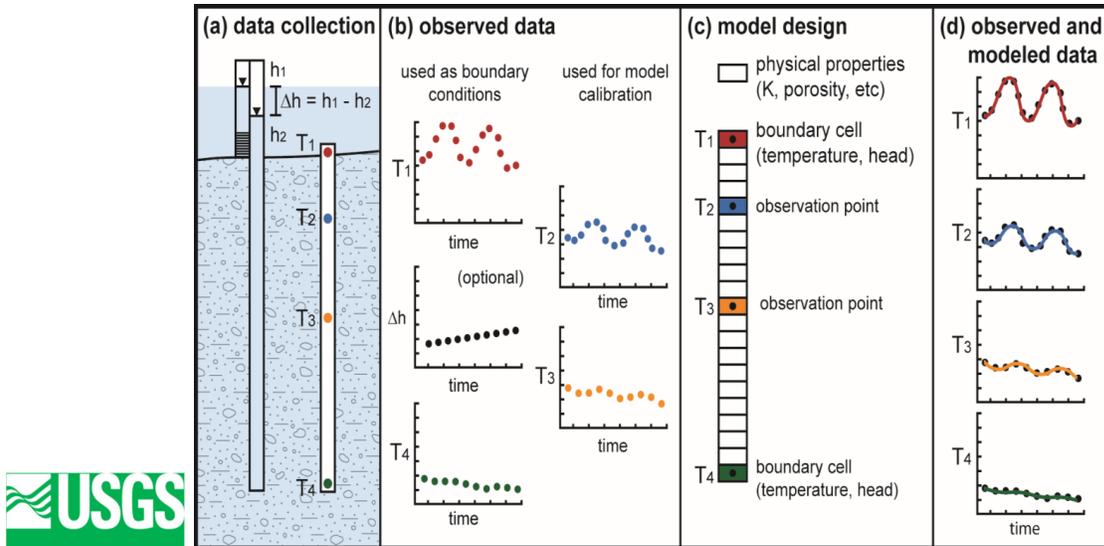


Computer Exercise: 1DTempPro

Objectives

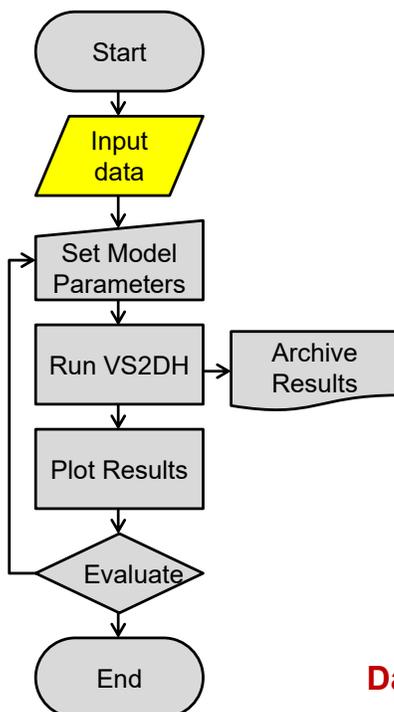
1. Learn how to estimate seepage flux from temperature data.
2. Develop intuitive understanding of heat transfer processes.



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

1

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

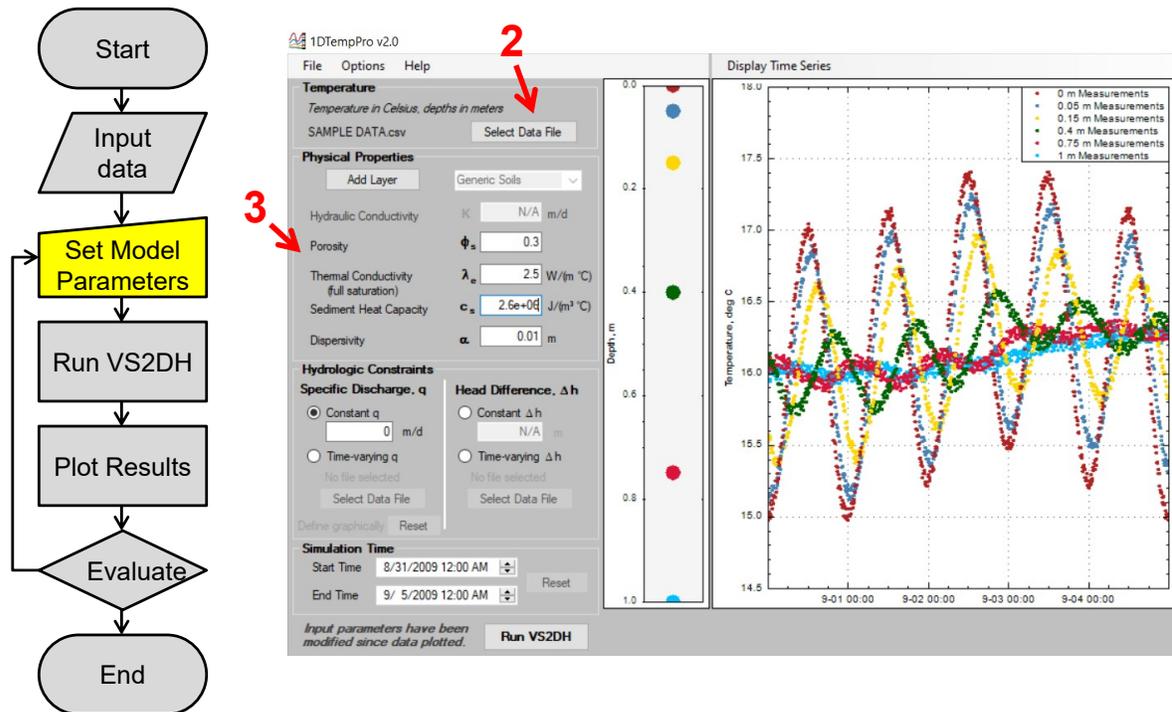


Line	Time	0	0.05	0.15	0.4	0.75	1
1							
2	8/31/2009 0:00	14.96	15.16	15.57	16.17	16.03	15.97
3	8/31/2009 0:10	14.97	15.13	15.52	16.12	16.01	16.02
4	8/31/2009 0:20	15.03	15.14	15.54	16.09	16.09	15.99
5	8/31/2009 0:30	15.00	15.16	15.57	16.12	16.07	16.00
6	8/31/2009 0:40	14.99	15.16	15.55	16.06	16.11	15.94
7	8/31/2009 0:50	15.02	15.15	15.54	16.14	16.04	15.96
8	8/31/2009 1:00	15.00	15.11	15.47	16.07	16.06	15.99
9	8/31/2009 1:10	15.08	15.11	15.44	16.06	16.08	16.02
10	8/31/2009 1:20	15.05	15.18	15.45	16.09	16.02	15.99
11	8/31/2009 1:30	15.11	15.21	15.49	16.05	16.03	16.02
12	8/31/2009 1:40	15.09	15.21	15.44	16.07	16.06	15.99
13	8/31/2009 1:50	15.15	15.14	15.39	16.00	16.07	16.01
14	8/31/2009 2:00	15.14	15.14	15.37	16.04	16.05	16.02
15	8/31/2009 2:10	15.13	15.20	15.40	16.00	16.09	16.02
16	8/31/2009 2:20	15.13	15.25	15.41	16.01	16.05	15.98
17	8/31/2009 2:30	15.17	15.20	15.40	16.01	16.06	16.01

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

2

- (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).



3

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 × 10⁶ J m⁻³ °C⁻¹

Dispersivity (α) = 0.01 m

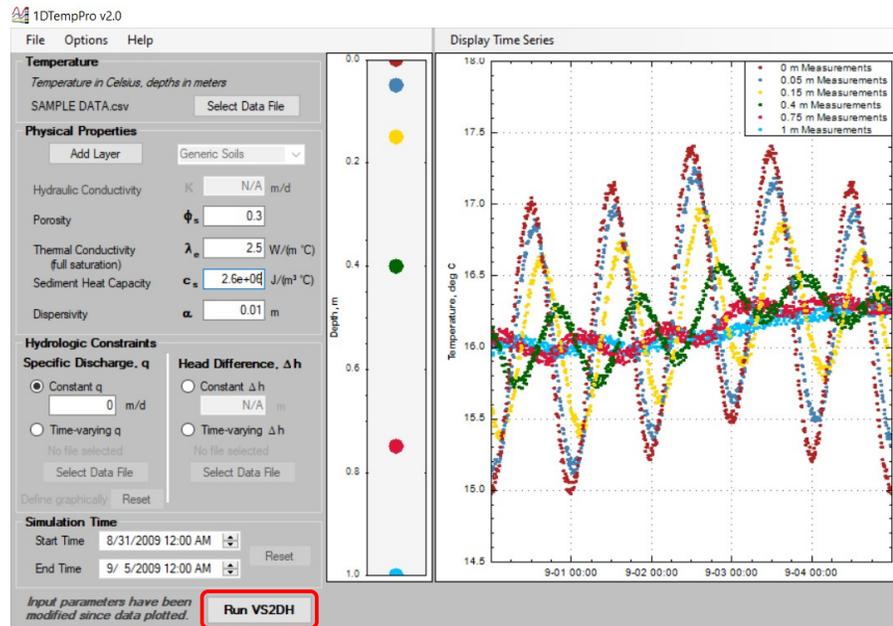
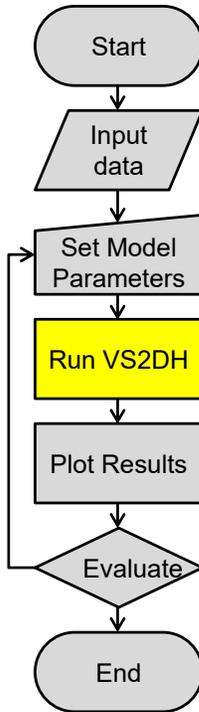
- See Lecture 11 slides for thermal properties of common sediments.
- Heat capacity of water (4.2 × 10⁶ J m⁻³ °C⁻¹) and common minerals (1.9 × 10⁶ J m⁻³ °C⁻¹) are well constrained. Therefore, C_s can be estimated reliably from porosity: e.g., for $\phi_s = 0.3$,

$$C_s \approx 0.3 \times 4.2 \times 10^6 + 0.7 \times 1.9 \times 10^6 = 2.6 \times 10^6 \text{ J m}^{-3} \text{ °C}^{-1}.$$

water mineral grains
- 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

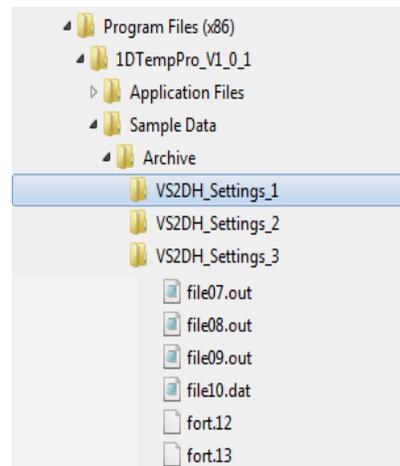
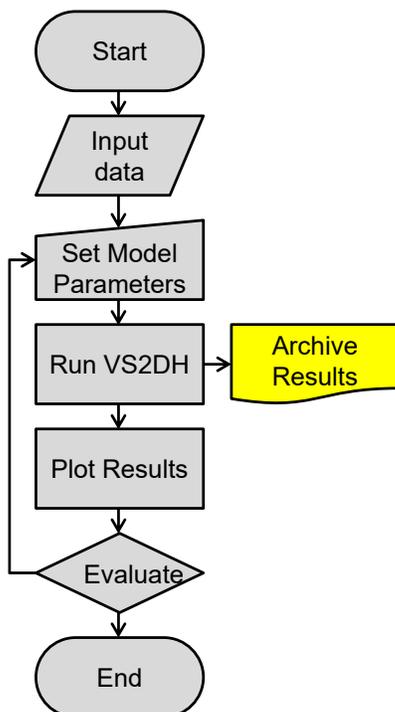
(4) Run VS2DH model. It uses the top and bottom temperatures as the boundary conditions to simulate temperatures at other depths.



Variably Saturated 2-Dimensional flow with Heat

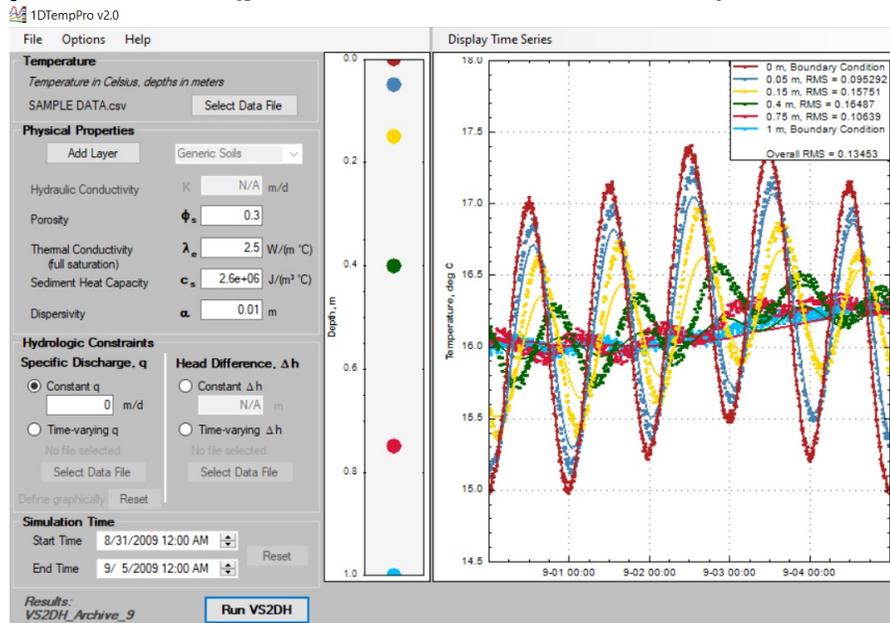
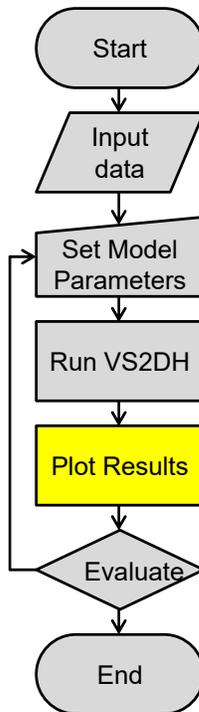
<https://pubs.er.usgs.gov/publication/wri964230>

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.



VS2DH_Settings_112	10/24/2011 5:05 PM	File folder
VS2DH_Settings_113	10/24/2011 5:05 PM	File folder
VS2DH_Settings_114	10/24/2011 5:05 PM	File folder
VS2DH_Settings_115	10/24/2011 5:05 PM	File folder
VS2DH_Settings_116	10/24/2011 5:05 PM	File folder
VS2DH_Settings_117	10/24/2011 5:05 PM	File folder
VS2DH_Settings_118	10/24/2011 5:05 PM	File folder

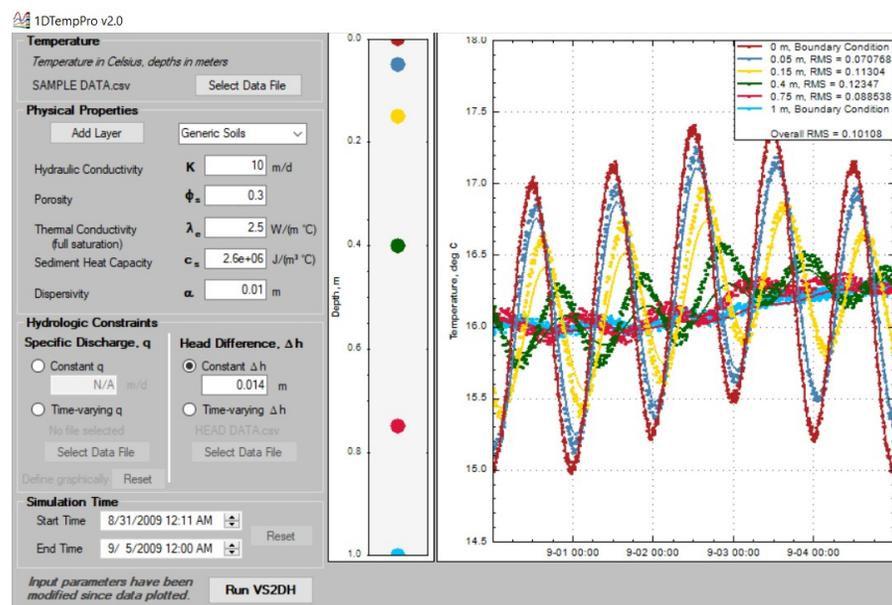
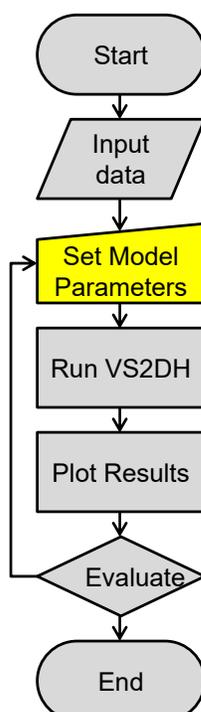
(5) Evaluate the match between observed and modeled temperature. In this case $q = 0$ is used (positive for downward flow).



- 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?

7

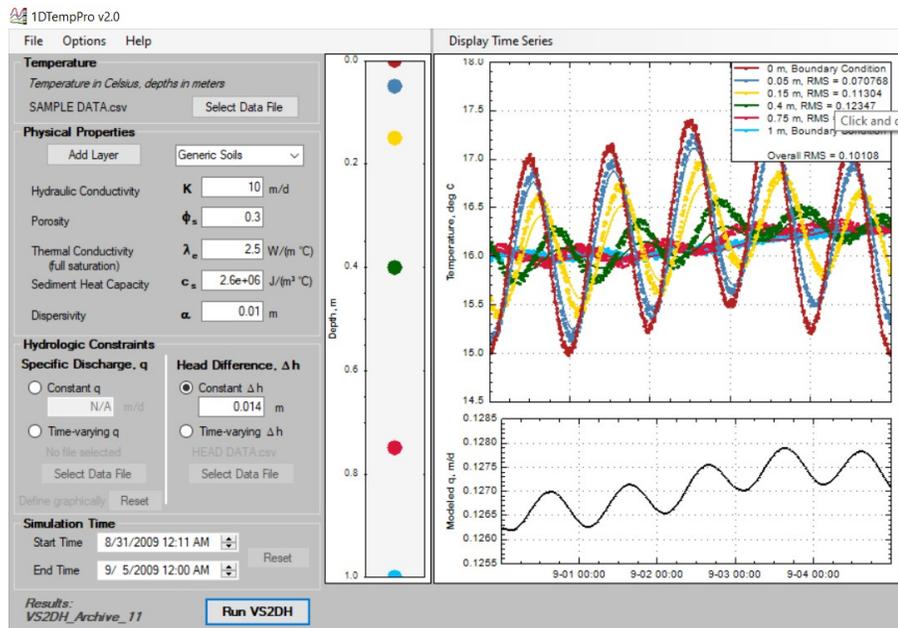
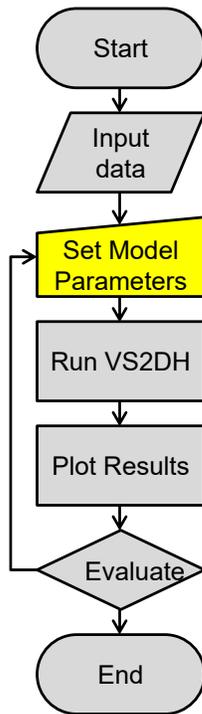
(6) When hydraulic head is measured, we can use the data to specify the gradient, and estimate hydraulic conductivity (K) and q . For example, enter $\Delta h = 0.014\text{m}$ and $K = 10\text{ m d}^{-1}$.



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

8

- (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 ?

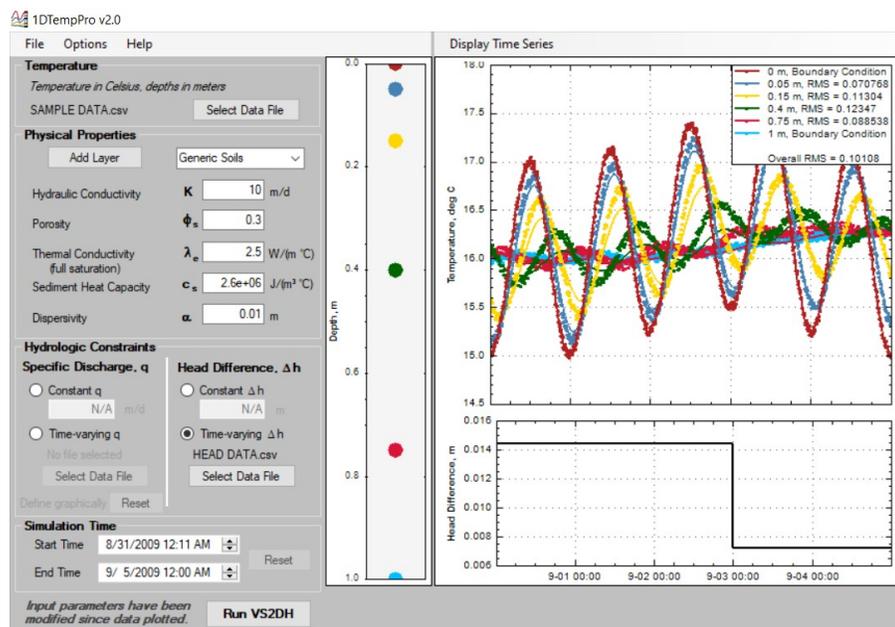
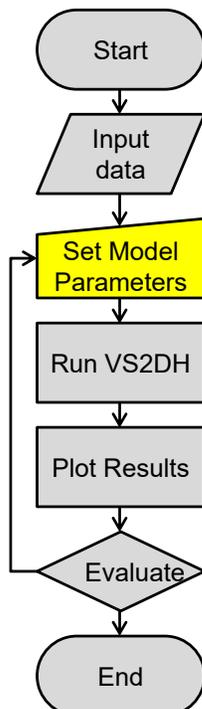


Note: K is entered as the value at 20 °C. VS2DH adjusts K according to temperature.

9

- (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 .



10

Shingobee Lake, Minnesota

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



11

(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:

$$q = 0 \text{ m d}^{-1}, \phi_s = 0.3, \lambda_e = 0.99 \text{ W m}^{-1} \text{ }^\circ\text{C}^{-1}$$

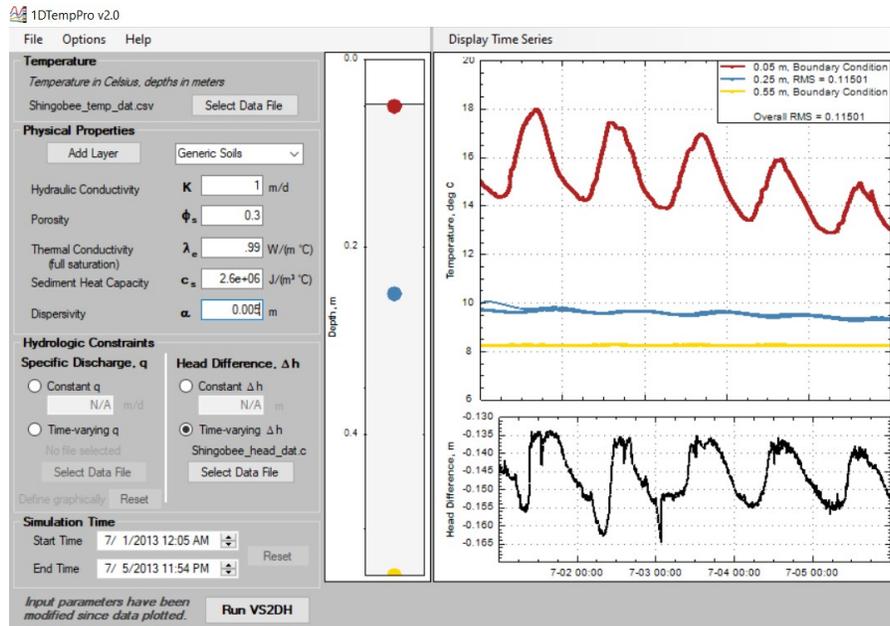
$$C_s = 2.6 \times 10^6 \text{ J m}^{-3} \text{ }^\circ\text{C}^{-1}, \alpha = 0.005 \text{ m}$$

(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.

12

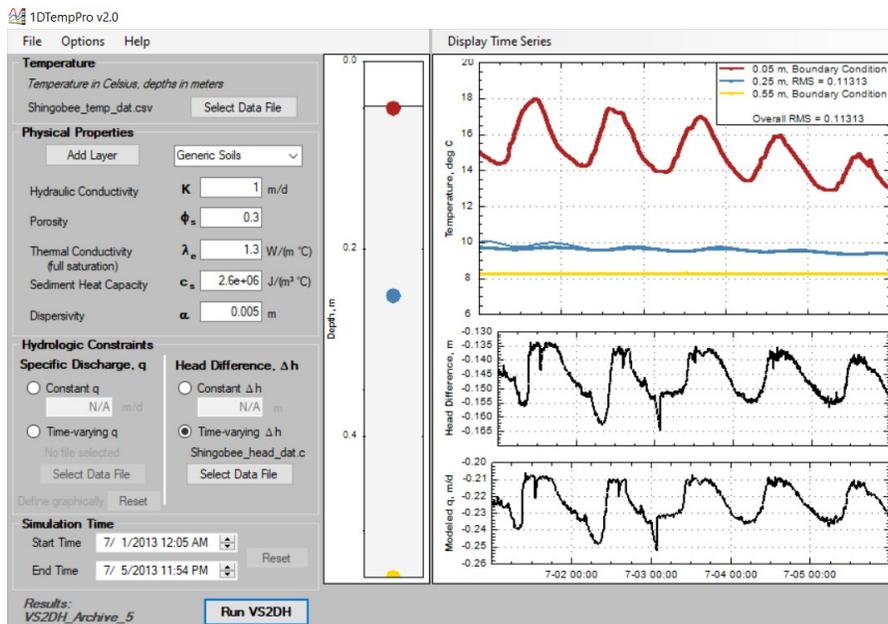
(13) Import time-varying Δh data, Shingobee_head_dat.csv, and enter a reasonable value of K (e.g., 1 m d⁻¹).



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

13

(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)**

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