BATTELLE 2023 SEDIMENTS CONFERENCE

Quantifying Flow and Contaminant Flux for Groundwater/Surface Water Interactions: Techniques for Different Site Conditions

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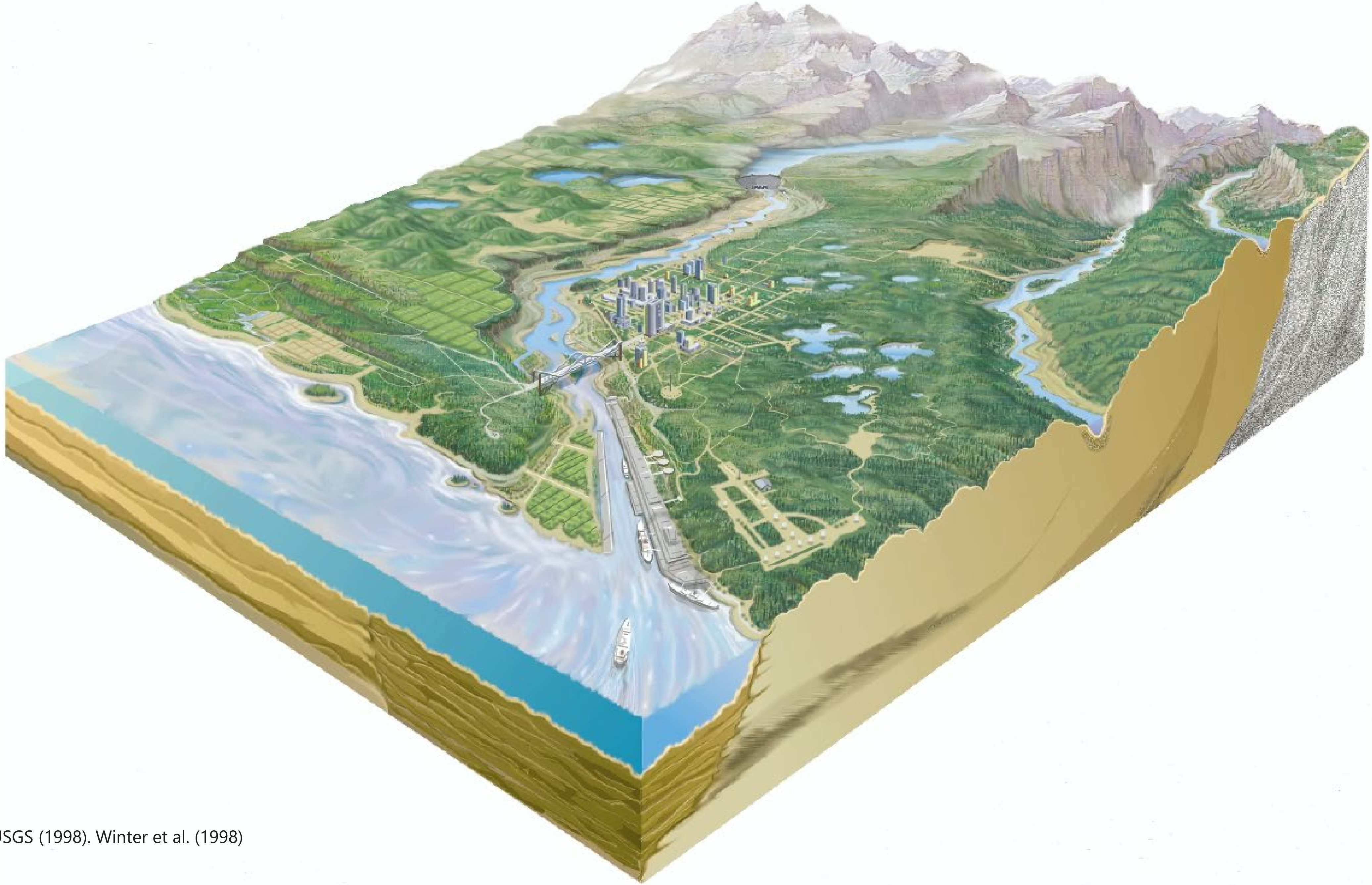
ANCHOR QEA



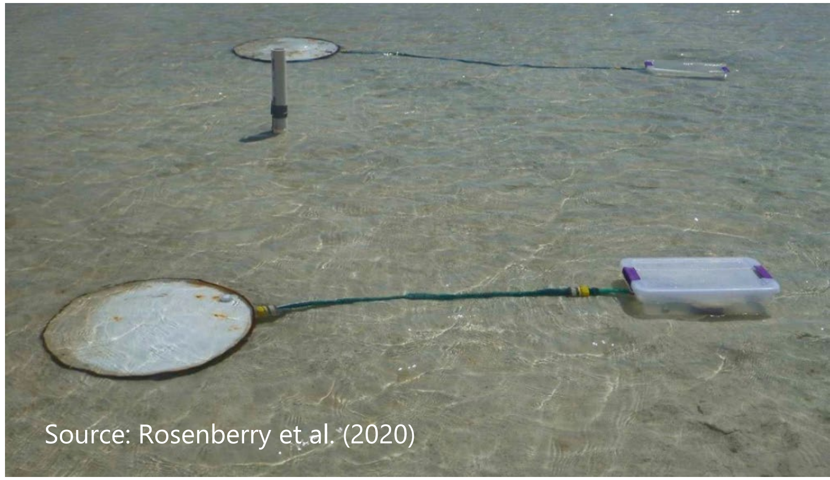
Source: USGS (1998). Winter et al. (1998)

CHALLENGE

There are many approaches to quantify groundwater/surface water interactions—which should be used at my site?

Field Measurements

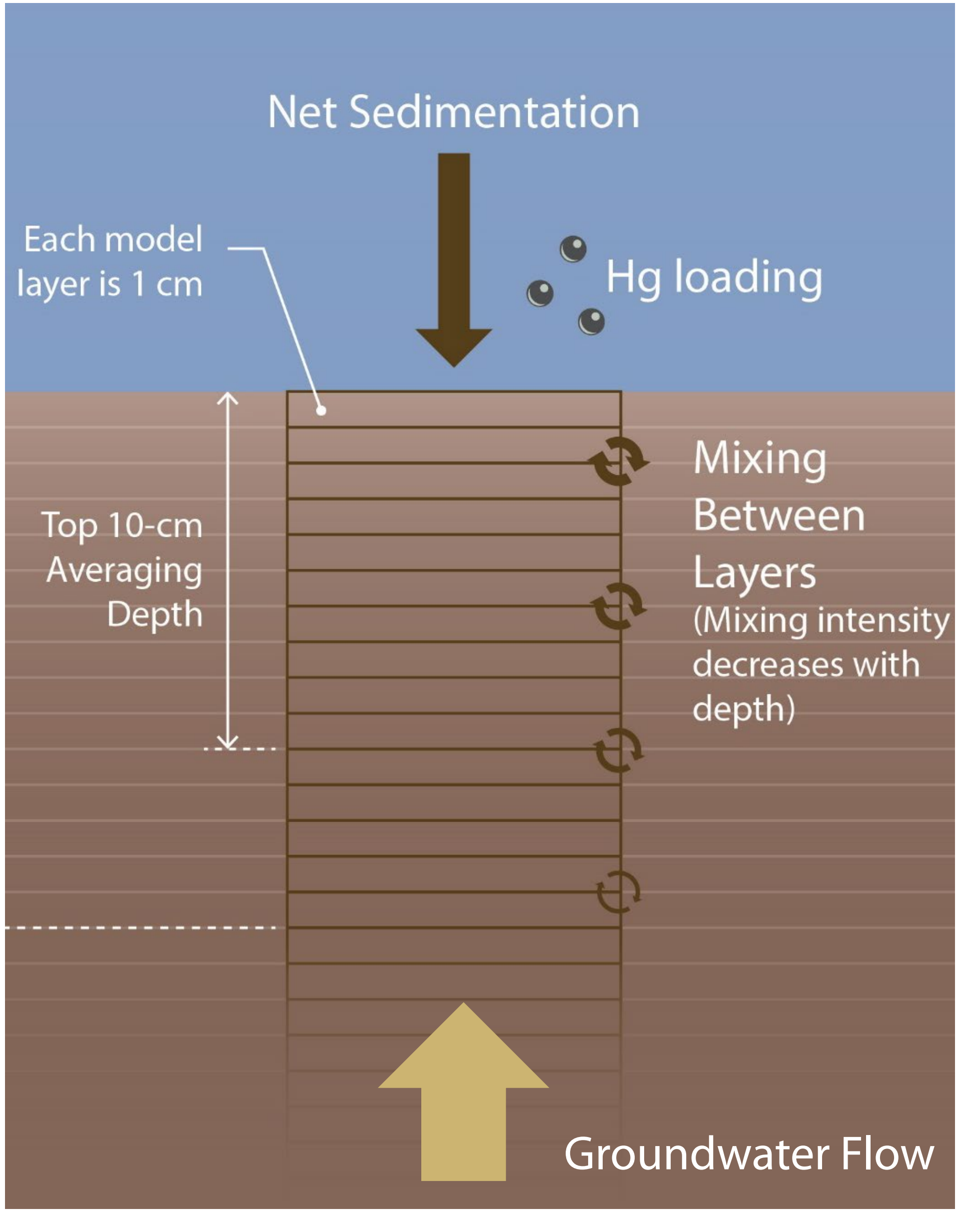
- Upland hydrogeology
  - Borings/lithology, hydraulic conductivity tests, and water levels
- Surface water hydrology
  - Flows and water surface elevations
- Seepage rates
  - Piezometers, seepage meters, and thermal methods
- Contaminant concentrations
  - Groundwater (GW) and surface water (SW) sampling
  - Porewater sampling



Source: Rosenberry et.al. (2020)

Calculations/Modeling

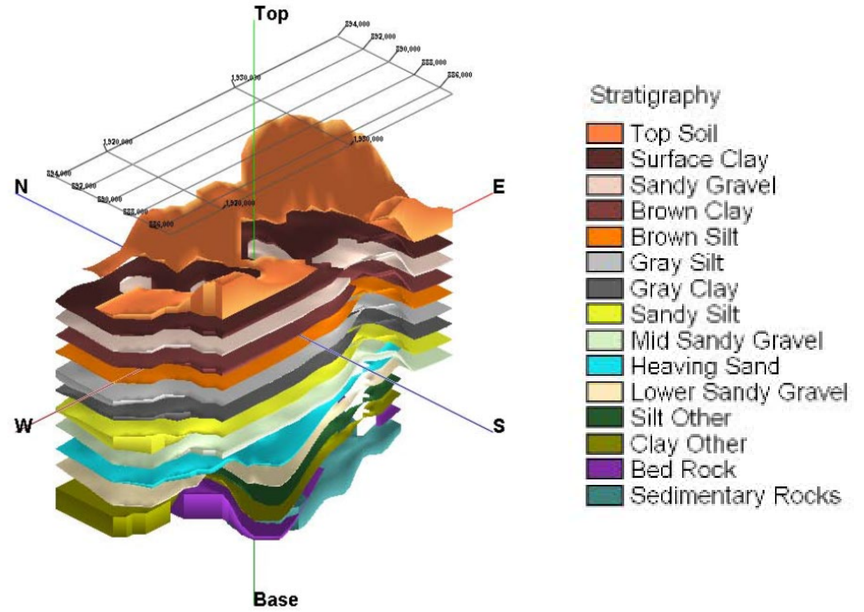
- Solution techniques
  - Analytical; numerical
- Domain
  - GW, SW, and transition zone; coupled or uncoupled
- Spatial dimensionality
  - 1D, 2D (laterally or vertically averaged), and 3D
- Temporal scale
  - Steady state or time variable

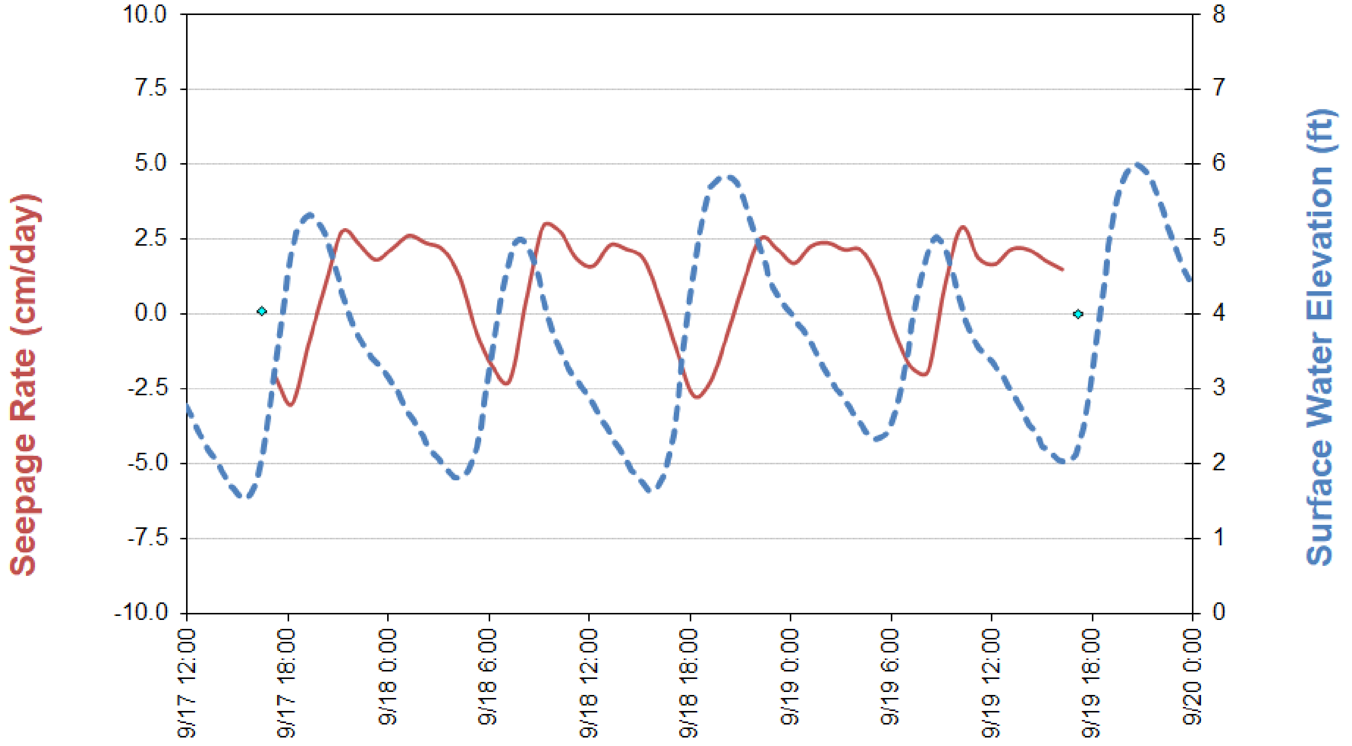


Example 1D: Representation of a GW/SW transition zone

Site Conditions That Affect Approach

- Type of waterbody
- Hydrogeological properties
- Contaminant properties
  - Presence of NAPL requires specialized approaches
- Surface water dynamics
  - Tidal more complex





Factors That Inform Approach

- Questions to be answered
- Site setting and conditions and spatial/temporal scales
- Phase of project and acceptable level of uncertainty
- Phased/adaptive approach often works best

LESSONS

Case Studies

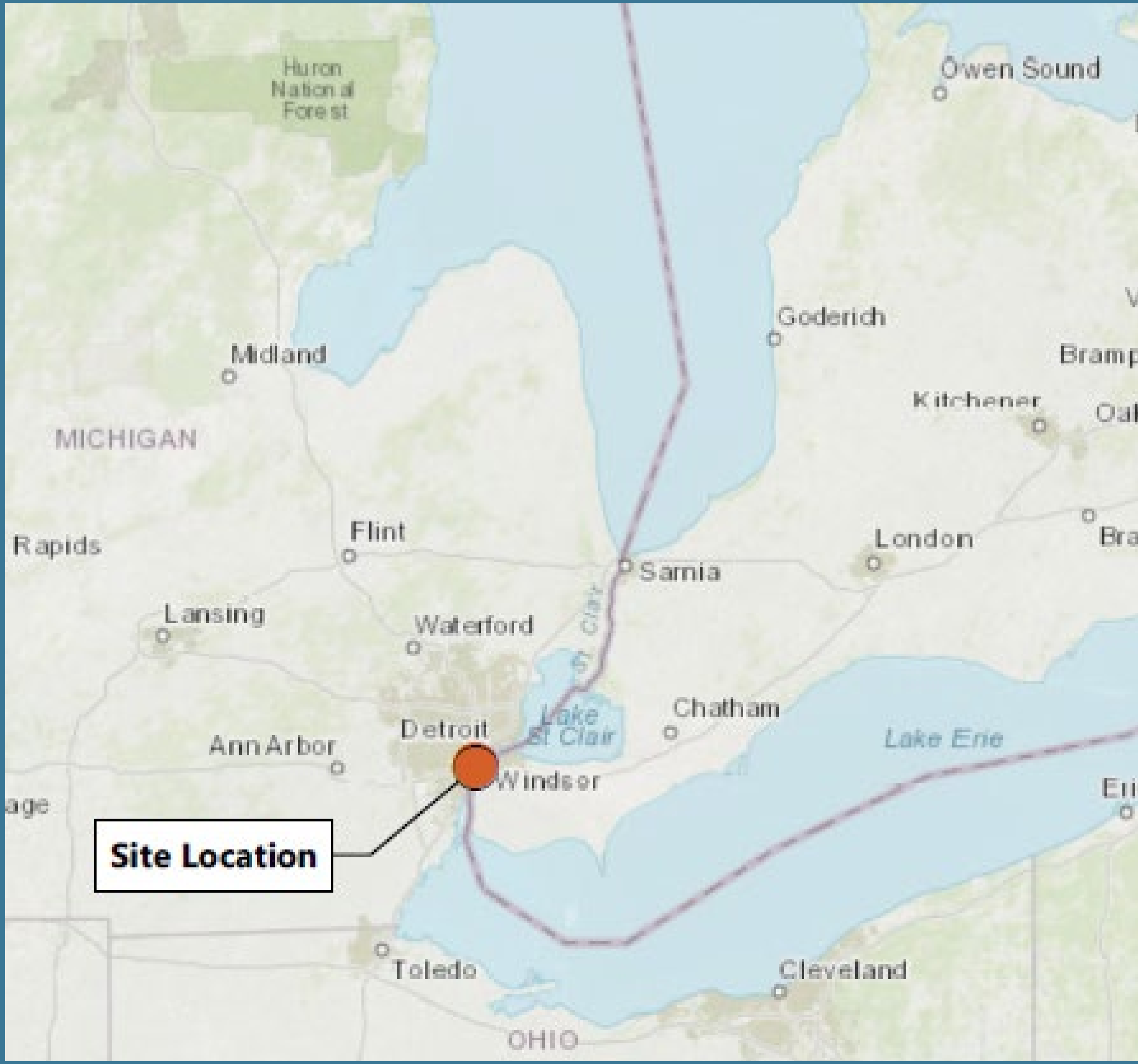
- Project objectives
- Investigation techniques
- Calculations/modeling

EXAMPLE 1

Estimate Groundwater Seepage Rate in Freshwater River Channel

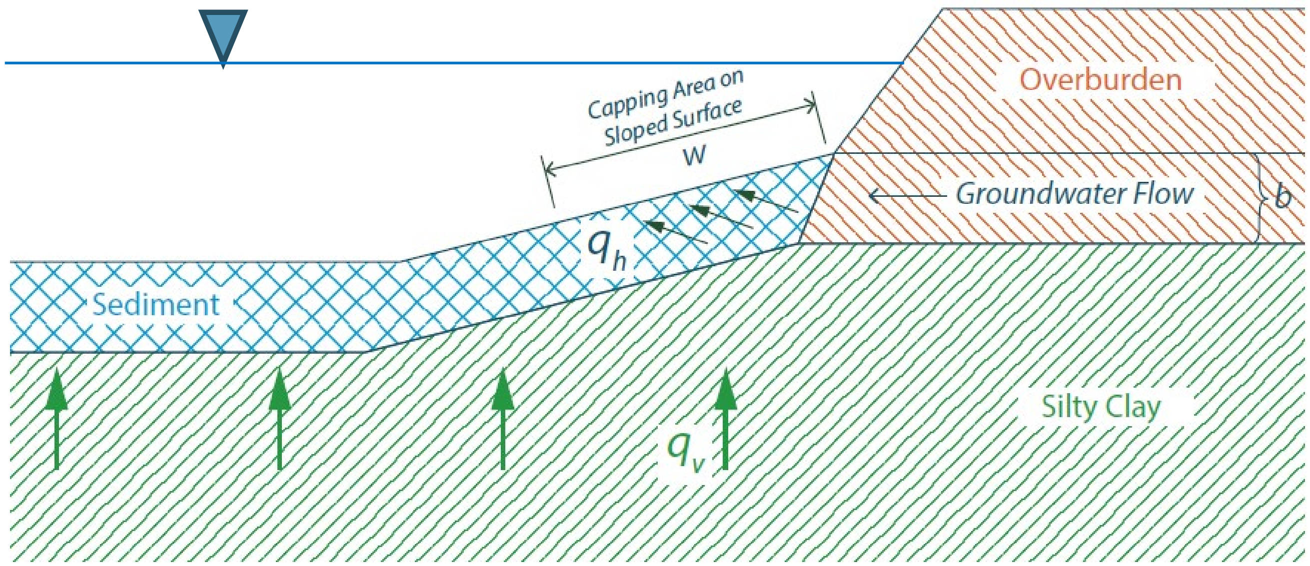
Project Objective: Estimate groundwater seepage rate to support design of remediation cap

Location: Lower Rouge River, Michigan



Seepage Rate in Freshwater River Channel

- Field Investigation
  - Upland borings, slug/pump tests, and GW and SW elevations; thermal study offshore
- Calculations/Modeling
  - Darcy's Law
  - Site geometry requires differing approaches by area

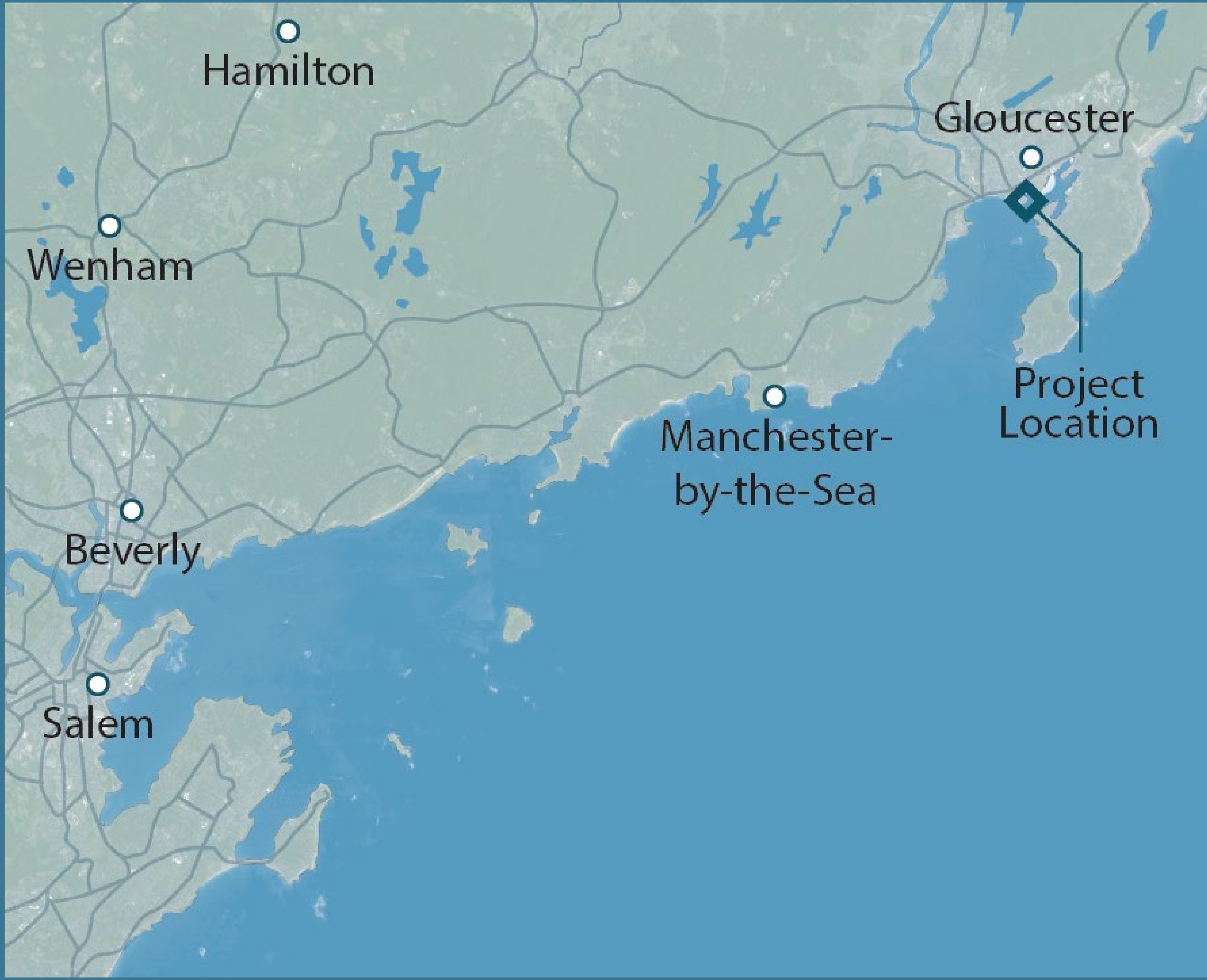


$$q_h = K_h \times i_h \times \frac{b}{w} = 10^{-3}\,\frac{cm}{sec} \times 0.01 \times \frac{20\,ft}{40\,ft} = 160\,\frac{cm}{year}$$

K_h = horizontal hydraulic conductivity
i_h = horizontal hydraulic gradient
b = saturated thickness
w = characteristic leakage length (Hunt et al. [2003]; Haitjema [2006])

EXAMPLE 2

Quantify Physical Transport Characteristics in Tidal Harbor

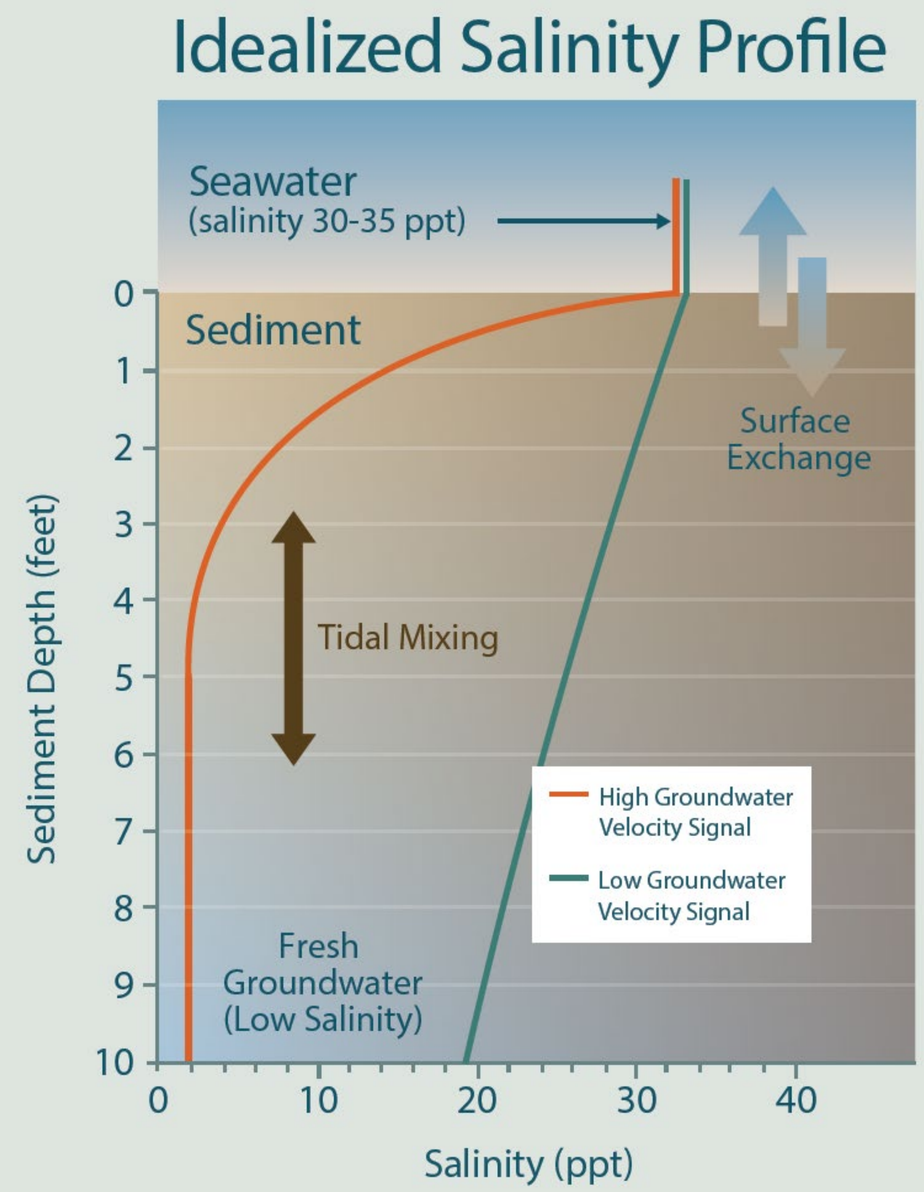


Project Objective: Quantify flow and tidal mixing in porewater to support sediment cap design

Location: Gloucester Harbor, Massachusetts

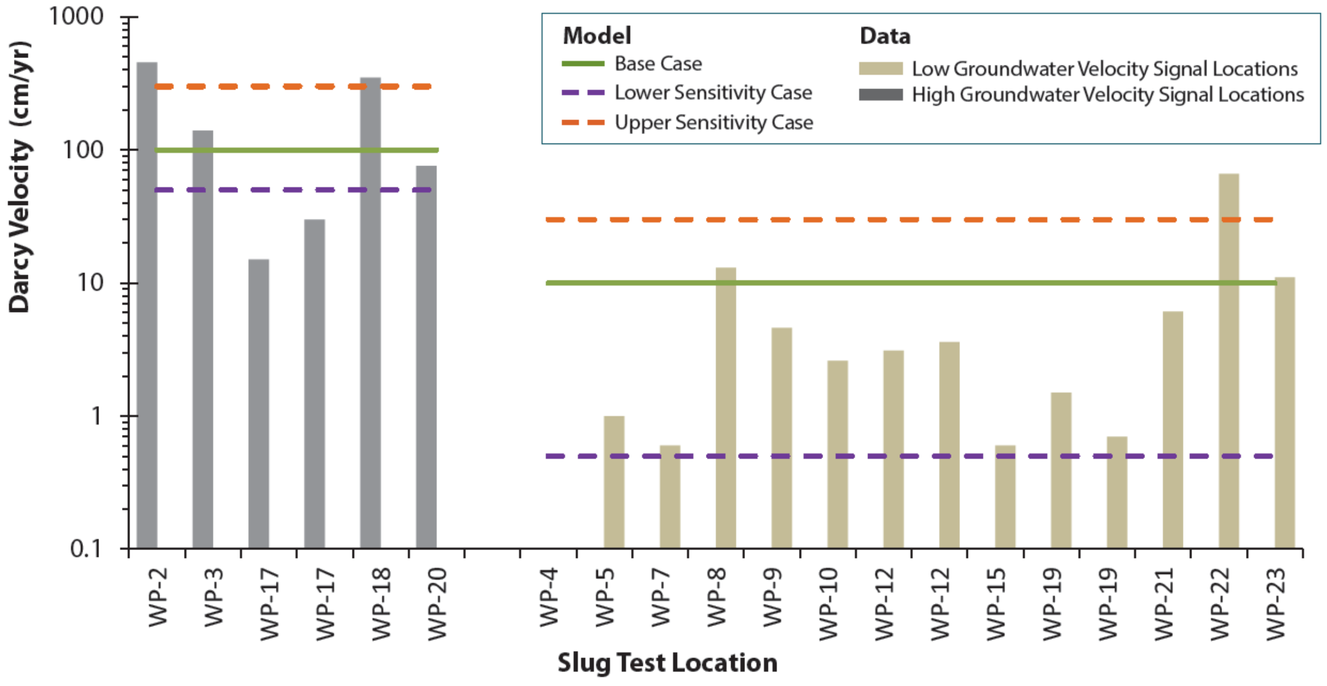
Field Investigation

- Offshore borings and monitoring wells
- Slug tests
- Water levels
- Detailed vertical profiles of porewater salinity



Calculations/Modeling

- 1D analytical solute transport model
- Calibrated seepage rate and tidal mixing to match salinity profiles
- Corroborated using Darcy's Law calculations from monitoring wells
- Developed range of bounding simulations



EXAMPLE 3

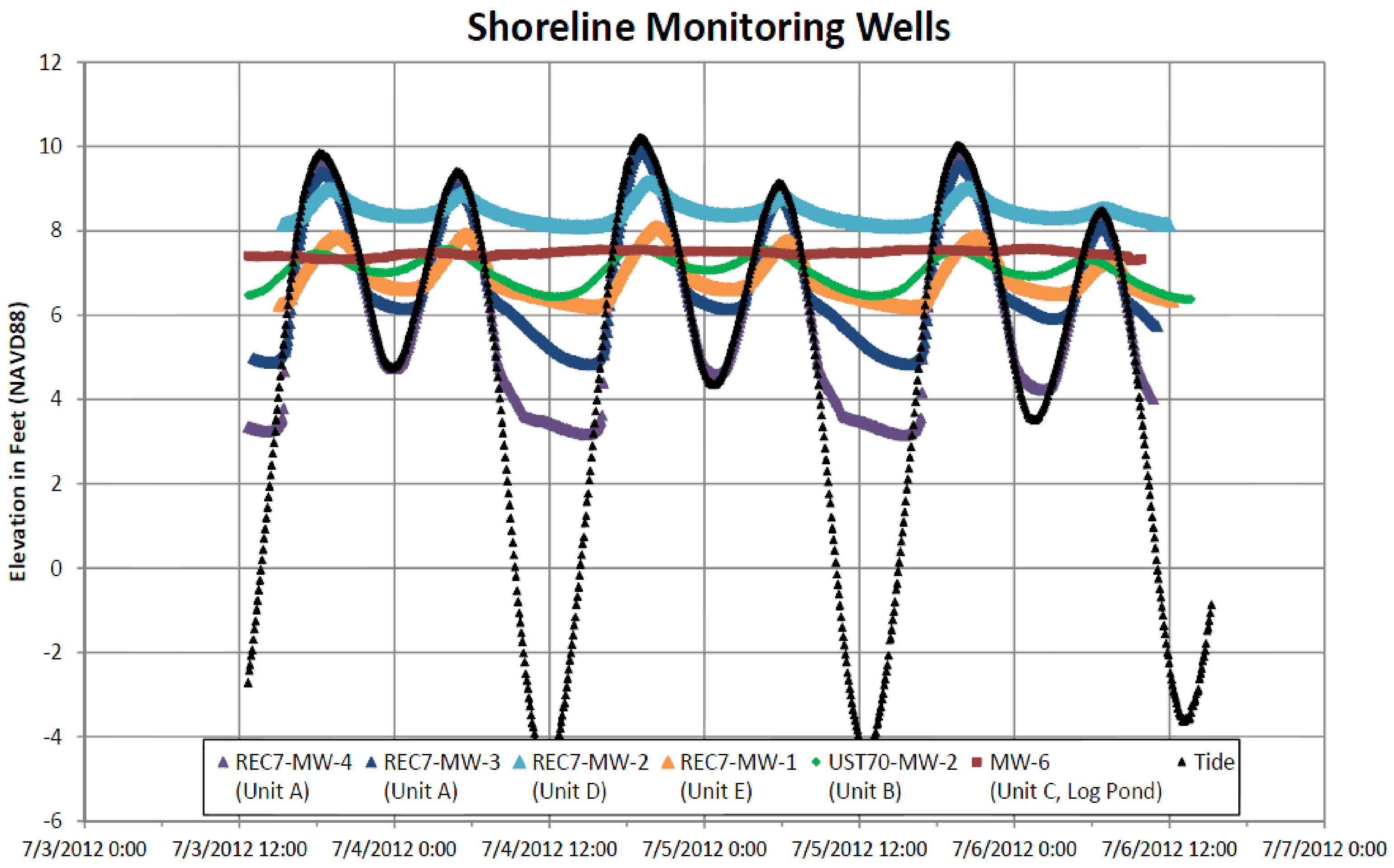
Evaluate Effects of Plume Discharge on Surface Sediments of Tidal Waterway

Project Objective: Quantify long-term concentrations in surface sediment porewater to support upland GW remedial design

Location: East Waterway, Washington

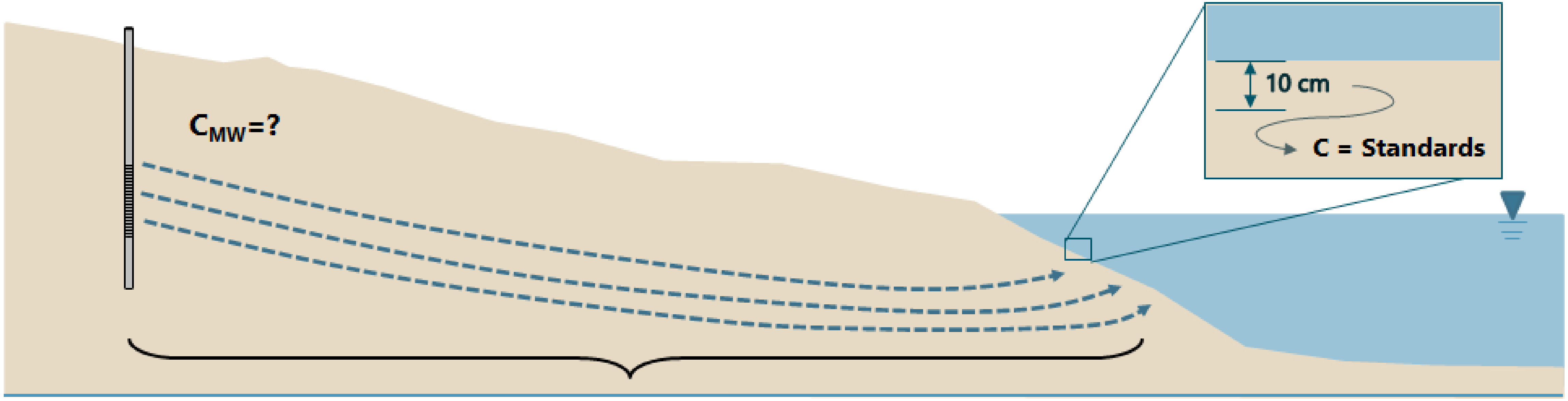
Field Investigation

- Upland lithology and slug/pump tests
- Piezometric surface and tidal elevations in GW and SW
- Contaminant concentrations (heavy metals) in GW and surface porewater



Calculations/Modeling

- 1D analytical solution for contaminant transport in GW and sediment/porewater system
- Iterative process to evaluate need for GW remediation and calculate GW to porewater attenuation factors



EXAMPLE 4

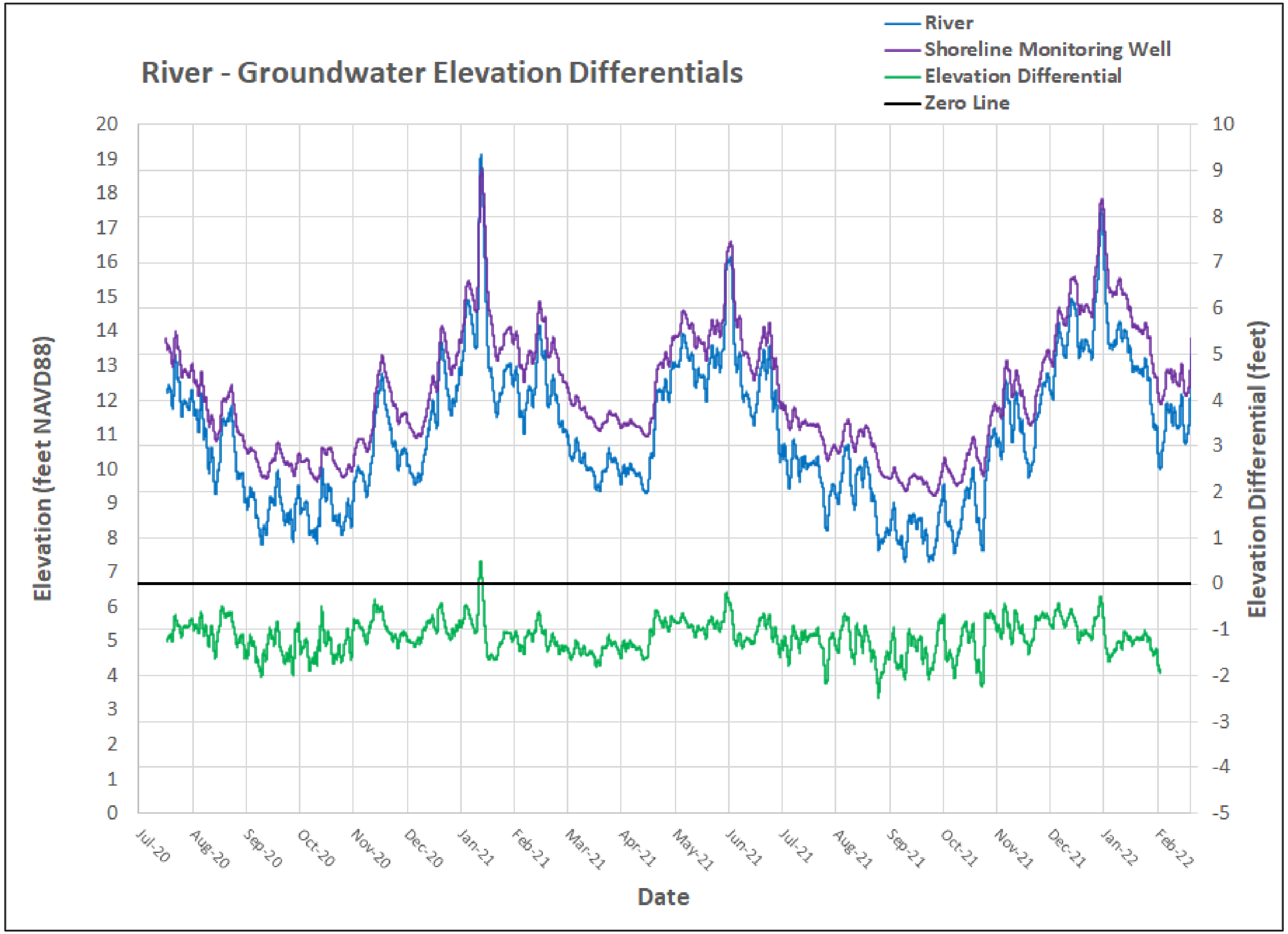
Predict Restoration Time Adjacent to a Dynamic River Delta

Project Objective: Quantify contaminant flux to two adjacent surface water bodies with differing hydrologic controls and predict GW restoration time

Location: High-energy river system in the Pacific Northwest

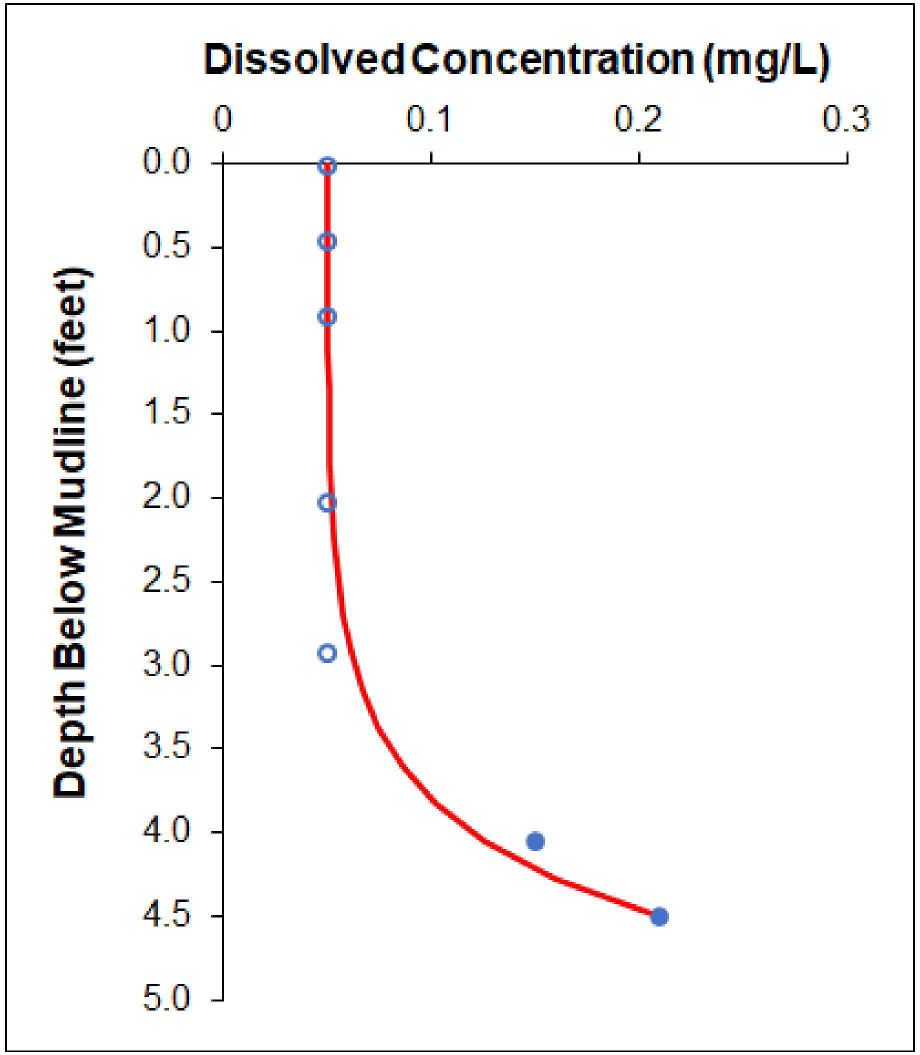
Field Investigation

- Network of hydrostatic pressure transducers in GW and SW
- Characterization of geochemical parameters
- Concentration profiles (inorganic ions) at 1-foot intervals in transition zone



Calculations/Modeling

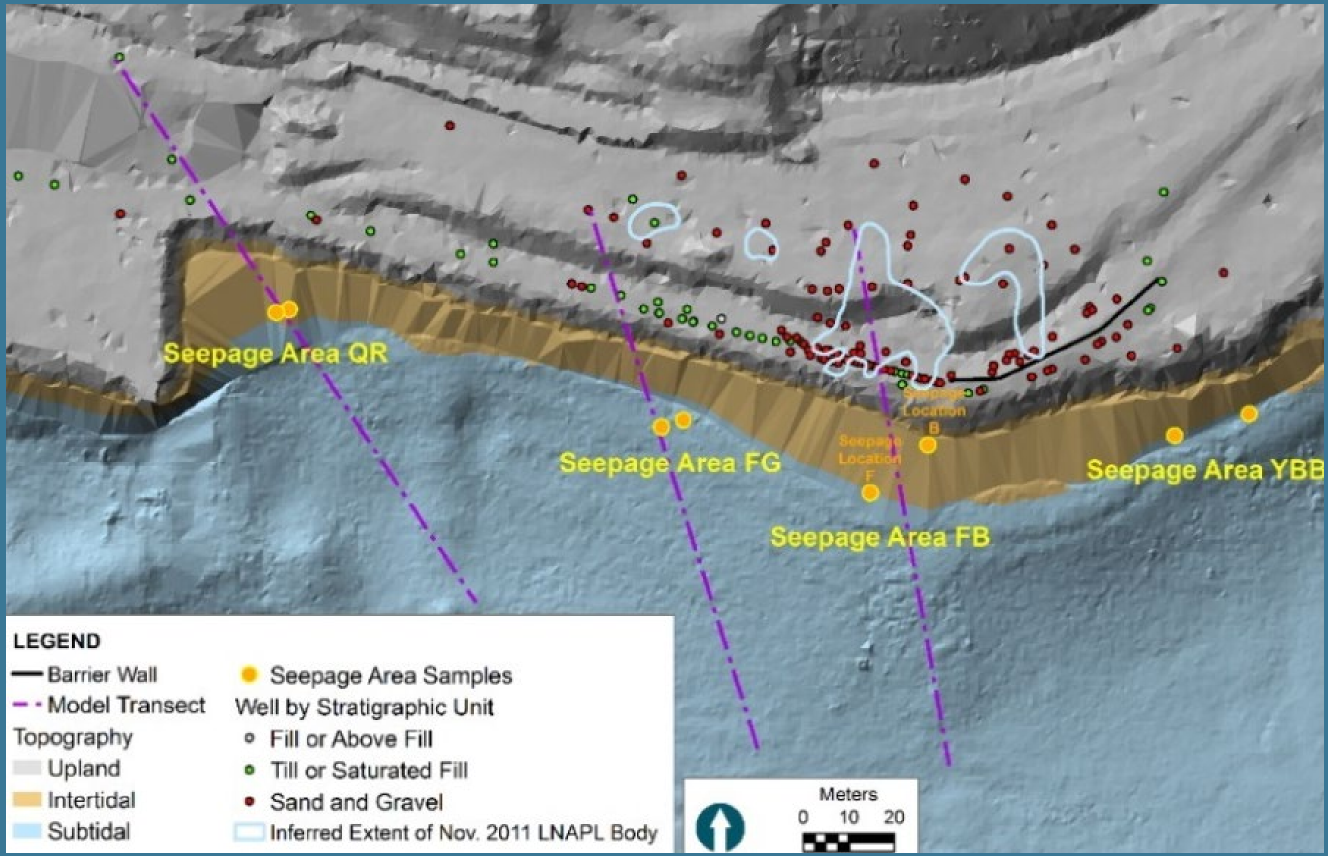
- Continuous hydraulic gradient calculations
- Sitewide 3D transient groundwater flow and reactive transport model paired with a local scale model of attenuation in the transition zone
- Used to evaluate GW restoration time frame



Simulation for downward advection rate of 0.01 foot per day

EXAMPLE 5

Evaluate Impacts from NAPL Plume on Adjacent Intertidal Area



Project Objective: Understand flux and pathways from upland LNAPL plumes to intertidal sediment/porewater, including spatial variations

Location: Tidal inlet adjacent to former refinery site in Western Canada

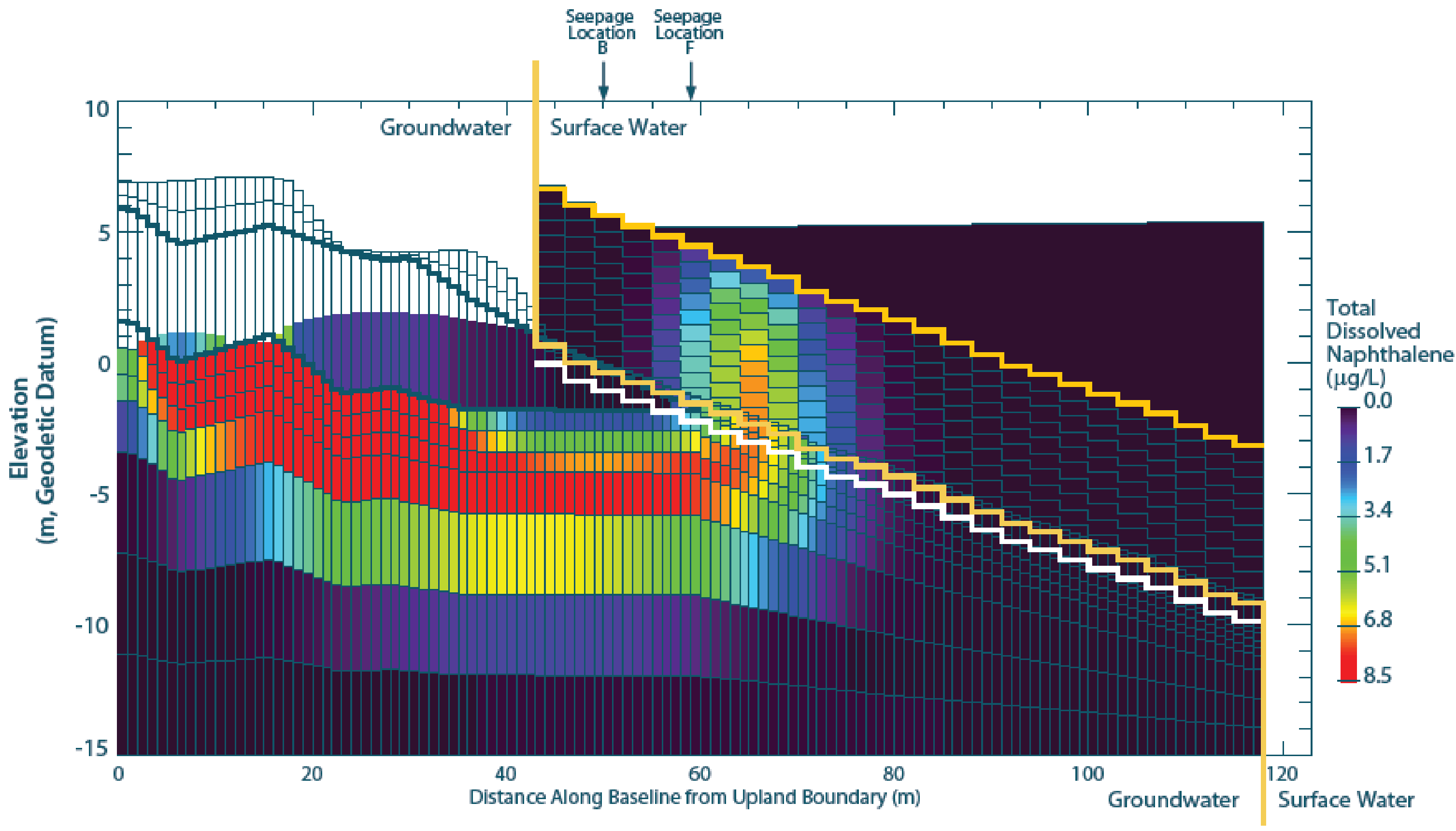
Evaluate NAPL Impacts on Intertidal Area

Field Investigation

- Borings, tidal GW levels
- Thermal seepage mapping, porewater sampling

Calculations/Modeling

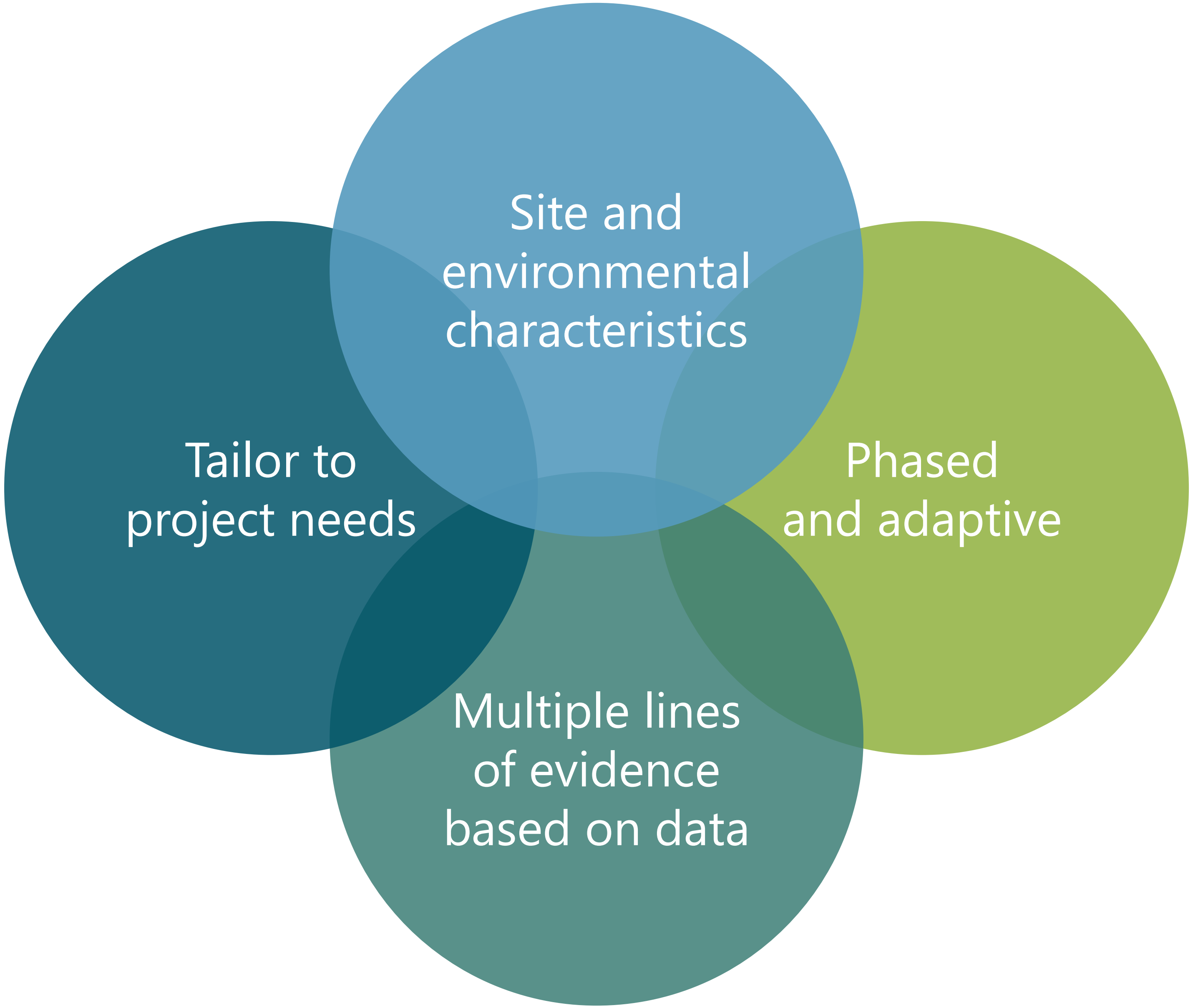
- 2D numerical linked flow and transport model
- Used to corroborate identified seepage zones and understand potential role of degradation



Source: Mugunthan, P., K. Russell, B. Gong, M. Riley, A. Chin, B. McDonald, and L. Eastcott, 2016. "A Coupled Groundwater-Surface Water Modeling Framework for Simulating Transition Zone Processes," *Groundwater* 55:302-315.

LESSONS

There is no singular approach to quantifying GW/SW interactions



THANK YOU

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REFERENCES

Haitjema, H., 2006. “The Role of Hand Calculations in Ground Water Flow Modeling,” *Groundwater* 44:786–791.

Hunt, R.J., H.M. Haitjema, J.T. Krohelski, and D.T. Feinstein, 2003. “Simulating Ground Water-Lake Interactions: Approaches and Insights,” *Groundwater* 41:227–237.

Mugunthan, P., K. Russell, B. Gong, M. Riley, A. Chin, B. McDonald, and L. Eastcott, 2016. “A Coupled Groundwater-Surface Water Modeling Framework for Simulating Transition Zone Processes,” *Groundwater* 55:302–315.

Rosenberry, D.O., C. Duque, and D.R. Lee, 2020. “History and Evolution of Seepage Meters for Quantifying Flow Between Groundwater and Surface Water: Part 1 – Freshwater Settings.” *Earth Science Reviews* 204(103167). DOI: 10.1016/j.earscirev.2020.103167.

Winter, T.C., J.W. Harvey, O.L. Franke, and W.M. Alley, 1998. *Ground Water and Surface Water: A Single Resource*. Denver, Colorado: U.S. Geological Survey.