Insights from a Detailed Study of Groundwater/Surface Water Interactions at a Closed Landfill

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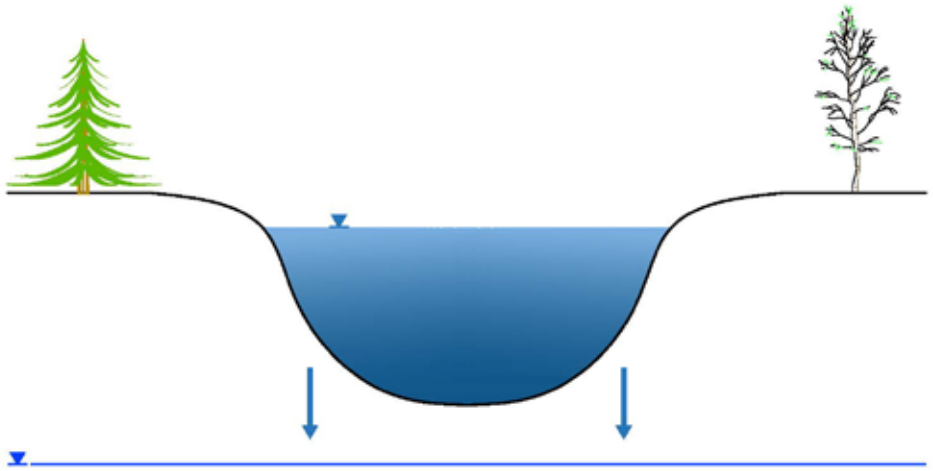
Outline

- Project objective
- Site setting and history
- Multiple lines of evidence approach
  - Geophysics
    - Waterborne ERT and EM surveys
    - Distributed Temperature Sensing (DTS)
  - Monitoring component transects
    - Design and installation
    - Datalogger data analysis
    - Hydrogeochemical analysis
- **Insights and lessons learned**
- Questions

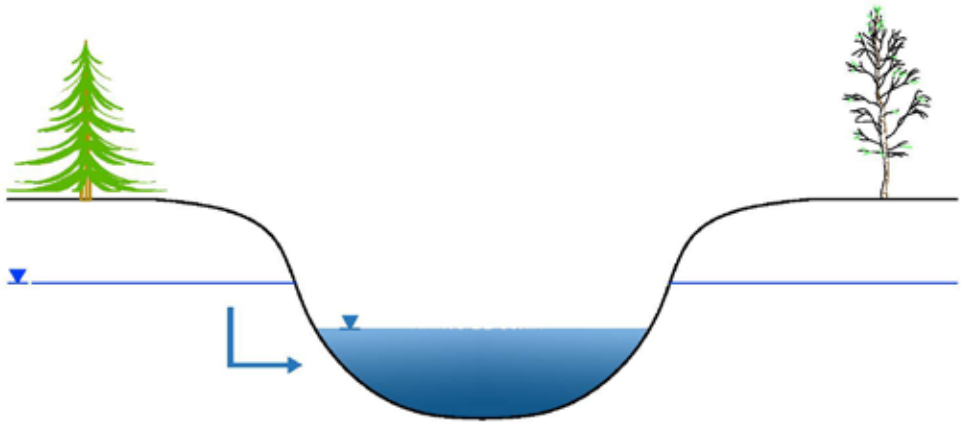
Project Objective

Evaluate spatial, temporal, and hydrogeochemical interactions between groundwater and a nearby surface water body (Nose Creek)

Nomenclature Clarification



Groundwater Recharge
(losing stream)



Groundwater Discharge
(gaining stream)

Site Setting and History

Site Setting

- 1.5 km Stretch of Nose Creek within the City of Calgary
  - Upstream of the confluence with the Bow River
  - Parallel to Deerfoot Trail
- External Influences
  - Deerfoot Trail (salting)
  - Railroad
  - Storm water run off
  - Bow River
  - Former oxbows
  - Western Irrigation District Weir

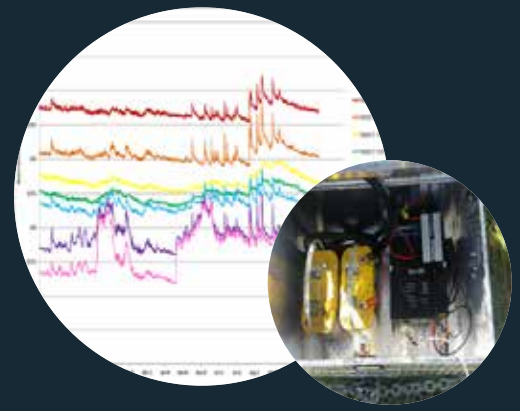
Site History

- Nose Creek Landfill closed in 1968
  - Municipal and construction/demolition waste
- Other historical activities in the area
  - Creosote plant
  - Meat packing plant
  - Dog food plant
  - Farm/feed lot
  - Fueling facilities
- Our study area extended beyond the closed landfill area

Approximate area of closed landfill area

1966 Air Photo. Source: The City of Calgary WRS

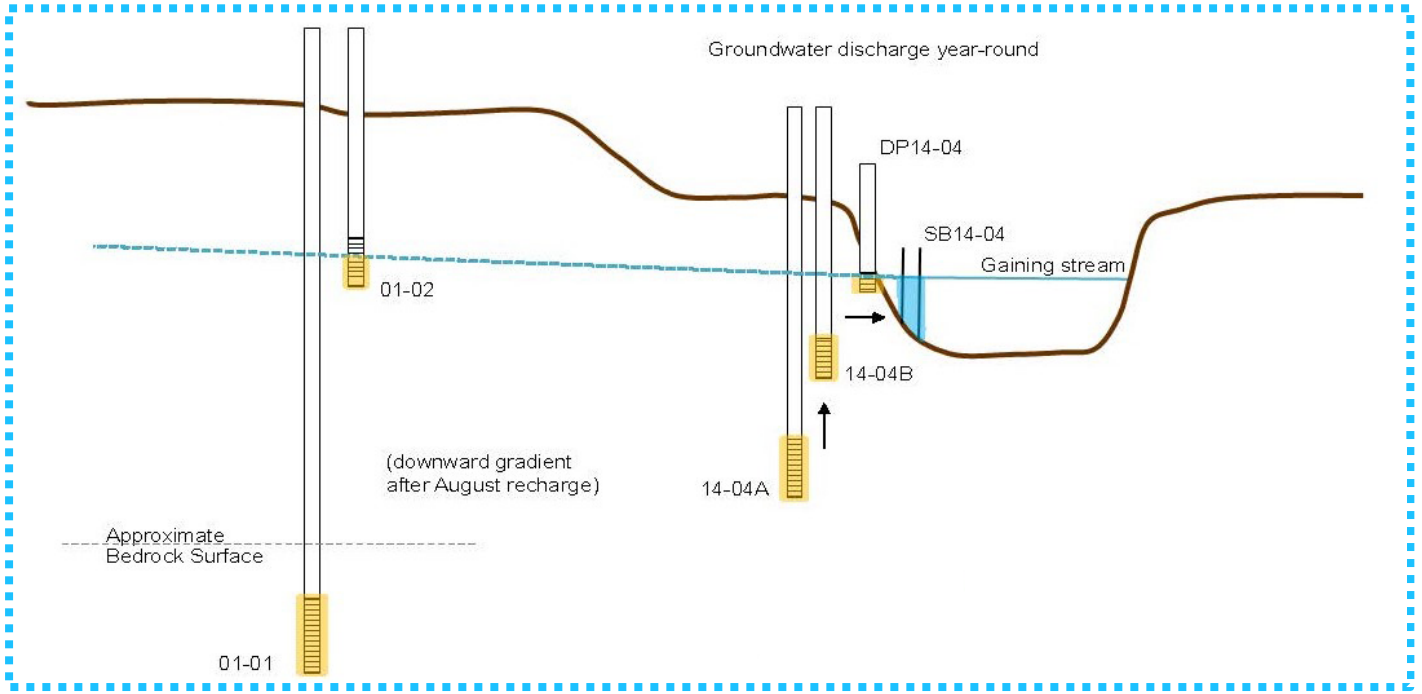
Multiple Lines of Evidence Data Collection



- Site History
- Geophysics
- Monitoring transects
  - Nested monitoring wells
  - Drive points
  - Stilling basins
- Dataloggers
  - Hydraulic head/gradient
  - Temperature
  - Electrical conductivity
- Weather station

Scales of Interest

- Study area scale
- Closed landfill scale
- Transect scale
- Hyporheic scale



Geophysics

- Used to assess site-scale conditions
- Waterborne ERT and EM
- Distributed Temperature Sensing (DTS)
  - 1.8 km of fibre optic cable submerged and secured to the west bank of Nose Creek
  - Cable records temperature to assess discrete areas with temperature anomalies due to groundwater discharge
  - Data collected once per month from July 2014 to February 2015
  - Continuous DTS monitoring occurred from May 2015 to October 2015

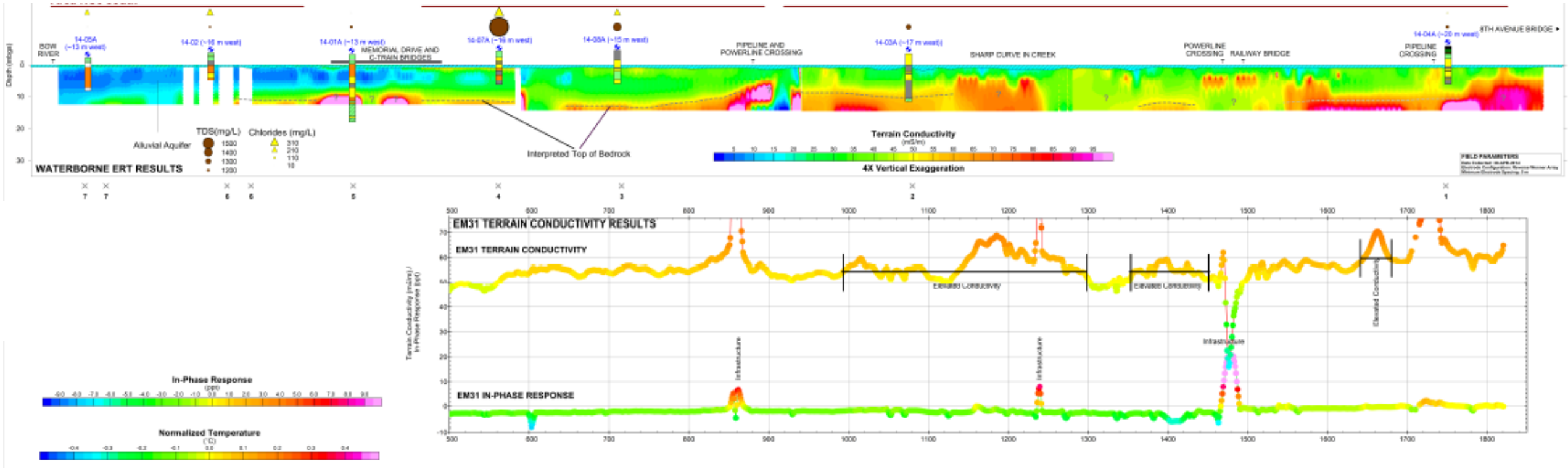
Geophysics

- 1800 m of DTS cable from the Bow to 8th Ave
  - All plots shown are from south to north with axis showing station numbers in metres

Geophysics

ERT, EM31 terrain conductivity, and EM31 in-phase

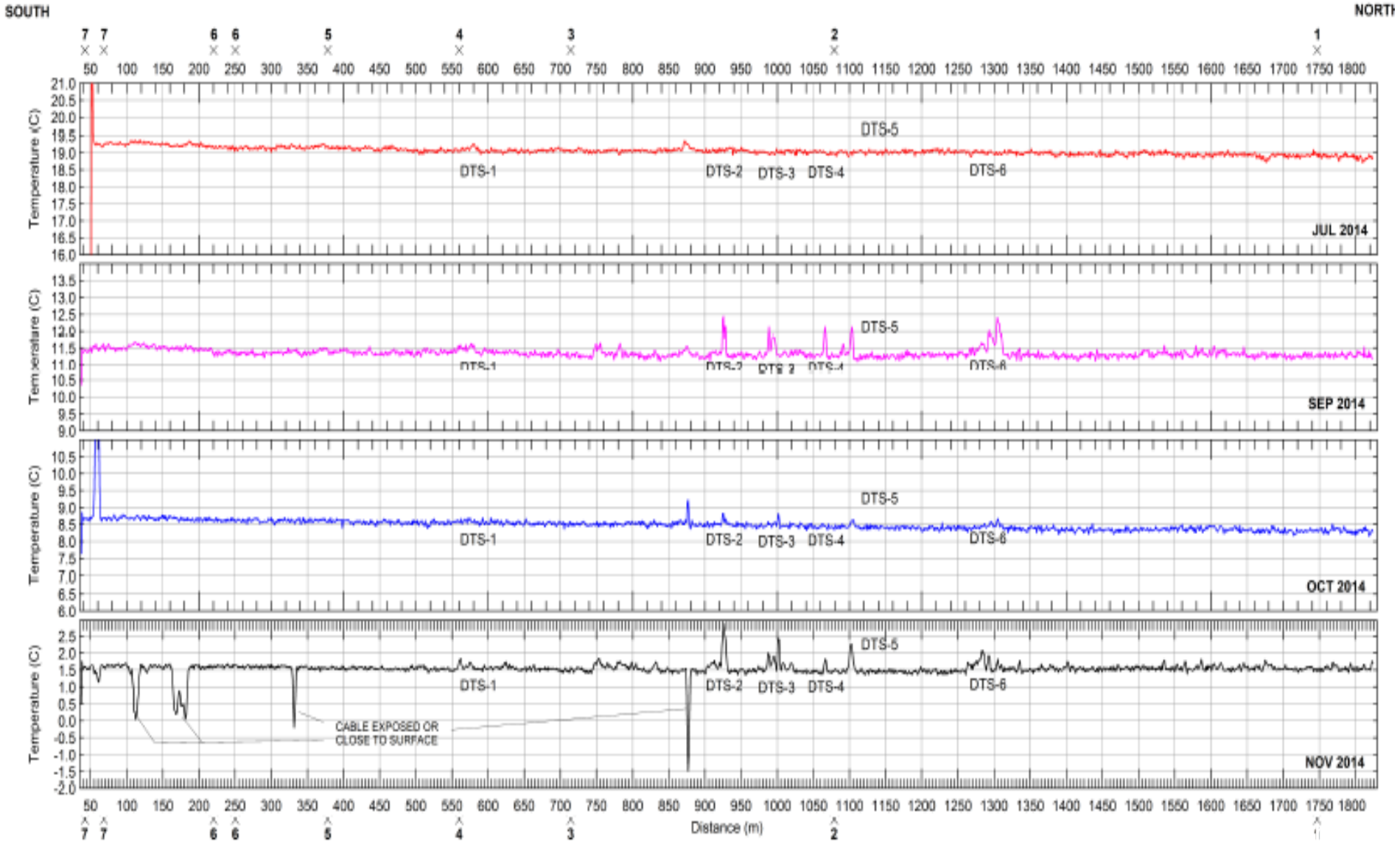
S N



ERT = electrical resistivity tomography
EM = electromagnetic

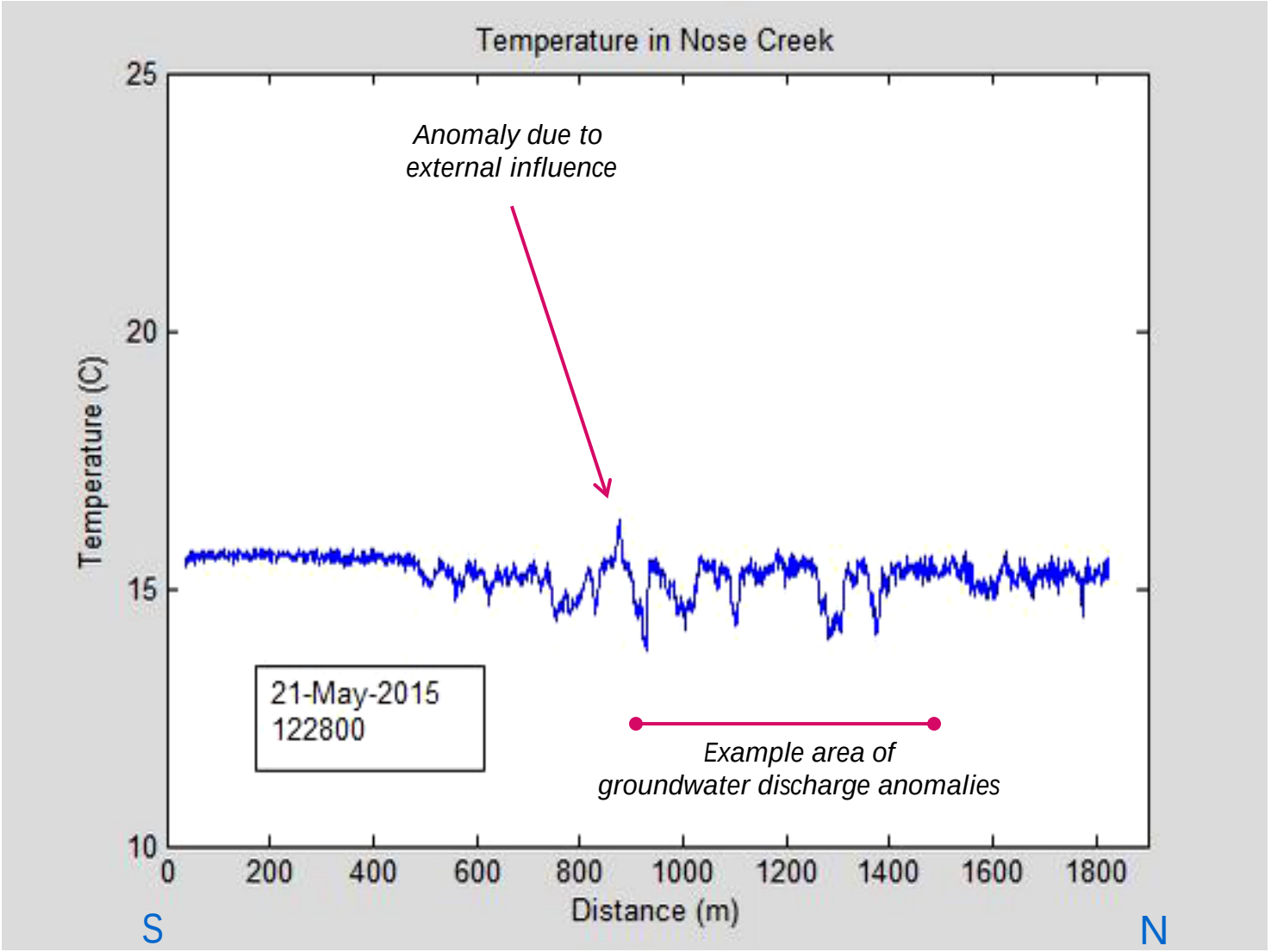
Geophysics

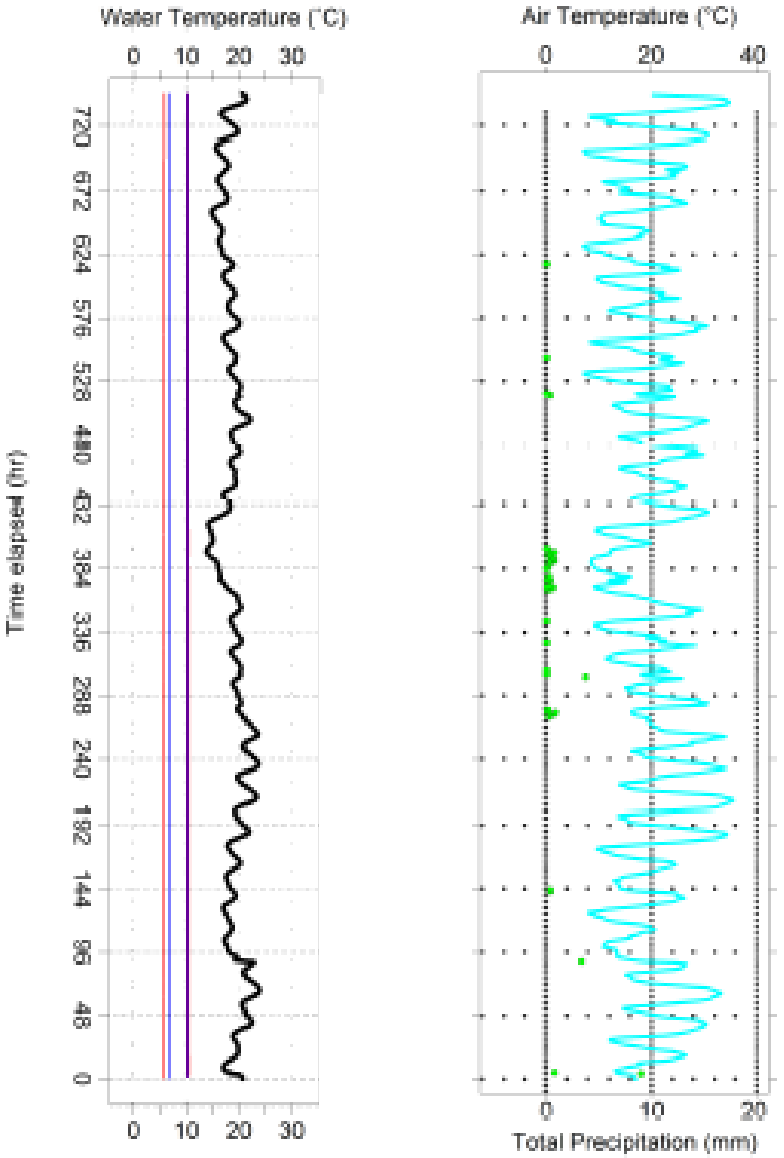
DTS Data Profiles from 4 Discrete Time Windows



Geophysics

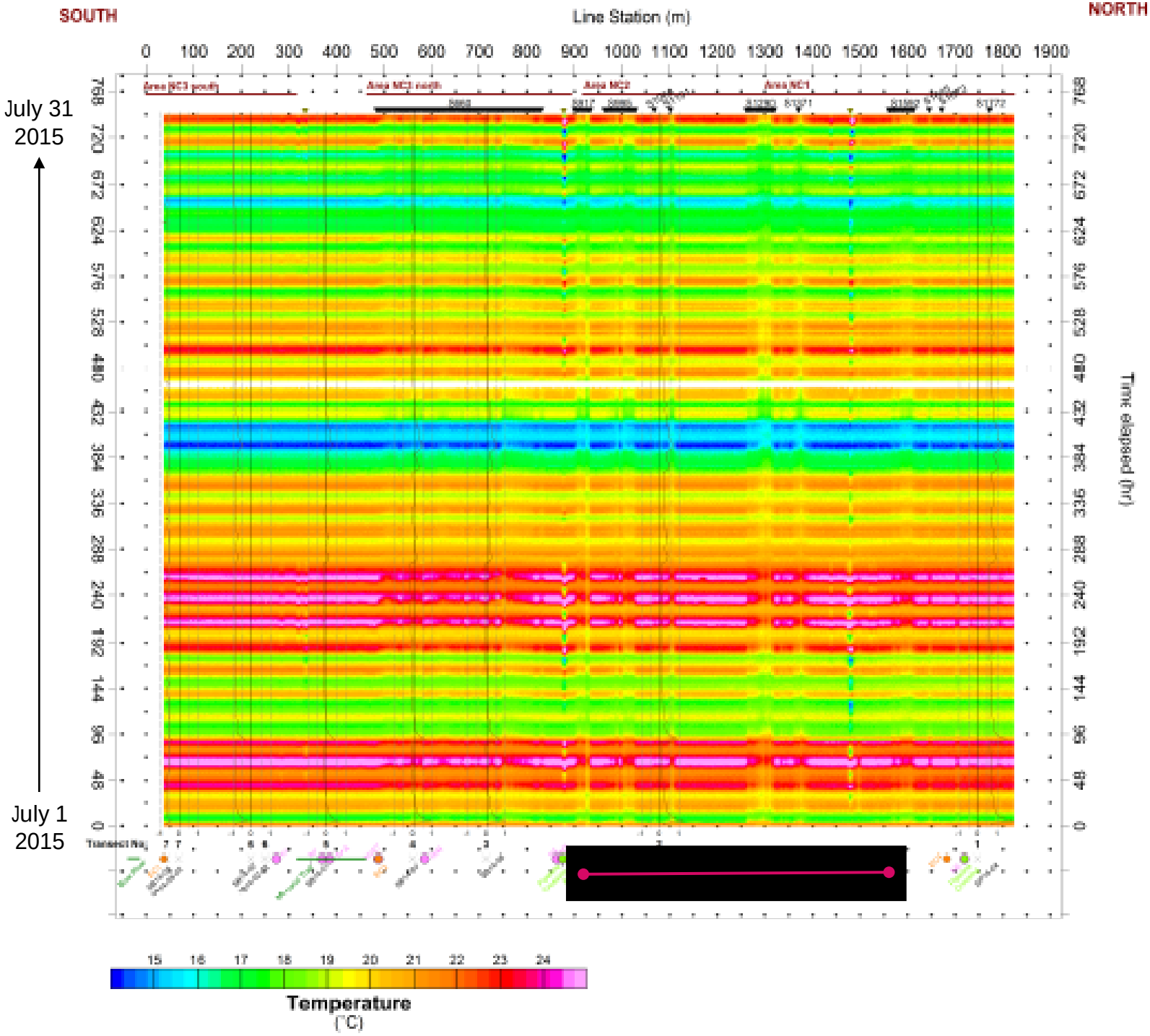
Continuous DTS Monitoring Video





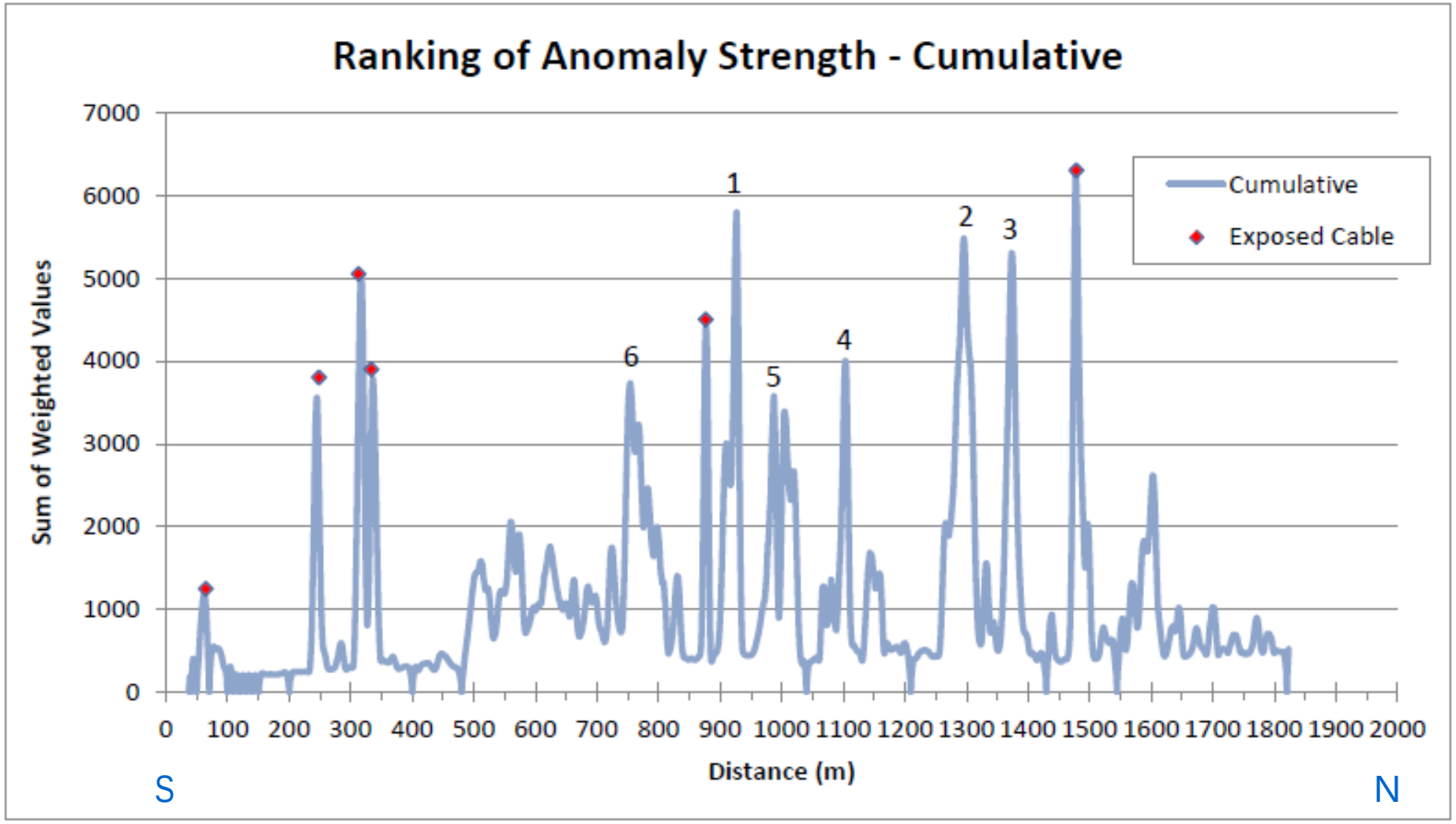
Geophysics

Continuous DTS Data



Geophysics

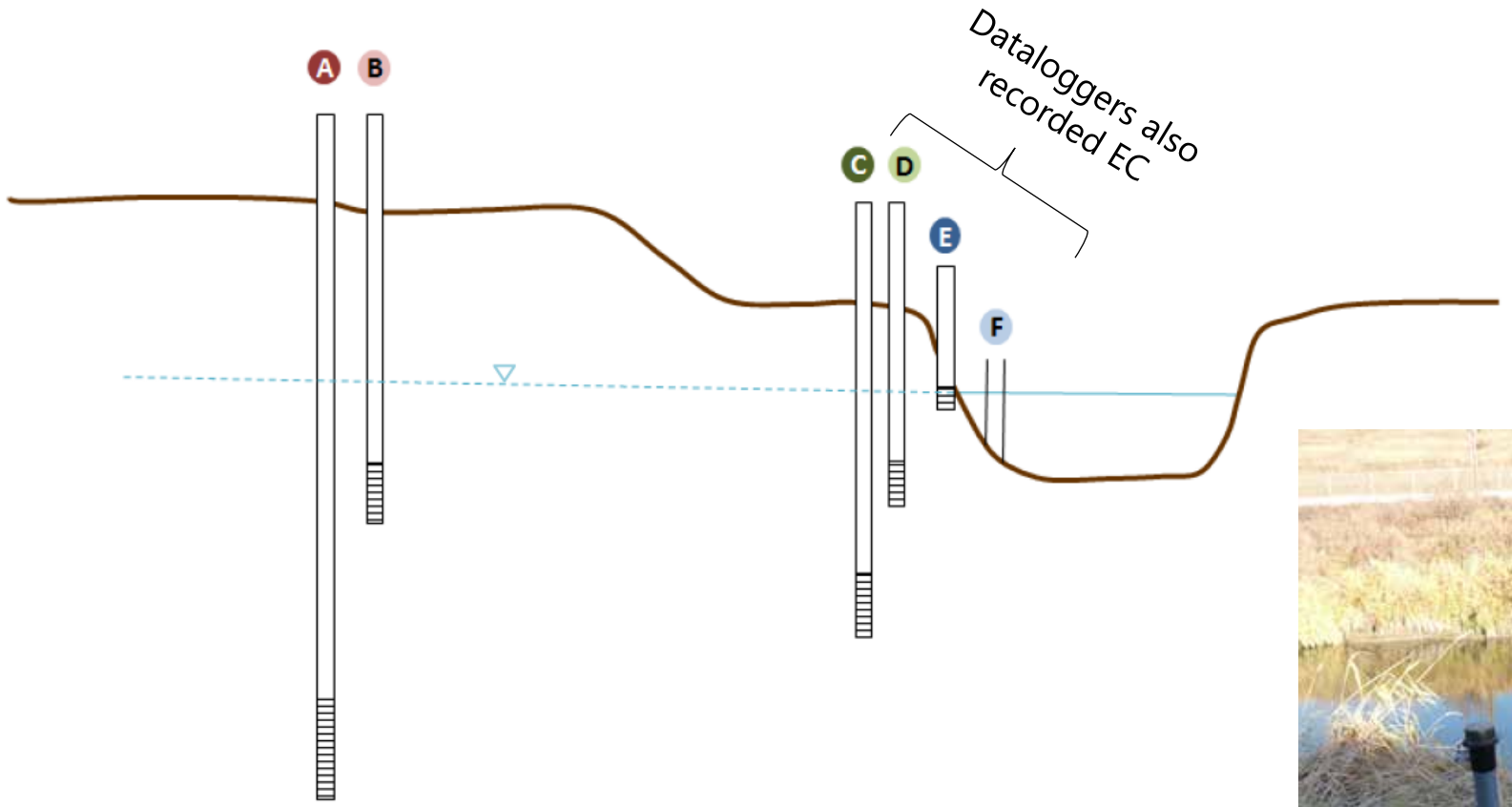
Results



Transects

- Monitoring components were installed in a configuration that would allow for observation of groundwater-surface water interaction through a 2D cross section
- Existing monitoring wells used when available
  - New installations added
    - Some monitoring wells
    - Drive points and stilling basins
- Instrumented with 42 dataloggers
  - Head and temperature
  - EC at some locations
  - Barologger
- Weather station
  - Donated to Telus Spark

Transects – 6 components

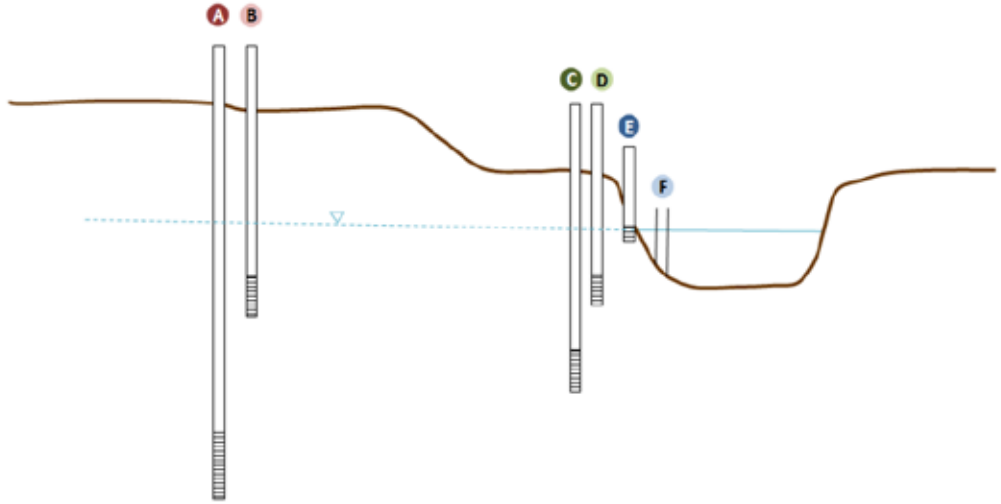


Transect Components:

- A. Deep well in former landfill area, screened at bedrock/overburden interface
- B. Shallow well in former landfill area, screened in overburden
- C. Well adjacent to creek, screened below base of creek
- D. Well adjacent to creek, screened beside the base of the creek
- E. Drive point well adjacent to creek
- F. Stilling basin for surface water measurement

Transects

Transect Number	Deep Landfill Area Well (Component A)	Shallow Landfill Area Well (Component B)	Deep Creek Adjacent Well (Component C)	Shallow Creek Adjacent Well (Component D)	Drive Point (Component E)	Stilling Basin (Component F)
1	01-01	01-02	14-04A	14-04B	DP14-04	SB14-04
2	---	01-04	14-02	14-03B	DP14-03	SB14-03
3	11-01A	*11-01B*	14-08A	14-08B	DP14-08	SB14-08
4	08-02A	08-02B	14-07A	14-07B	DP14-07	SB14-07
5	*14-01A*	---	14-01B	14-01C	DP14-01	SB14-01
6	08-06A	08-06B 08-06C	08-04B	14-02	DP14-02	SB14-02 SB14-02-02
7	14-06A	14-06B	14-05A	14-05B	DP14-05	SB14-05 SB14-05-02
Extra	05-15	92-04	08-03C	Barologger	Staff gauges: memorial bridge, CP bridge	

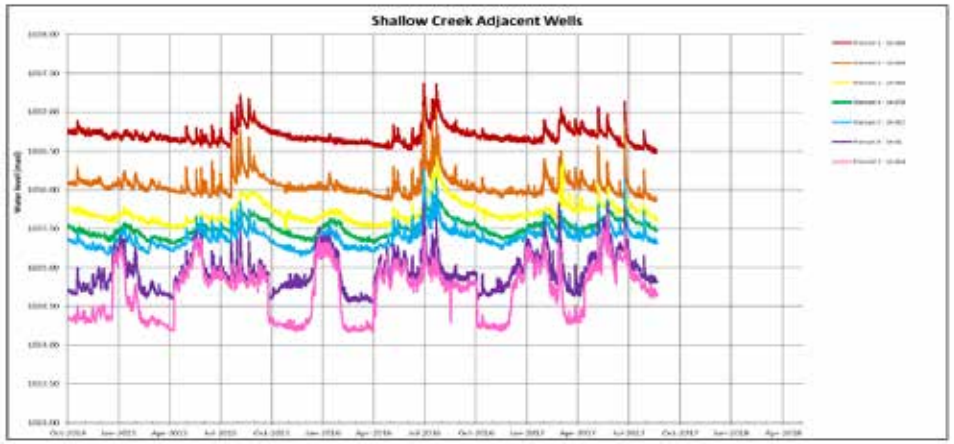


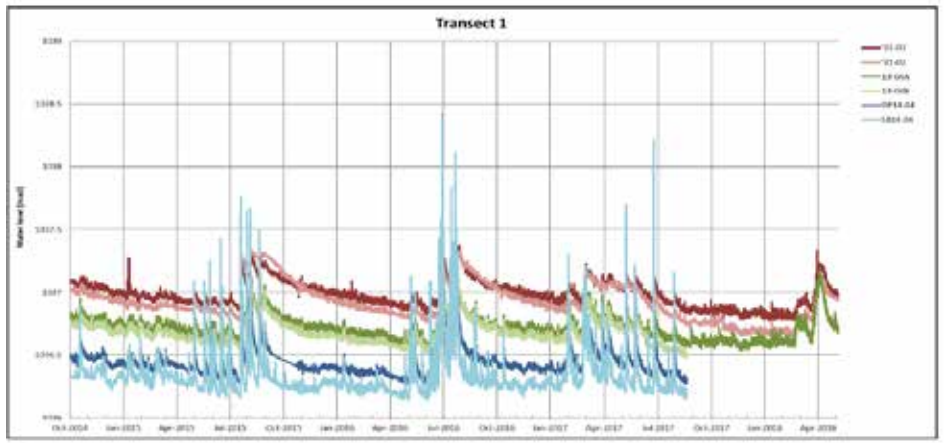
No data logger installed
--- No monitoring location

Transects – Data collection

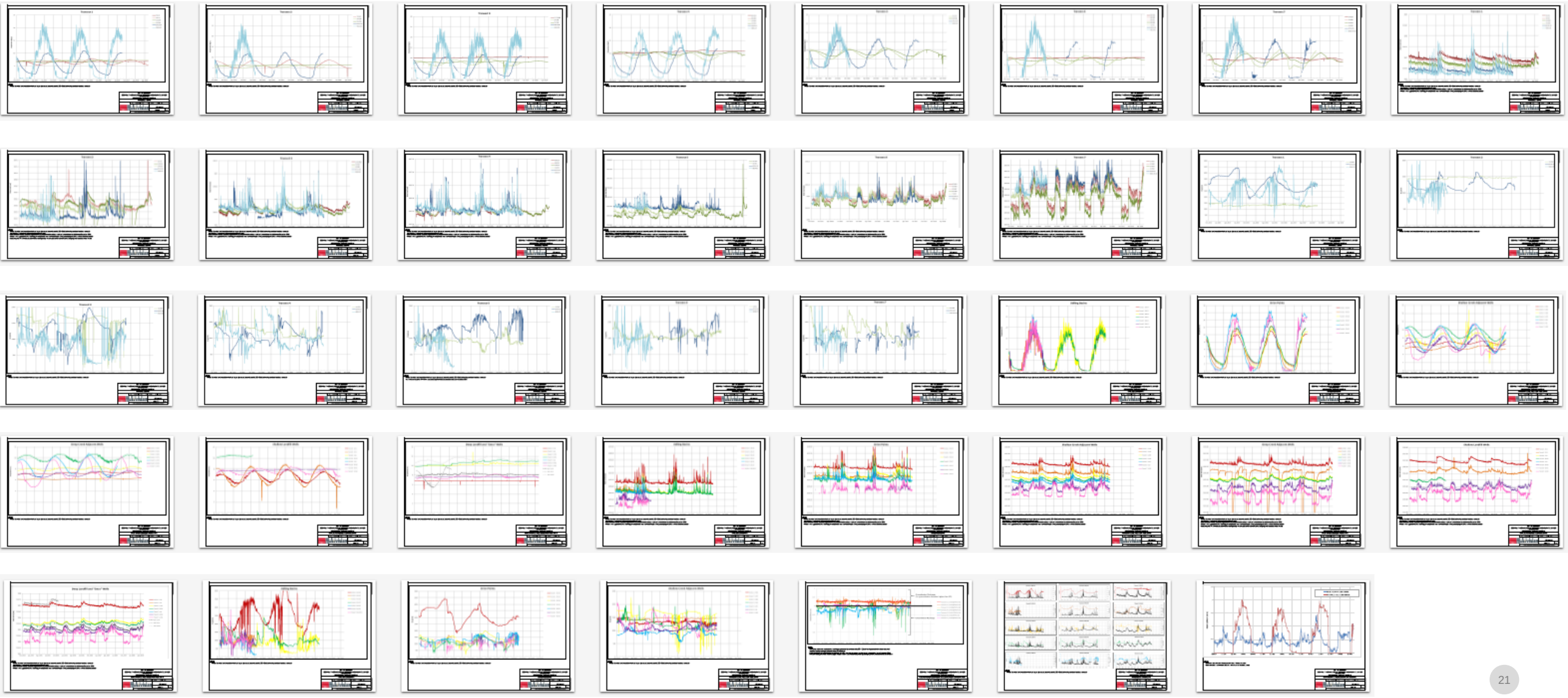
3.5 years of continuously logged data (Oct. 2014 – May 2018)

Data (head, temperature, EC) plotted by monitoring component and by transect



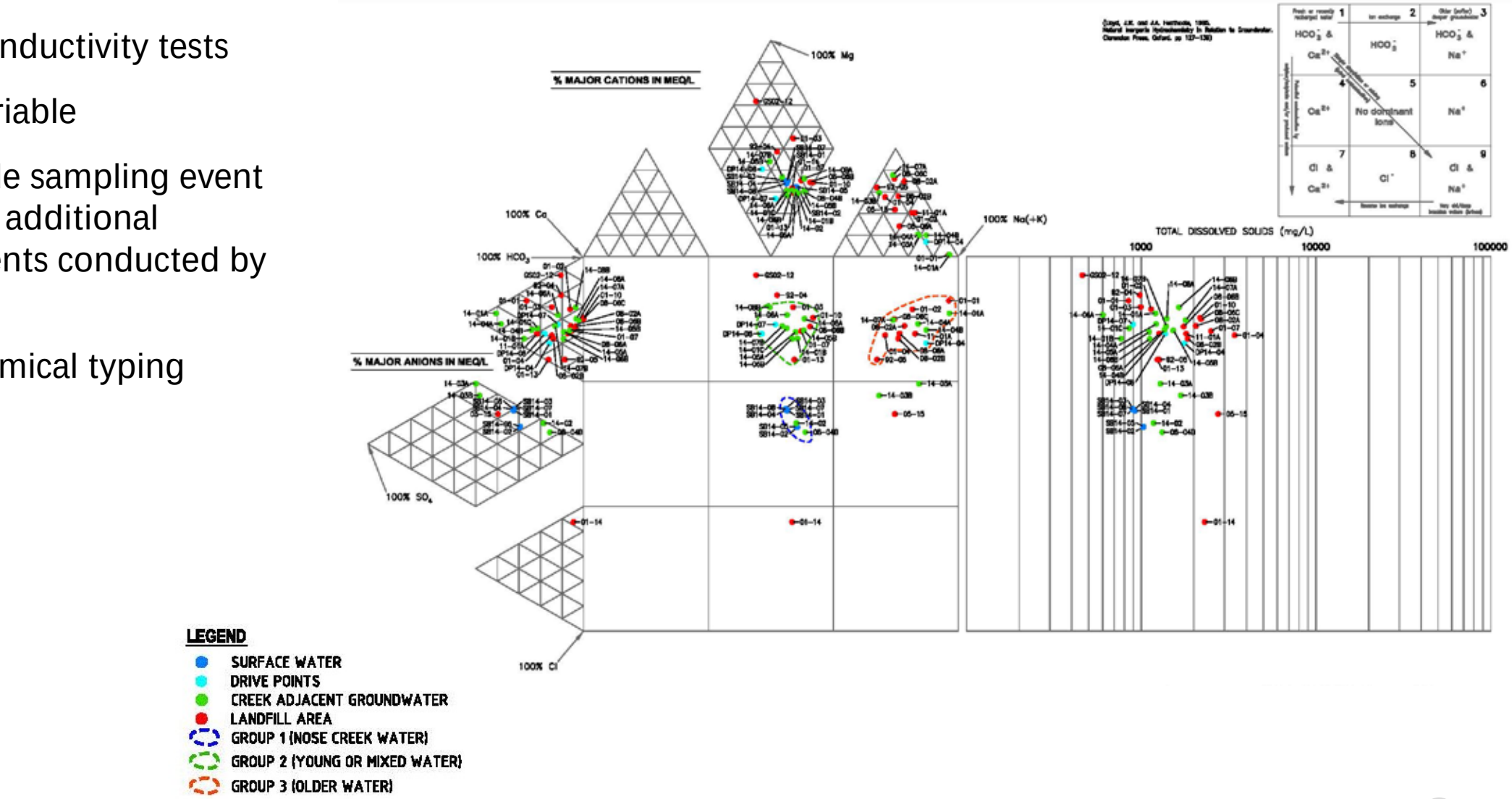


Transects – Data collection



Transects – Data collection

- Hydraulic conductivity tests
  - Highly variable
- One site-wide sampling event in 2015 with additional biannual events conducted by the City
  - Hydrochemical typing



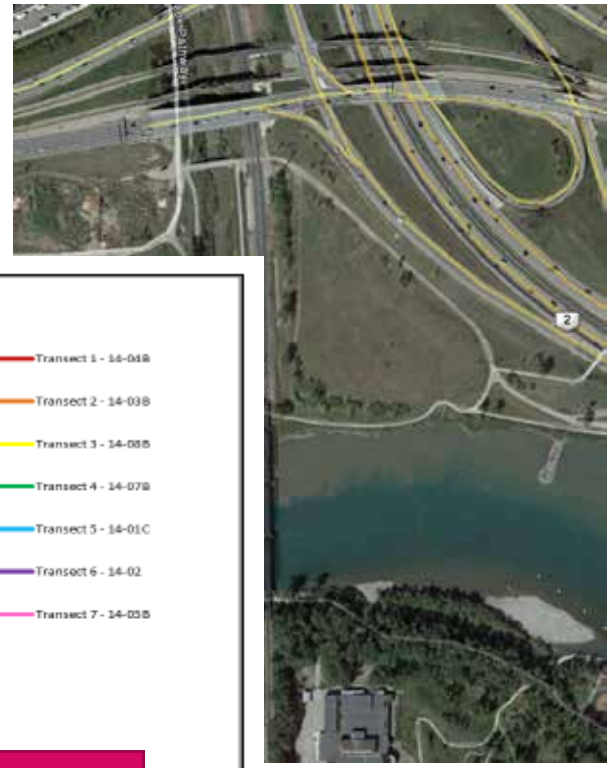
Insights and Lessons Learned

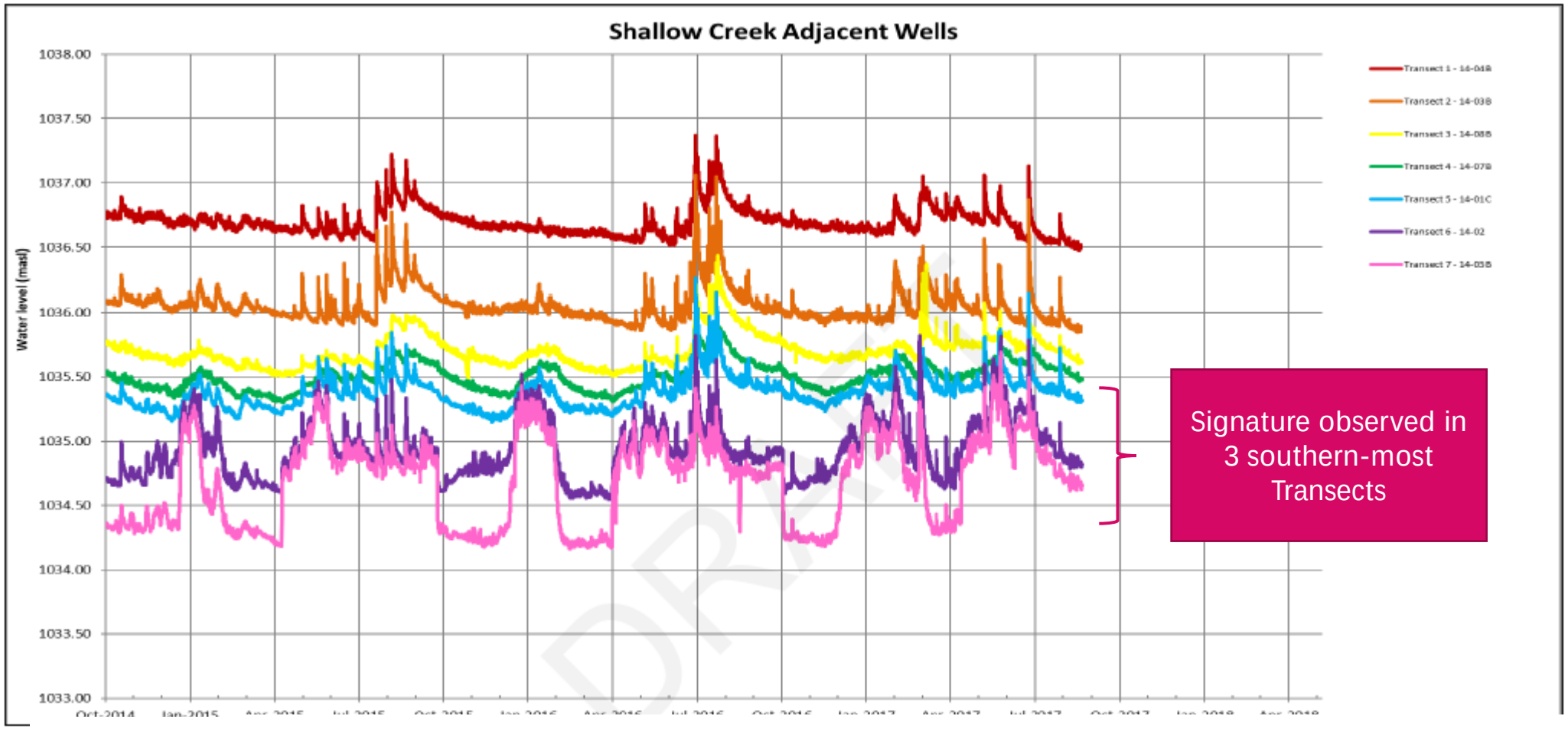
Shallow Groundwater Flow

Bedrock Groundwater Flow

Insights: Influence of the Bow River

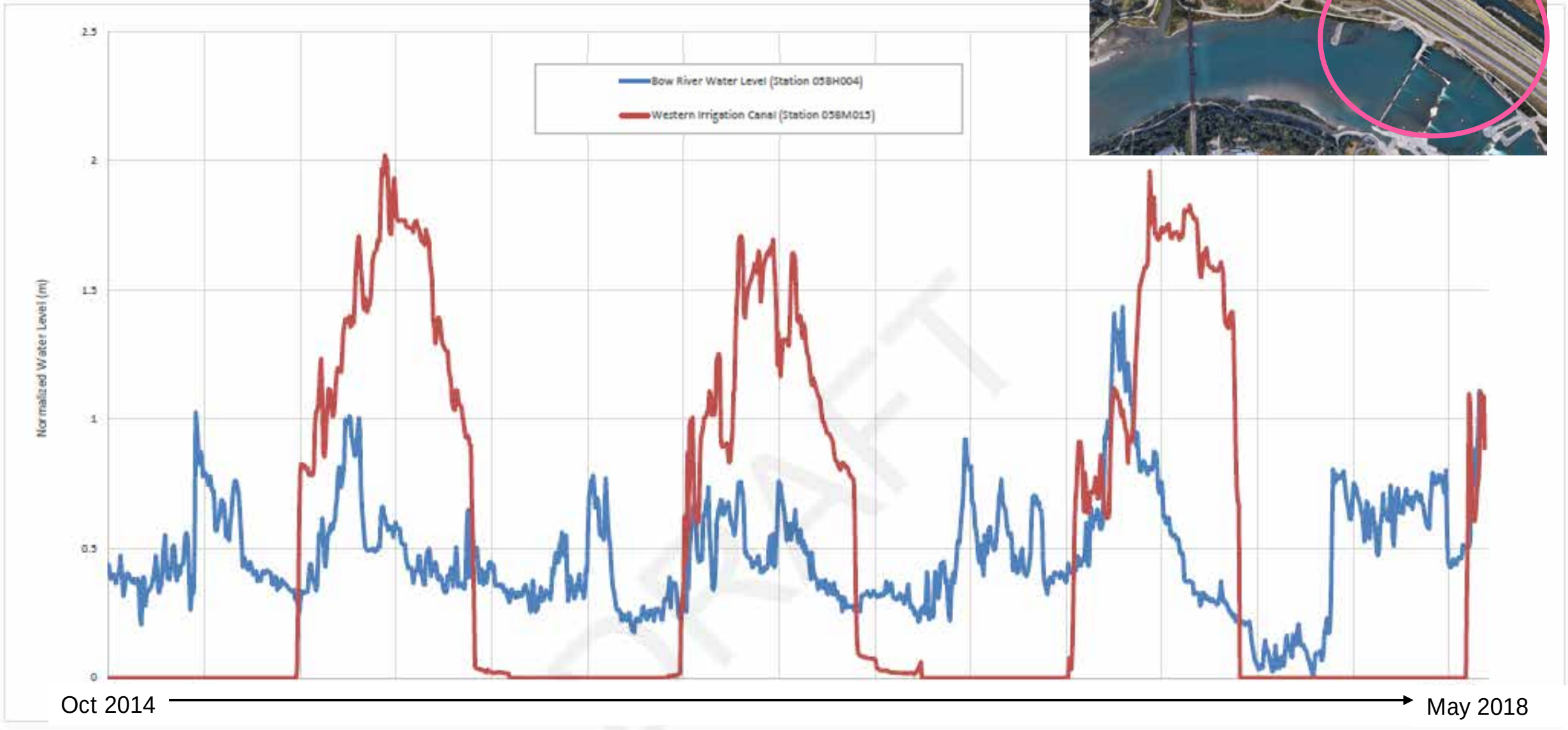
- Bow River connection observed through Western Irrigation Canal operation





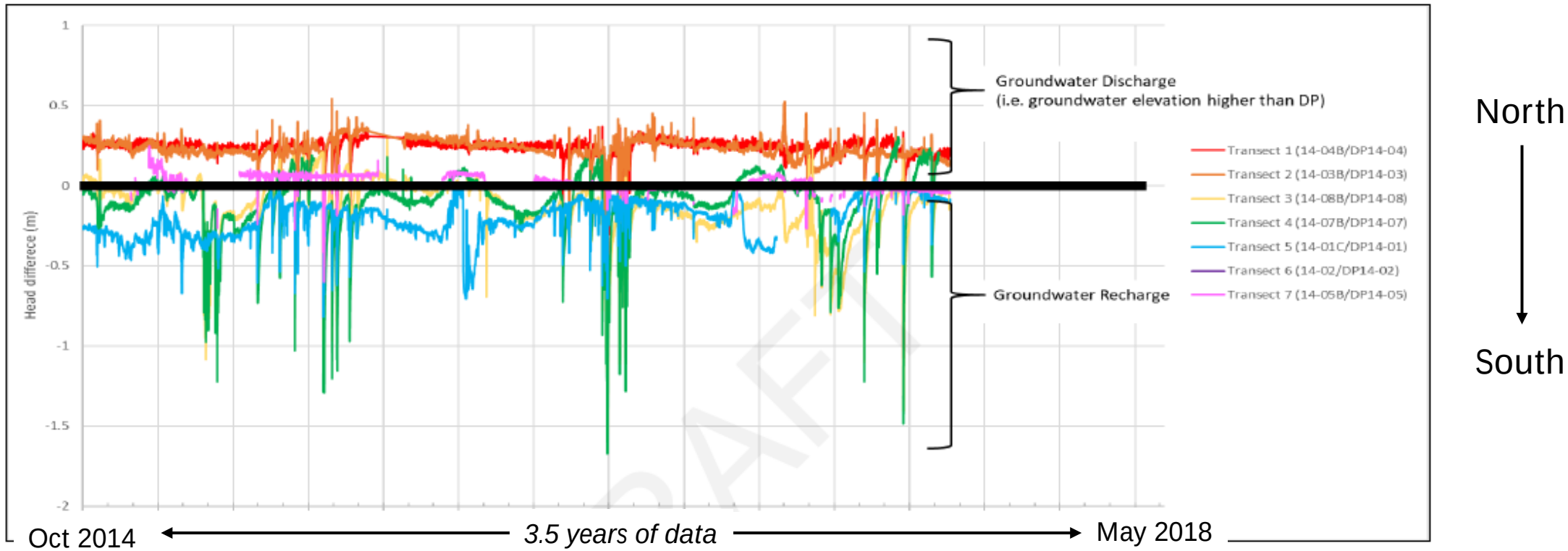
Oct 2014 → May 2018

Insights: Influence of the Bow River



Insights: Recharge/Discharge Conditions

- Difference in water levels on a transect scale shows local recharge/discharge
- Variable recharge/discharge conditions depending on creek levels at some transects
    - In-stream hydraulic controls could potentially manage transect-scale flow regime for areas with variable conditions



Insights: Conceptual Site Model from Lines of Evidence

North

South
(Bow River)

North of closed landfill area

Discharge/recharge with respect to groundwater

	Head	Temperature	Logged EC	Chemistry	DTS
1	Discharge	Discharge	Discharge	Discharge	Discharge
2	Discharge	Discharge	Discharge	Discharge	Discharge
3	Variable	Indeterminate	Indeterminate	Variable	Discharge
4	Variable	Indeterminate	Variable	Variable	Discharge
5	Recharge* and Bow River Influence	Recharge	Recharge	Recharge	Indeterminate
6	Bow River influence	Recharge	Recharge	Variable	Indeterminate
7	Bow River influence	Recharge	Variable	Variable	Indeterminate

** Recharge observed on transect scale*

Insights: Conceptual Site Model

Geophysics

DTS anomalies (continuous and temporally variable groundwater discharge zones)

1 DTS anomaly rank

Water level elevations

Groundwater hydraulically connected to Bow River

Chemistry

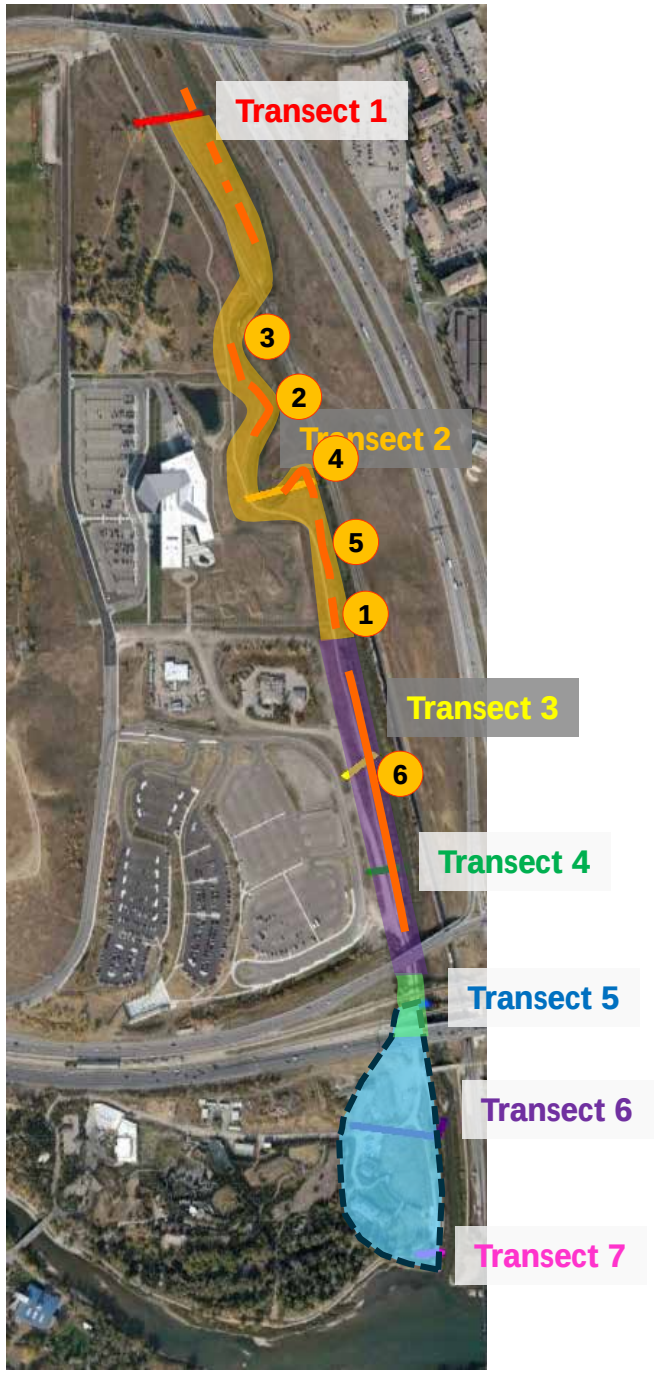
Nose Creek chemistry consistent across site

Resultant Zones

Groundwater discharge to Nose Creek

Variable groundwater discharge/recharge to Nose Creek (landfill-adjacent)

Groundwater recharge from Nose Creek on transect scale



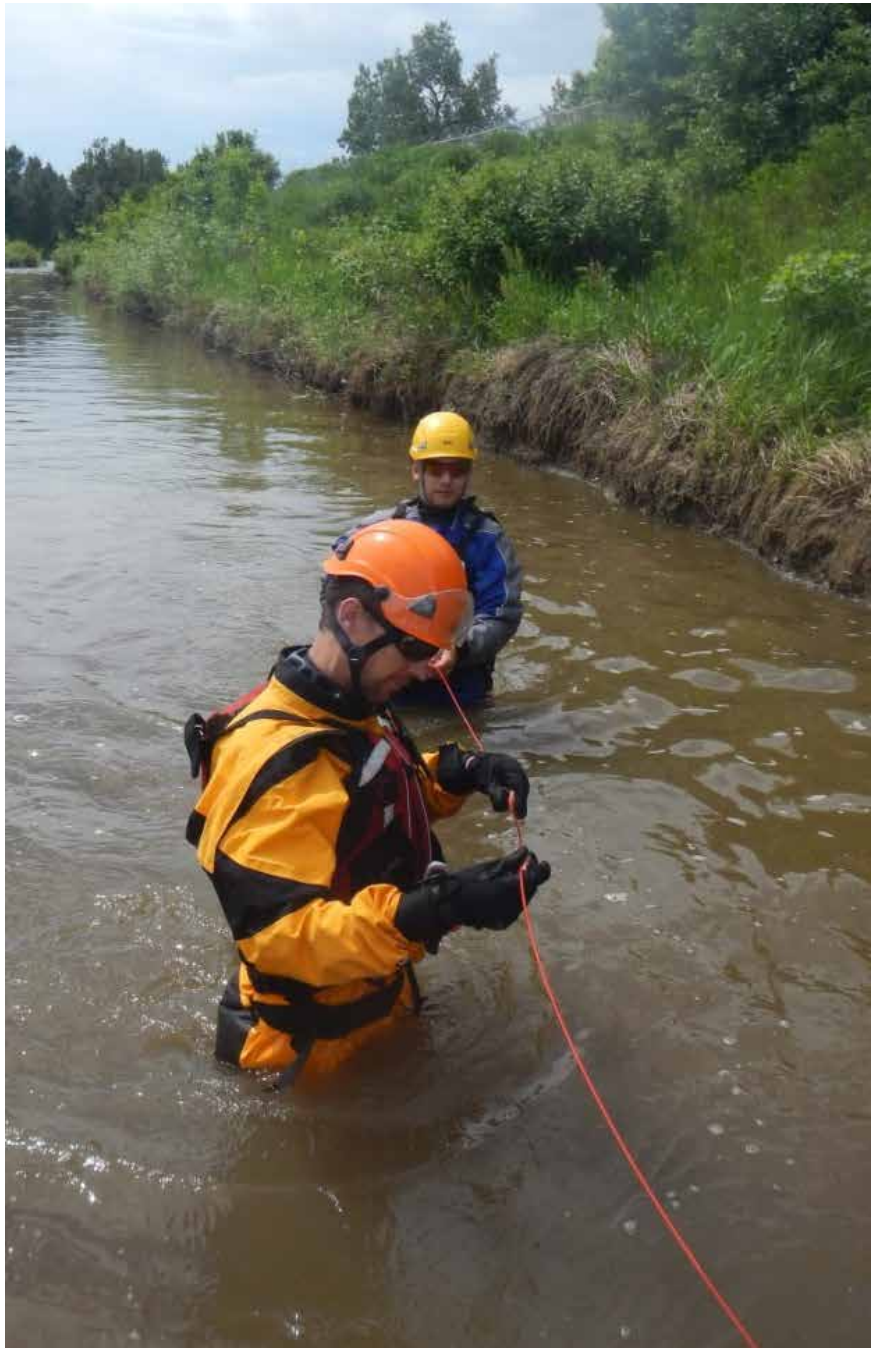
A comprehensive picture of the groundwater/surface water interactions at the closed Nose Creek landfill was developed through assessing multiple lines of evidence.

Conclusions

- Consistent groundwater discharge is only observed in the north area
- Areas adjacent to the closed landfill show temporally variable recharge/discharge conditions influenced by creek level (reflecting seasonal variation and precipitation)
- Southern reach of study area largely influenced by the Bow River
- Demonstrated negligible potential risk to receptors:
  - discharge zones are spatially and temporally limited
  - no indication of significant geochemical impacts to Nose Creek from the landfill

Lessons Learned

- Multiple lines of evidence provided confidence in the conclusions drawn
- DTS results (especially the continuous data) outline both broad and discrete areas of discharge that may easily be missed with a standard monitoring well installation program
  - Collecting a year of DTS data prior to transect placement would have been beneficial



Acknowledgements

- Mark Ponto, Marc Adams and other City of Calgary Waste and Recycling Services staff
- Advisian Geophysics Team lead by Paul Bauman
- Advisian LMD&R Team: Marc Bowles, Kim McLeish, Mike McBride
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Thank you

Questions?