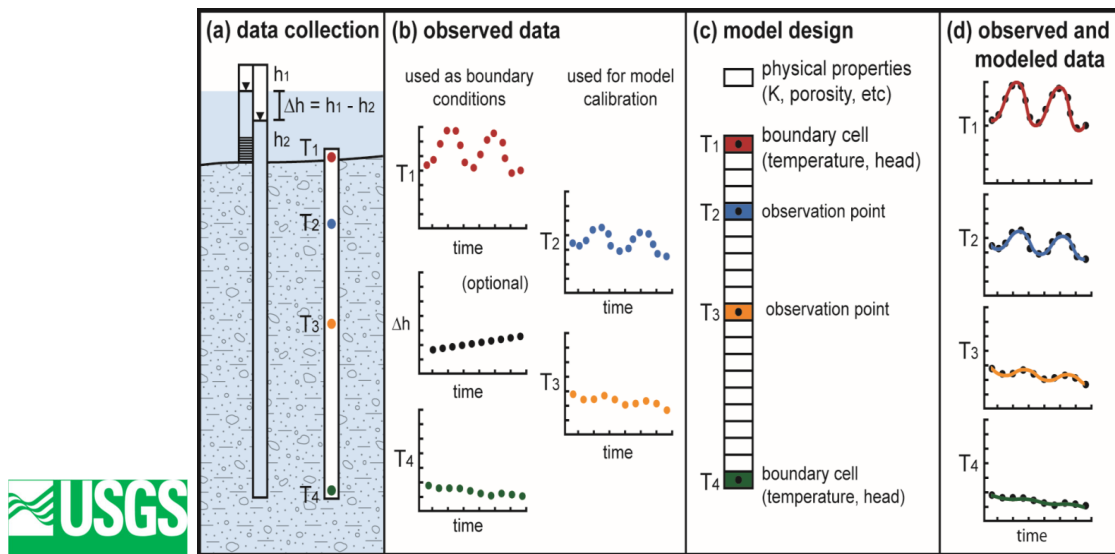


Computer Exercise: 1DTempPro

Objectives

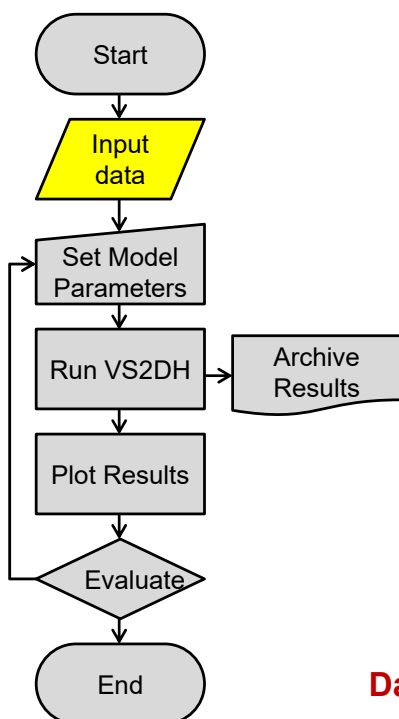
1. Learn how to estimate seepage flux from temperature data.
2. Develop intuitive understanding of heat transfer processes.



<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.

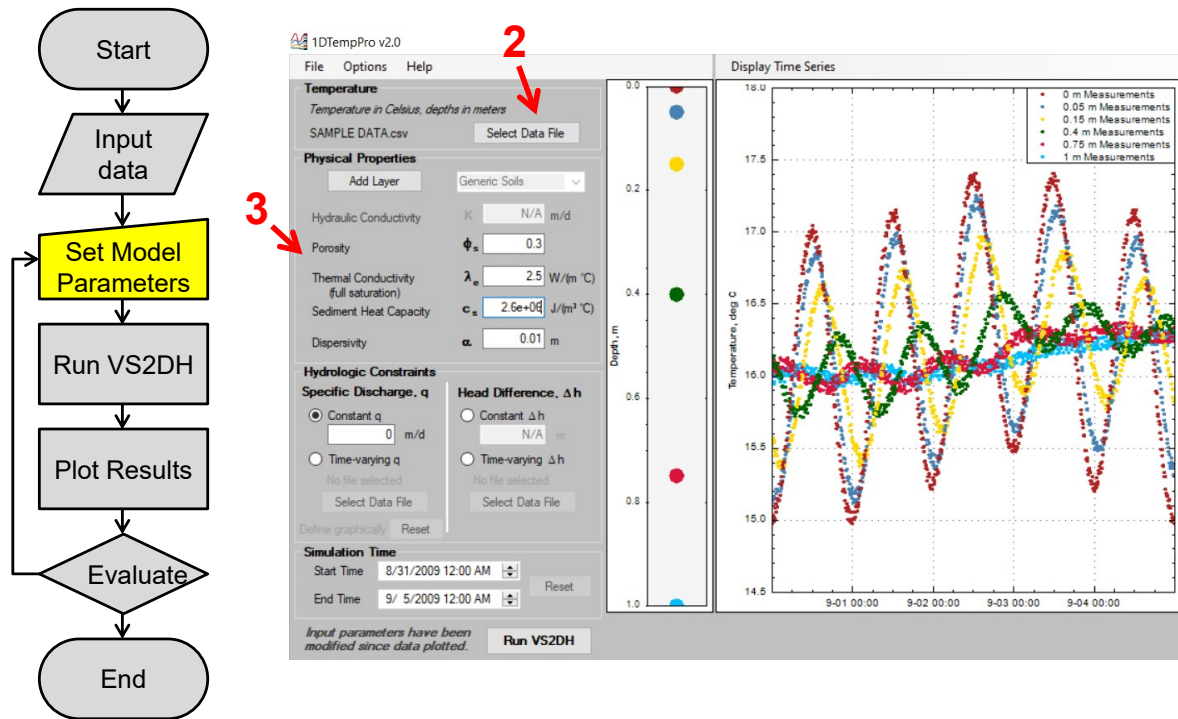


	Depths (m)
1	,0,0.05,0.15,0.4,0.75,1
2	8/31/2009 0:00,14.96,15.16,15.57,16.17,16.03,15.97
3	8/31/2009 0:10,14.97,15.13,15.52,16.12,16.01,16.02
4	8/31/2009 0:20,15.03,15.14,15.54,16.09,16.09,15.99
5	8/31/2009 0:30,15.00,15.16,15.57,16.12,16.07,16.00
6	8/31/2009 0:40,14.99,15.16,15.55,16.06,16.11,15.94
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

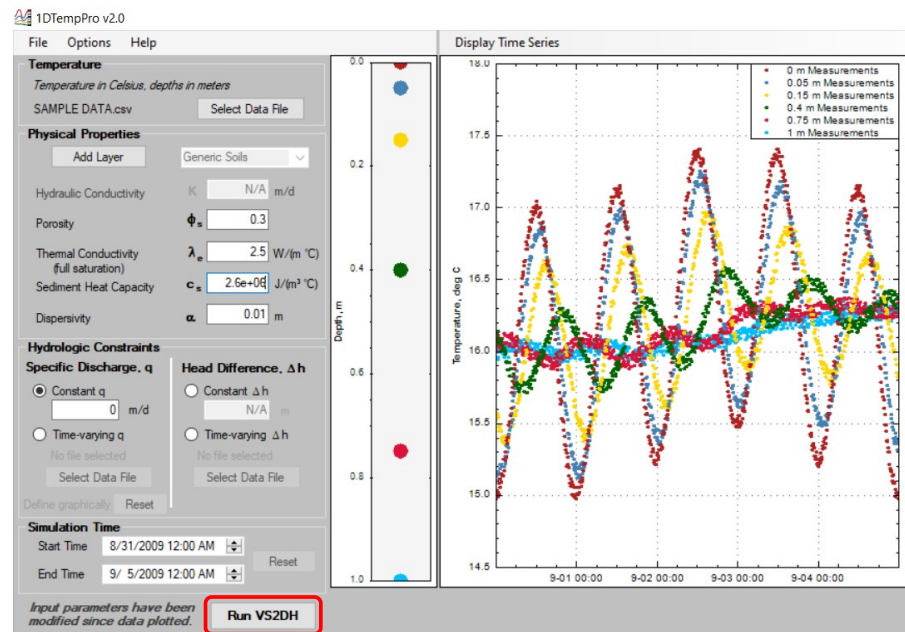
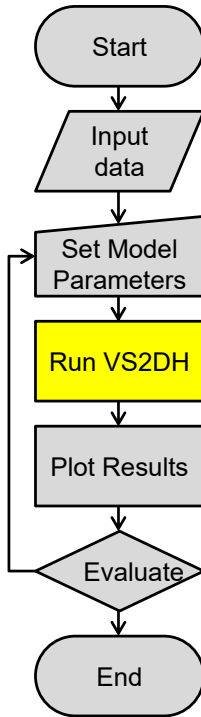
- See Lecture 11 slides for thermal properties of common sediments.
- Heat capacity of water (4.2 × 10⁶ J m⁻³ °C⁻¹) and common minerals (1.9 × 10⁶ J m⁻³ °C⁻¹) are well constrained. Therefore, C_s can be estimated reliably from porosity: e.g., for $\phi_s = 0.3$,

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

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.

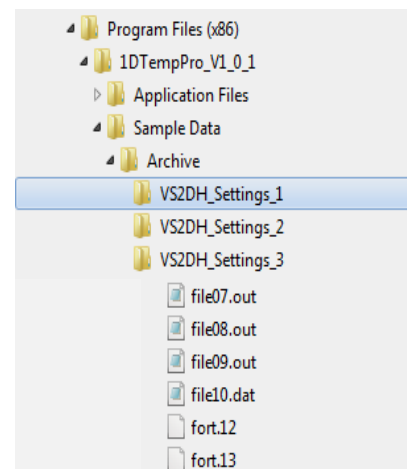
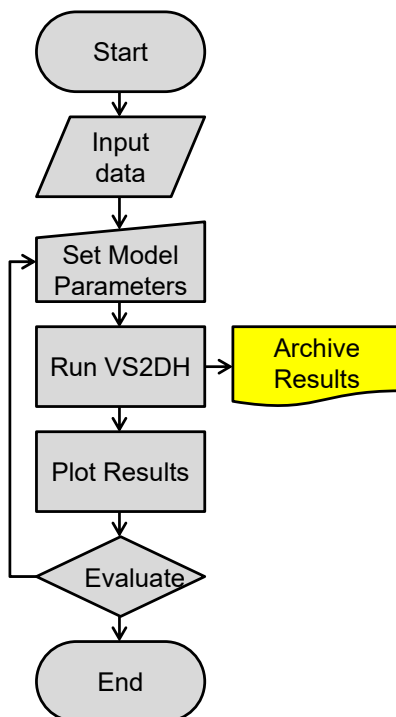


Variably Saturated 2-Dimensional flow with Heat

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

5

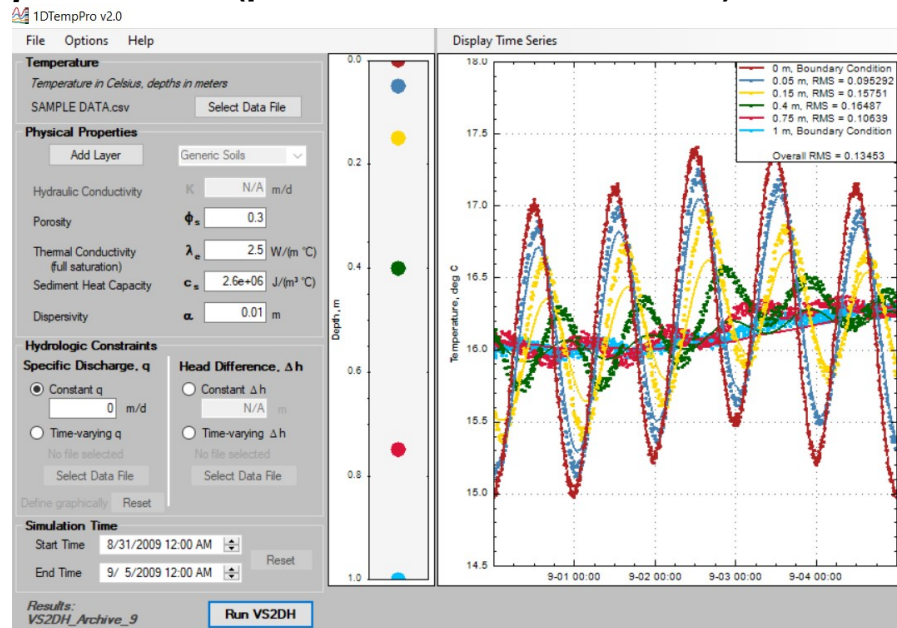
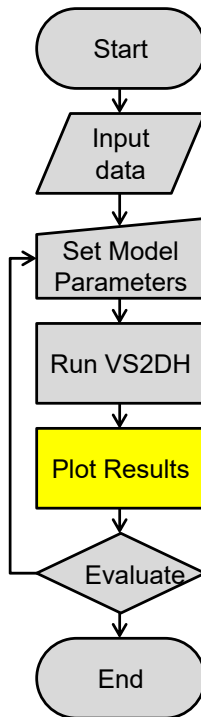
For each model run, VS2DH generates a set of output files stored in Archive folder. Delete the files occasionally to prevent excessively large disk-space usage.



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

6

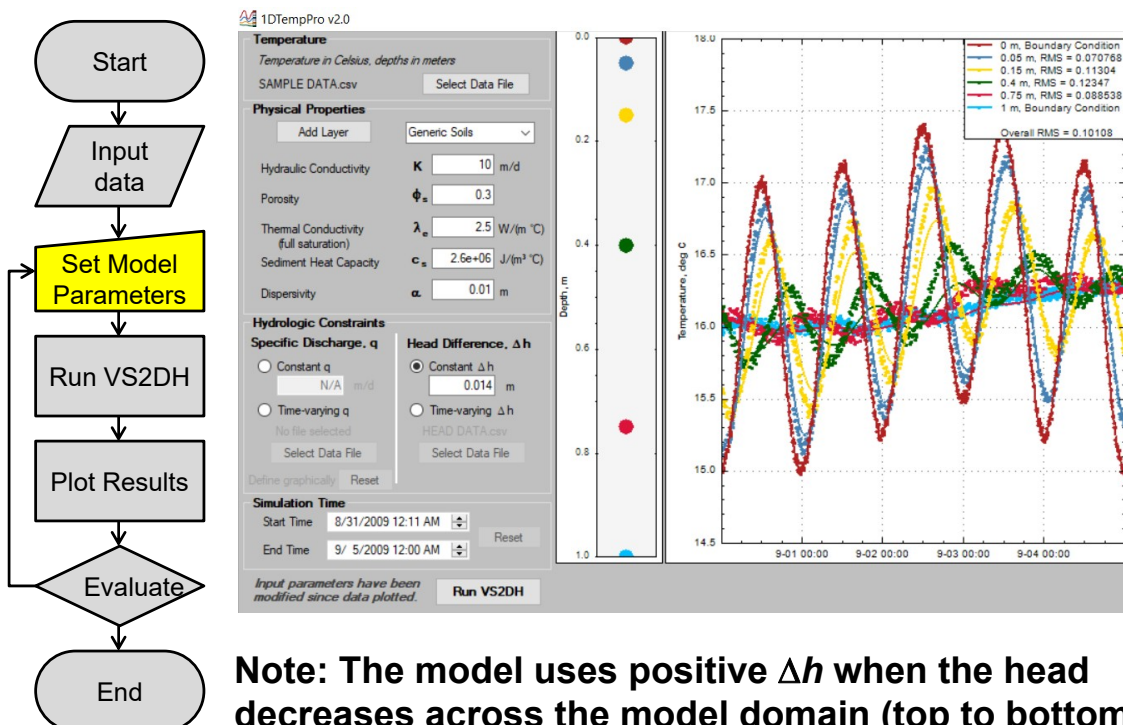
(5) Evaluate the match between observed and modeled temperature. In this case $q = 0$ is used (positive for downward flow).



- 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

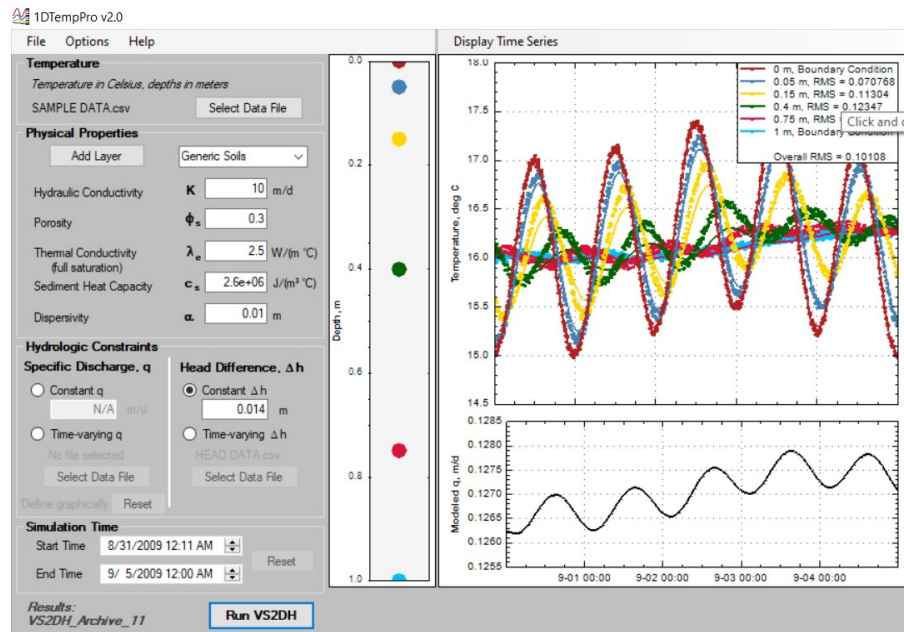
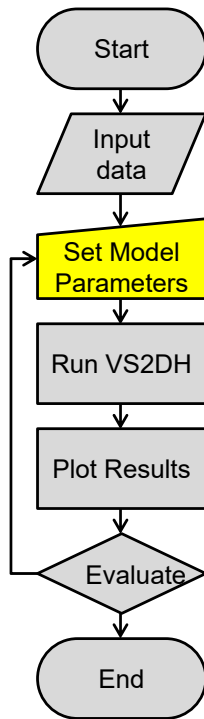
(6) When hydraulic head is measured, we can use the data to specify the gradient, and estimate hydraulic conductivity (K) and q . For example, enter $\Delta h = 0.014\text{m}$ and $K = 10\text{ m d}^{-1}$.



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 ?

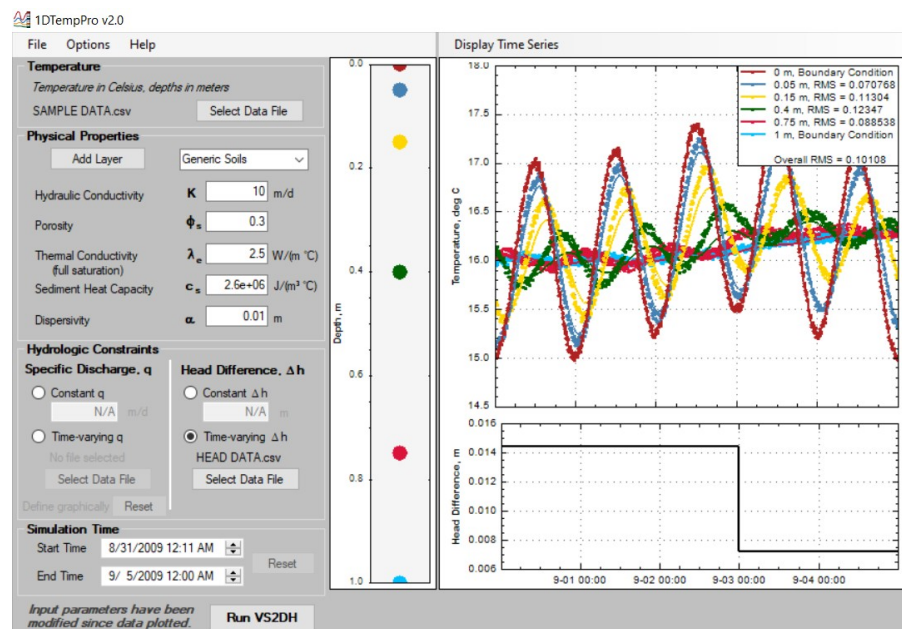
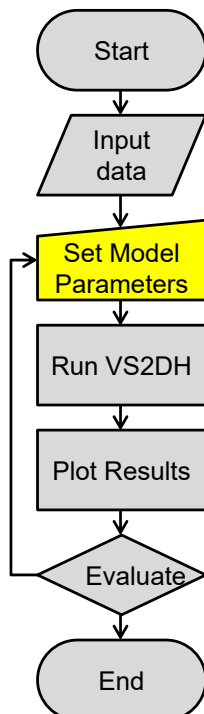


Note: K is entered as the value at 20 °C. VS2DH adjusts K according to temperature.

9

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

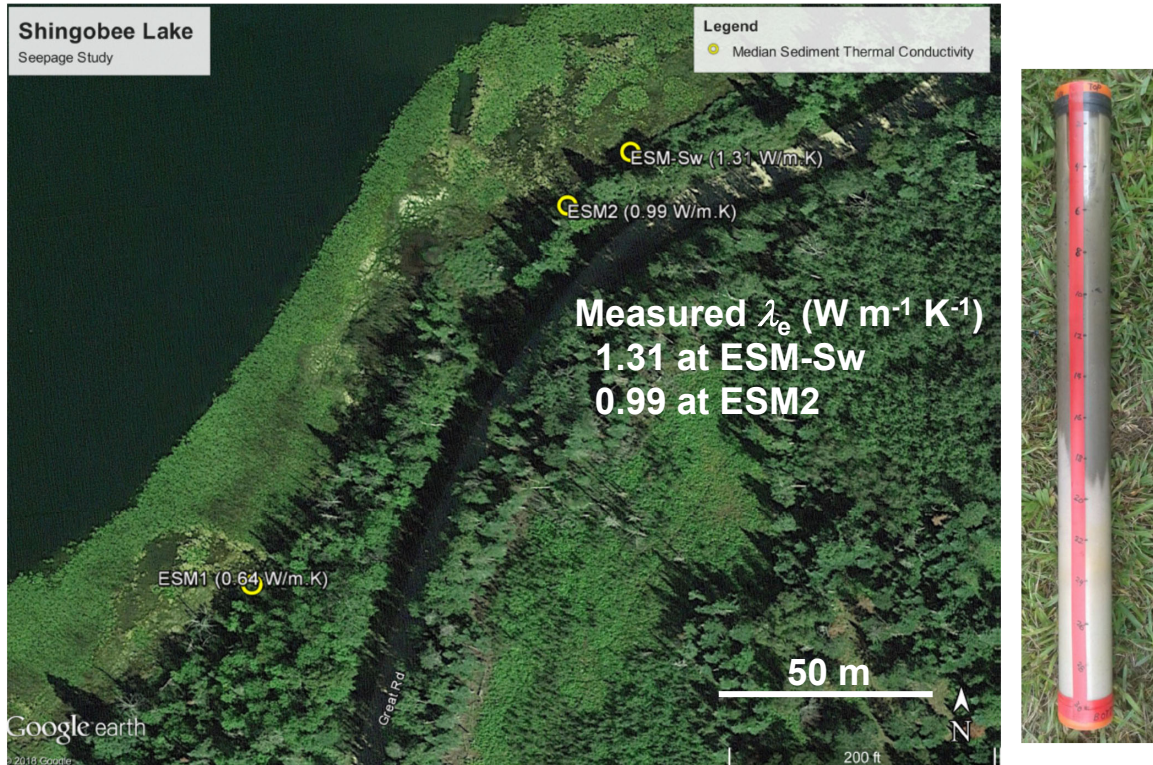
→ Find the best-fit value of K .



10

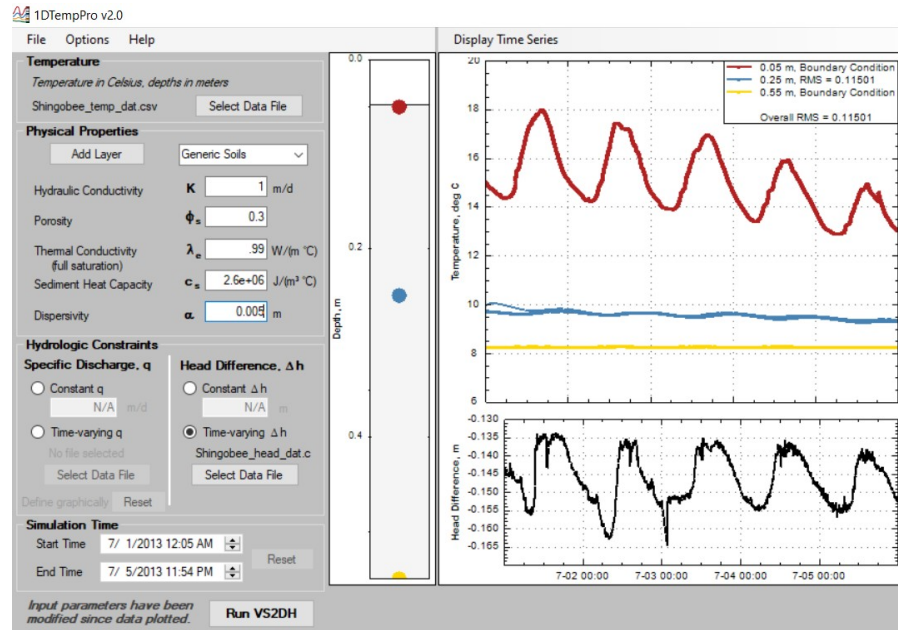
Shingobee Lake, Minnesota

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



- (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.

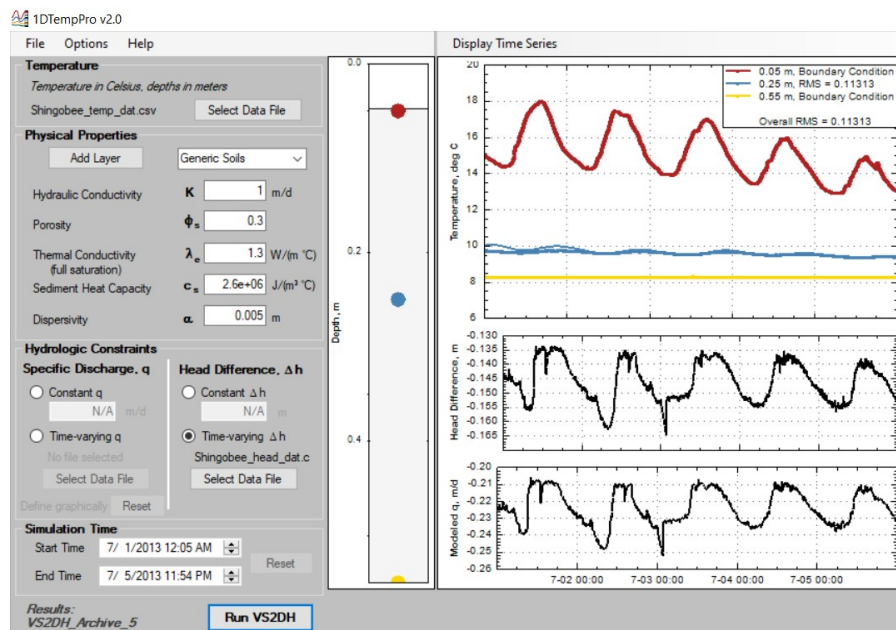
(13) Import time-varying Δh data, Shingobee_head_dat.csv, and enter a reasonable value of K (e.g., 1 m d⁻¹).



(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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