Apply integrated models to evaluate sediment cap effectiveness

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Objective

- Integrate GFLOW 2000 and 1-D fate & transport model to evaluate the effectiveness of capping
- Focusing on modeling approaches and concepts rather than the specific merits of the project or outcome of the study
GFLOW 2000 (Haitjema software)

- analytic element model solves conjunctive steady state groundwater and surface water flow
- allows display of binary base maps for streams, lakes, roads, legal boundaries, etc.
- streams and lakes are represented by strings of line-sinks with each assigned a head that is set equal to the water level in the stream or lake
Step 1: Get a binary base map of the model area into GFLOW

http://www.epa.gov/ceampubl/gwater/whaem/us.htm
Step 2: Annotate the base map with water levels. Add test points.
**Step 3**: Decide on a conceptual model

Conceptual model of a stream with a bottom resistance layer.
Cross section over the aquifer and the line-sinks representing the stream.
A stream modeled by two line-sink strings on either stream boundary.
Step 4: Decide what part of the model area is near-field and what part is far-field

The **near field** of the model area is the area of interest. In the near field the hydrography is represented by line-sinks in a relatively high resolution.

The **far field** of the model is the area with hydrologic features that surrounds the actual area to be modeled (near field). The far field hydrography is represented by line-sinks in a relatively low resolution. The purpose of the far field line-sinks is to form a boundary for the model area.
Step 5: Creating line-sink in the near-field and far-field
Step 6: Define inhomogeneity properties
Step 7: Enter estimated aquifer properties in GFLOW

- **Aquifer Properties**
  - Base Elevation: 330 feet
  - Thickness: 400 feet
  - Hydraulic Conductivity: 50 feet/day
  - Porosity: 0.2 [dimensionless]

- **Interface Flow**
  - Add a Saltwater Interface
  - Fresh Water Specific Gravity: 1
  - Salt Water Specific Gravity: 1.035
  - Average Sea Level: 0 feet
Step 8: Run the model & presenting results
Step 9: Calibrate the model
Step 10: Obtain the groundwater discharge vector
5.32 ft²/d / 580 ft
= 0.0092 ft/d
= 0.28 cm/d
1-D Fate & Transport Model

- a beta version of sediment cap evaluation model
- based on the analytical solutions (Freijer et al. 1998) of the convection-dispersion transport equation

\[ R \frac{\partial C}{\partial t} = D \frac{\partial^2 C}{\partial z^2} - v \frac{\partial C}{\partial z} - R k C \]

- describes fate and transport of pollutant in contaminated sediment over-laid by a clean cap
Processes Considered in Modeling

- 1-D advection and dispersion through the liquid phase
- sorption to the solid phase
- biological degradation
Assumptions

- the water content, flow velocity, and dispersion coefficient are constant
- advection and dispersion occur only in a vertical direction
- the retardation factor is independent of the concentration
- transformations in the liquid and solid phases occur at the same rate
Initial Conditions:

\[ C(z,0) = C_0, \quad -l < z \leq 0 \]
\[ C(z,0) = 0, \quad 0 < z < \infty \]
Boundary Conditions

- the groundwater is free of contaminant
- there is no concentration gradient at infinite distance
Spatial Concentration Profile after 1E-99 years

Mass Fraction Remains in Sediment is 99.94%
Spatial Concentration Profile after 3 years

Mass Fraction Remains in Sediment is 75.92%
Spatial Concentration Profile after 1E-99 years

Mass Fraction Remains in Sediment is 99.94%
Spatial Concentration Profile after 3 years

Mass Fraction Remains in Sediment is 100.00 %
Conclusion

• demonstrated the sensitivity of groundwater discharge in sediment cap performance

• illustrated the need to carefully monitor the groundwater surface water interaction at capping sites

• knowledge of the regional hydrologic interactions is essential for local sediment cap effectiveness to be evaluated correctly