Considerations for Modeling Contaminant Transport at Confined Disposal Sites

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Outline

- Overview of disposal options for contaminated dredge material
- Contaminant transport pathways at disposal sites
- Setting up long-term contaminant transport evaluation
- Case studies

Confined Disposal Facility

- "**Engineered structure** [...] that extends above any adjacent water surface and enclose a disposal area **for** containment of dredged material, **isolating the dredged material from adjacent waters or land**"
  - USACE Upland Testing Manual
- Disposal sites may be
  - Above water (CDFs)
  - In/under water (CADs)
  - Upland (upland CDFs)

Huron Harbor CDF
Source: USACE Great Lakes/Ohio River Division

Port Hueneme Confined Aquatic Disposal Site

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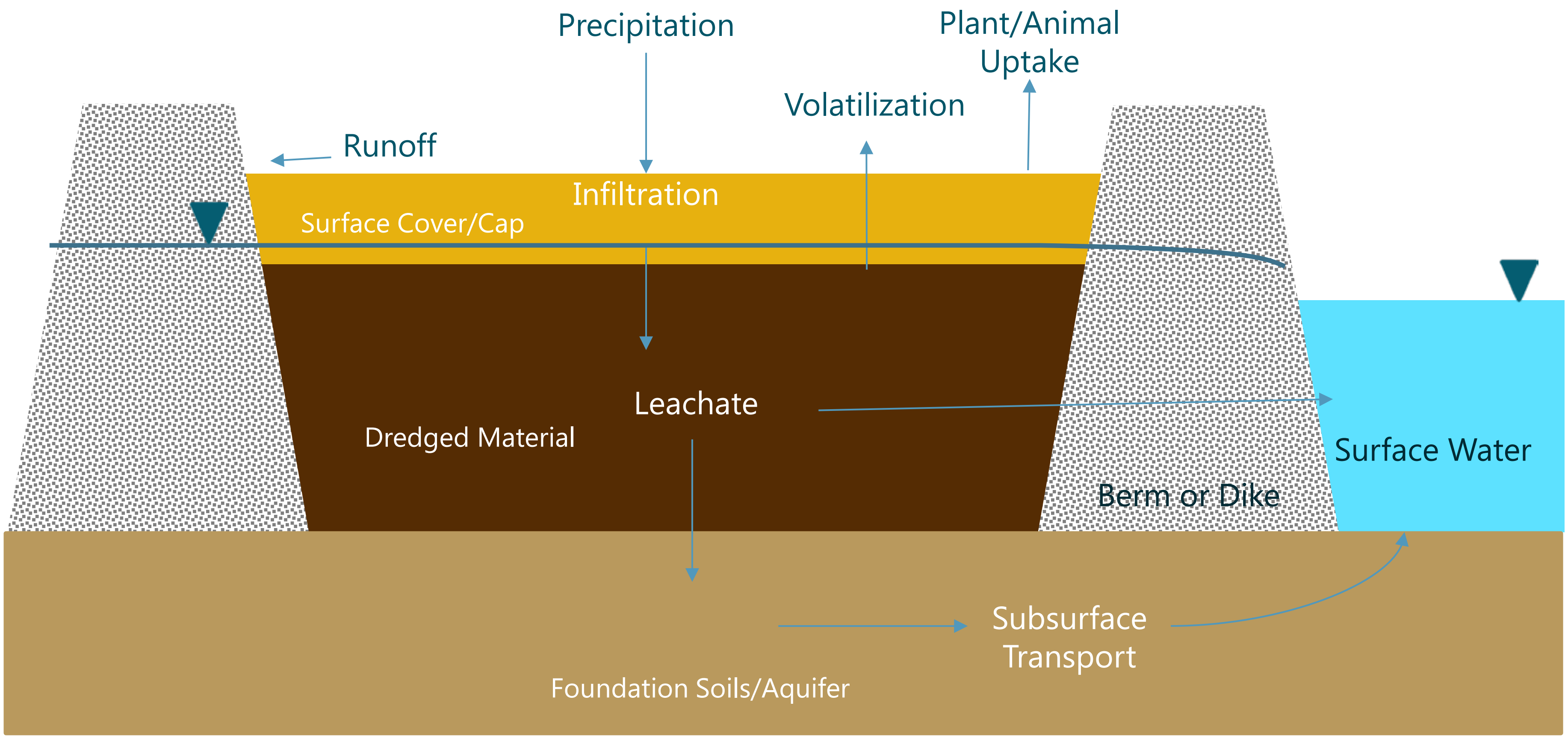
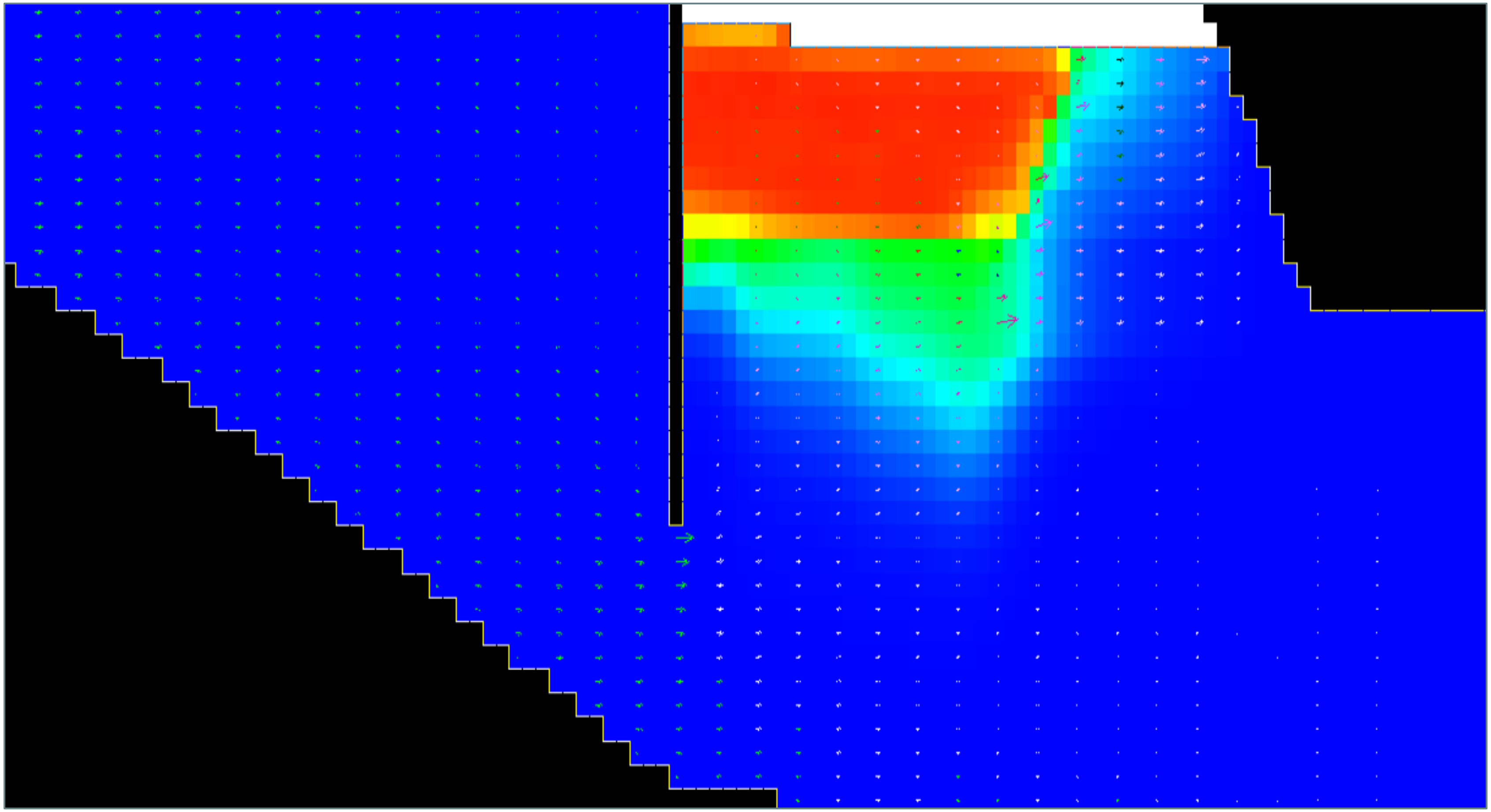
Contaminant Transport Pathways



Adapted from Upland Testing Manual (USACE 2015)

Modeling Contaminant Transport in Leachate



Key Considerations in Evaluating Contaminant Transport in Leachate

What's Inside?

- CDF construction
  - Physical dimensions of dredged material, fill etc.
  - Presence/absence of cover
  - Berm/dike properties
- Dredged material
  - Porosity/bulk density
  - Hydraulic conductivity
  - Organic carbon content
  - Contaminants of potential concern (COPCs)
    - Concentration
    - Solubility

What's Around?

- Local conditions
  - Groundwater gradient
  - Tidal conditions/river stage fluctuations
  - Flow barriers (e.g., sheetpile wall)
  - Precipitation
- Properties of underlying soil/aquifer
- Ecological and human health risk considerations

Defining Contaminant Transport Modeling Objectives

- Is a contaminant transport model needed?
  - Does dredged material concentrations and/or leachate testing indicate a potential risk?
  - Are other bounding calculations possible?
- What is the model being developed for?
  - Evaluate site suitability
    - Assess surface/groundwater resources impacts from COPCs
  - Support design of CDF
    - Potential amendments to dredge material/berm
    - Options on closure and cap
  - Effects of existing flow barriers or other structures

Model Selection

- Vertical transport to vadose zone
  - 1-D models are typically sufficient (for example, HELPQ [Aziz and Schroeder, 1999])
- Longitudinal and vertical transport to saturated zone
  - 2- or 3-D models maybe needed
  - Several groundwater contaminant fate and transport modeling frameworks are available
    - Examples, MODFLOW/MT3DMS family of models, MULTIMED suite of models

Selection of Spatial and Temporal Scales

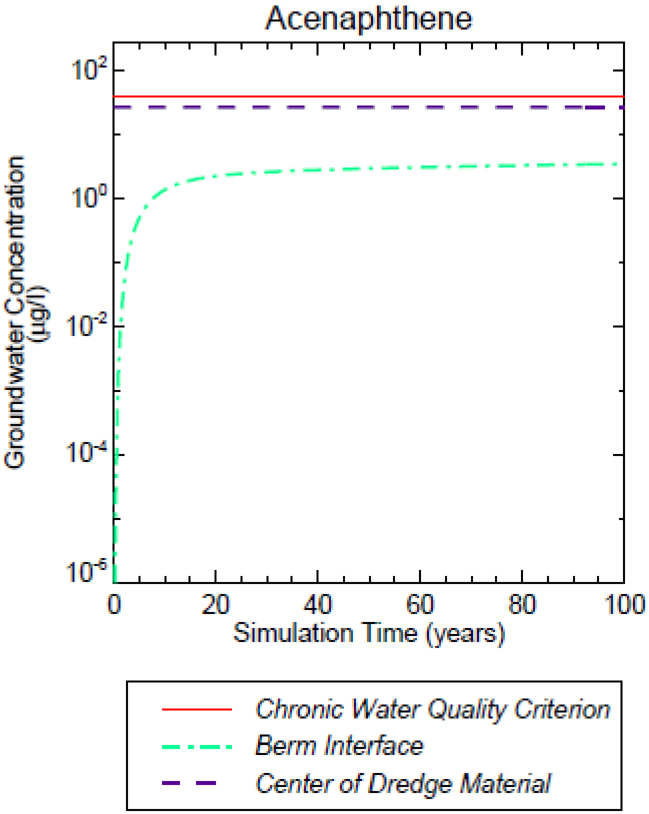
- Physical configuration of the CDF
- Operational life of the CDF
- Data availability for specifying boundary conditions
- Risk receptors
- Complexity of the selected modeling framework
- Transient or steady-state conditions
  - Steady-state flow conditions typically appropriate for long-term transport
  - Contaminant transport is evaluated until steady COPC concentrations are achieved at key exposure locations (for example, outer edge of the berm)

Process Resolution

- Groundwater transport
  - Upland gradient/inflows
  - Recharge/precipitation
  - Tidal mixing/river stage changes
- Partitioning
  - Equilibrium partitioning is the most common approach and usually provides conservative results
- Degradation
  - Dredge material typically anaerobic after CDF closure
  - Conservative/bounding simulations are performed without degradation

Interpreting Model Results

- Time series plots of contaminant concentrations at key locations (breakthrough plots)
  - When does the breakthrough occur?
  - Does it exceed any applicable standards over the time scale of interest?
- Sensitivity to key inputs
  - Dispersion
  - Degradation
  - Uncertain boundary conditions



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Recognizing Key Uncertainties in Modeling

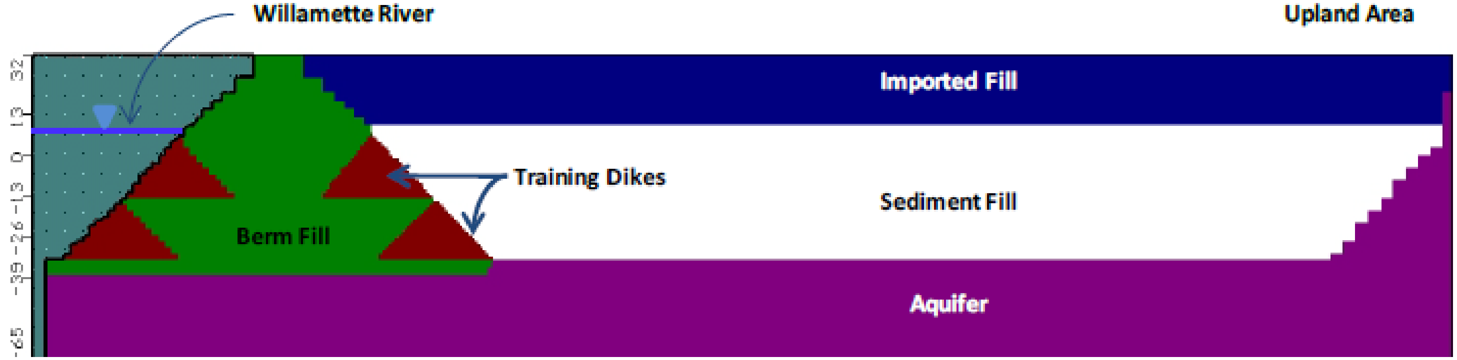
- Parameters are often uncertain or unknown
  - Site-specific estimates (for example, leachate testing conducted on dredged materials) could help reduce uncertainty
- It is seldom possible to calibrate a transport model for a CDF since it does not exist
  - Comparisons to past modeling efforts in similar settings
  - Conservative parameters to provide reasonable worst-case conditions
- Future conditions could change (for example, changes in long-term precipitation from climate change)
  - Sensitivity to reasonable alternative boundary conditions

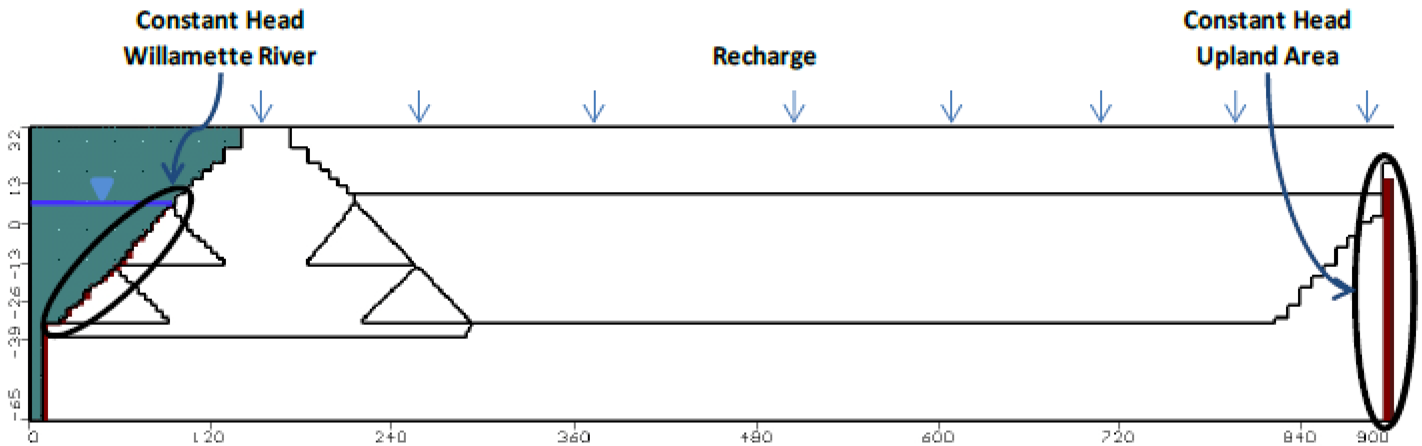
Case Studies

Portland Harbor – T4 CDF

- Background
  - Prospective disposal site for contaminated sediments from Portland Harbor Superfund site
  - COPCs include copper, PAHs, Total PCBs and DDx
  - CDF to be constructed in Slip 1
- Modeling objectives
  - Assess potential for contaminant migration from the CDF
  - Evaluate long-term protection of water quality in the Willamette River

Portland Harbor – T4 CDF: Model Summary



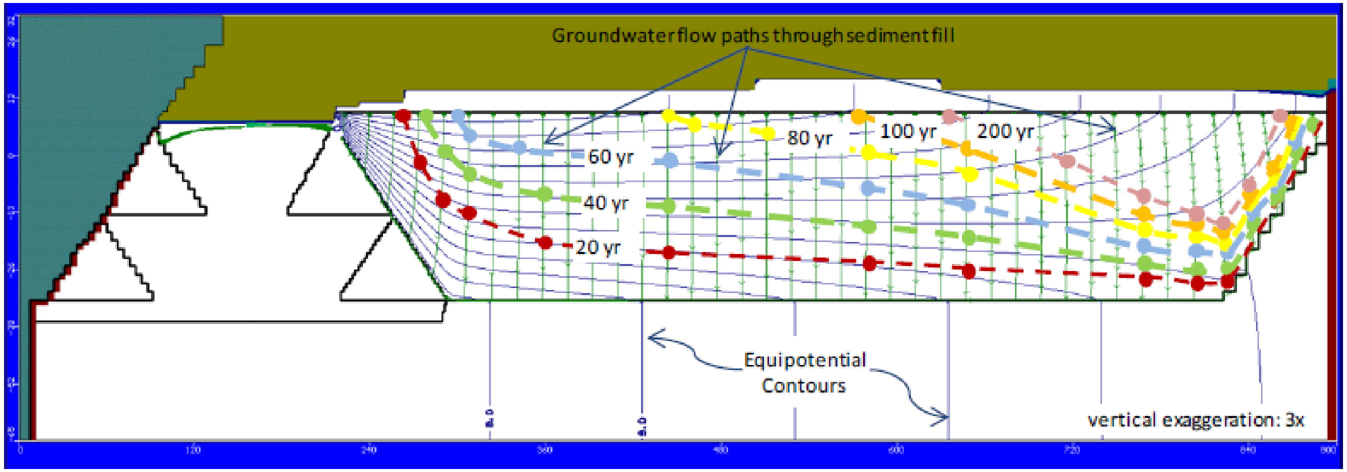


- MODFLOW/MT3DMS modeling framework
- 900-foot-long cross-sectional (2-D) model
  - 2 to 8-foot-long columns, 1 to 5-foot-thick layers
- Model simulations performed for 475 years (design seismic event return period)

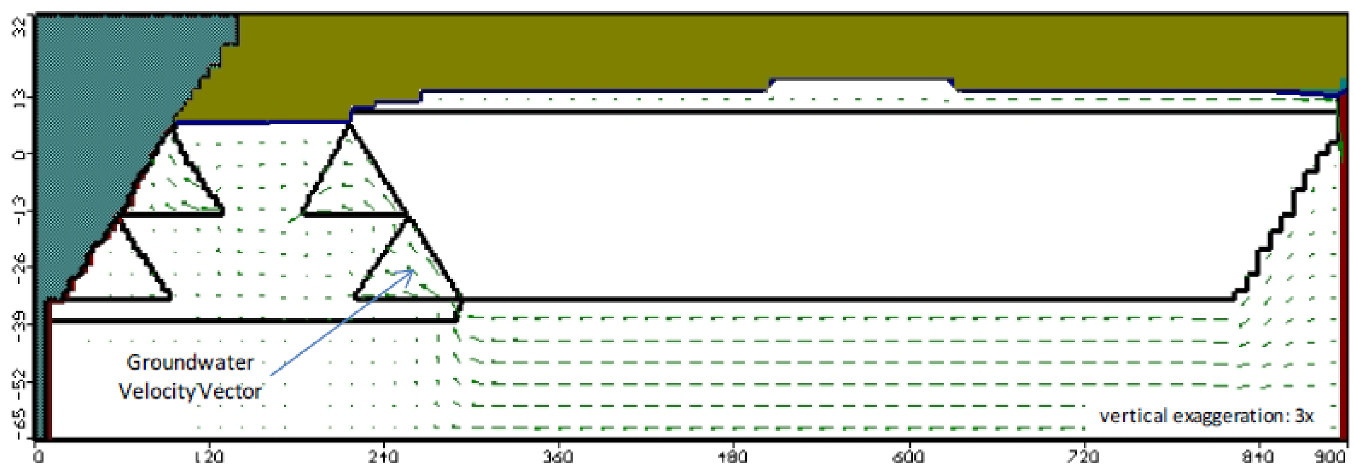
Portland Harbor – T4 CDF: Key Model Processes

- Dispersion
  - Tidal dispersion estimated from a transient tracer simulation and applied for long-term contaminant simulations
- Partitioning
  - Coefficients in dredge material from SBLT leachate concentrations
  - Coefficients in berm from literature
- Biodegradation
  - Anaerobic degradation in dredge material
  - Aerobic rates for berm
  - Values from literature

Portland Harbor – T4 CDF: Groundwater Flow

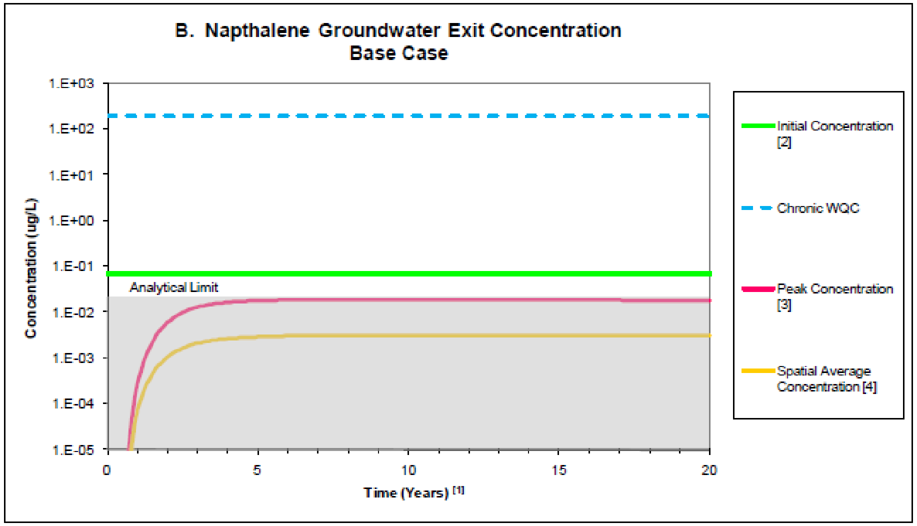


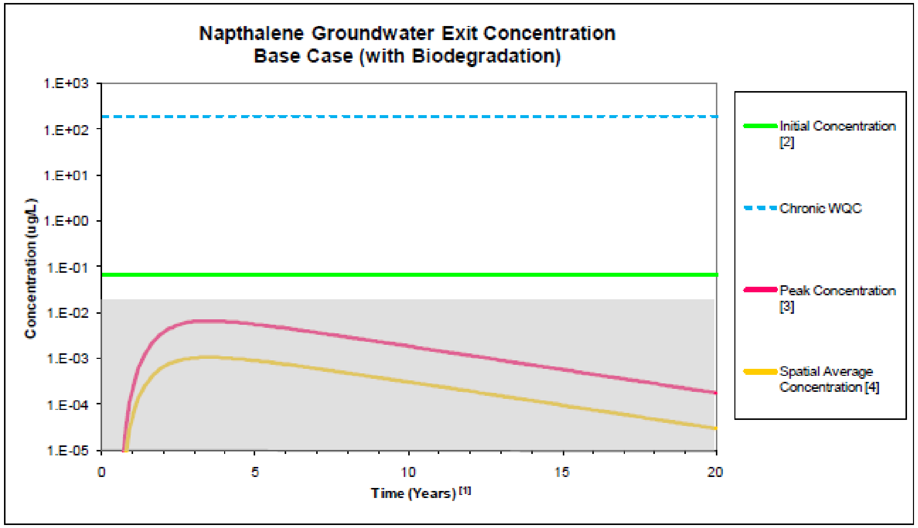
A. Groundwater Flow Paths and Residence Times

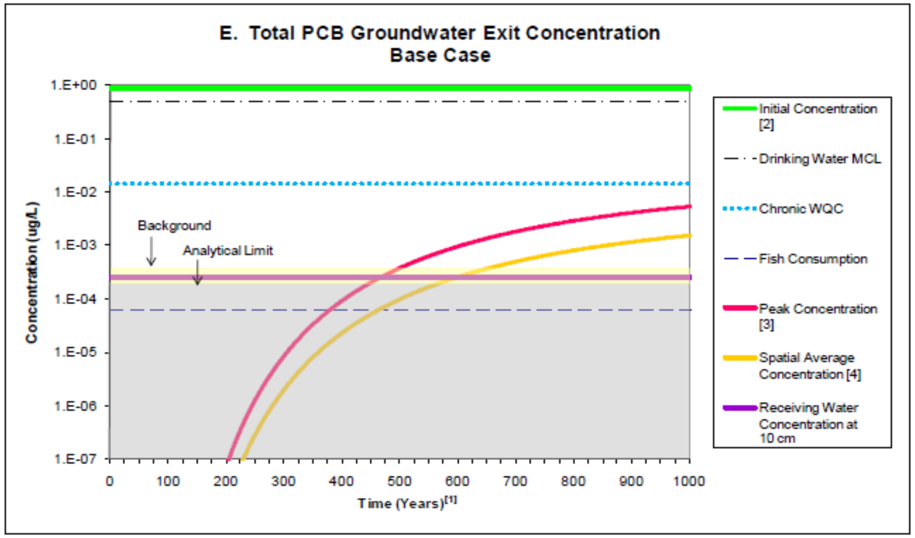


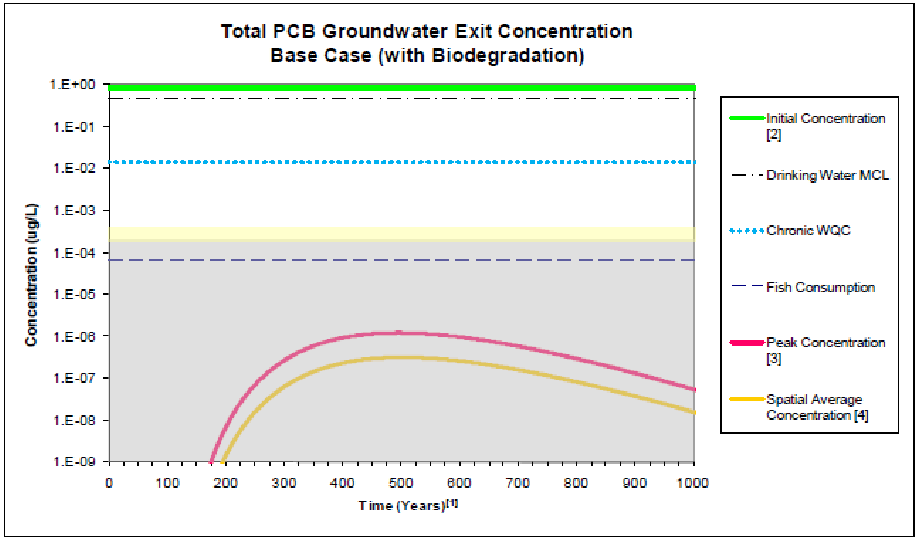
B. Groundwater Velocity Vectors

Portland Harbor – T4 CDF: Modeling Results









Portland Harbor - T4 CDF: Summary of Findings

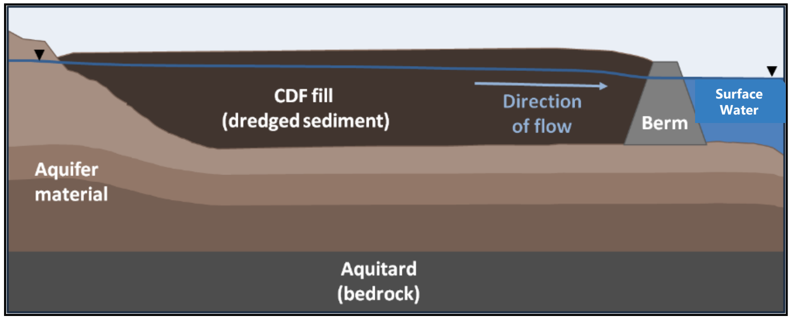
- Residence time in dredge material varied from 20 years (front of the CDF) to 200 years (upper rear portions)
- COPCs were predicted to remain below applicable water quality criteria for the 475-year design period for conservatively low biodegradation
  - Even for no biodegradation, all but one contaminant were below applicable water quality criteria
- Mass loading was estimated to be <0.01% of existing in-situ contaminant loads to river over the design period

CDF Design Support – Alcoa Baie Comeau, Quebec

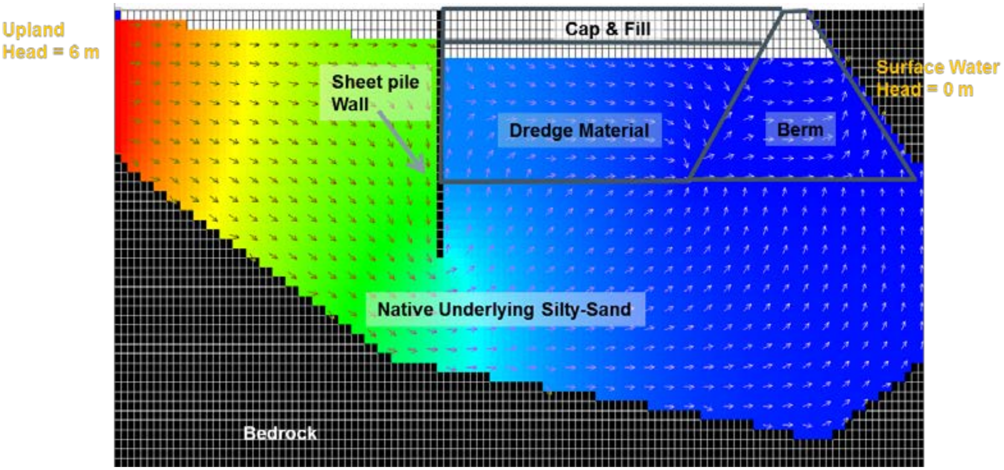
- Site background
  - Sediment contaminants include PAHs and PCBs
  - 50,000 m^3 of sediments to be dredged as part of site remedy
  - Tidally influenced surface water body
- Modeling Objectives
  - Support CDF effectiveness evaluation
  - Detailed evaluations to support design

Baie Comeau, Quebec: CDF Model Summary

- Processes simulated
  - Groundwater flow: MODFLOW
  - Contaminant transport: MT3DMS
    - Dispersion
    - Sorption
    - Partitioning
    - Degradation
- Model parameters based on:
  - Site data
  - Past experience / literature

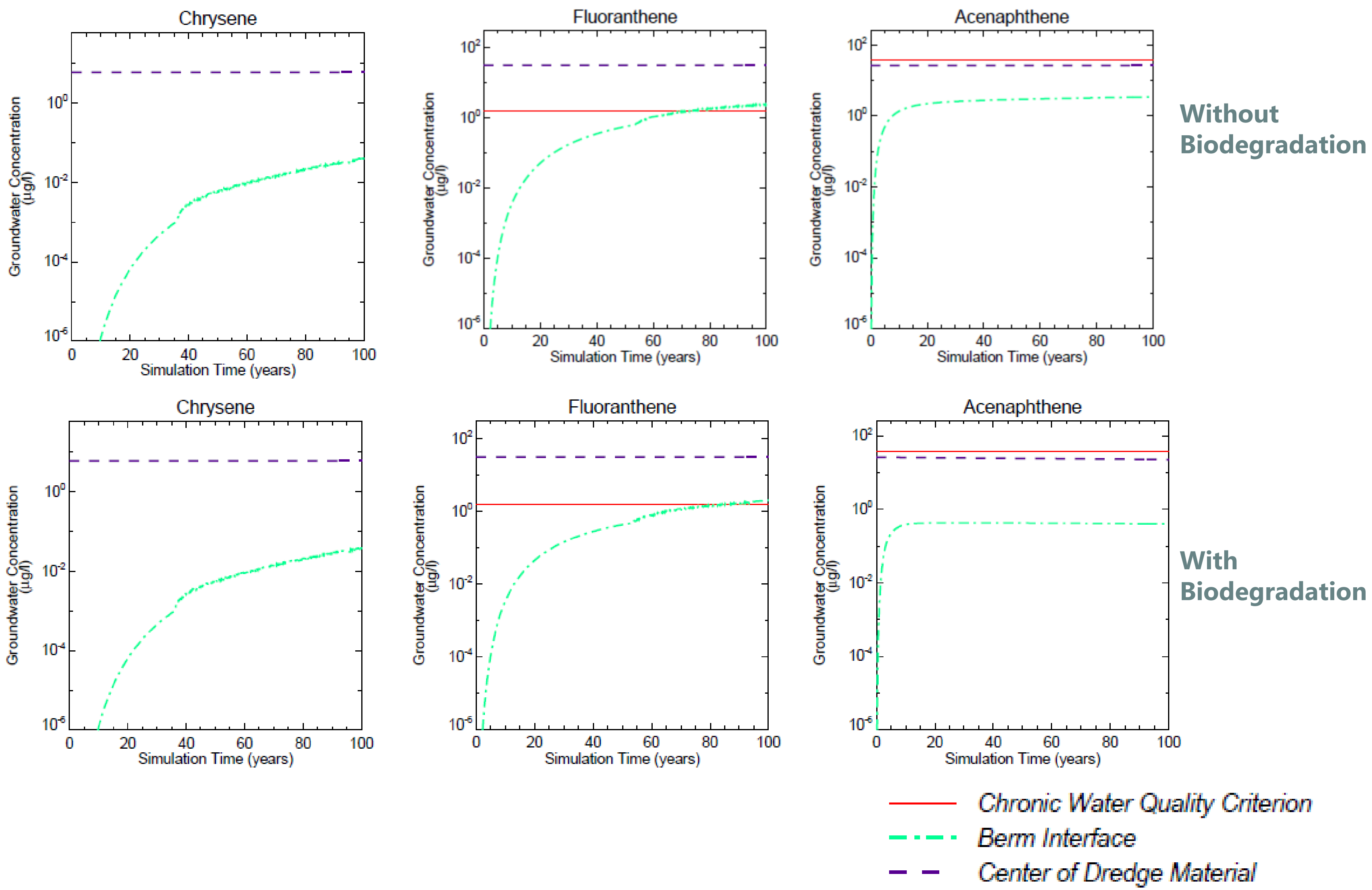


Conceptual Model of Flow and Transport in CDF



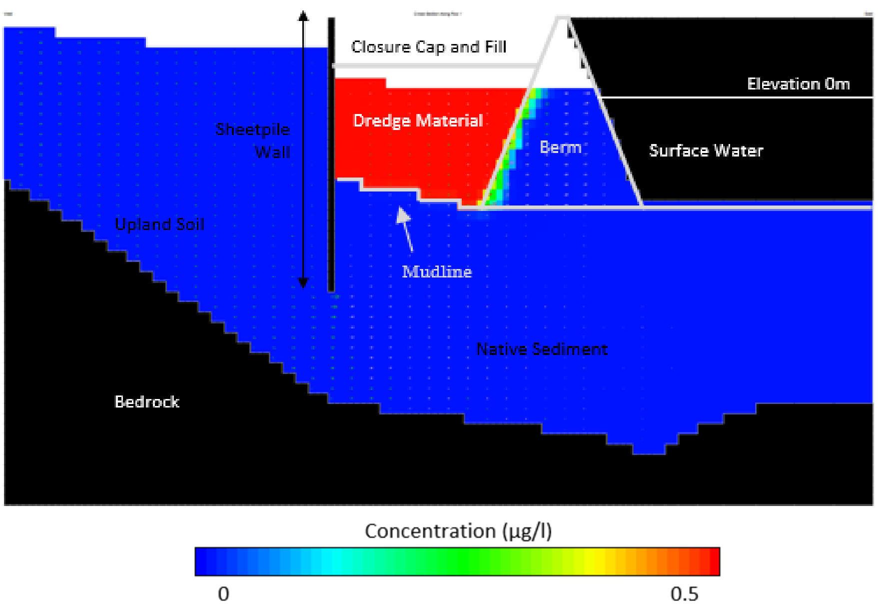
Model grid and Steady-state Flow Vectors

Baie Comeau, Quebec: CDF Model Contaminant Transport Results

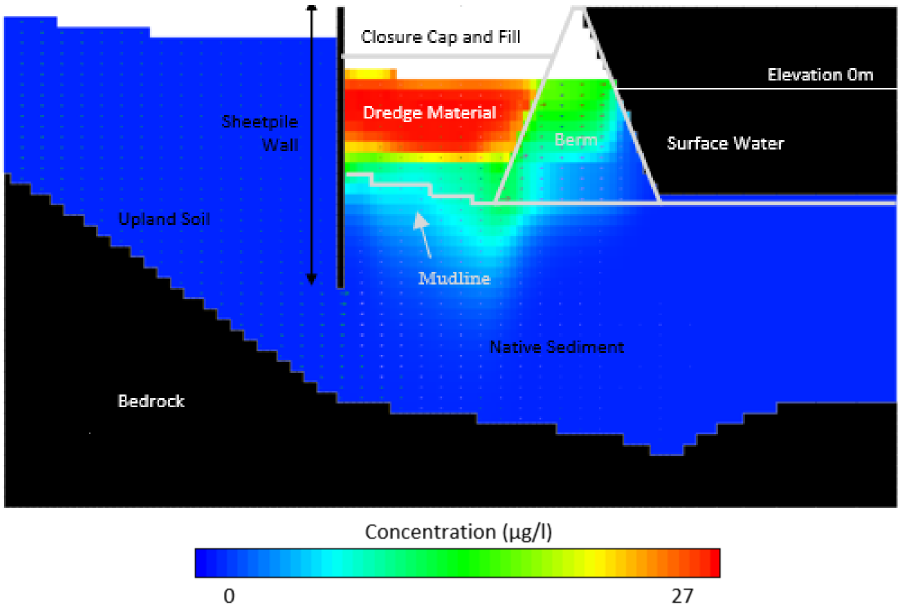


Baie Comeau, Quebec: CDF Modeling Results - Effect of Contaminant Sorption

Total PCBs (log *Koc* = 5.8)



Acenapthene (log *Koc* = 3.9)



Concentrations shown at the end of 100 years

Baie Comeau, Quebec: Summary of Findings

- 1 to 2 orders of magnitude dilution at the outer edge of the berm at steady-state
  - Relative to the porewater concentration in dredge material
- Simulations with degradation showed some reduction in COPC concentrations at the berm
  - Effect dependent on anaerobic degradation rate of COPC
- One COPC showed a potential to exceed chronic water quality criteria
  - Amendments to dredge materials to limit mobility may be evaluated in the design phase

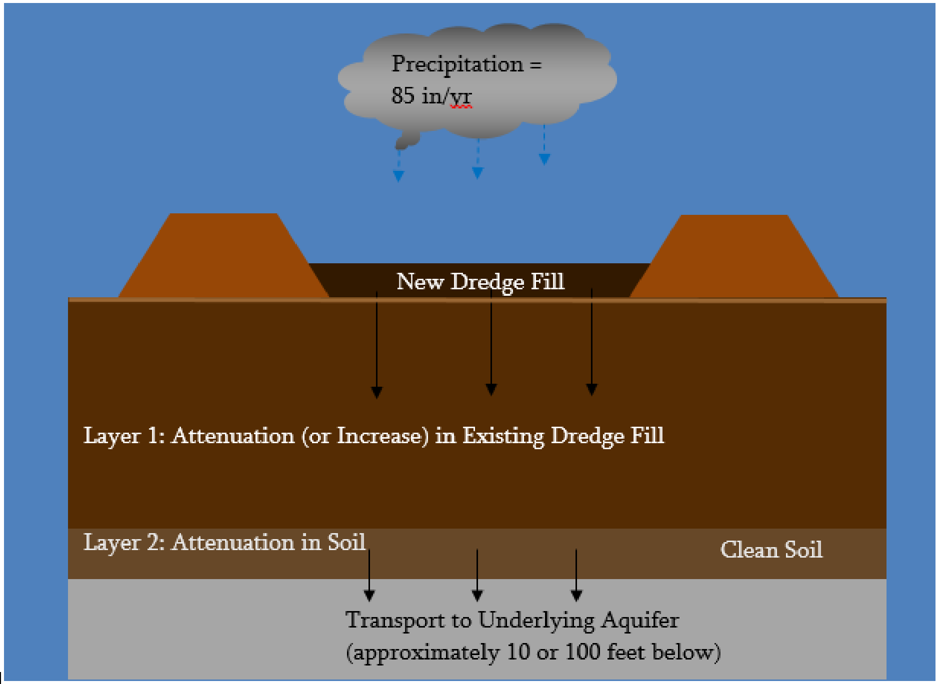
Guam – Field 5N and Orote Point CDFs

- Background
  - Sediments from maintenance dredging in the Inner Apra Harbor to be placed over foundation soils/existing material
  - Orote Point CDF is approximately 100 feet above MSL
  - Field 5N is approximately 10 feet above MSL
  - Underlying aquifer is not potable
  - COPCs include pesticides, metals PAHs and PCBs
- Modeling Objectives
  - Evaluate risk of leachate migration to underlying aquifer
  - Support evaluation of alternative placement options

Source: Google Maps

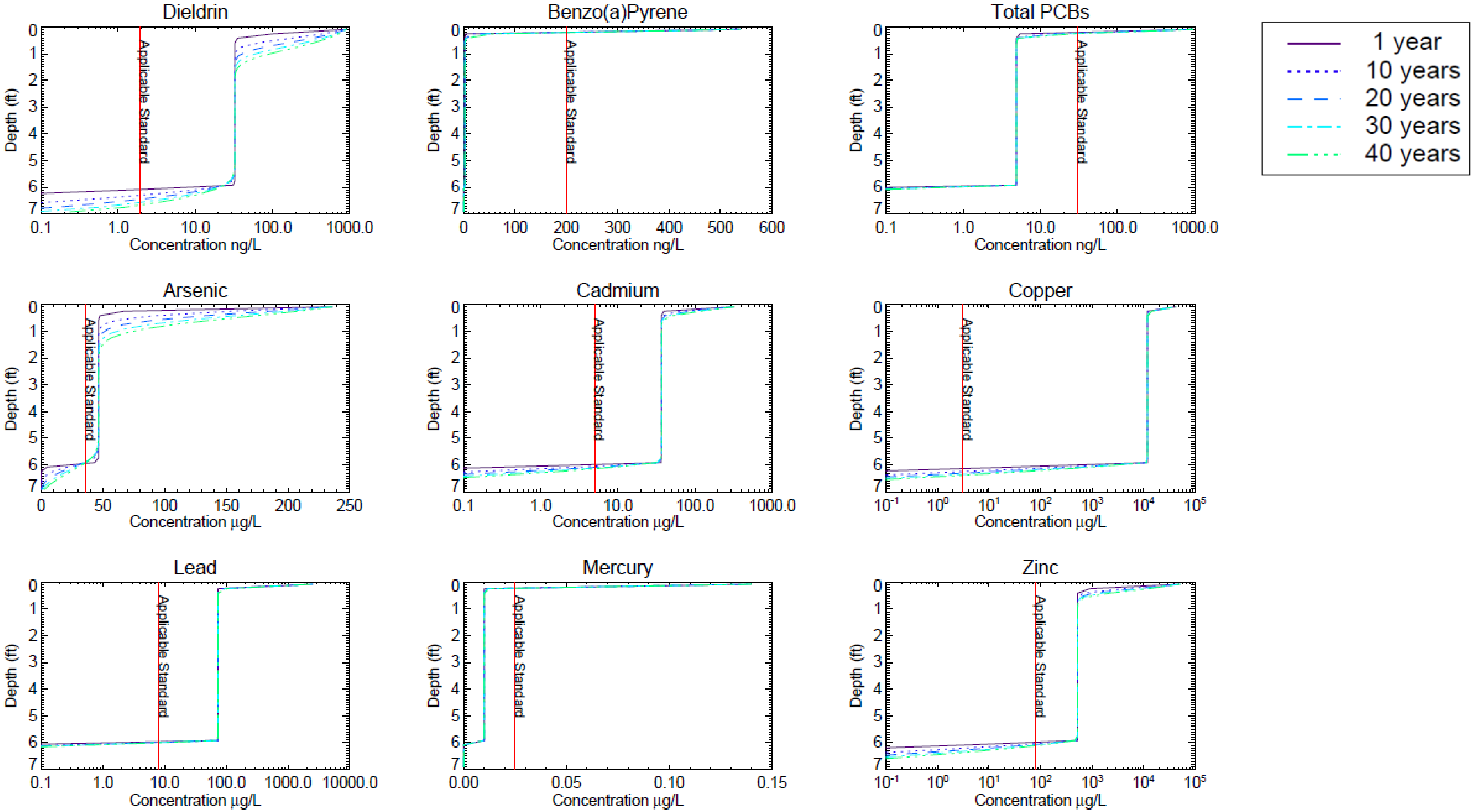
Guam – Field 5N and Orote Point CDFs: Modeling Approach

- Precipitation is the primary contributor to flow within and out of CDF
  - Both CDFs above water table
- 1-D model to evaluate vertical migration
  - Assumes saturated conditions at all times (worst-case analysis)
- Key processes simulated
  - Recharge
  - Partitioning in existing dredge material and foundation soils
- Model parameters based on site-specific data (dredge material properties) and literature (partitioning coefficients)

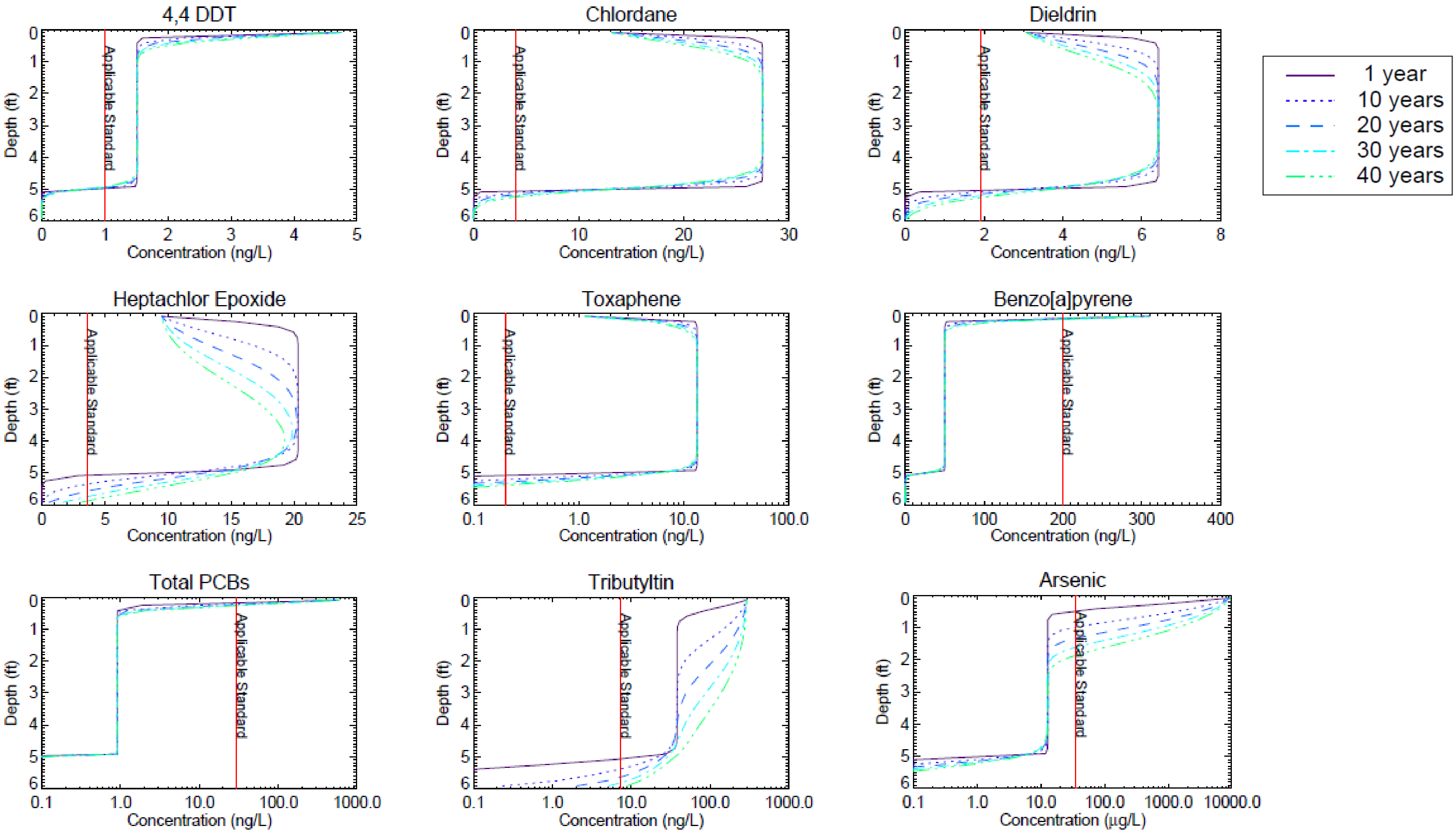


Conceptual Model of Attenuation in Soils and Existing Dredge Material

Guam – Orote Point CDF Modeling Results



Guam – Field 5N CDFs Modeling Results



Guam CDFs: Modeling Summary

- A 1-D approach was useful in screening for COPCs that could exceed applicable standards
- Approach is a worst-case analysis since it considers saturated conditions at all times
- Existing conditions largely result in attenuation of contamination below applicable standards
- Concentrations in existing dredge material in some areas is uncertain
  - Higher detection limit in past sampling events

Conclusion/Summary

- Modeling can evaluate contaminant migration and inform design
- Simplifying calculations and 1-D models can be effective screening tools
- Contaminant properties and boundary conditions should be selected to provide conservative estimate of transport
  - Sensitivity analysis can be an effective approach to inform decision makers on inherent uncertainties

Questions/Discussion