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ENVIRONMENT & ENGINEERING

Calculating Groundwater Flux and Mass Discharge to Support Risk Management Plan Development

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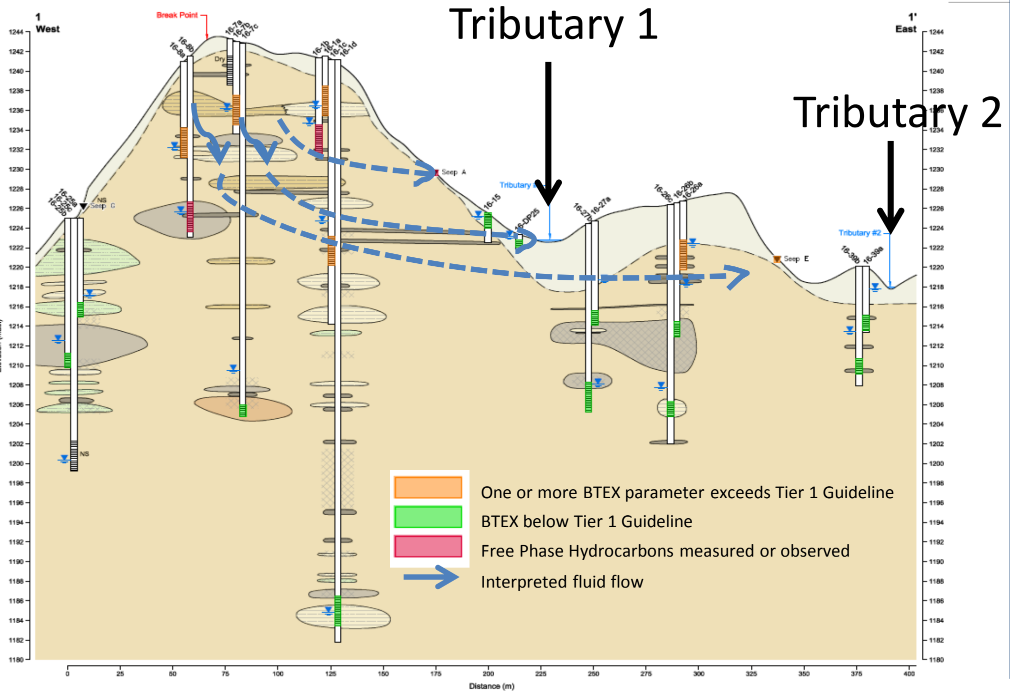
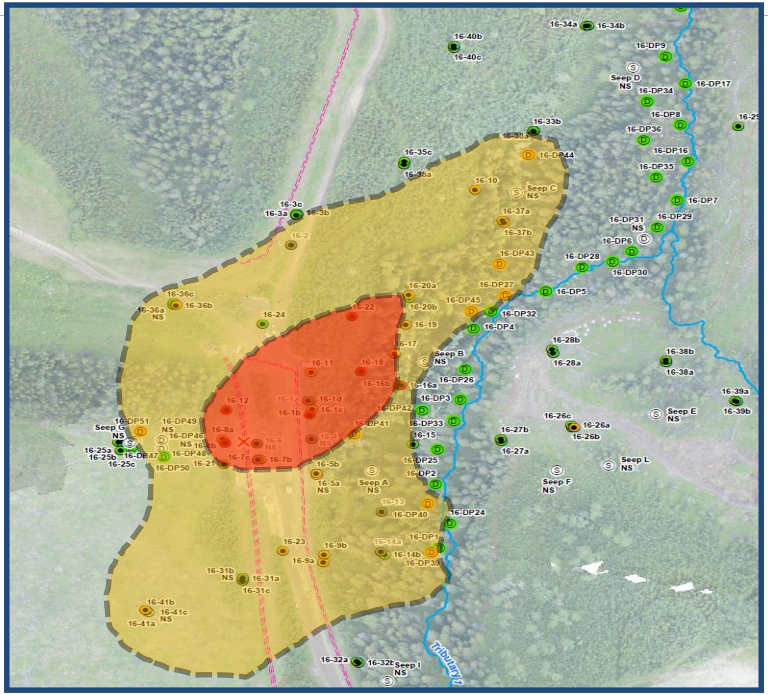
Spill Description and Response

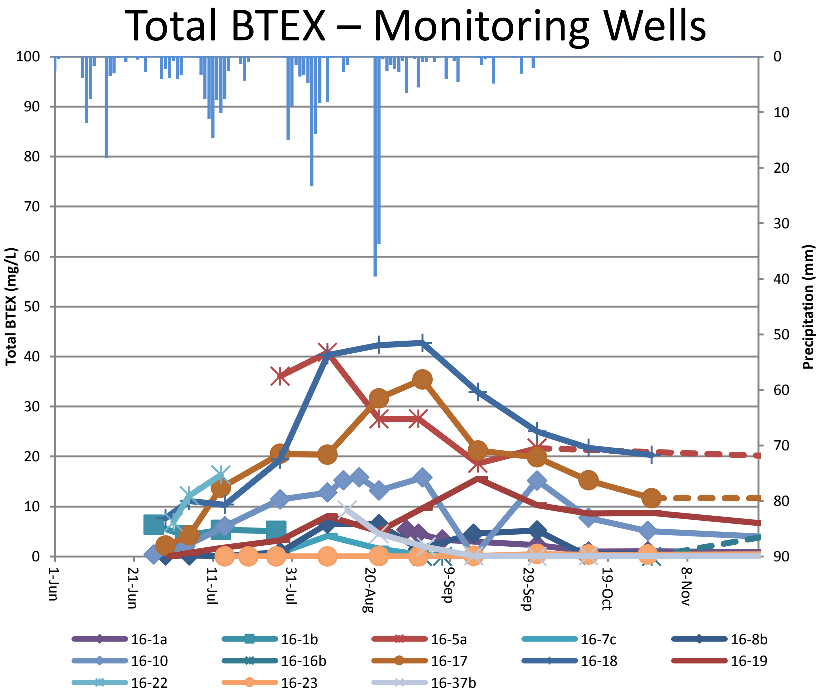
- 400 m^3 condensate released from a pipeline
- Remote location in Alberta Foothills
- Hydrocarbons observed discharging from mid-slope seeps
- Initial containment and recovery
- Assessment

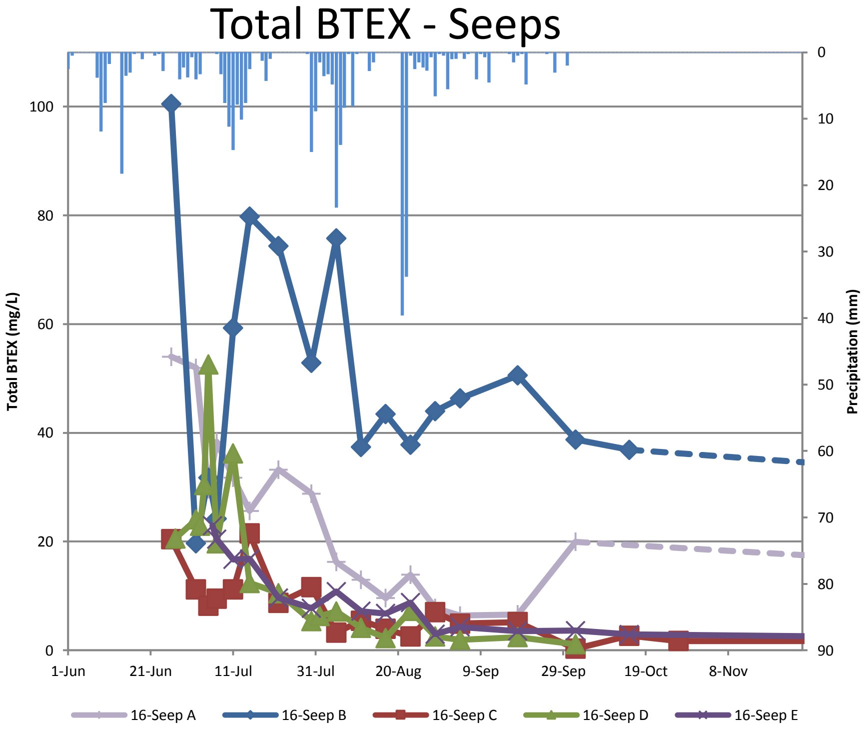
CSM Development





Dynamic Pathways





Dynamic Pathways

CHART 3 Hydrographs of Select Monitoring Wells

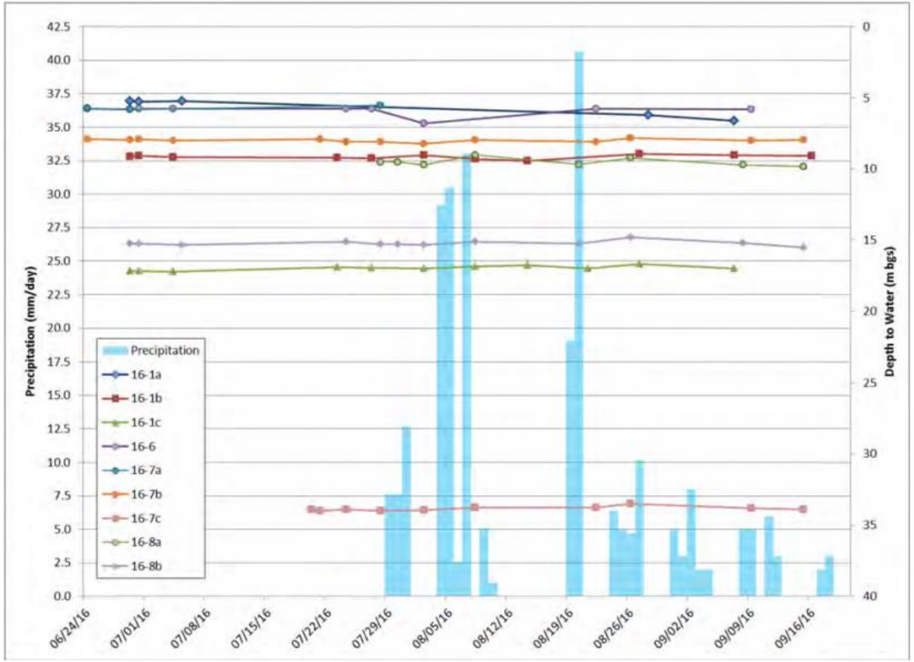
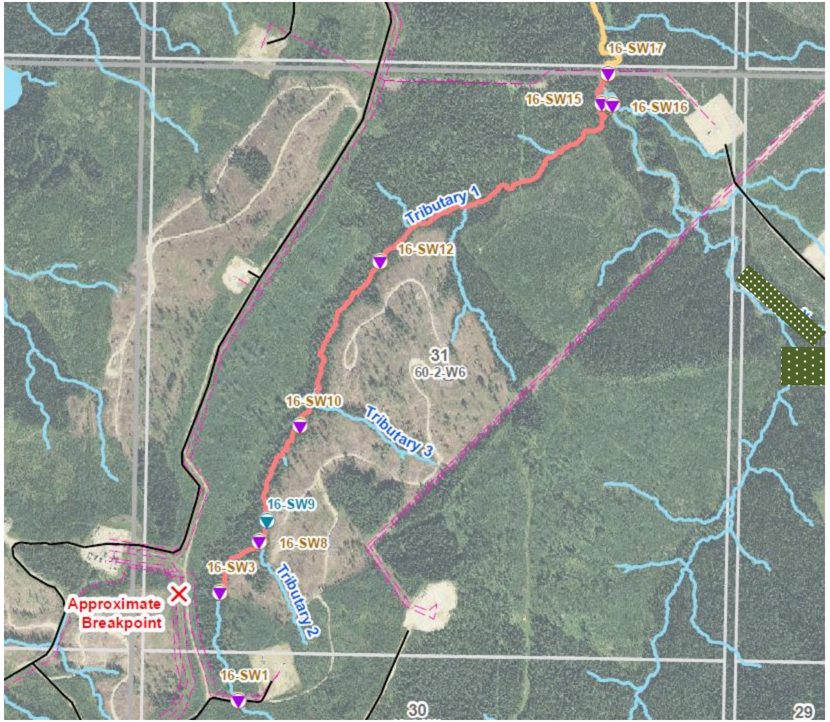


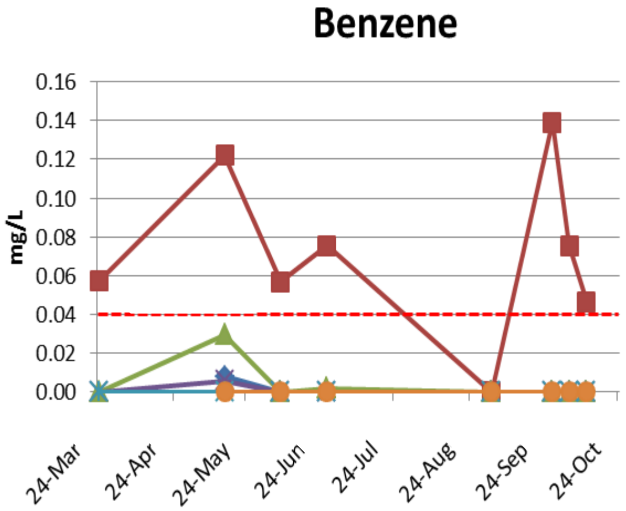
CHART 4 Comparison of Seep Discharge and Precipitation over Time

CSM Development

- Source characterization ✓
- Surface water receptor (Trib 1) ✓
- Dynamic pathways ✓
- Contaminant loading into Trib 1 ✓
  - How much ?
  - Spatial and temporal variation ?

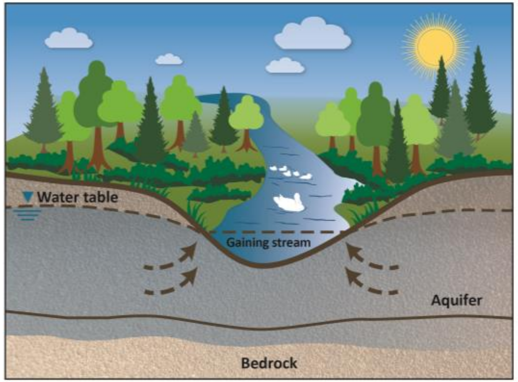
Risk Assessment Challenges

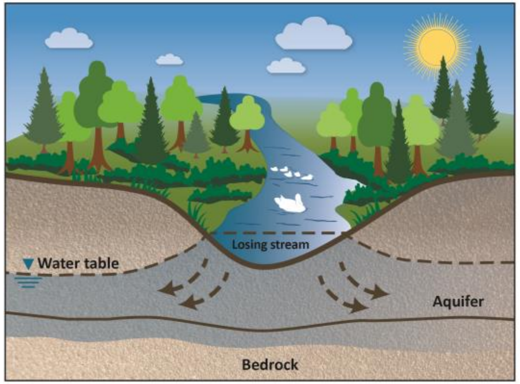


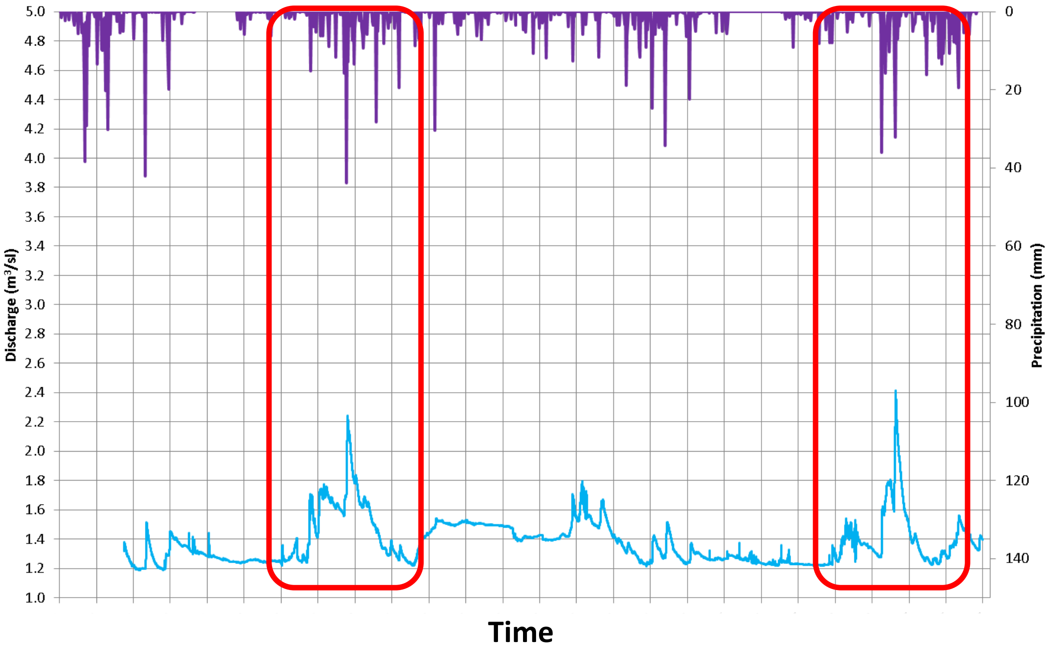


Key Question:
Spatial and temporal groundwater discharge that results in the integrated stream concentration

Risk Assessment Challenges

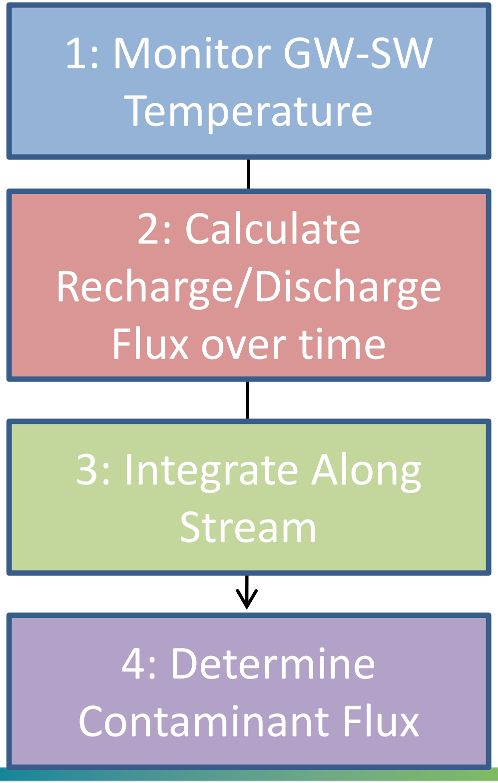






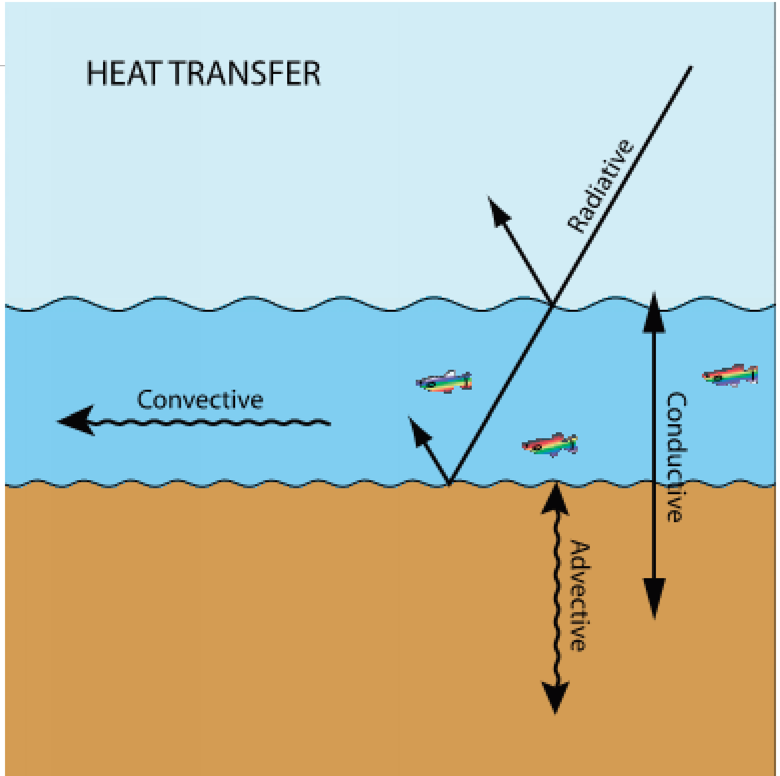
Proposed Approach

- Compute SW-GW flux over time using temperature measurements
- Integrate with continuous stream flow and concentration measurements.
- Determine mass flux



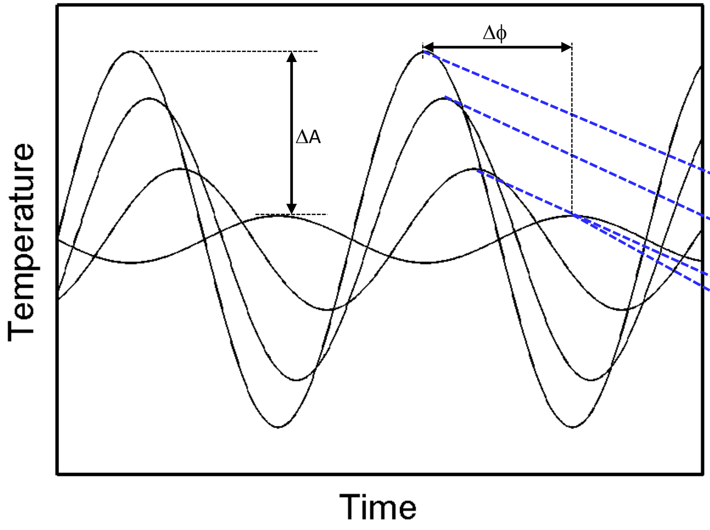
Concept

- Advection and conduction are the main heat transfer component for determining heat exchange between water and underlying sediments

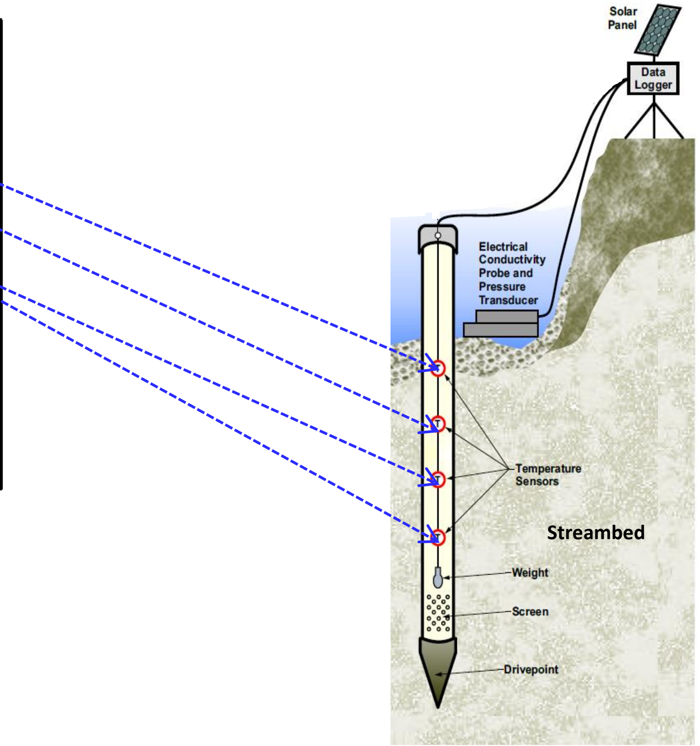


Constantz, J. (2008)

Concept



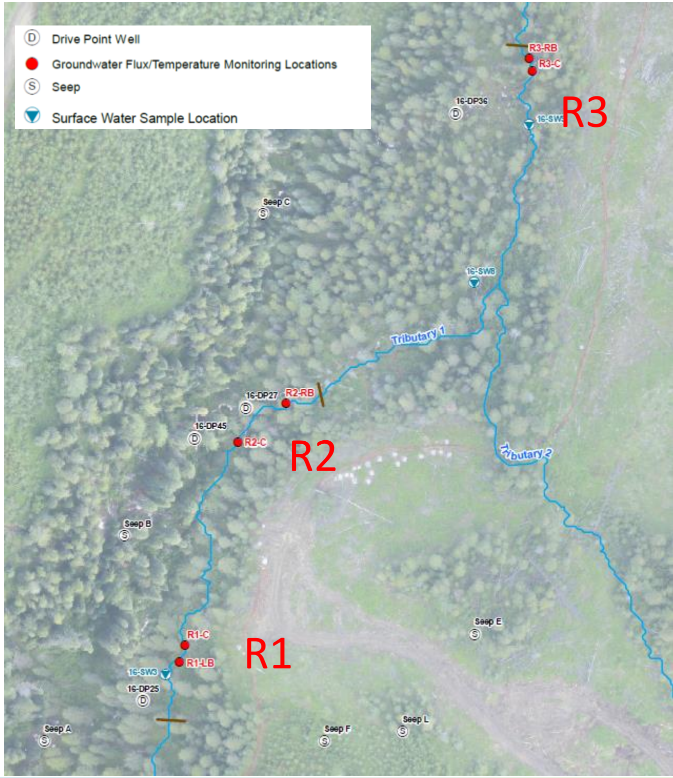
$$\mathbf{q}_z = \left(\frac{C_m}{C_w}\right) v_d v^*$$



Field Reconnaissance

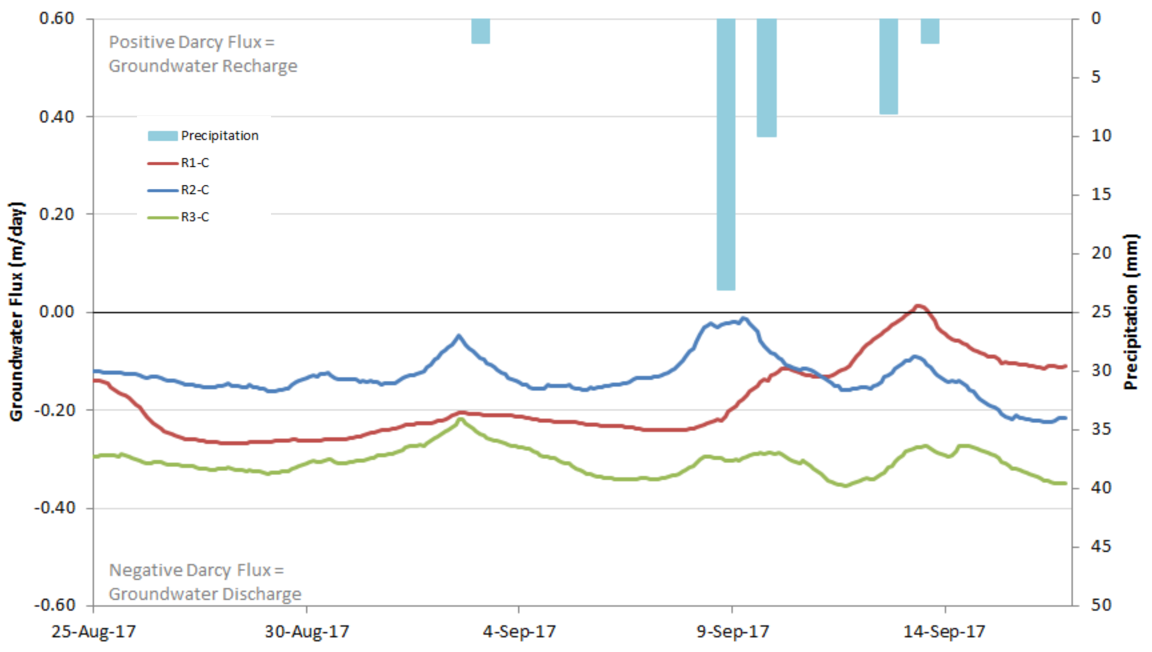
1: Monitor GW-SW Temperature

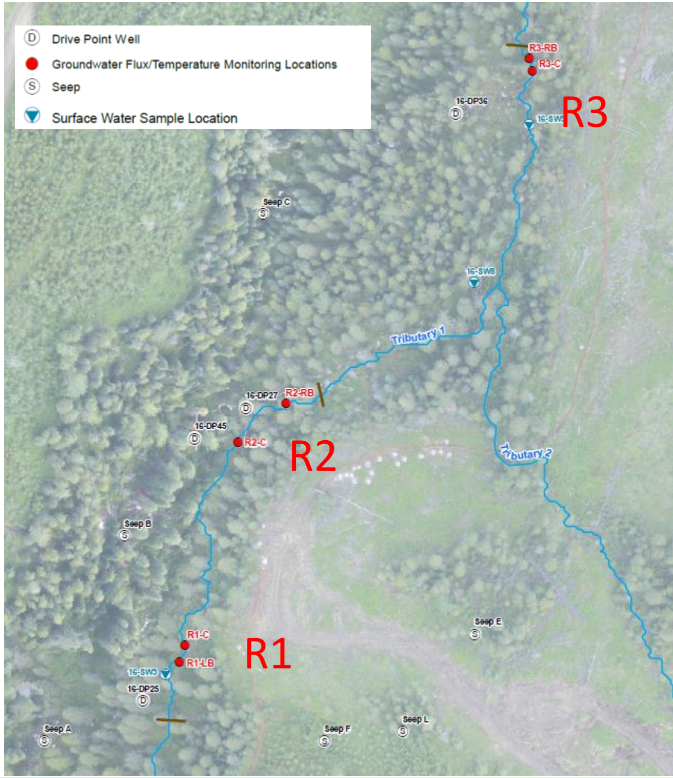
- Objective: Identification of GW discharge locations



Calculated GW Flux

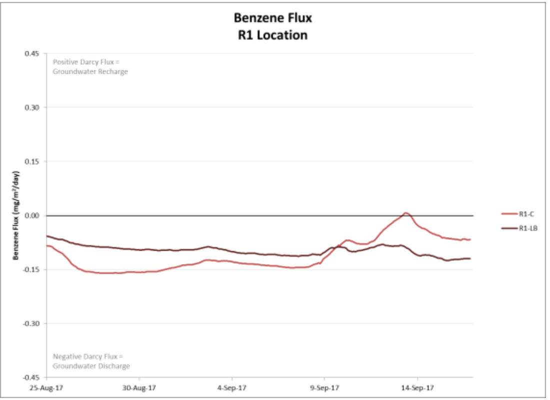
2: Calculate Recharge/Discharge Flux over time

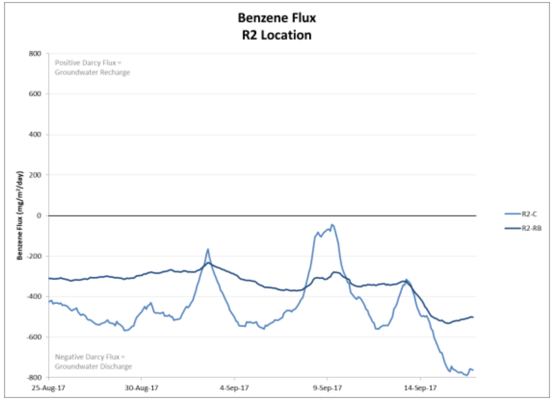


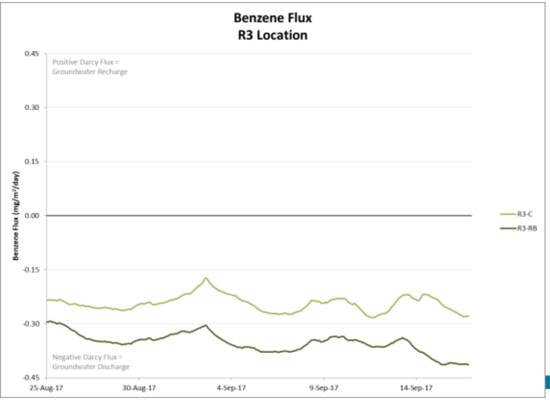


Transient Mass Flux

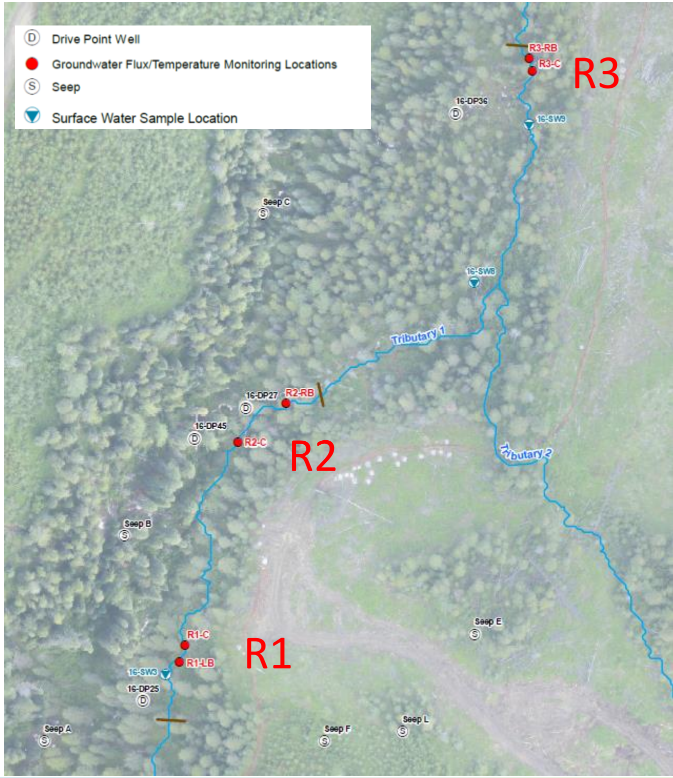
2: Calculate Recharge/Discharge Flux over time







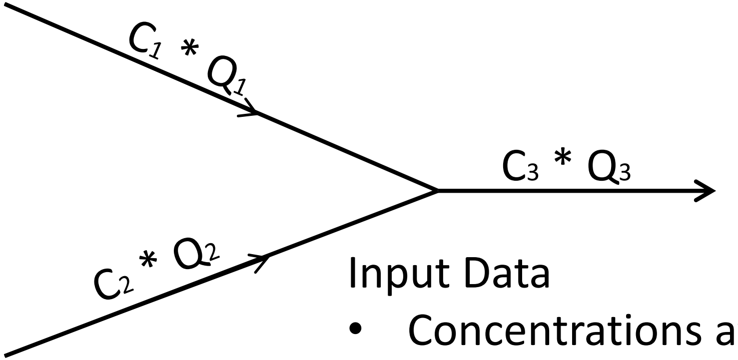
Reach	Closest Groundwater Sampling Location with Available Data	Groundwater Benzene Concentration Measured on Sep. 30, 2017 (mg/L)
Reach 1	16-DP25	0.0006
Reach 2	16-DP45	3.51
Reach 3	16-DP36	0.0008



Integration Along Stream

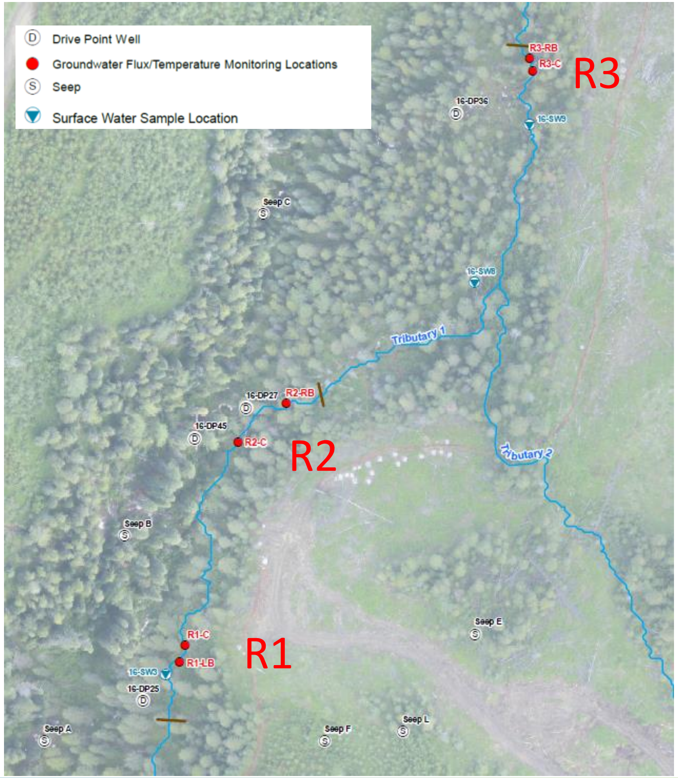
3: Integrate Along Stream

- Iterative mass balance approach
- Conservative tracer



Input Data

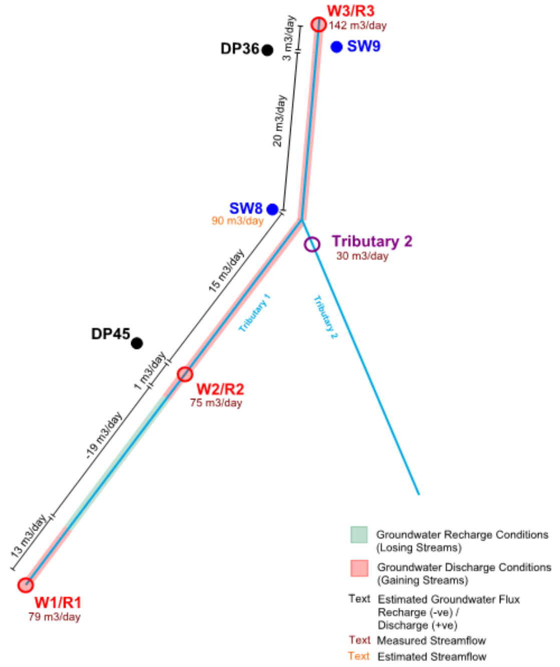
- Concentrations at SW locations
- Concentrations at Drive Points
- Flow Discharge Measurements
- GW/SW fluxes (temperature signals)



Water Balance

3: Integrate Along Stream

- Determine the water entering and exiting the system
- Validate lengths using water/mass balance

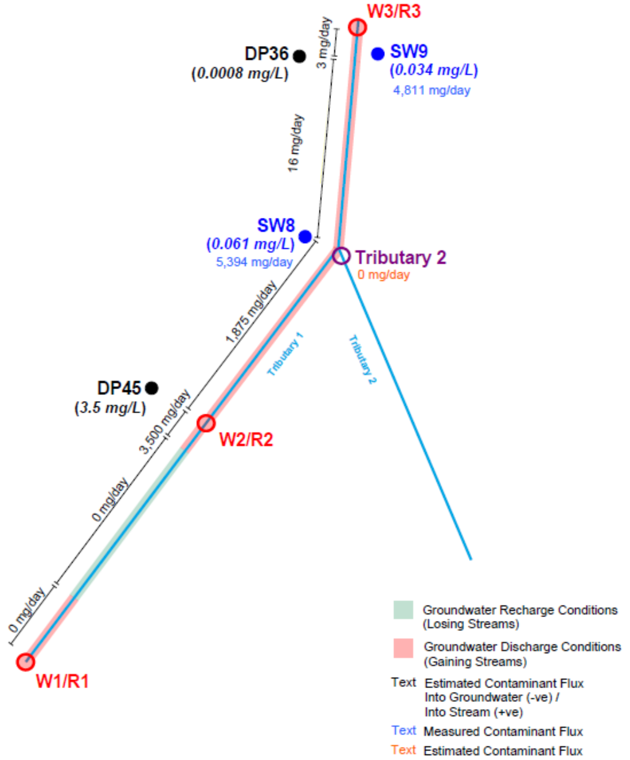


Mass Balance

4: Determine Contaminant Flux

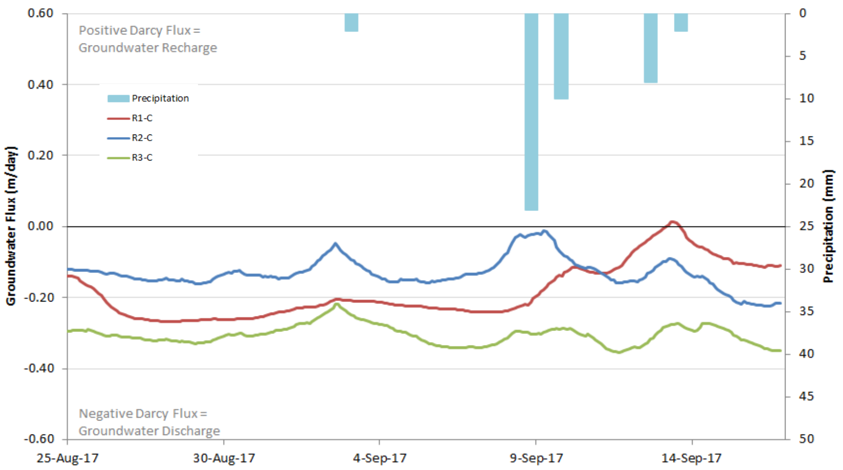
- SW contaminant flux = $C_{sw} * Q$
- GW contaminant flux = $C_{gw} * q * L$

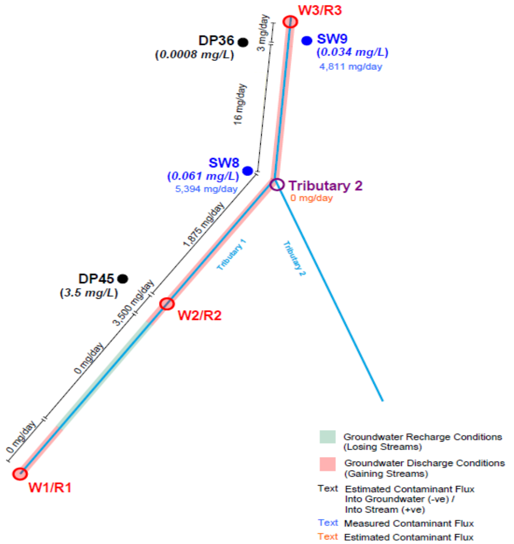
- Contaminant mass flux at any downgradient SW location should approx. equal upgradient mass inputs



What we learned

- GW discharge and mass loading inversely related to precipitation
- GW discharge at R1, R2 and R3 but recharge predicted between Weir 1 and Weir 2
- Discharge and mass loading variable along the entire reach of the stream
- Mass loading is localized; minimal contaminant mass enters the stream downgradient of R2.





Why is this important for RMPs?

- Validate and enhance CSMs
- Understanding variability →understanding of risk
- Inform monitoring programs/predictive models

Take-aways

1) Heat can be used as a tracer to estimate GW-SW interaction
2) Integrating groundwater and surface water data can provide a robust understanding of contaminant mass flux
3) Better understanding of migration pathways → better CSMs → better information for risk assessment/management

Acknowledgements

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