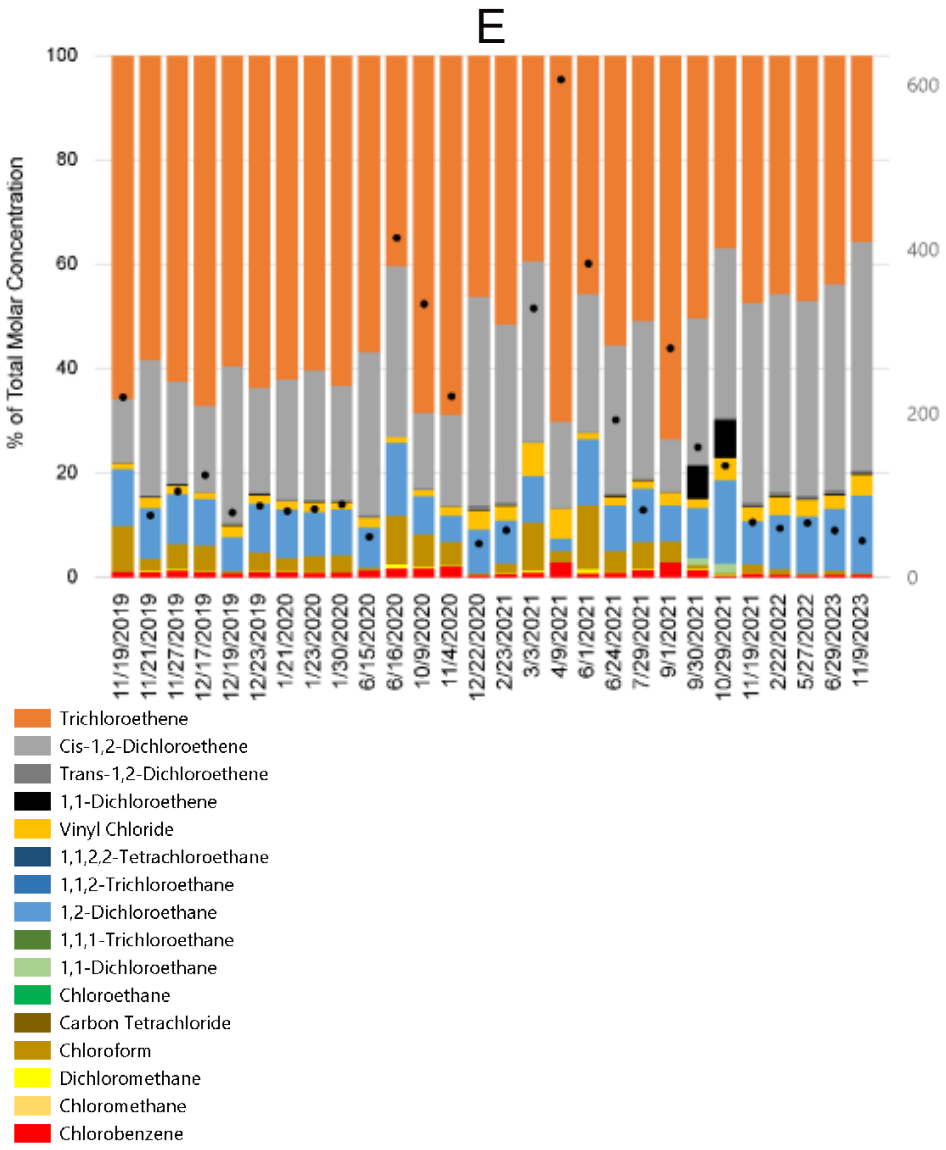


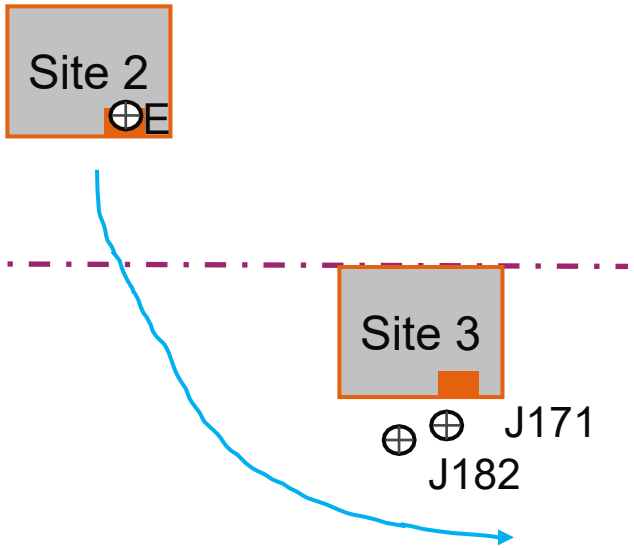
ARCADIS

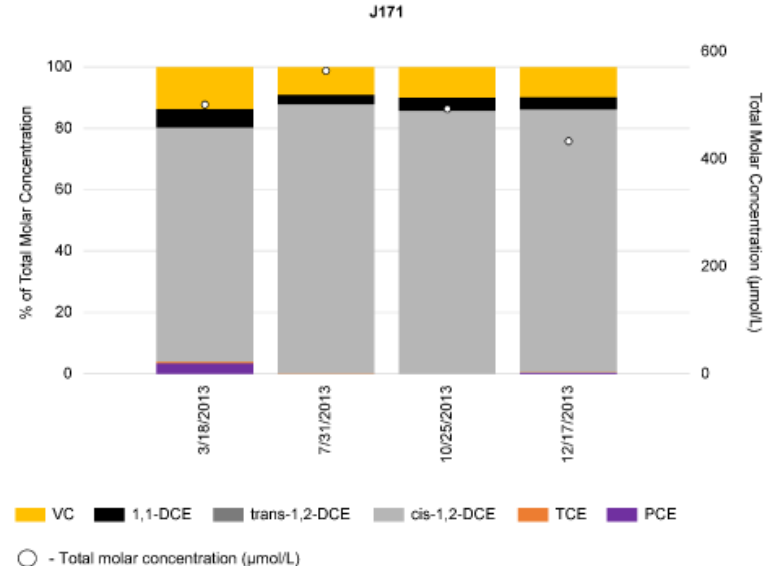


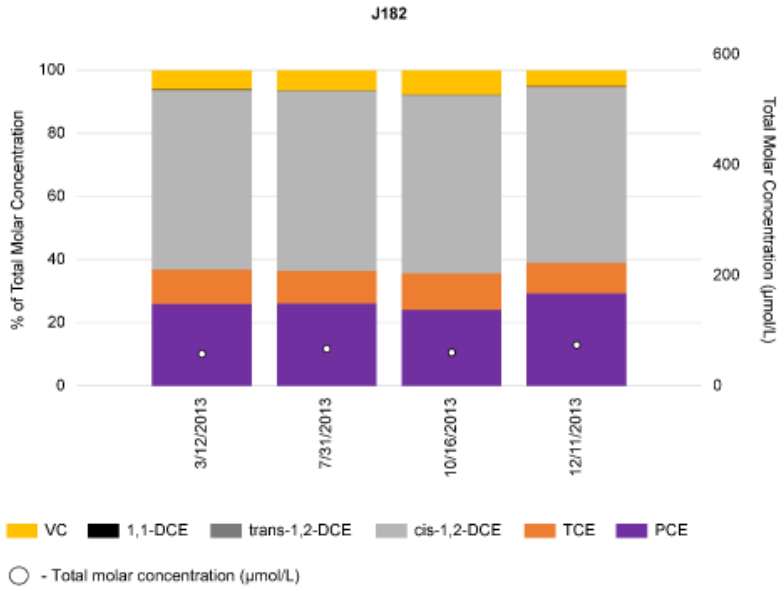
**Simplified and anonymized depiction

Case Study 2



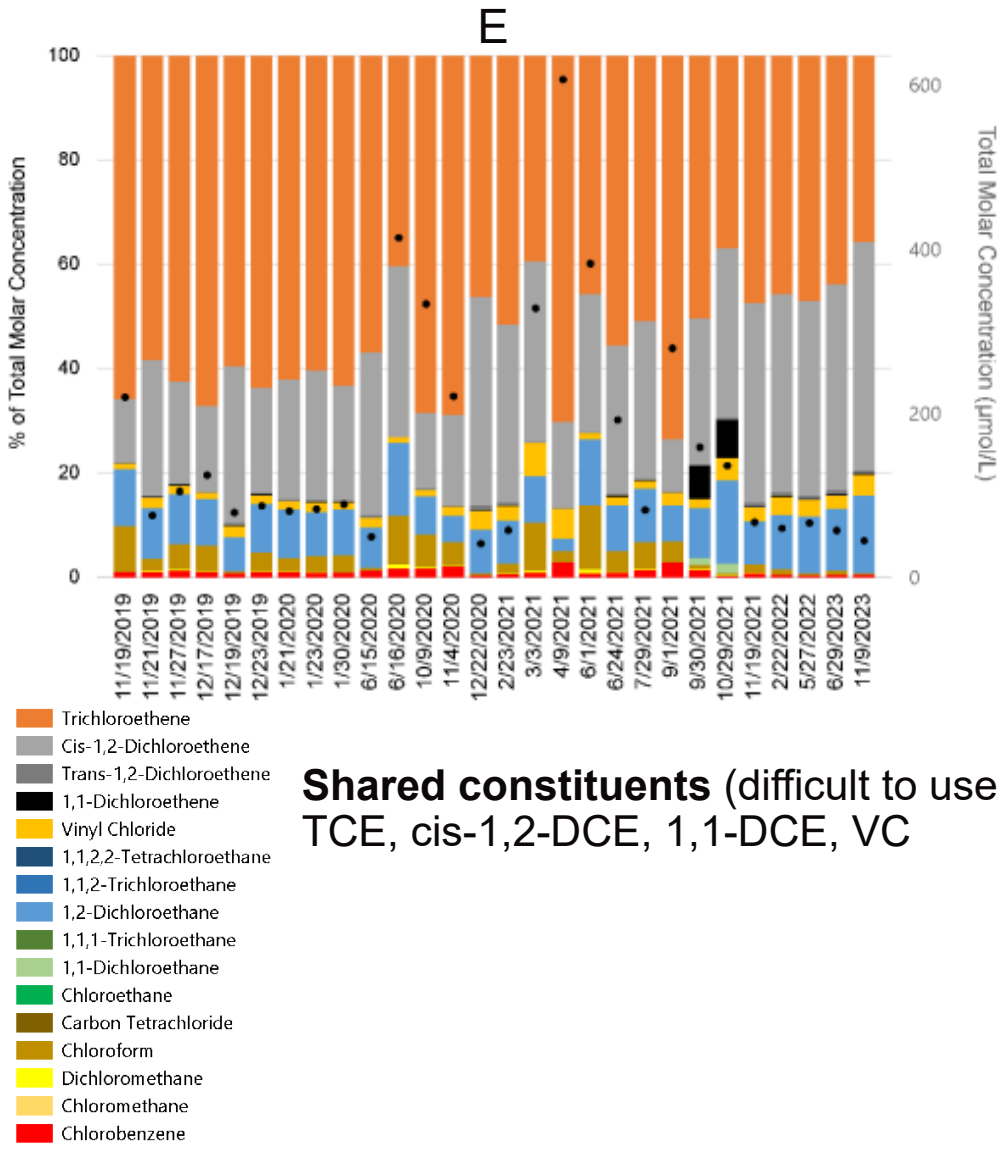


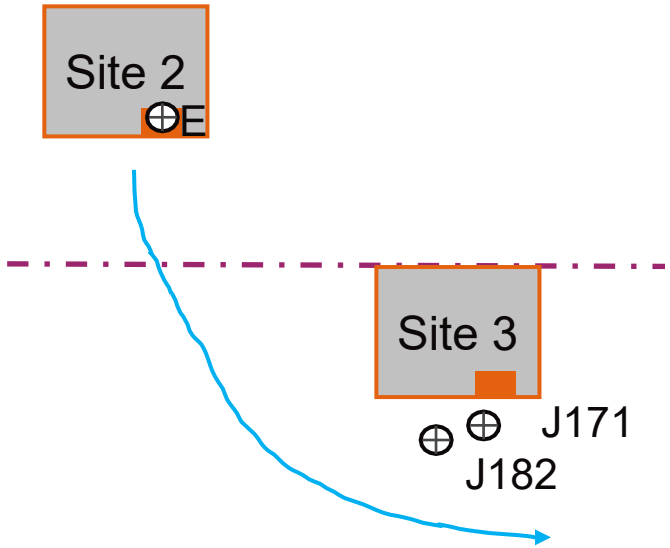


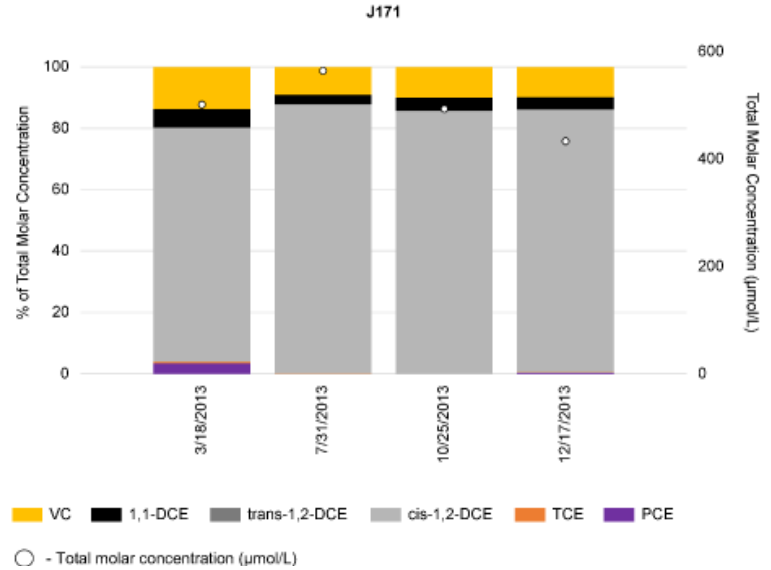


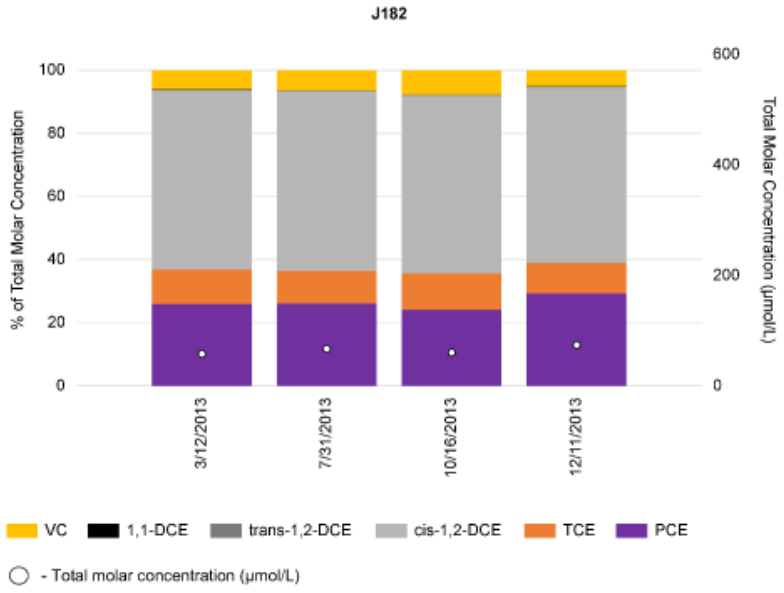
**Simplified and anonymized depiction

Case Study 2





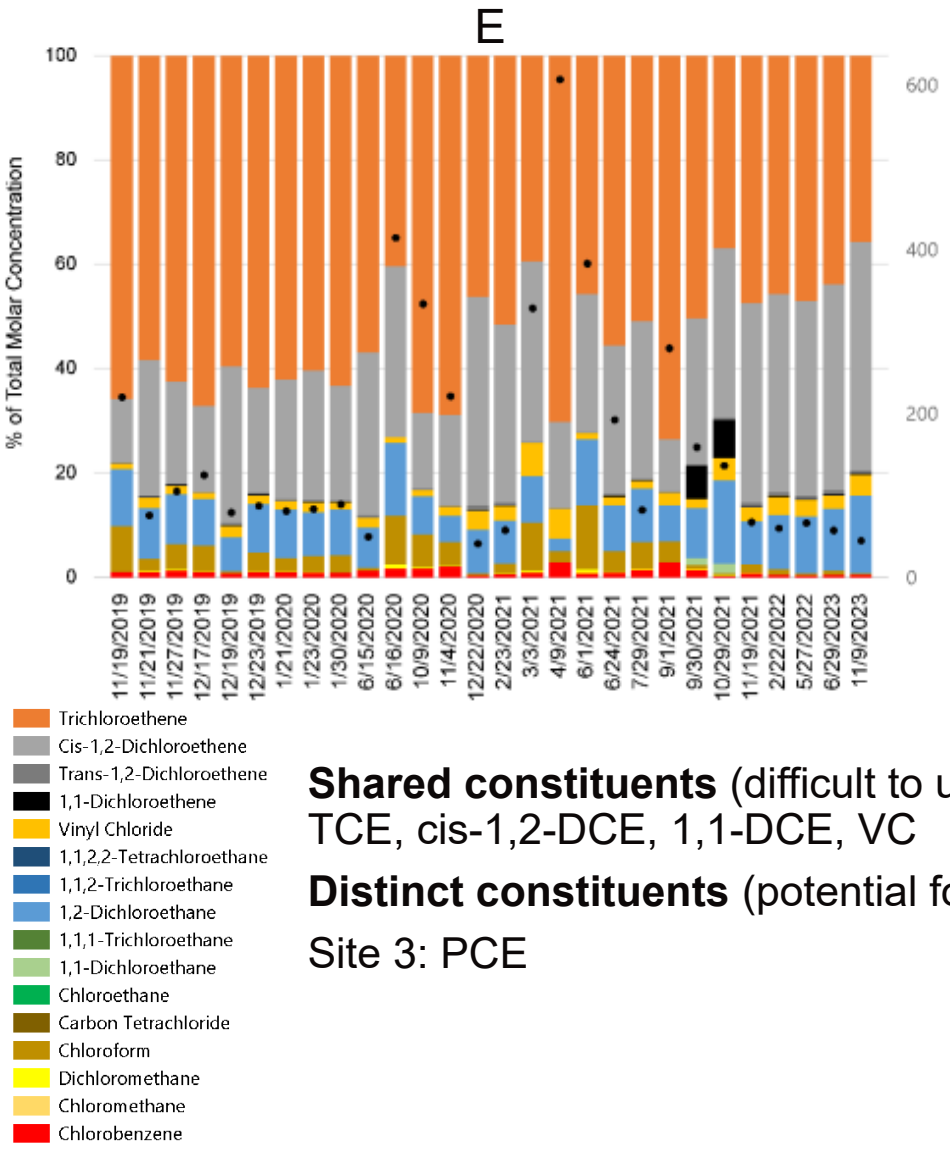


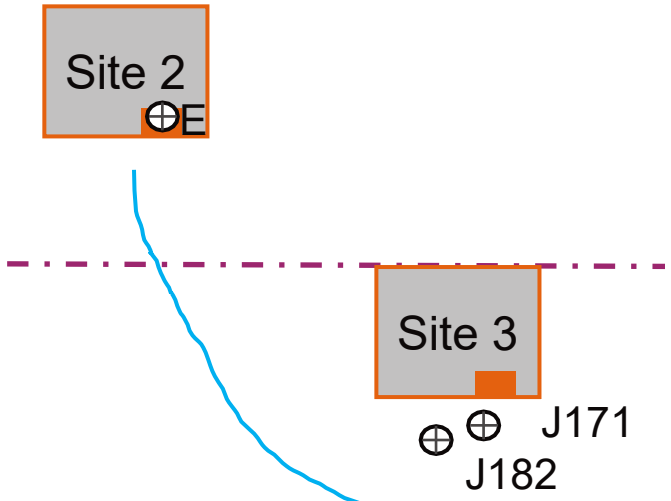


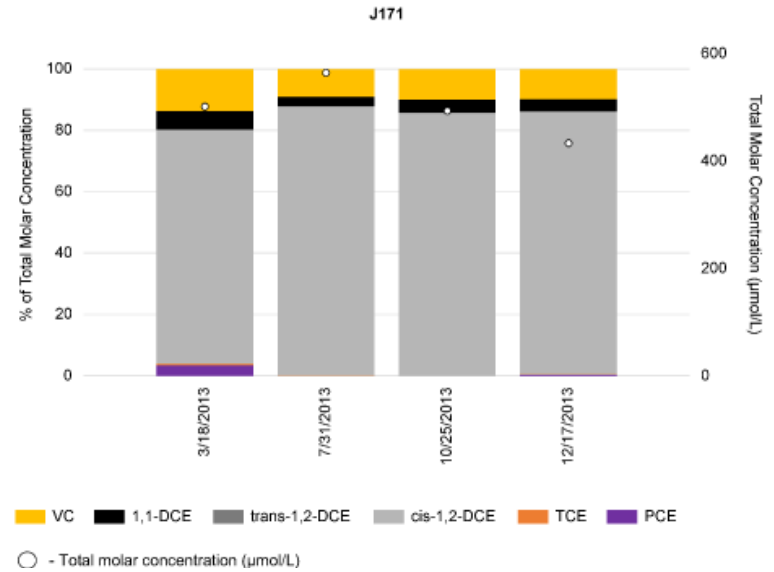
Shared constituents (difficult to use for commingled plume delineation): TCE, cis-1,2-DCE, 1,1-DCE, VC

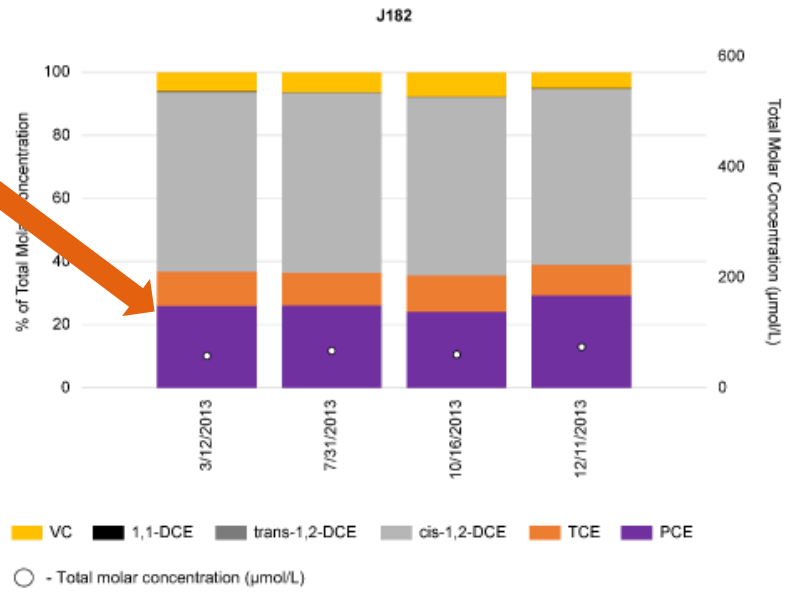
**Simplified and anonymized depiction

Case Study 2









Shared constituents (difficult to use for commingled plume delineation): TCE, cis-1,2-DCE, 1,1-DCE, VC

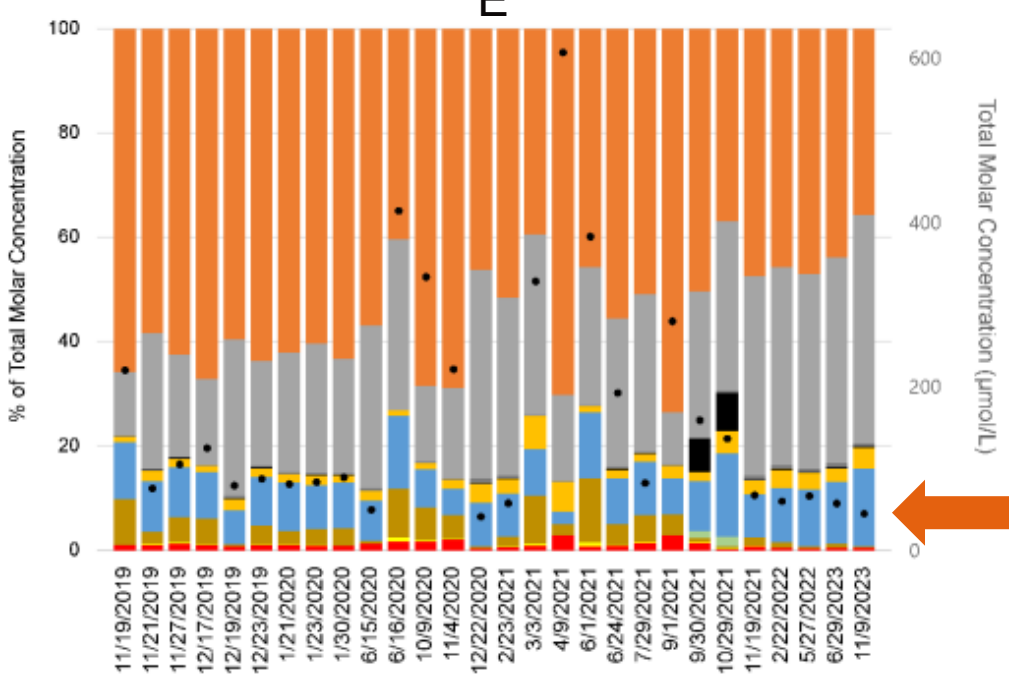
Distinct constituents (potential for commingled plume delineation):

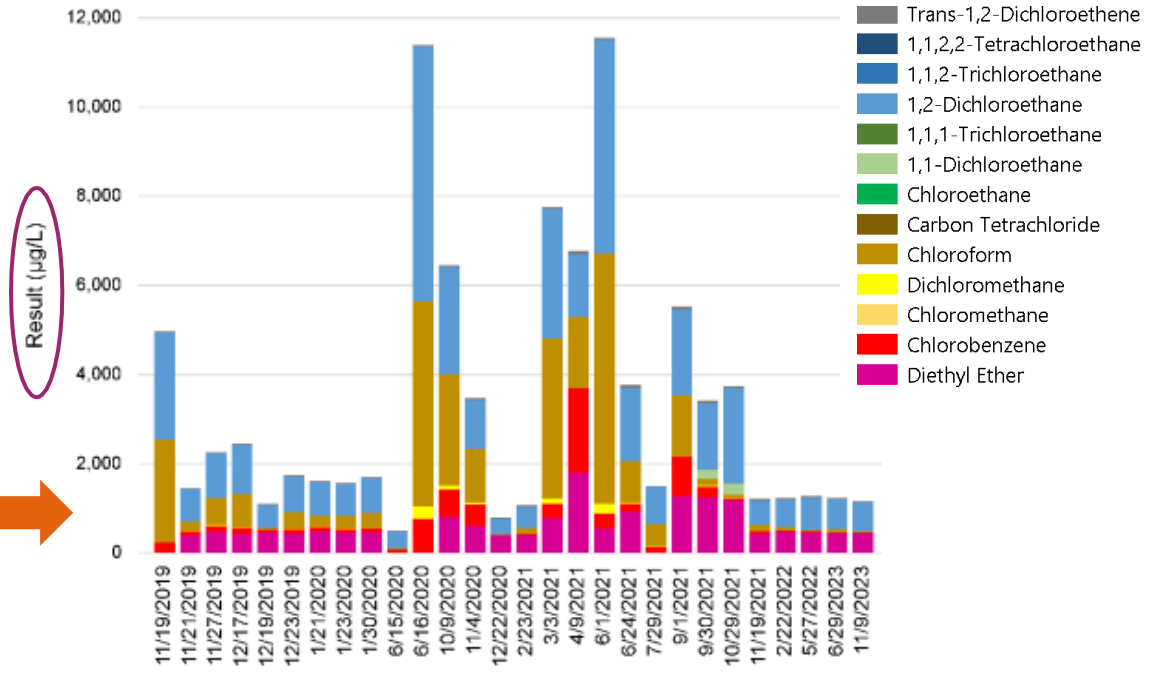
Site 3: PCE

**Simplified and anonymized depiction

Case Study 2

E





Trichloroethene
Cis-1,2-Dichloroethene
Trans-1,2-Dichloroethene
1,1-Dichloroethene
Vinyl Chloride
1,1,2,2-Tetrachloroethane
1,1,2-Trichloroethane
1,2-Dichloroethane
1,1,1-Trichloroethane
1,1-Dichloroethane
Chloroethane
Carbon Tetrachloride
Chloroform
Dichloromethane
Chloromethane
Chlorobenzene

Shared constituents (difficult to use for commingled plume delineation):
TCE, cis-1,2-DCE, 1,1-DCE, VC

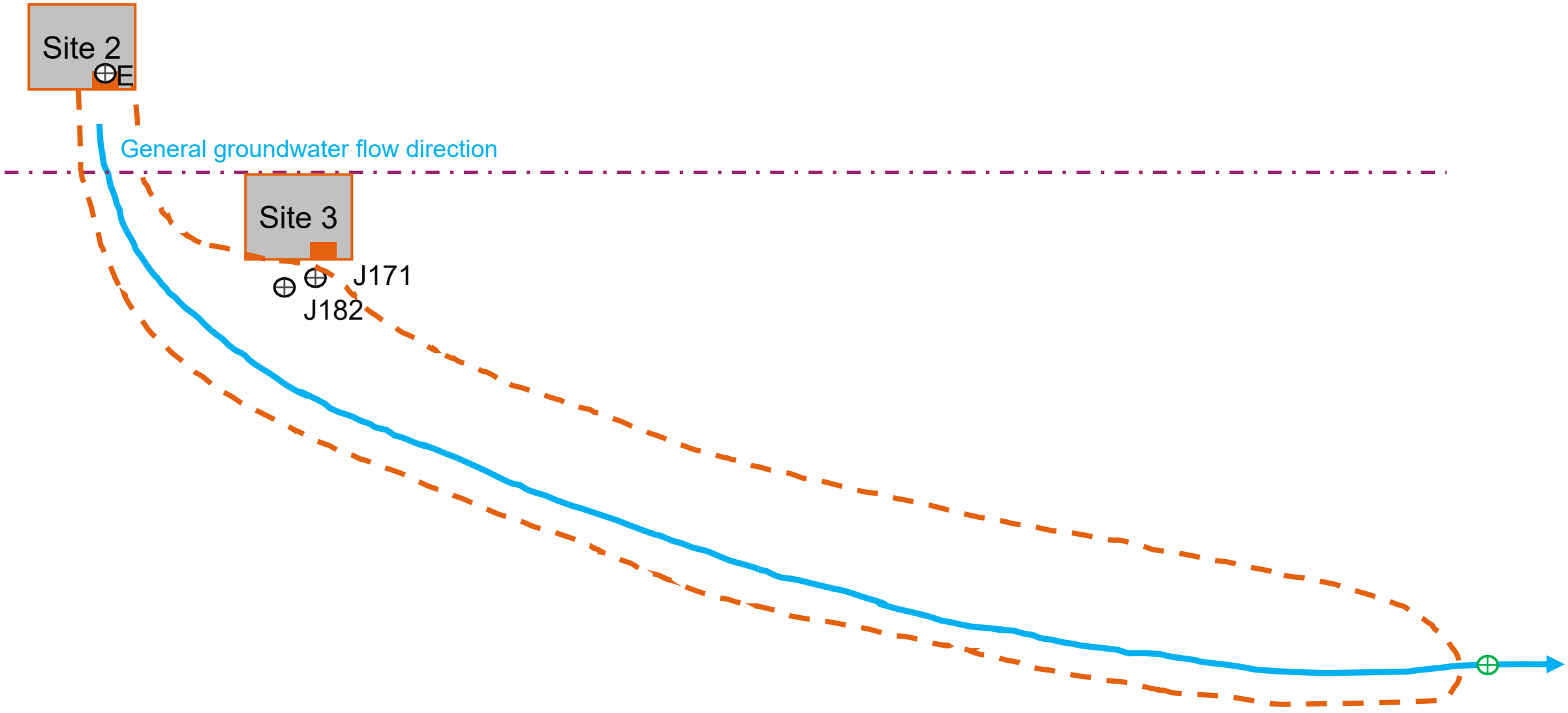
Distinct constituents (potential for commingled plume delineation):

Site 3: PCE

Site 2: 1,2-DCA, 1,1-DCA, chloroform, chlorobenzene, diethyl ether

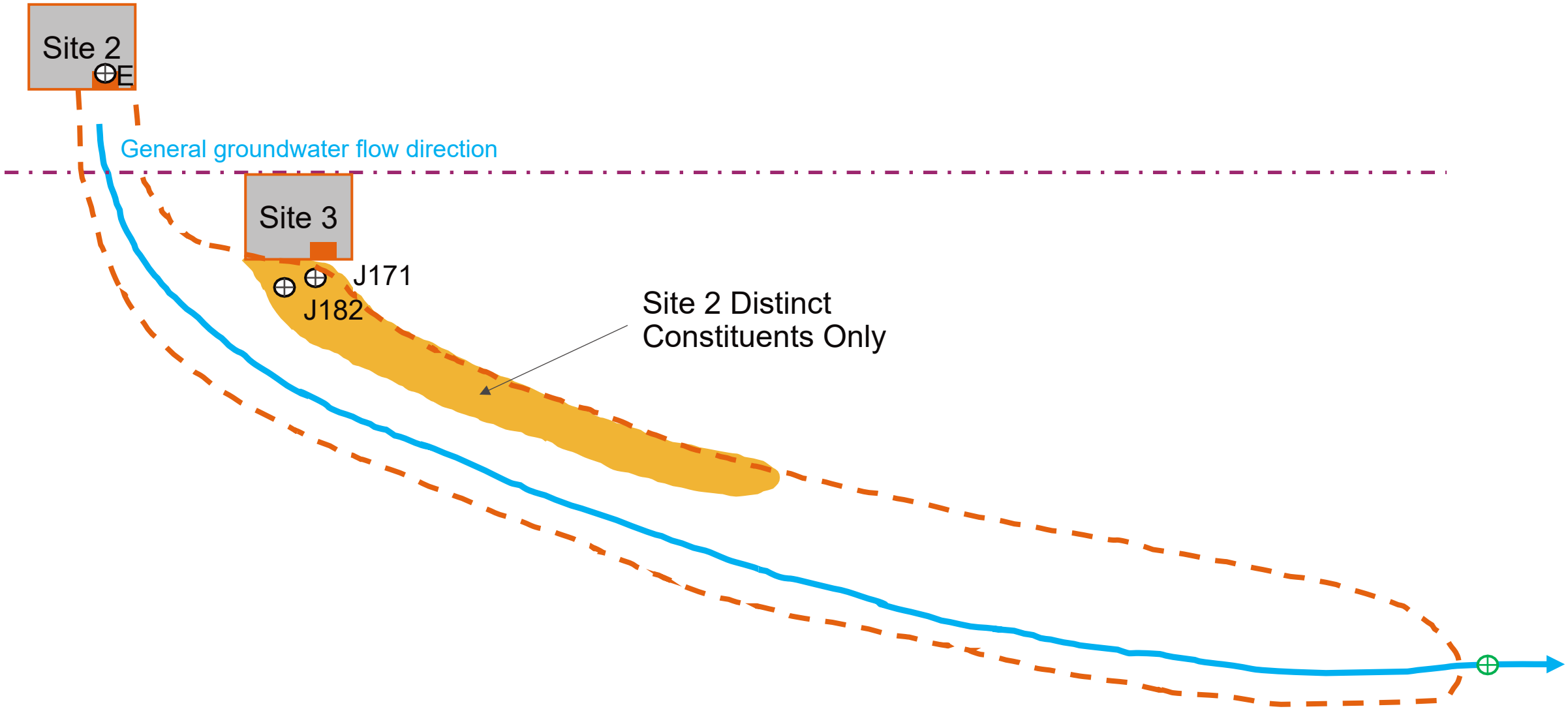
**Simplified and anonymized depiction

Case Study 2

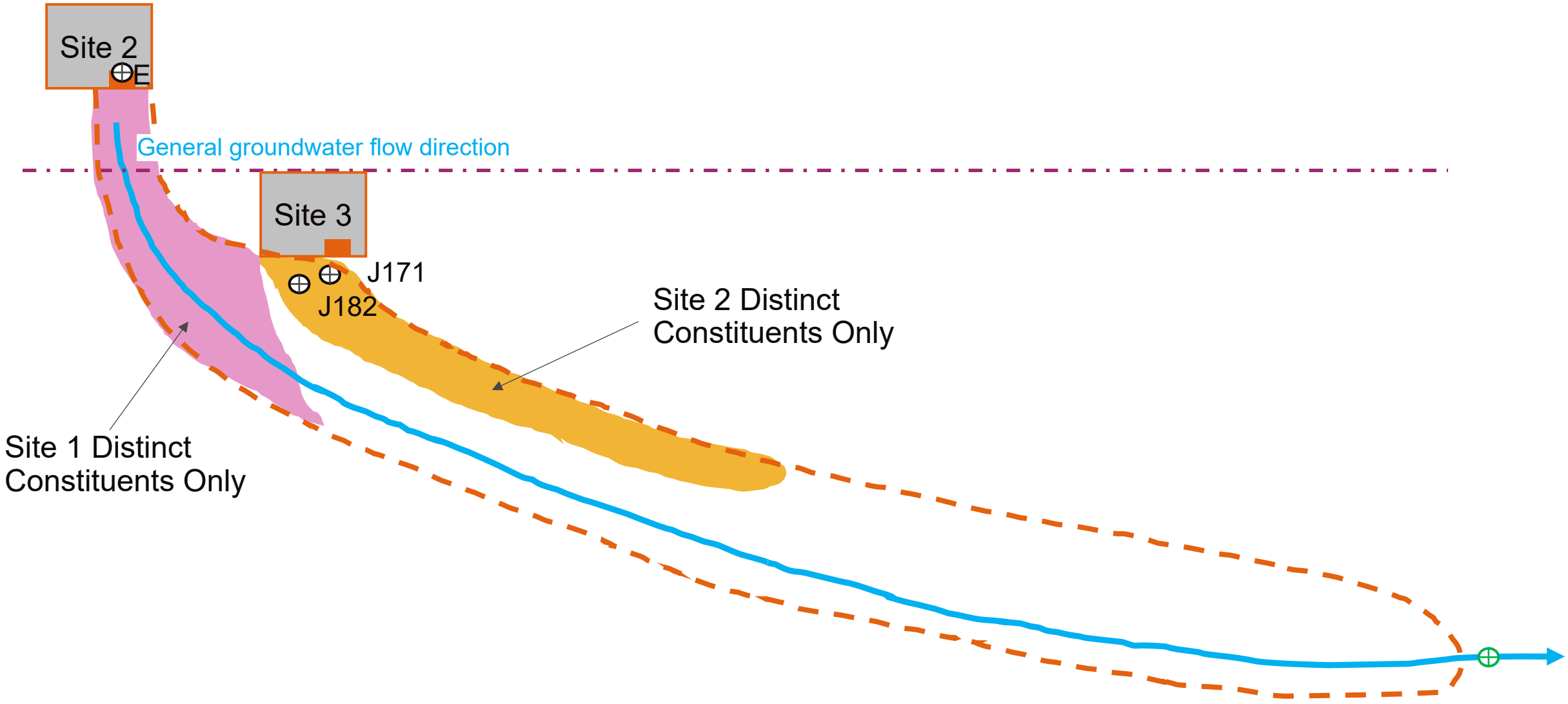


**Simplified and anonymized depiction

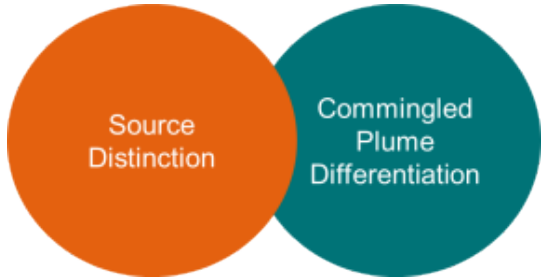
Case Study 2


Site 2
E
General groundwater flow direction
Site 3
J171
J182
Site 2 Distinct
Constituents Only

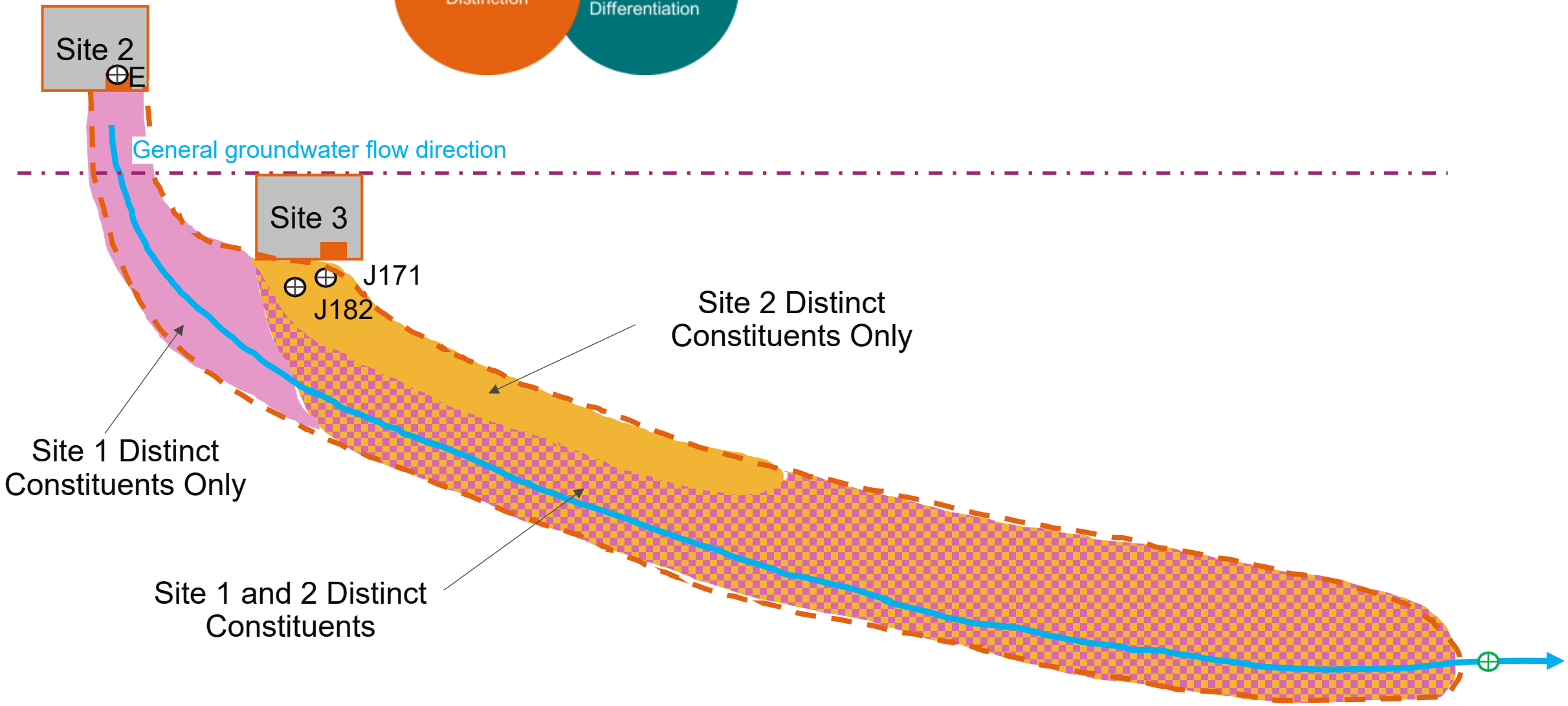
Case Study 2


Site 2
E
General groundwater flow direction
Site 3
J171
J182
Site 2 Distinct
Constituents Only
Site 1 Distinct
Constituents Only

Case Study 2



ARCADIS

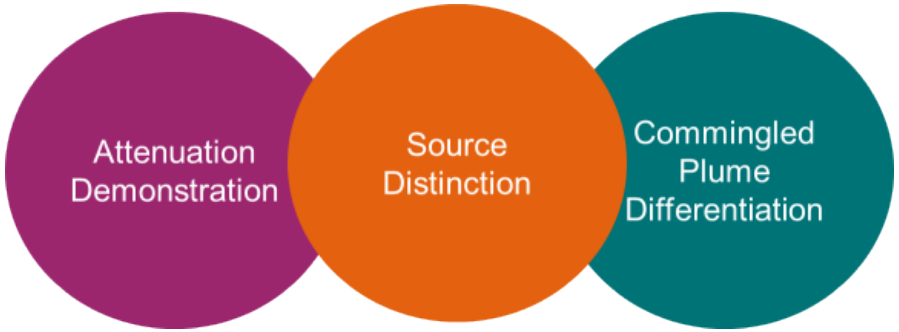


Minor Components may play a critical role in differentiating between commingled plumes

Conclusions

- CVOC profiles are a forensic evaluation method that relies on readily available data from standard analytical methods.
- Data processing and presentation has historically been a time-limiting step
  - This was overcome with application of PowerBI Report Builder
- The case studies presented demonstrate:
  - The importance of considering total molar concentration over time to reveal offsite influence
  - The critical role that minor constituents can play in delineating a commingled plume

We hope this work will inspire you to take a closer look at CVOC profiles at your sites!



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