Apply integrated models to evaluate sediment cap effectiveness

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Objective

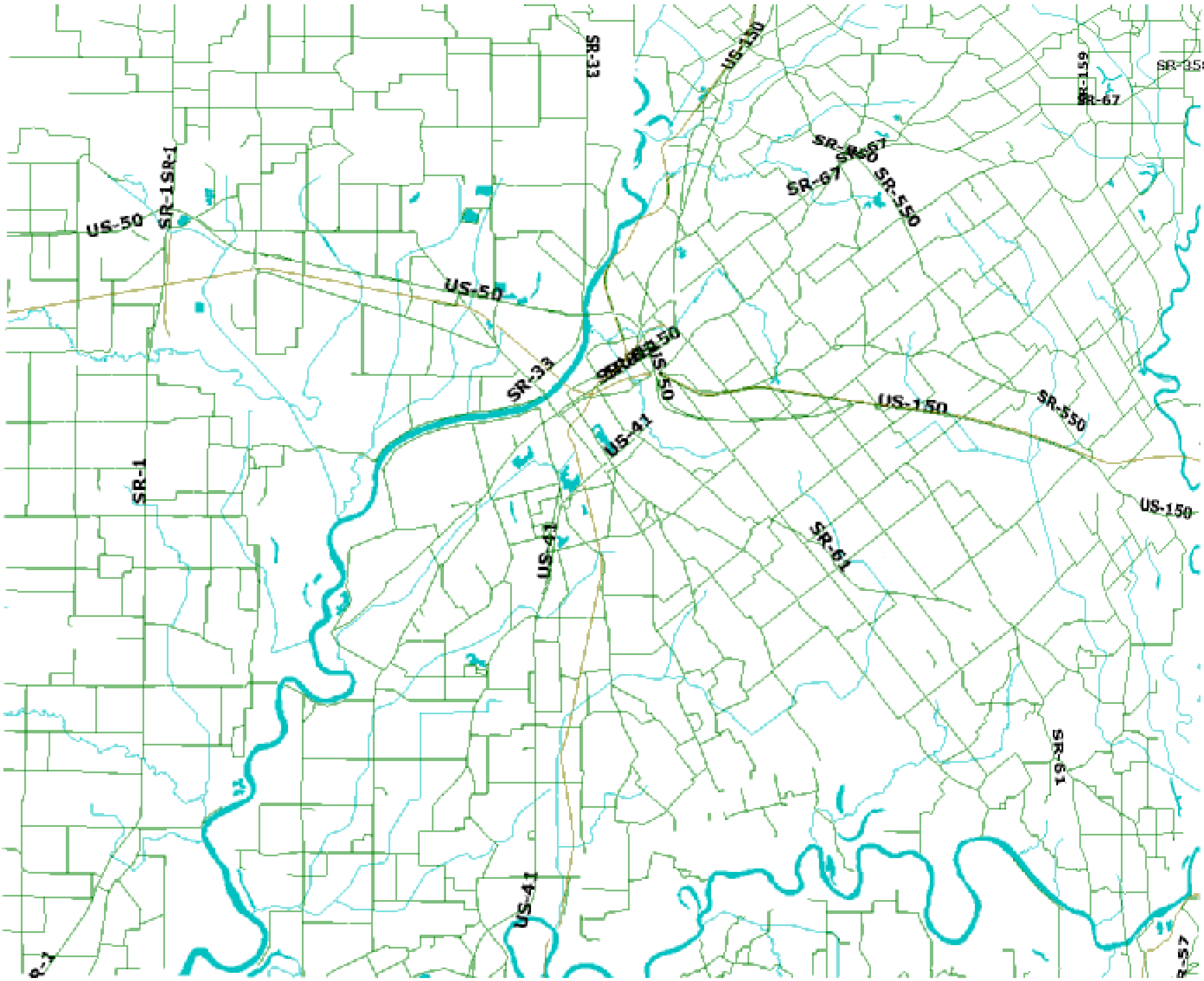
- Integrate GFLOW 2000 and 1-D fate & transport model to evaluate the effectiveness of capping
- Focusing on modeling approaches and concepts rather than the specific merits of the project or outcome of the study

GFLOW 2000 (Haitjema software)

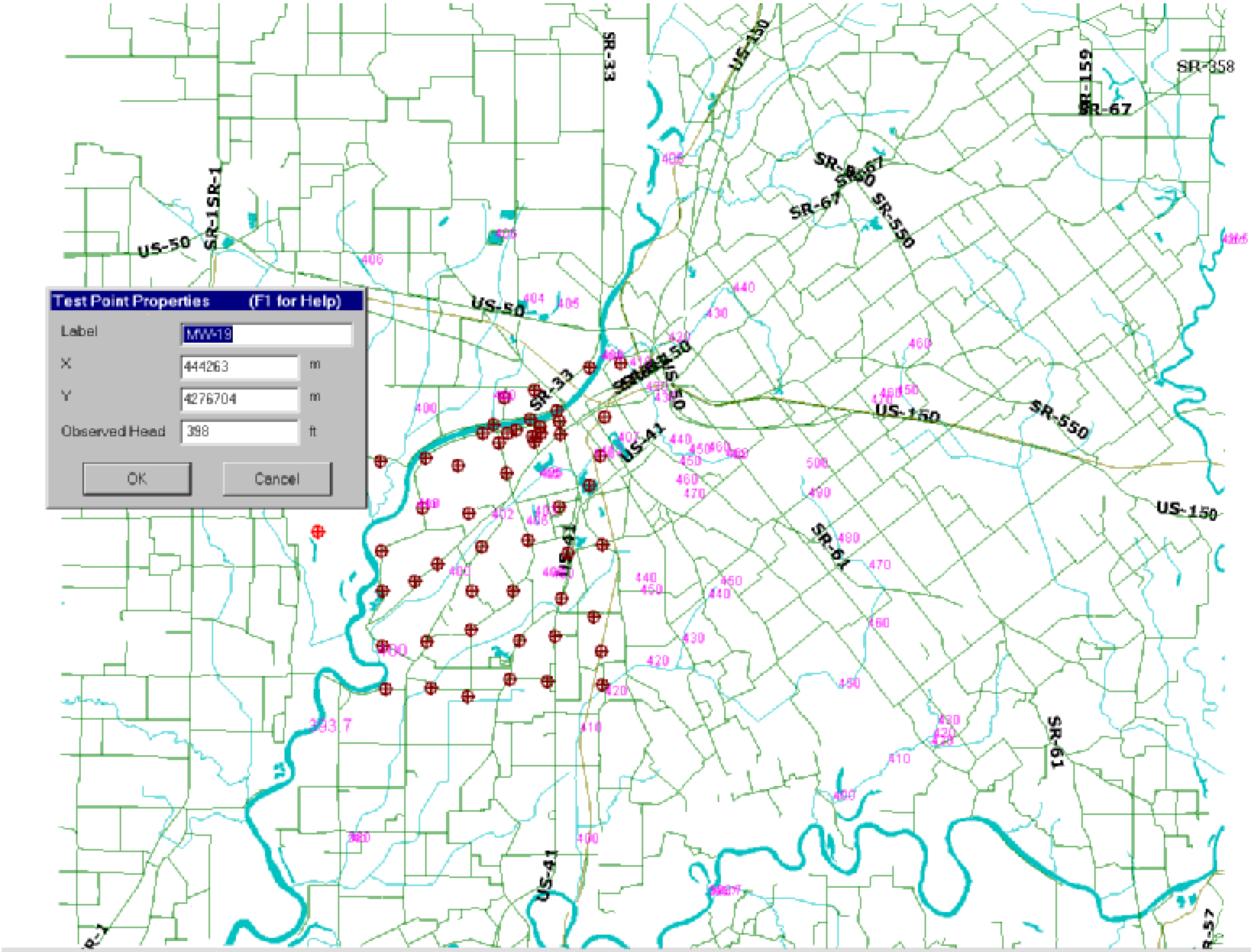
- analytic element model solves conjunctive steady state groundwater and surface water flow
- allows display of binary base maps for streams, lakes, roads, legal boundaries, etc.
- streams and lakes are represented by strings of line-sinks with each assigned a head that is set equal to the water level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

Step 1: Get a binary base map of the model area into GFLOW

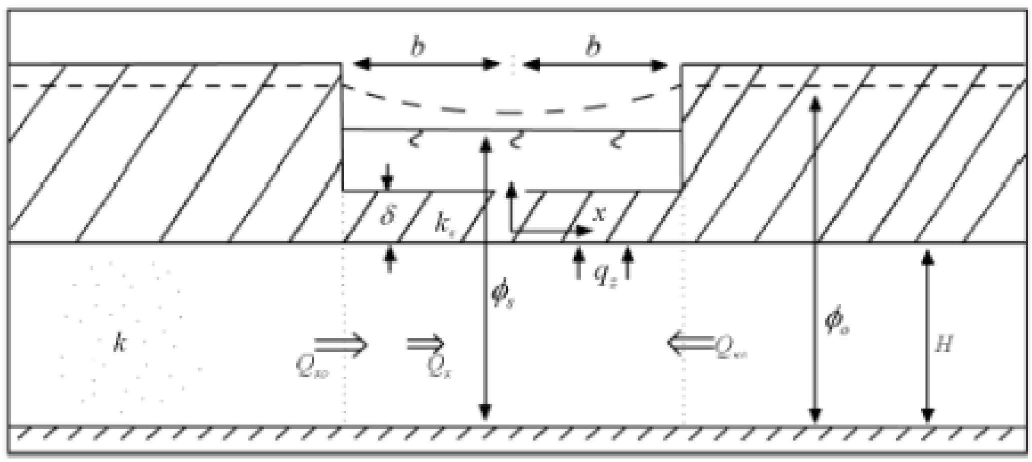
http://www.epa.gov/ceampubl/gwater/whaem/us.htm



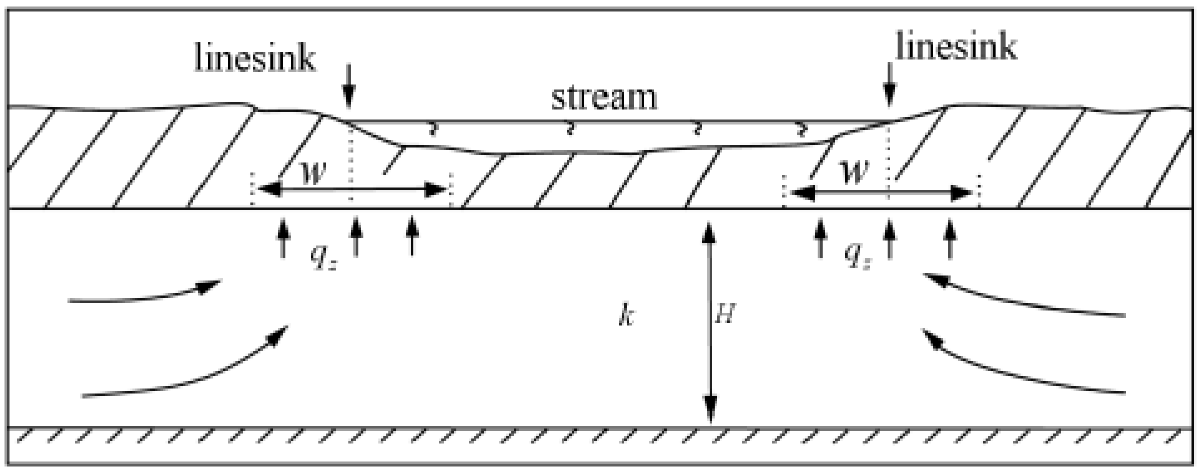
Step 2: Annotate the base map with water levels. Add test points.



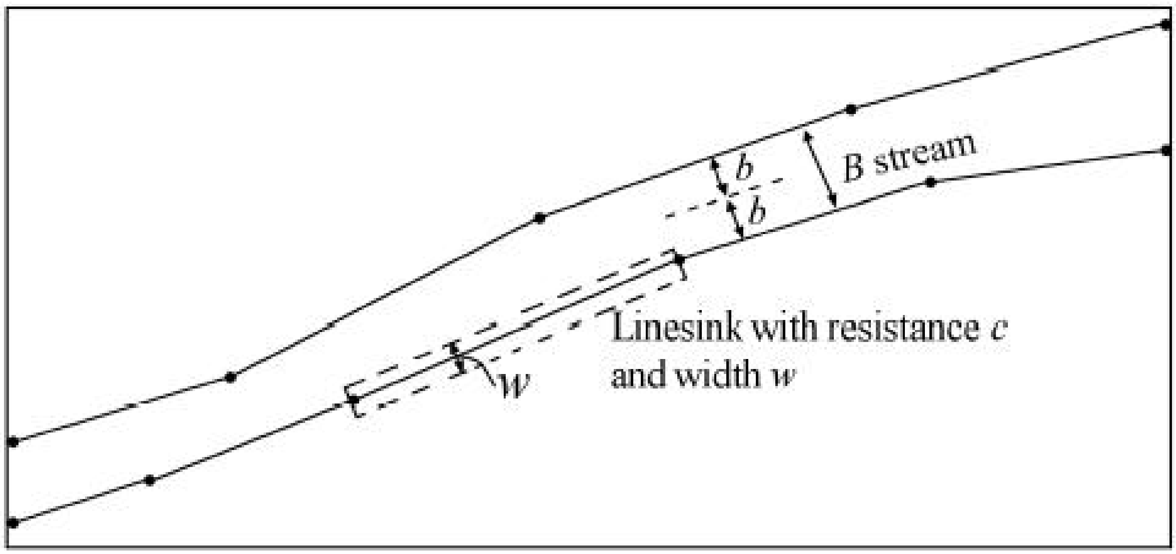
Step 3: Decide on a conceptual model



Conceptual model of a stream with a bottom resistance layer.



Cross section over the aquifer and the line-sinks representing the stream.



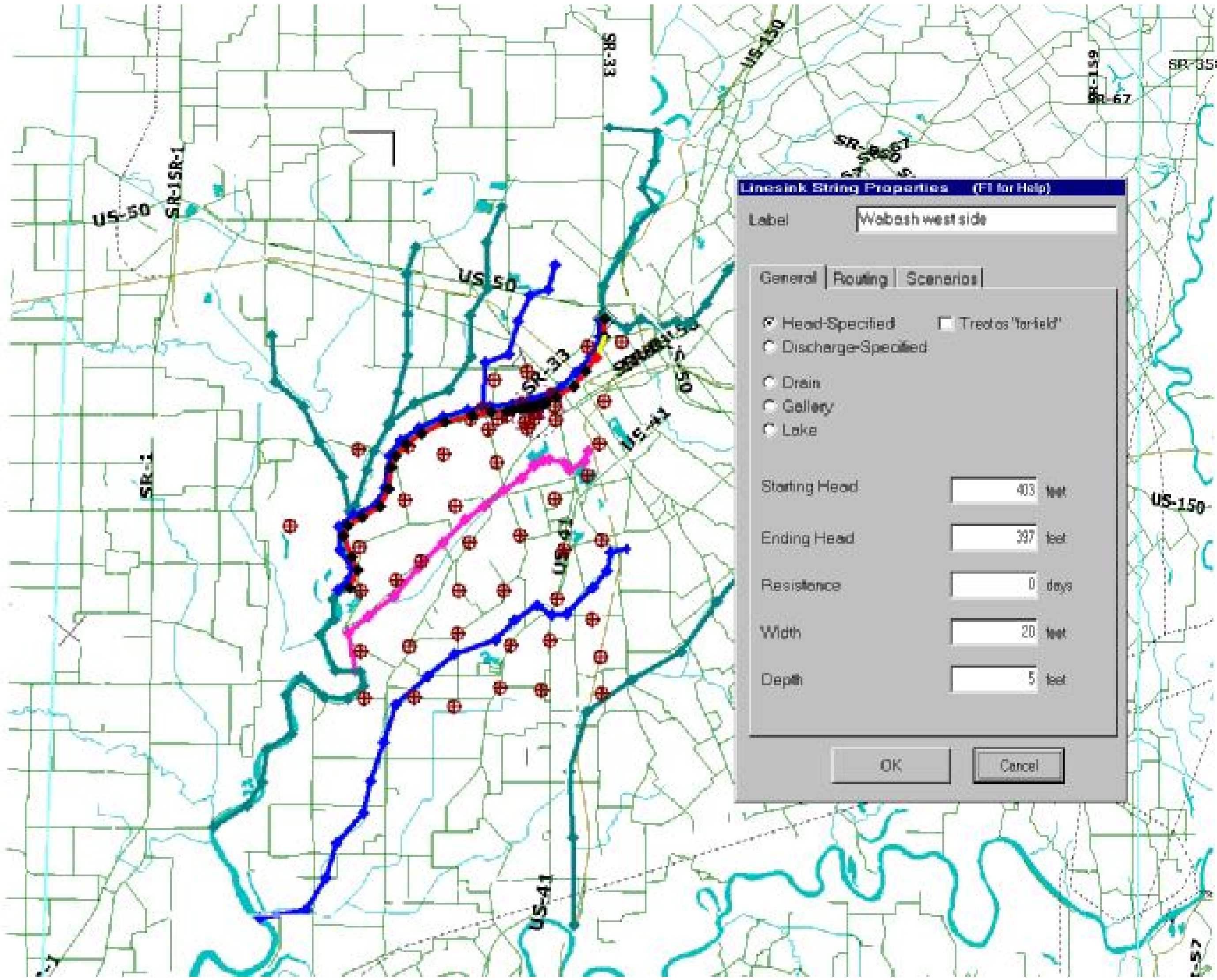
A stream modeled by two line-sink strings on either stream boundary.

Step 4: Decide what part of the model area is near-field and what part is far-field

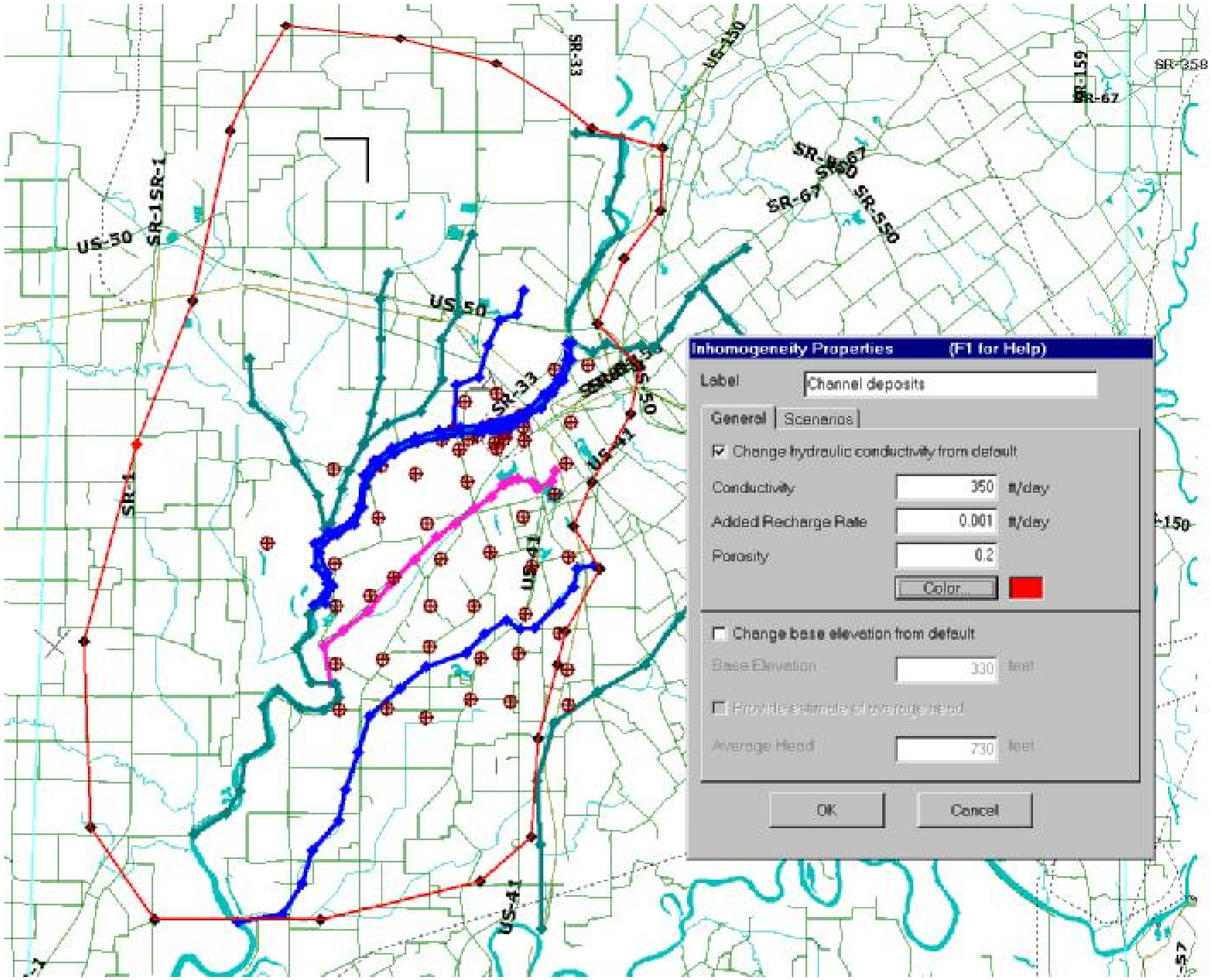
The **near field** of the model area is the area of interest. In the near field the hydrography is represented by line-sinks in a relatively high resolution.

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.

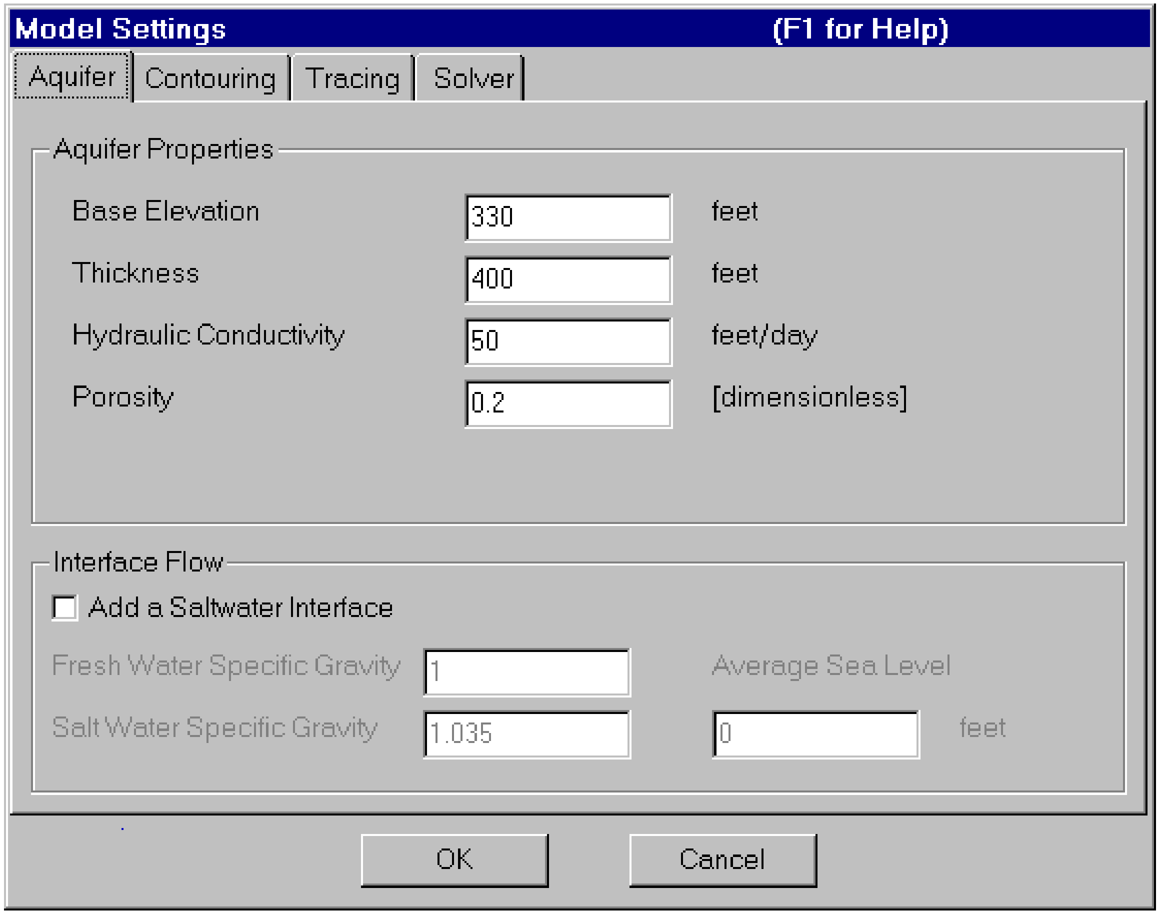
Step 5: Creating line-sink in the near-field and far-field



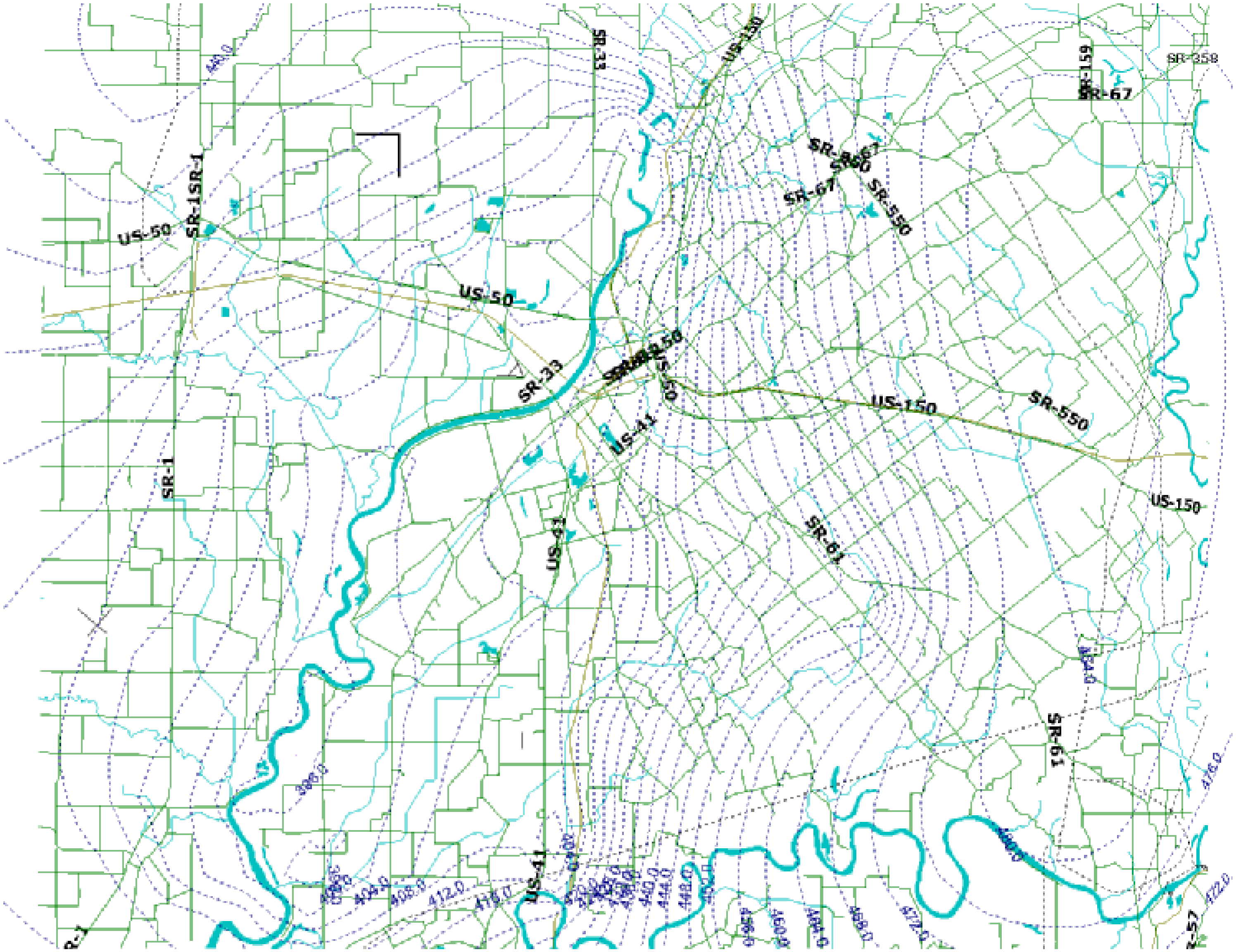
Step 6: Define inhomogeneity properties



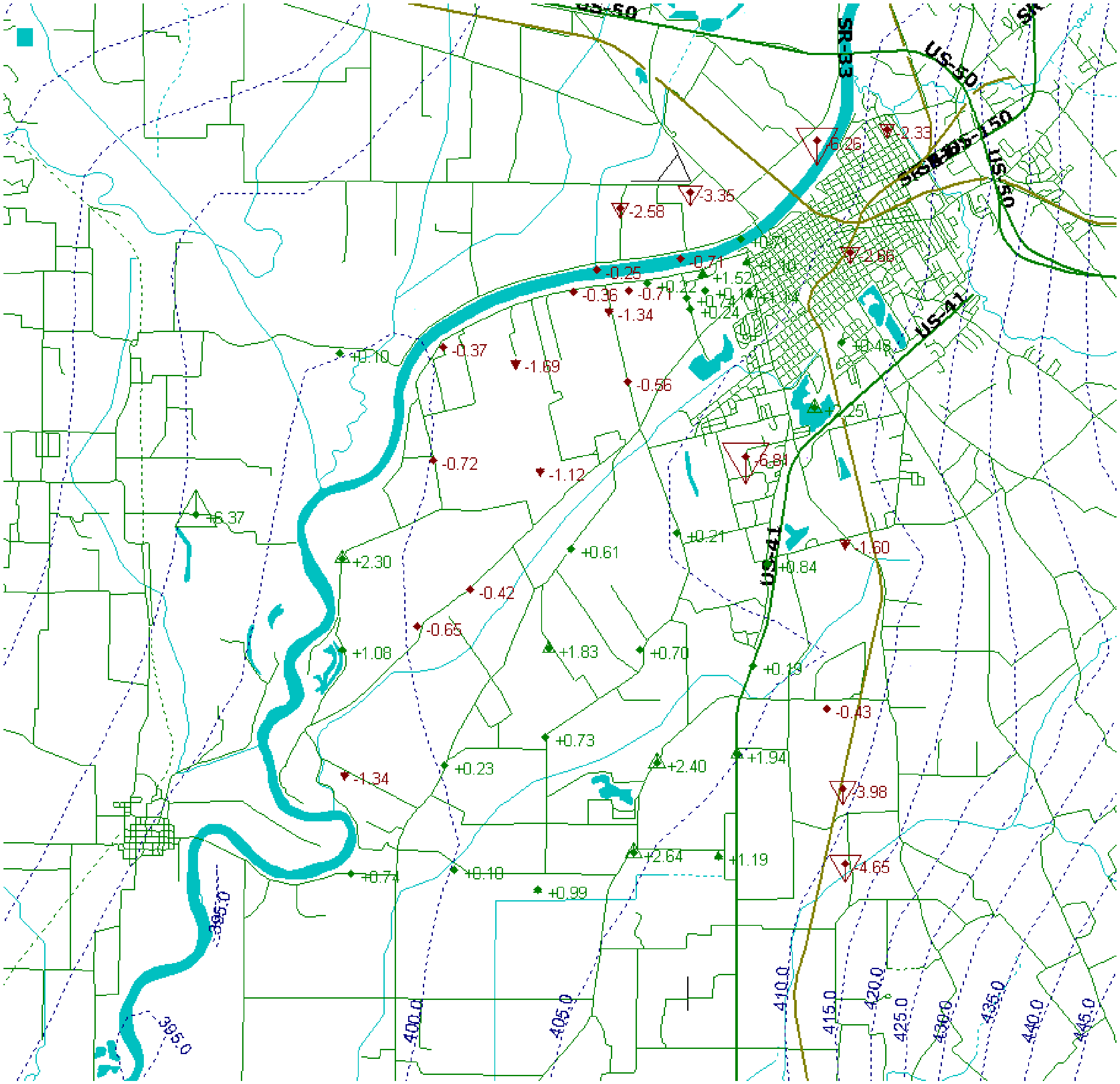
Step 7: Enter estimated aquifer properties in GFLOW



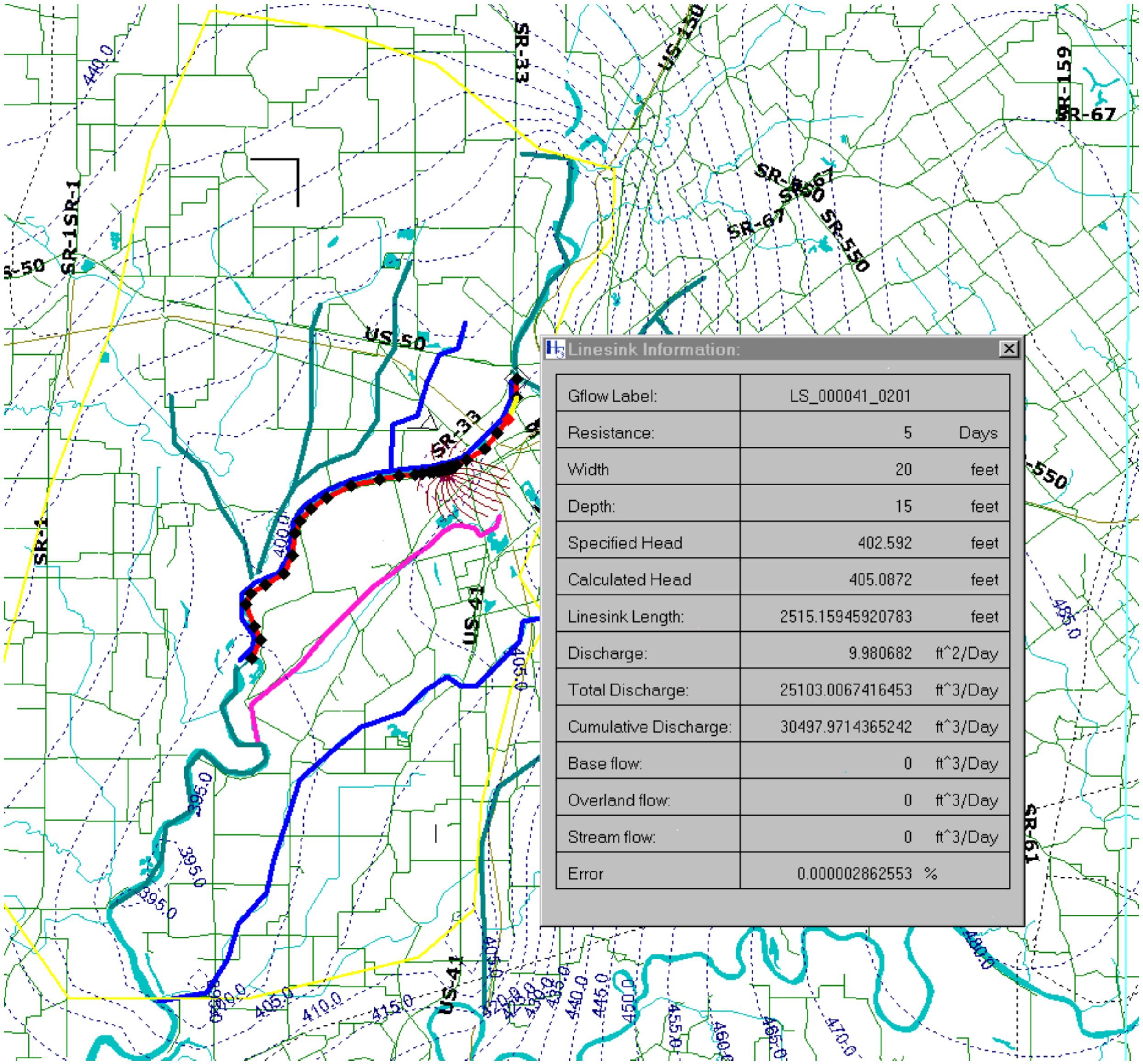
Step 8: Run the model & presenting results



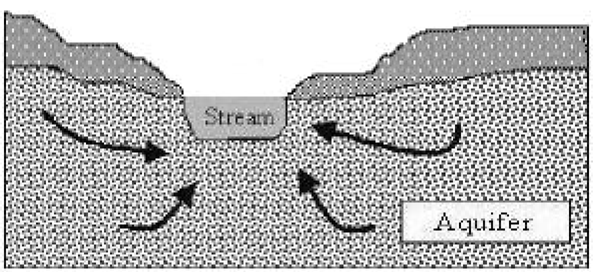
Step 9: Calibrate the model

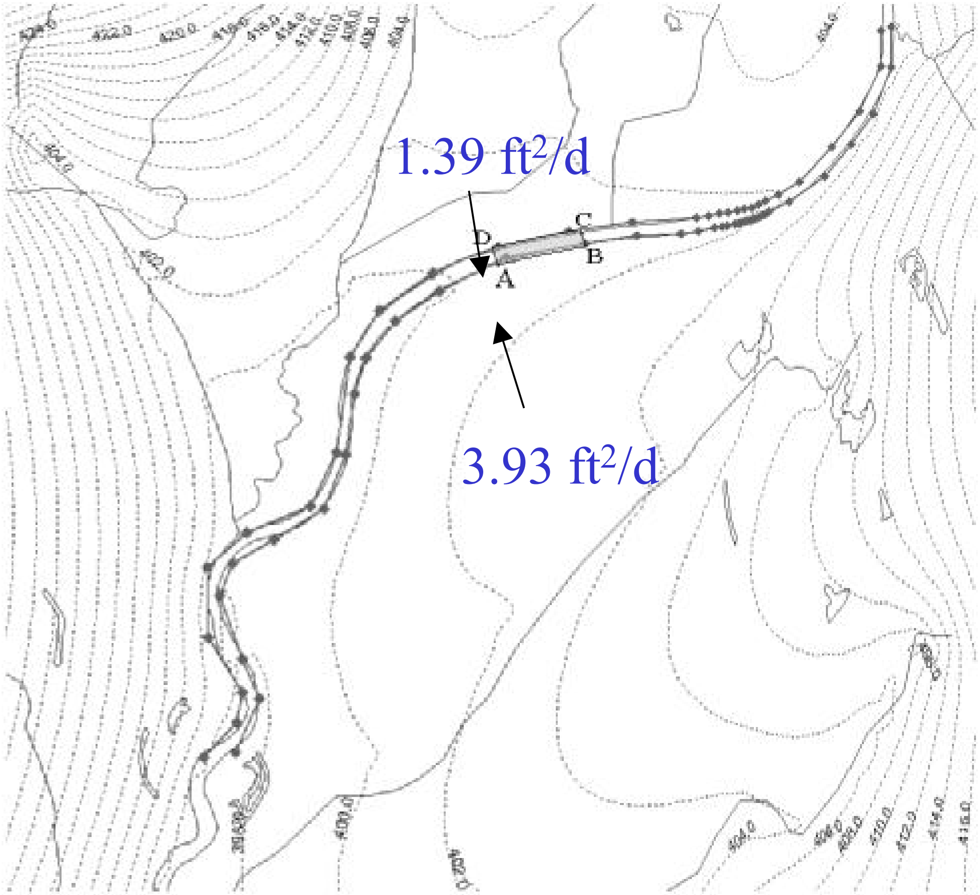


Step 10: Obtain the groundwater discharge vector



$5.32\ ft^2/d$ / 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

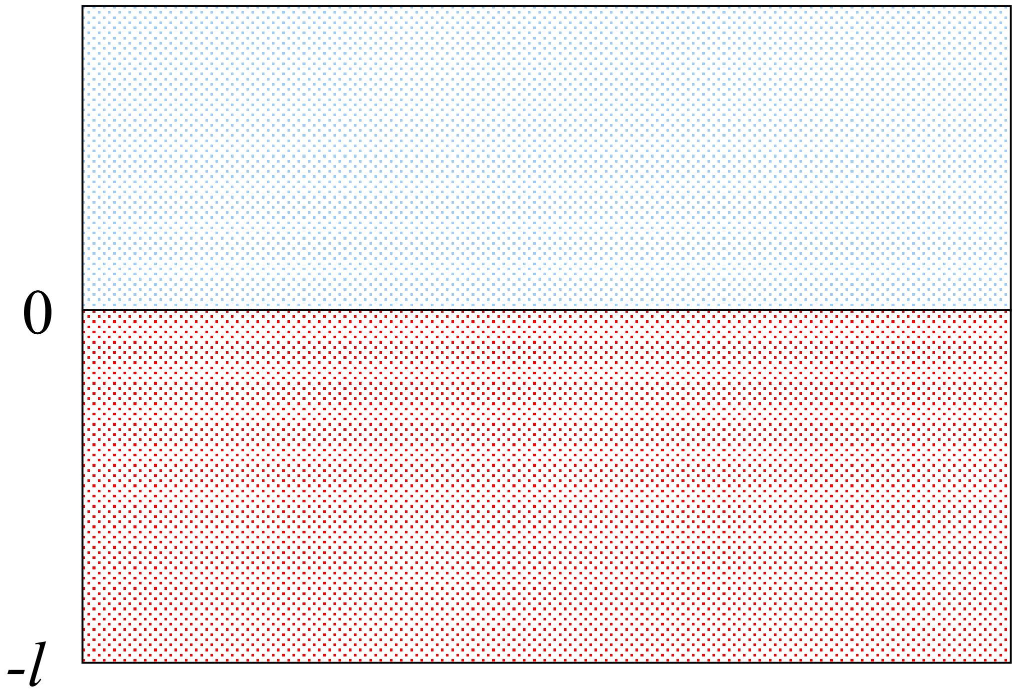
Processes Considered in Modeling

- 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:

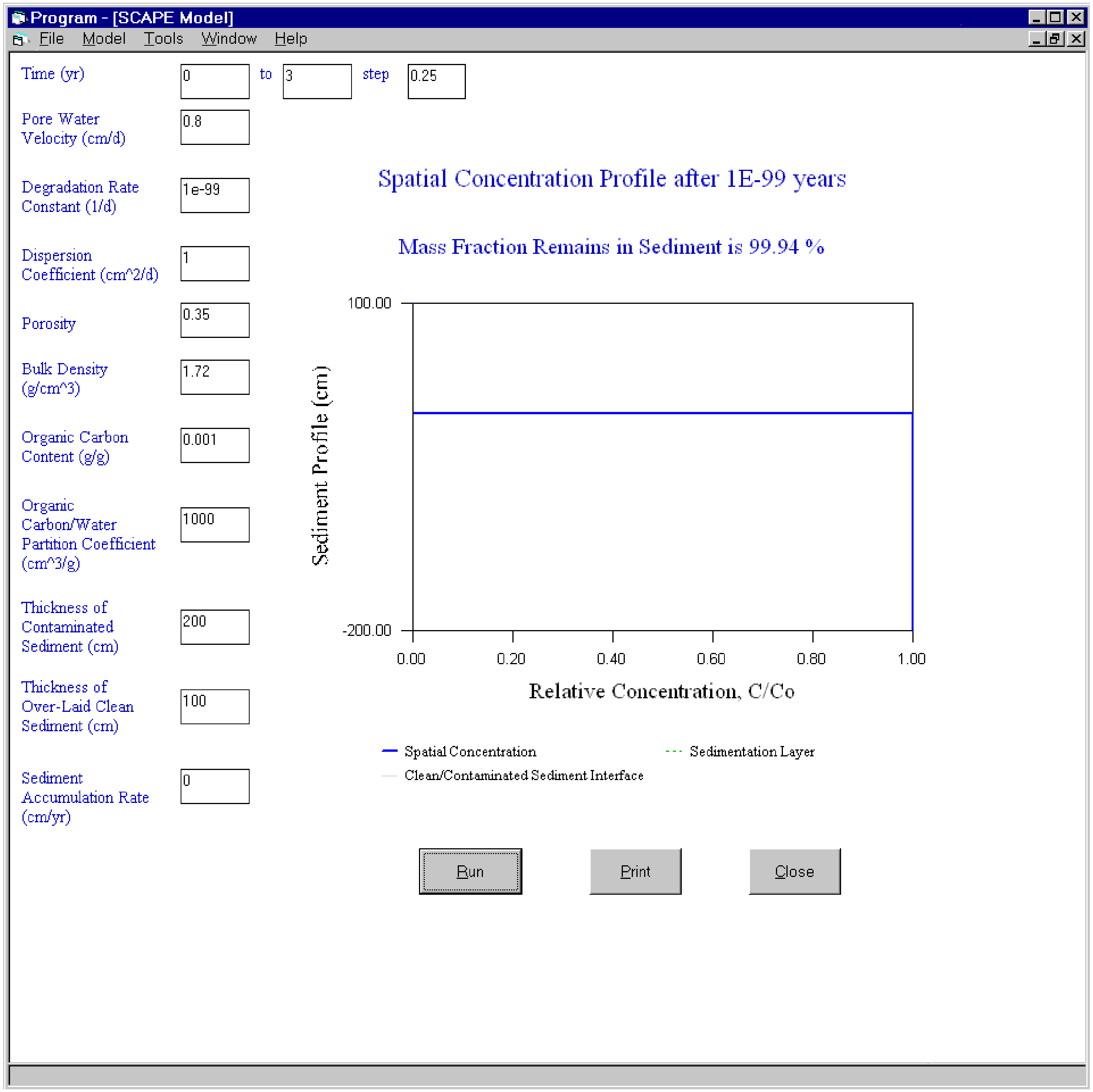


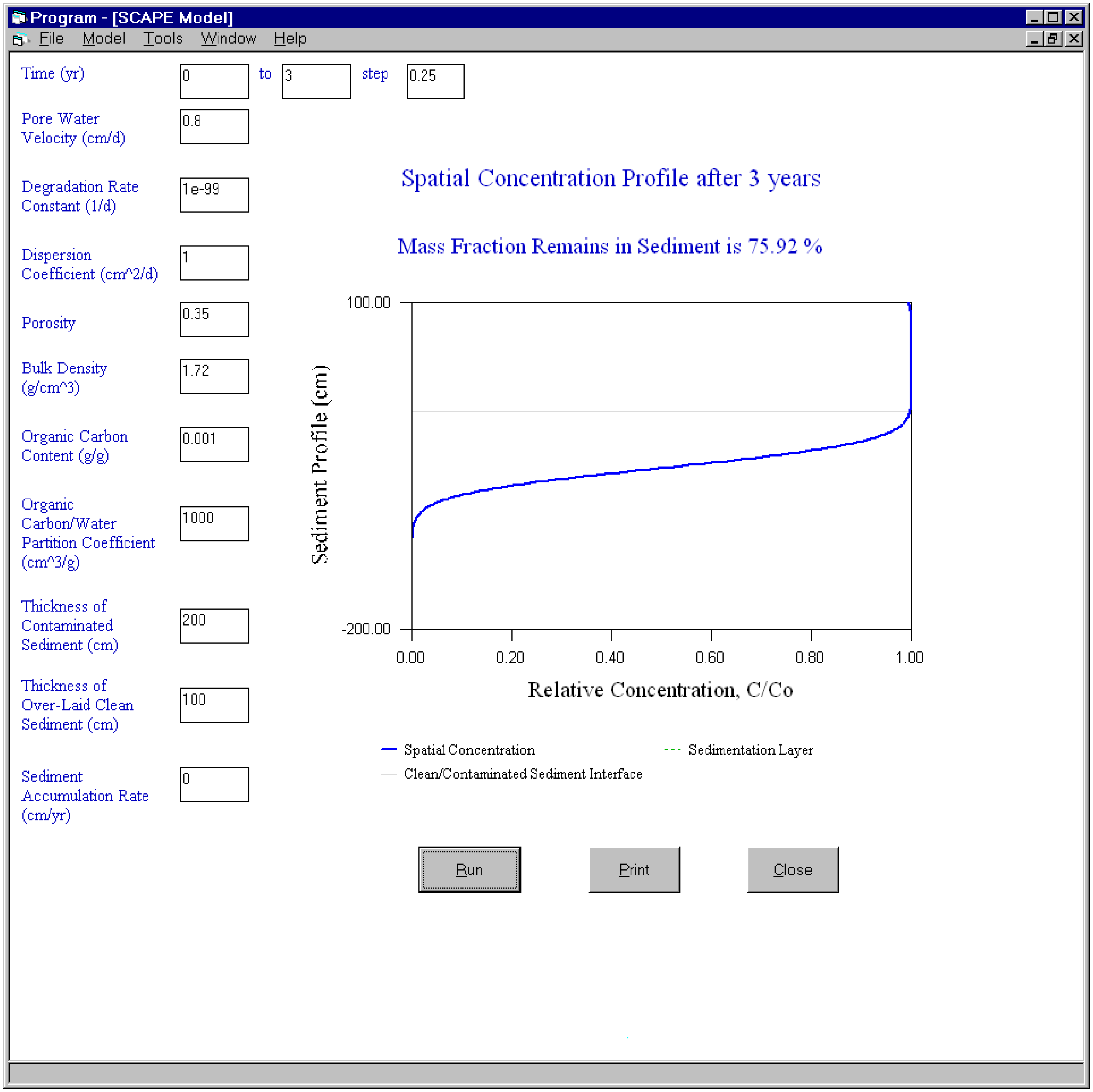
$$C(z,0) = C_o, \qquad -l < z \leq 0$$

$$C(z,0) = 0, \qquad 0 < z < \infty$$

Boundary Conditions

- the groundwater is free of contaminant
- there is no concentration gradient at infinite distance


Program - [SCAPE Model]
File Model Tools Window Help
Time (yr)
0
to
3
step
0.25
Pore Water Velocity (cm/d)
0.8
Degradation Rate Constant (1/d)
1e-99
Dispersion Coefficient (cm^2/d)
1
Porosity
0.35
Bulk Density (g/cm^3)
1.72
Organic Carbon Content (g/g)
0.001
Organic Carbon/Water Partition Coefficient (cm^3/g)
1000
Thickness of Contaminated Sediment (cm)
200
Thickness of Over-Laid Clean Sediment (cm)
100
Sediment Accumulation Rate (cm/yr)
0
Spatial Concentration Profile after 1E-99 years
Mass Fraction Remains in Sediment is 99.94 %
100.00
-200.00
Sediment Profile (cm)
0.00
0.20
0.40
0.60
0.80
1.00
Relative Concentration, C/Co
Spatial Concentration
Sedimentation Layer
Clean/Contaminated Sediment Interface
Run
Print
Close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Thickness of Over-Laid Clean Sediment (cm)
100
Sediment Accumulation Rate (cm/yr)
0
Spatial Concentration Profile after 3 years
Mass Fraction Remains in Sediment is 75.92 %
100.00
-200.00
Sediment Profile (cm)
0.00
0.20
0.40
0.60
0.80
1.00
Relative Concentration, C/Co
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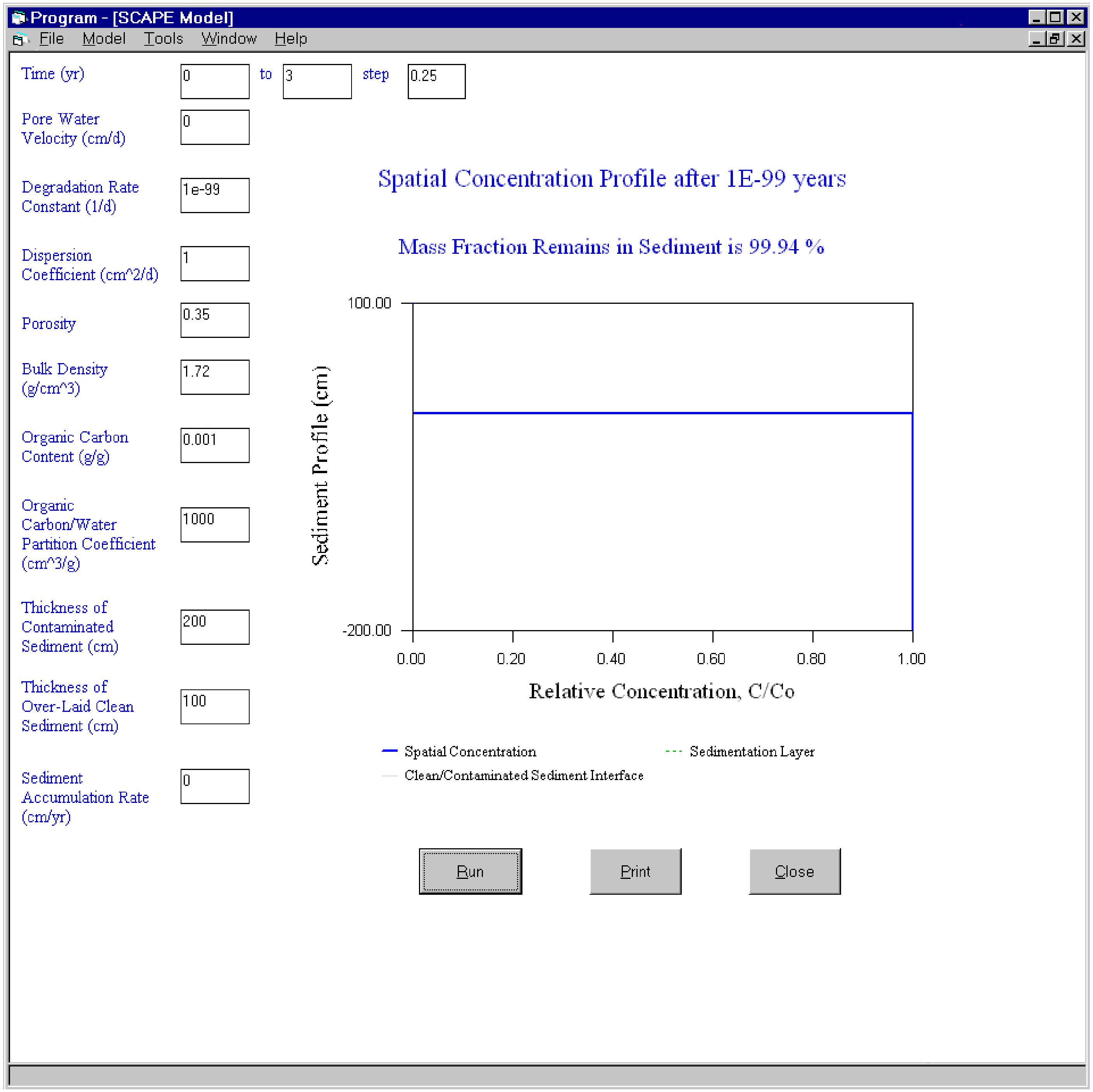
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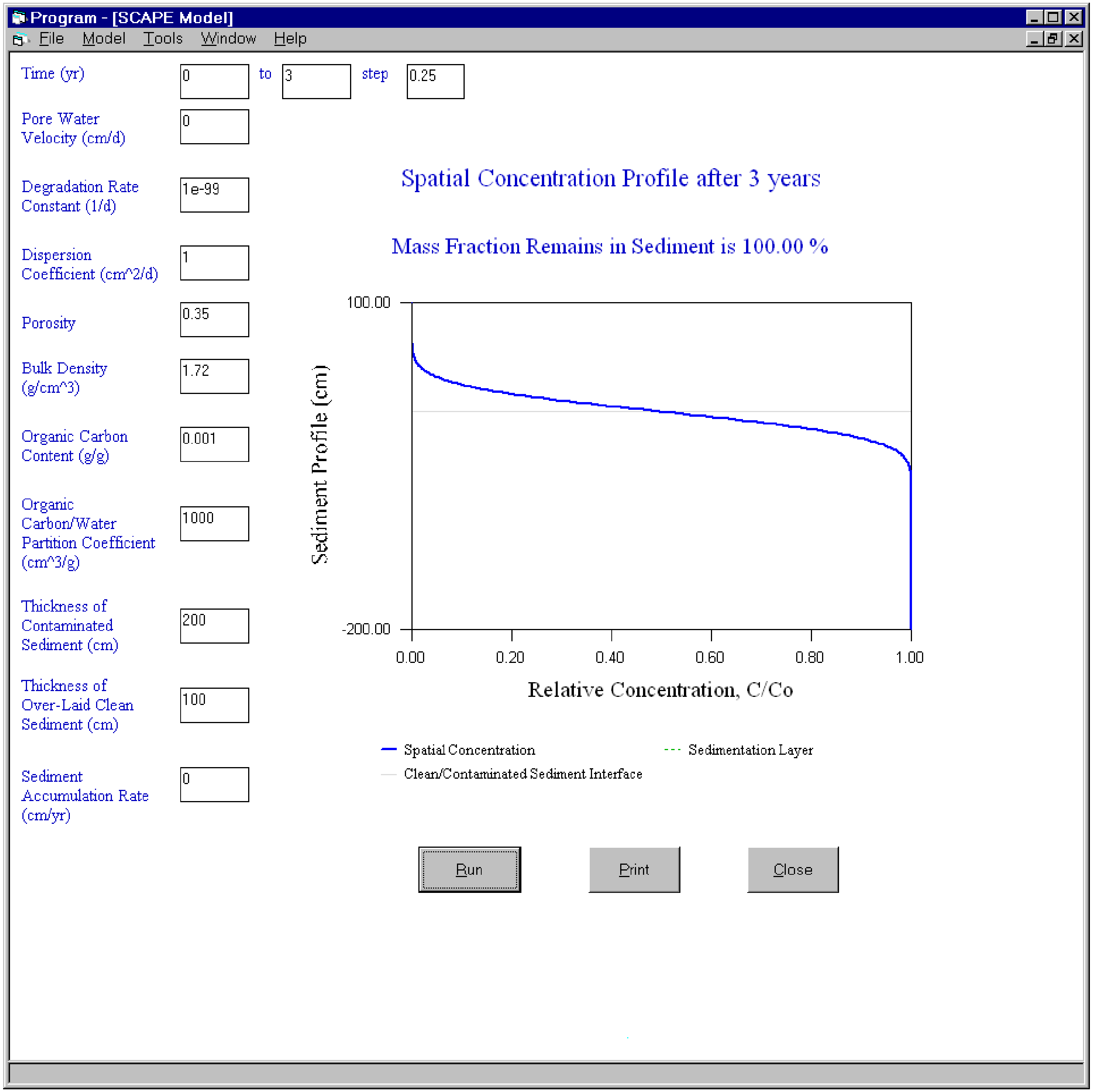
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Conclusion

- demonstrated the sensitivity of groundwater discharge in sediment cap performance
- illustrated the need to carefully monitor the ground water surface water interaction at capping sites
- knowledge of the regional hydrologic interactions is essential for local sediment cap effectiveness to be evaluated correctly