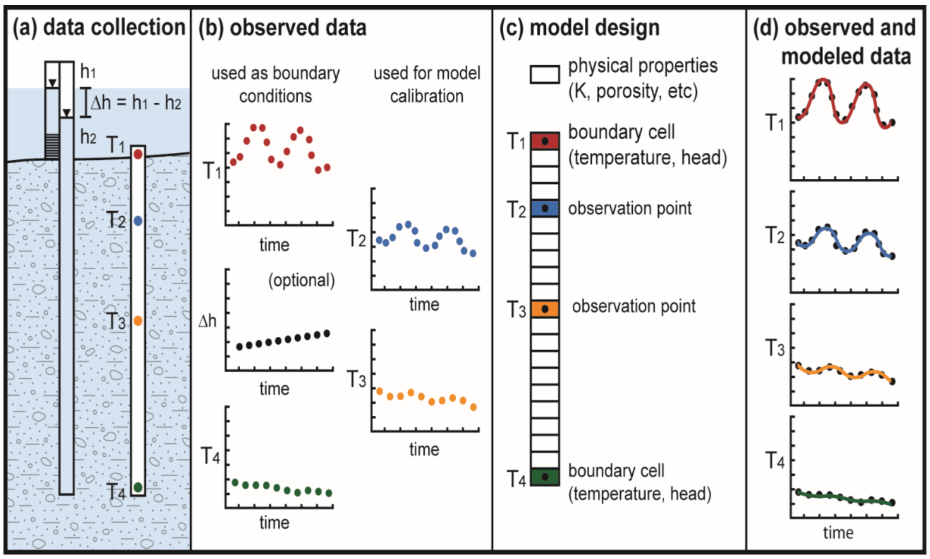
Computer Exercise: 1DTempPro

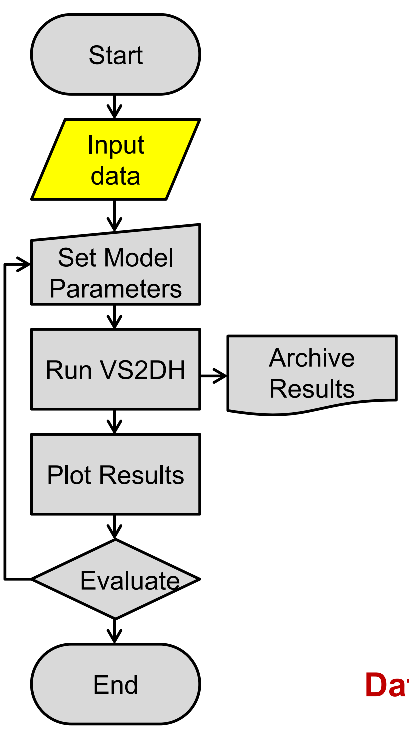
Objectives

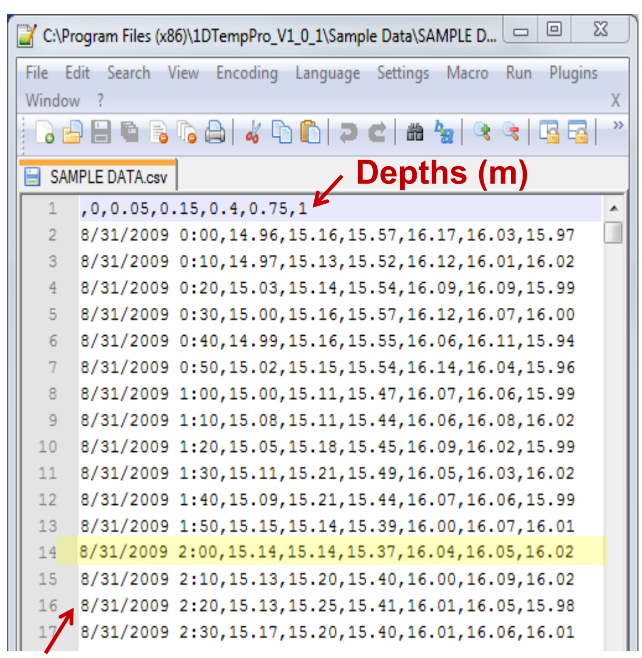
1. **Learn how to estimate seepage flux from temperature data.**
2. **Develop intuitive understanding of heat transfer processes.**



http://water.usgs.gov/ogw/bgas/1dtemppro/

(1) Extract the content of `1DTempPro.zip` file and open the input data file `SAMPLE DATA.csv` in `SampleData` folder using a text editor.

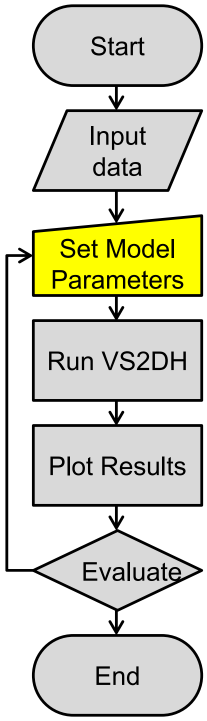


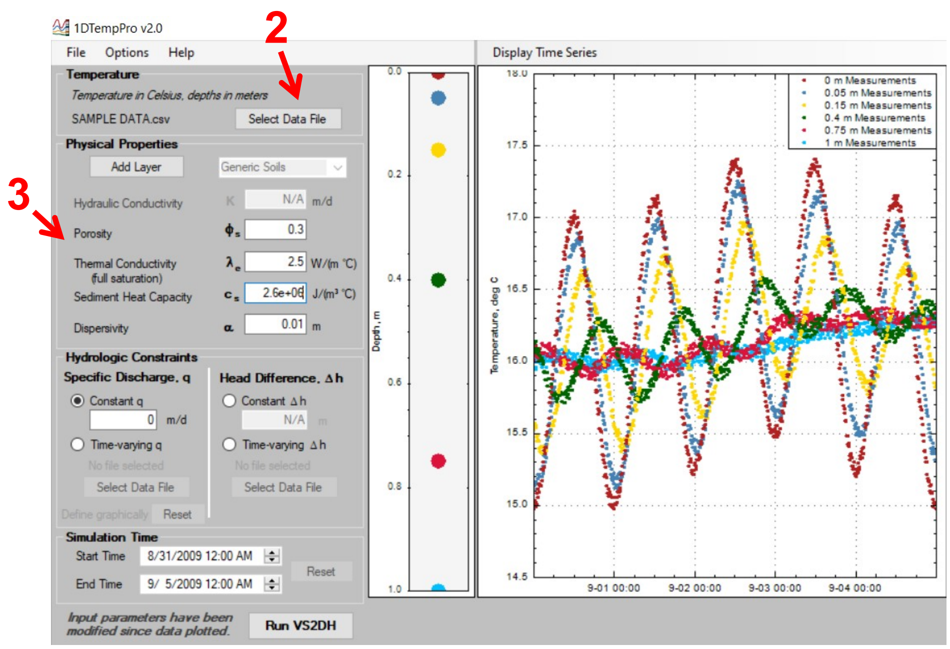


Date time (m/d/yyyy h:mm), temperatures (°C)

(2) Open 1DTempPro program and start a `New Workspace`.
Click `Select Data File` and choose `SAMPLE DATA.csv`.

(3) Set model parameters (see next slide).





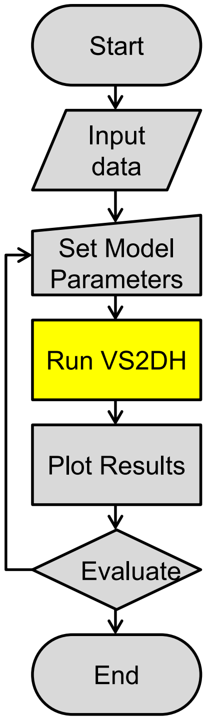
Enter the following model parameters.

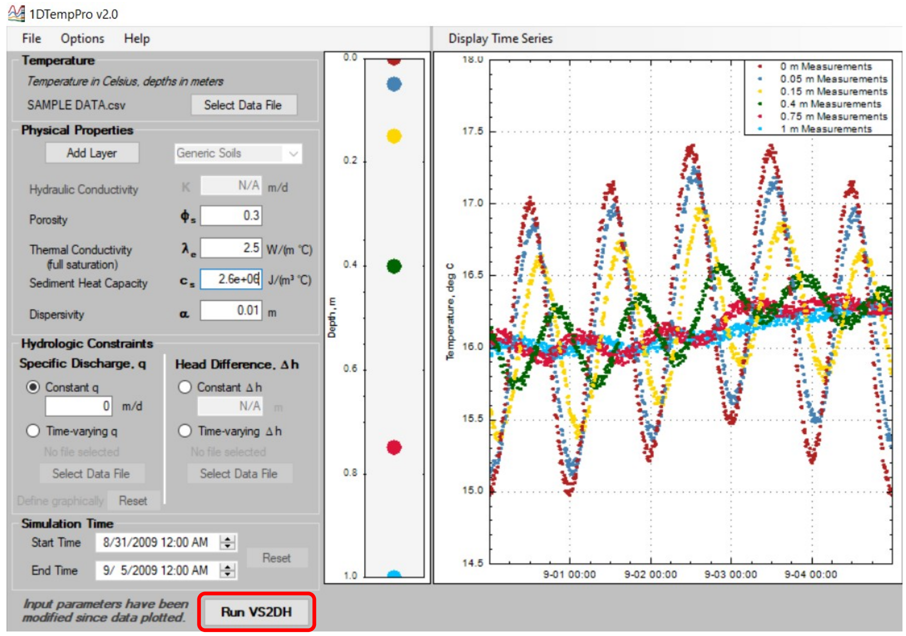
Seepage flux (q) = 0 m d^{-1} (positive value for downward flow)
Porosity (ϕ_s) = 0.3
Thermal conductivity (λ_e) = 2.5 W^{-1} m^{-1} °C^{-1}
Sediment heat capacity (C_s) = 2.6 × 10^6 J m^{-3} °C^{-1}
Dispersivity (α) = 0.01 m

- See Lecture 11 slides for thermal properties of common sediments.
- Heat capacity of water (4.2 × 10^6 J m^{-3} °C^{-1}) and common minerals (1.9 × 10^6 J m^{-3} °C^{-1}) are well constrained. Therefore, C_s can be estimated reliably from porosity: e.g., for ϕ_s = 0.3,

  $C_s \approx \underbrace{0.3 \times 4.2 \times 10^6}_{\text{water}} + \underbrace{0.7 \times 1.9 \times 10^6}_{\text{mineral grains}} = 2.6 \times 10^6$ J m^{-3} °C^{-1}.
- Common mineral sediments (clay, silt, sand, gravel), when saturated, have λ_e ranging from 1.0 to 2.5 W m^{-1} °C^{-1}.
- Dispersivity depends on the vertical scale, but usually < 0.01 m for scales of 1 m or less.

(4) Run VS2DH model. It uses the top and bottom temperatures as the boundary conditions to simulate temperatures at other depths.

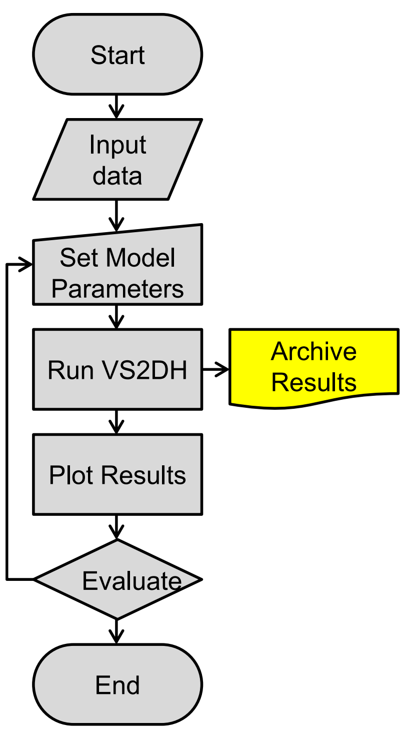


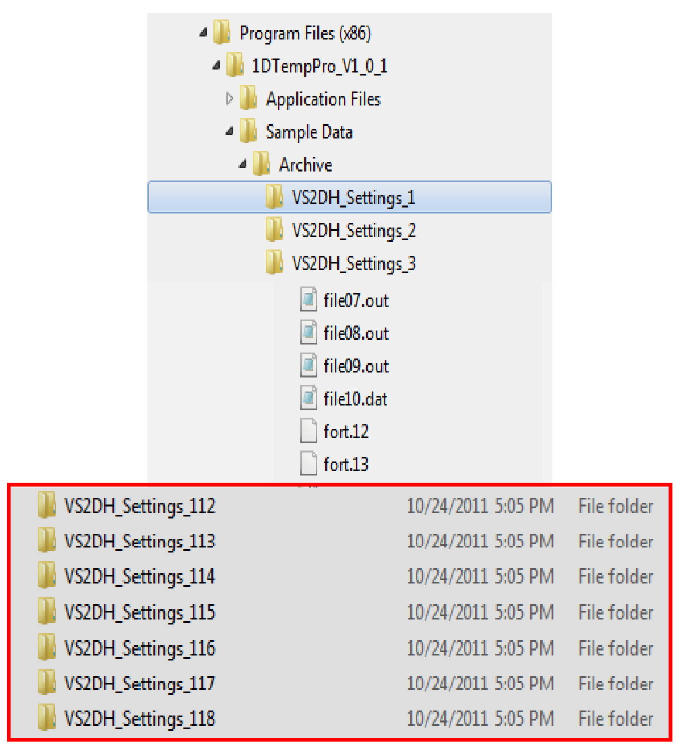


<u>V</u>ariably <u>S</u>aturated <u>2</u>-<u>D</u>imensional flow with <u>H</u>eat

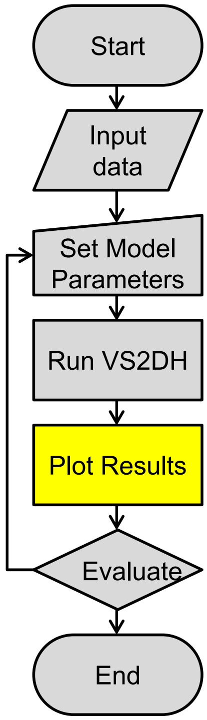
https://pubs.er.usgs.gov/publication/wri964230

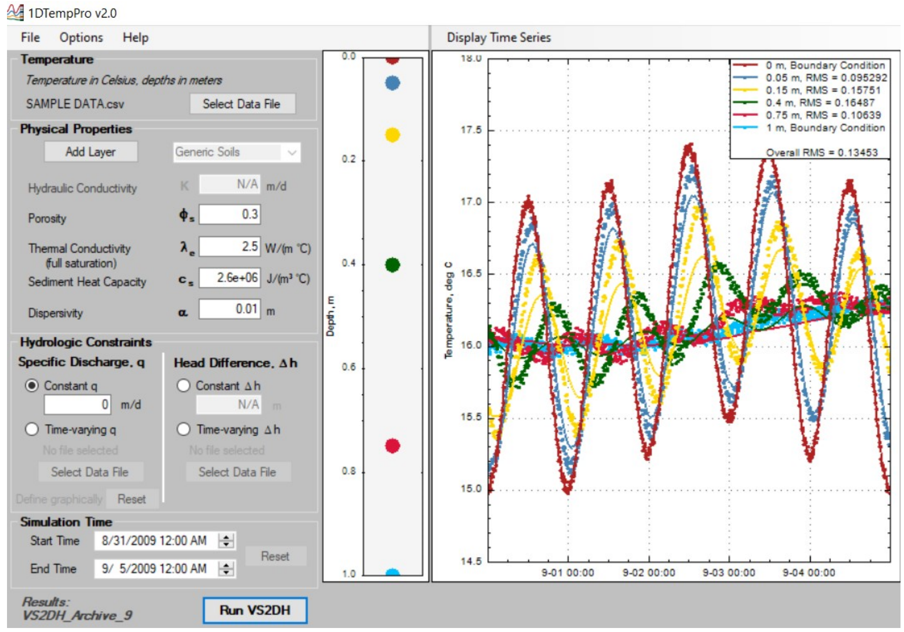
For each model run, VS2DH generates a set of output files stored in `Archive` folder. Delete the files occasionally to prevent excessively large disk-space usage.





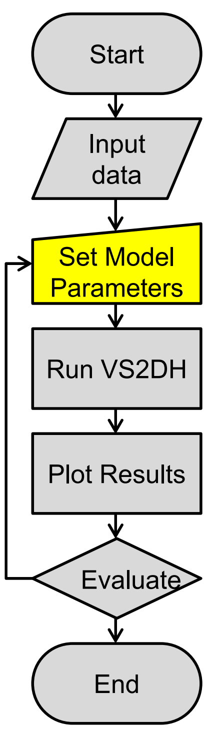
(5) Evaluate the match between observed and modeled temperature. In this case *q* = 0 is used (positive for downward flow).

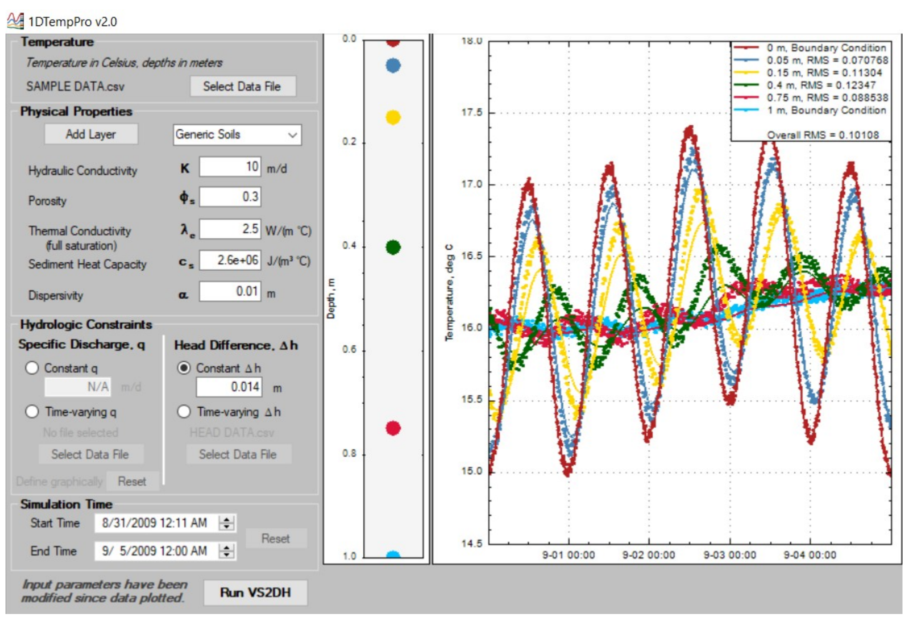




- **Should we increase or decrease *q* for a better fit?**
- **How about other parameters?**
- **What is the value of *q* that gives the smallest root-mean-squared (RMS) error?**

(6) When hydraulic head is measured, we can use the data to specify the gradient, and estimate hydraulic conductivity (*K*) and *q*. For example, enter Δh = 0.014m and *K* = 10 m d^{-1}.

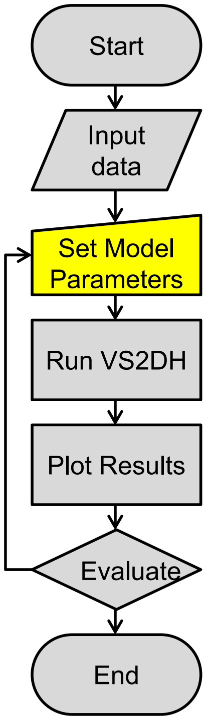


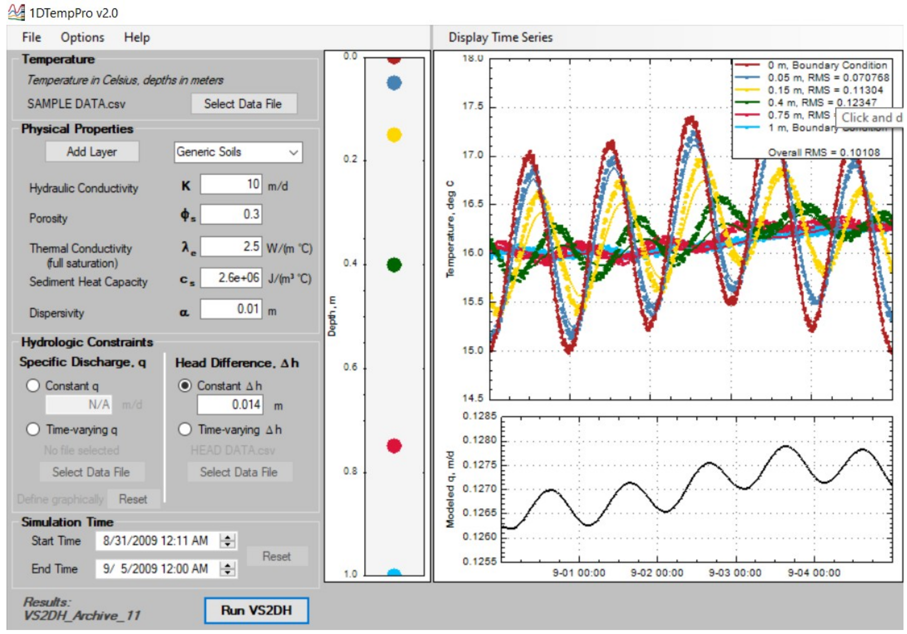


Note: The model uses positive Δh when the head decreases across the model domain (top to bottom).

(7) Observe the model fit and observe values of *q*.

Why does *q* vary with time even though *K* and Δh are constant?
What is the best-fit value of *K*?

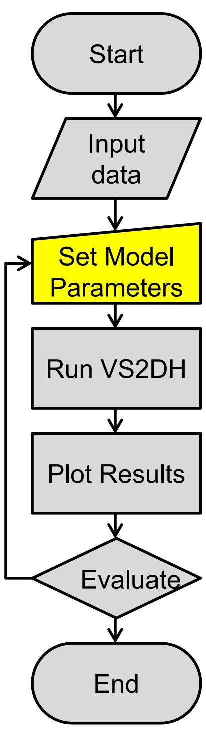


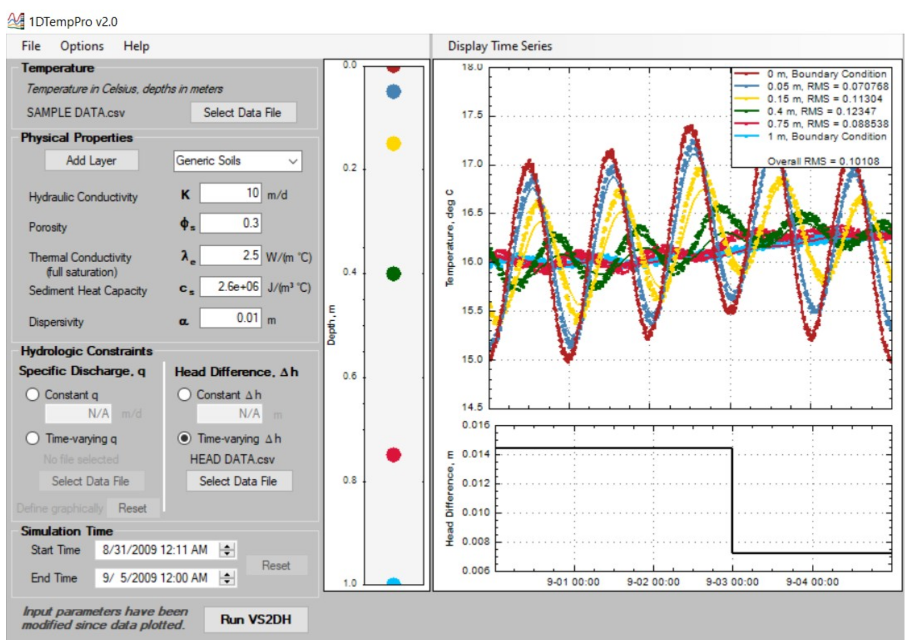


Note: *K* is entered as the value at 20 °C. VS2DH adjusts *K* according to temperature.

(8) We can use variable Δh when data are available. Select the data file `HEAD DATA.csv` and run VS2DH.

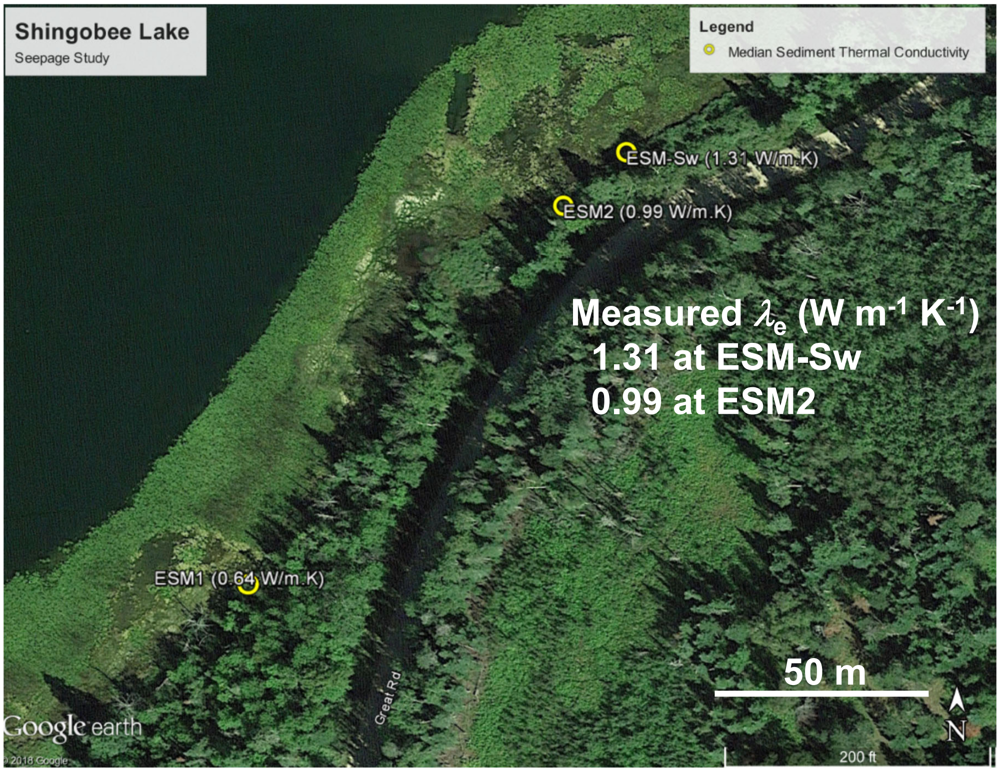
→ Find the best-fit value of *K*.





Shingobee Lake, Minnesota

Exercise designed by Don Rosenberry, U.S. Geol. Survey



(9) Select data file, `Shingobee_temp_dat.csv` consisting of the temperature data at 5 cm (top boundary), 25 cm, and 55 cm (bottom boundary) measured at the ESM2 site.

(10) Enter the following parameters:

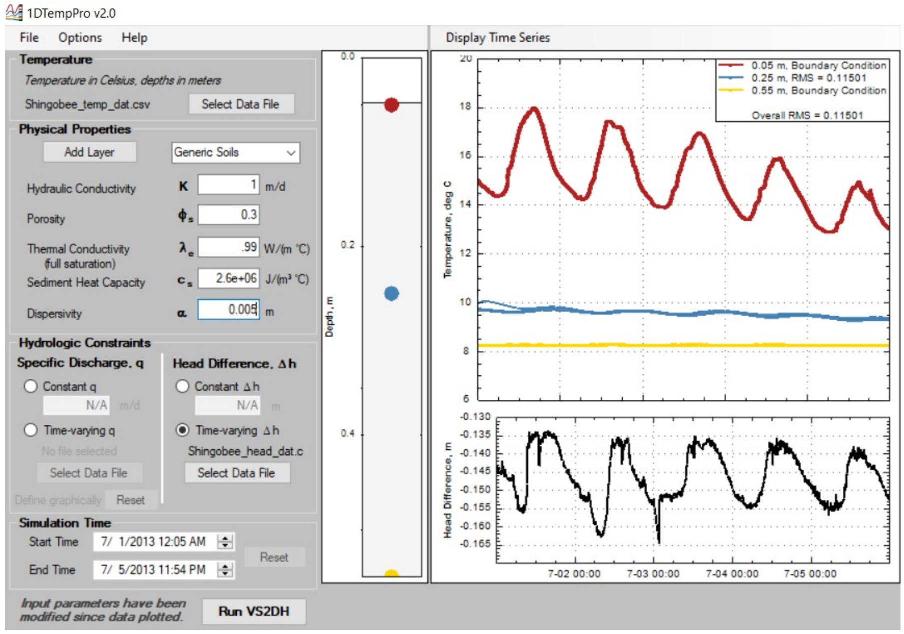
q = 0 m d^{-1}, ϕ_s = 0.3, λ_e = 0.99 W m^{-1} °C^{-1}

C_s = 2.6 × 10^6 J m^{-3} °C^{-1}, α = 0.005 m

(11) Run the model and observe the match.

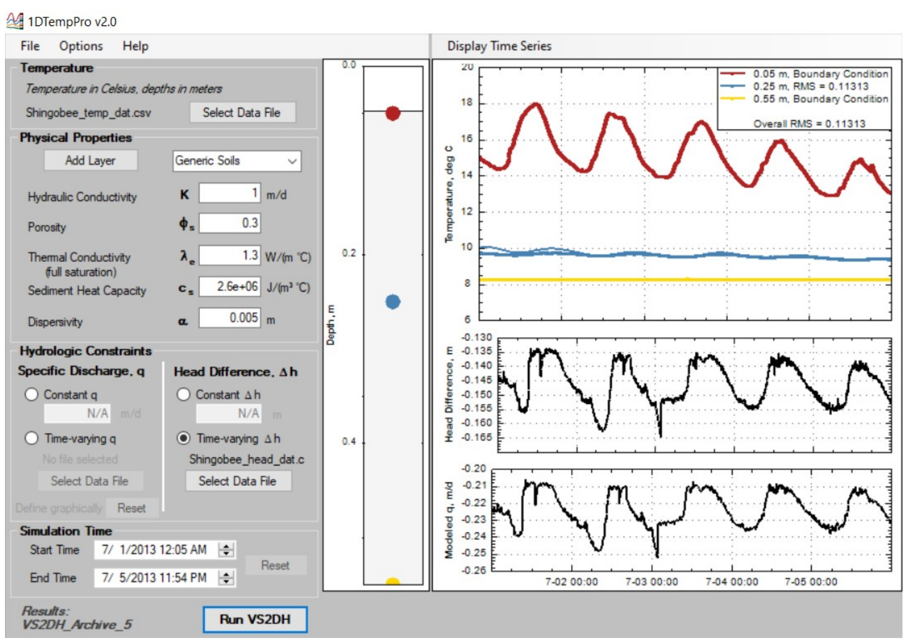
(12) Adjust q and find the value that gives the smallest value of root-mean-squared (RMS) error.

(13) Import time-varying Δh data, `Shingobee_head_dat.csv`, and enter a reasonable value of K (e.g., 1 m d^{-1}).



(14) Run the model and determine the K value that gives the smallest RMS value.

(15) Change λ_e to 1.3 W m^{-1} °C^{-1} and determine the best-fit value of K. Comment on the sensitivity of K to uncertainty in λ_e.



More information: Voytek et al., (2014, Groundwater, 52, 298-302)
Koch et al., (2016, Groundwater, 54, 434-439)