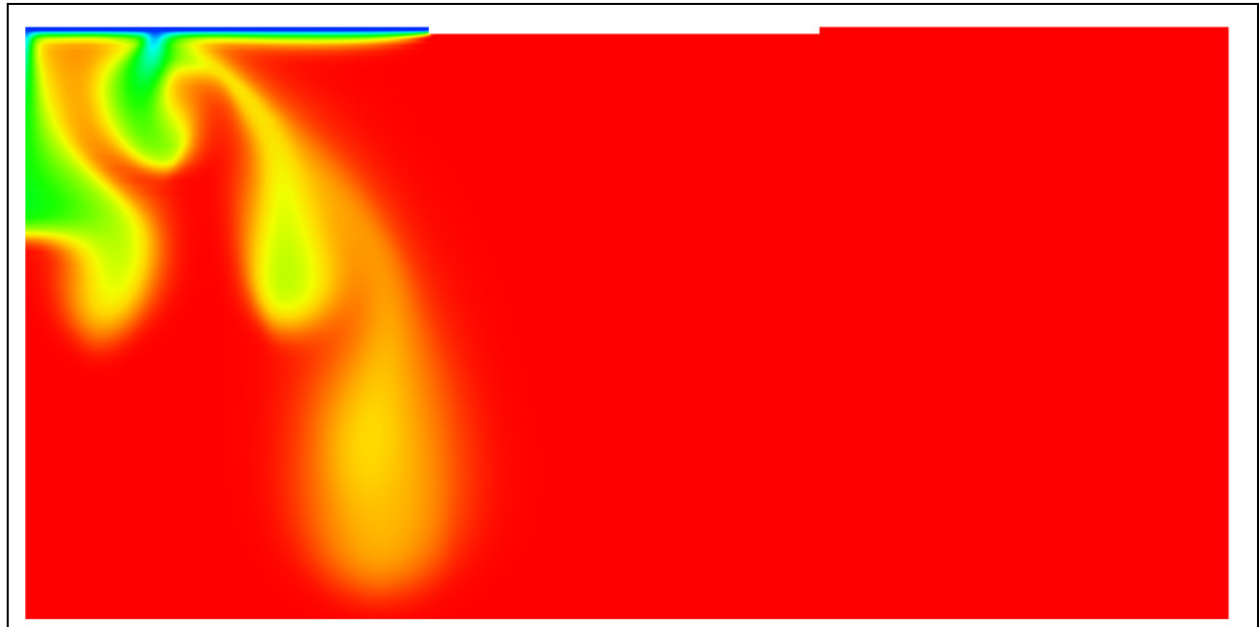*GMS 9.2 Tutorial*

SEAWAT – Hele-Shaw Experiment

Simulate the Hele-Shaw Salt Lake experiment using SEAWAT in GMS

Objectives

Construct and run a SEAWAT model in GMS using the grid approach. The model will mimic the Hele-Shaw Salt Lake experiment.

Prerequisite Tutorials	Required Components	Time
• None	• Grid • MODFLOW • MT3DMS • SEAWAT	• 30-60 minutes

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1   Contents

2   Introduction

"SEAWAT is a generic MODFLOW/MT3DMS-based computer program designed to simulate three-dimensional variable-density groundwater flow coupled with multi-species solute and heat transport. The program has been used for a wide variety of groundwater studies including those focused on brine migration in continental aquifers as well as those focused on saltwater intrusion in coastal aquifers. SEAWAT uses the familiar structure of MODFLOW and MT3DMS."[1]

This tutorial explains how to perform a SEAWAT simulation within GMS.

2.1   Outline

This is what you will do in this tutorial:

1.   Import an existing SEAWAT simulation.

2.   Run the simulation and view the results.

3   Description of Problem

The first problem we will be solving in this tutorial is the *Salt Lake* problem used in the SEAWAT manual.[2]

The design for the Hele-Shaw experiment is shown in Figure 1. Uniform evaporation of pure water occurs along line segment *AB,* leaving behind a salt-saturated fluid with a concentration of 110 grams per liter. Fluid with a potassium sulfate concentration of 84 grams per liter is injected at a constant head along segment *CD*. The remaining boundaries are impermeable. To prevent the fingers from forming too rapidly, the clear plates were tilted at an angle (ϕ)

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of 5 degrees from the horizontal. This tilt is represented in SEAWAT-2000 by calculating input variables (hydraulic conductivity and specific storage) with the component of gravity (g) that is parallel with the plate ($g \sin \phi$). Table 1 contains a list of the input variables for the salt lake problem.[2]
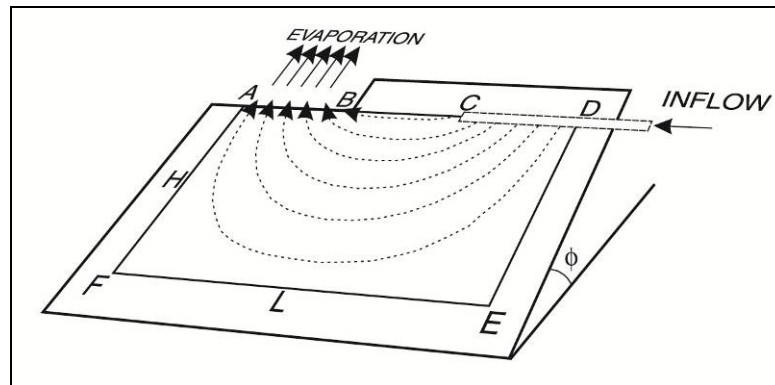

Figure 1.   Flow model from SEAWAT manual.[2]

Model input parameter	Variable (if applicable)	Value
Experiment height	H	75 mm
Experiment length	L	150 mm
Evaporation length	L_e	50 mm
Plate spacing	b_{gap}	0.2 mm
Equivalent freshwater hydraulic conductivity	$K_f = \dfrac{b_{gap}^2 \rho_f g \cdot \sin\phi}{12\mu}$	3.05 mm/s
Porosity	θ	1
Inflow fluid density	ρ_{in}	1.0646 g/cm^3
Saturated fluid density	ρ_{sat}	1.0814 g/cm^3
Diffusion coefficient	D_m	9 x 10^{-4} mm/s
Cell angle to the horizontal	ϕ	5 degrees
Initial evaporation rate		1.03 x 10^{-3} mm/s
Recharge rate		1.03 x 10^{-3} mm/s
Inflow fluid concentration	C_{in}	84 g/L
Saturated fluid concentration	C_{sat}	110 g/L
Fluid dynamic viscosity	m	1.1 x 10^{-3} kg/m·s
Density change per concentration change	$\delta\rho/\delta C$ or *DENSESLP**	0.646
Water compressibility	β_w	4.5 x 10^{-10} kPa^{-1}
Equivalent freshwater specific storage	$S_f = \rho_f g \theta \beta_w \sin\phi$	3.8 x 10^{-10} mm^{-1}
Longitudinal dispersivity	α_L	9 x 10^{-7} mm
Transverse dispersivity	α_T	9 x 10^{-7} mm
Acceleration due to gravity	$g \, \sin \, \phi$	855 mm/s^2

*Calculated based on the concentration and density of the inflow fluid and saturated fluid.

Figure 2.   Input parameters and values for salt lake Hele-Shaw experiment and SEAWAT 2000 simulation.[2]

A SEAWAT-2000 model was run for 24,000 seconds (400 minutes) using 60-second transport time steps. The variable-density flow equation was solved using the PCG solver, and the implicit finite-difference method was used with the GCG Package to solve the transport equation. [2]

4   Getting Started

Let's get started.

1. If necessary, launch GMS. If GMS is already running, select the *File | New* command to ensure that the program settings are restored to their default state.

5   Importing the existing model

We will start with a SEAWAT model that has already been created.

2. Select the 📂 *Open* button (or the *File|Open* menu command).

3. Browse to the *Tutorials\SEAWAT\Salt Lake* folder.

4. Change the *Files of type* popup menu to *All Files*.

5. Open the **seawat.nam** file.

6. Press *OK* to begin importing the model.

The *SEAWAT Translator* should run ending with a message saying SEAWAT terminated successfully.

7. Press *Done*.

The model is read into GMS and you should see a grid appear in the graphics window.

8. Click on the *Front View* button 🔲.

9. Click on the *Frame* button 🔍.

You should see a grid with symbols representing specified head boundary conditions similar to the figure below. Notice that the MODFLOW, MT3D, and SEAWAT menus are now shown in GMS. SEAWAT uses a combination of MODFLOW and MT3D inputs; the MODFLOW and MT3D portions of the SEAWAT inputs are edited in GMS through the MODFLOW and MT3D interfaces respectively. The SEAWAT interface includes the inputs that are specific to SEAWAT.
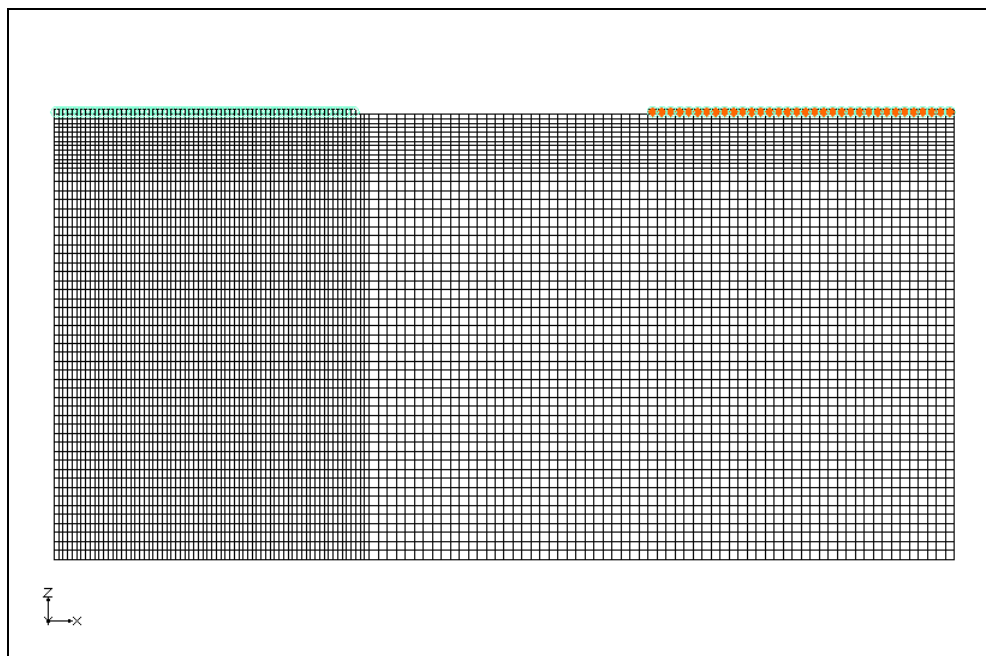

Figure 3.   Imported SEAWAT model.

6   Viewing the SEAWAT Inputs

We will now examine the inputs to the SEAWAT model.

1.   Select the *SEAWAT | Global Options* menu command.

Notice that this SEAWAT simulation includes transport and that the Variable Density Flow (VDF) Package is turned on.

2.   Select *OK* to exit the dialog.

3.   Select the *SEAWAT | VDF Package* menu command.

The VDF package controls how density is calculated by SEAWAT. Notice in the *Fluid Density Calculation* section of the dialog that MT3DRHOFLG is set to 1 to indicate that the concentration of "species_1" is used in the density calculations. DENSREF is set to the value of the incoming fluid density shown in Figure 2. DRHODC is set to the value of density change per concentration change shown in Figure 2. Also notice that NSWTCPL is set to 1 to indicate that the flow and transport are explicitly coupled. Check the SEAWAT documentation for more information on how these inputs affect the SEAWAT model.

4.   Select *OK* to exit the dialog.

7   Saving and running the model

Let's save the model with a new name and then run the model.

1.   Select the *File|Save As* menu command.

2.   Browse to the *Tutorials/SEAWAT/Salt Lake*.

3.   Change the project name to **Saltlake**.

4.   Save the project by clicking the *Save* button.

5.   Select the *SEAWAT|Run SEAWAT...* menu command.

6.   When the simulation is finished, close the window and return to GMS. The solution is imported automatically.

8   Viewing the Solution

We will now view the results of the SEAWAT model run.

1.   Select the *species_1* data set inside of *SaltLake (MT3DMS)* item.

If necessary, expand the *SaltLake (SEAWAT)* 📁 item in the *Project Explorer* to see the *SaltLake (MT3DMS)* 📁 item.

2. In the *Time Step* list below the *Project Explorer*, select time step 23215.

The solution should look similar to the following figure:
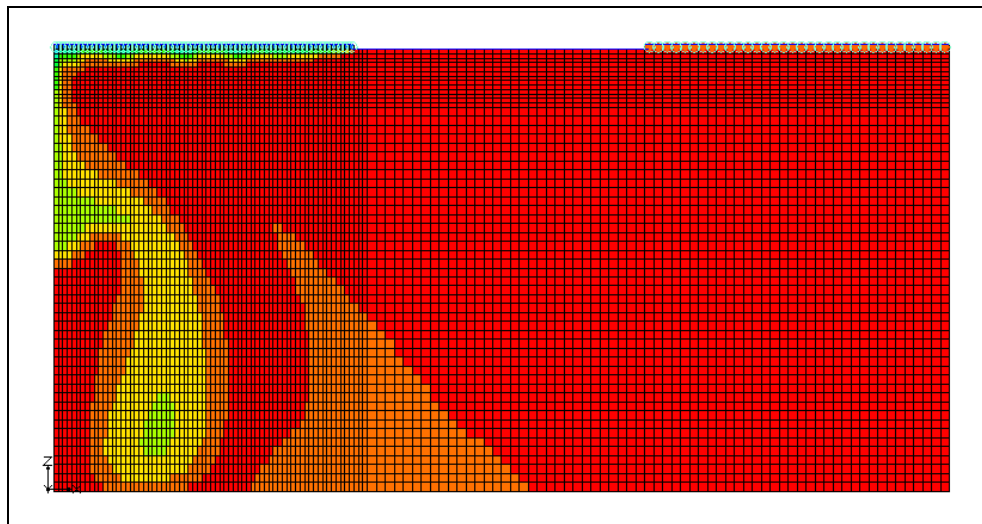

Figure 4.   SEAWAT solution.

The model results look very similar to the result from the real experiment which is shown below.
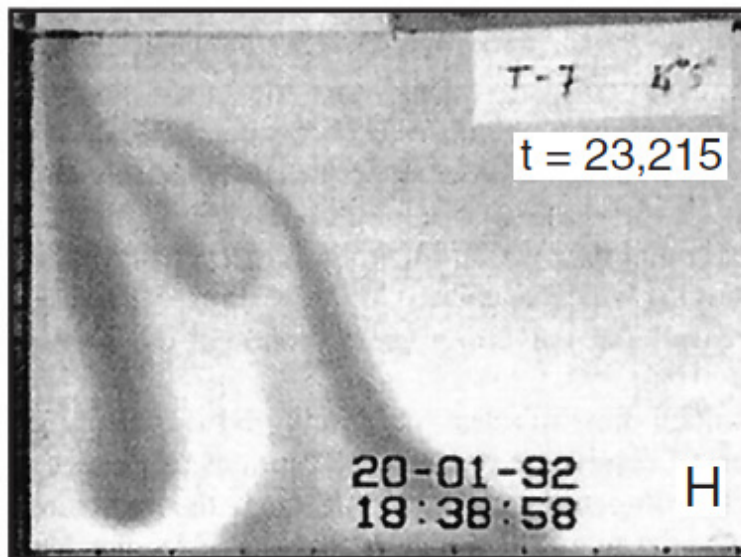

Figure 5.   Result from Hele-Shaw experiment of the Salt Lake problem at time step 23215s.

You may wish to step through the time steps of the solution.

9   Creating an Animation

Now we will create an animation of the concentration over time.

1. Select the *Display | Animate...* command to bring up the Animation Wizard dialog.

The defaults should work fine for creating an animation.

2. Select the *Next* button on the first page and the *Finish* button on the second page to create the animation.

The animation will pop up in its own window and begin playing. You may wish to change the contour options or rerun SEAWAT with different options and animate the results.

10   Conclusion

This concludes the tutorial. Here are the things that you should have learned in this tutorial:

- SEAWAT combining both MODFLOW and MT3D can be used to solve variable density groundwater flow and solute transport equations.

- You can import existing SEAWAT models into GMS easily.

- GMS has multiple options for viewing the results of a SEAWAT model run.

11   Notes

1. http://water.usgs.gov/ogw/seawat/

2. Langevin, C.D., Shoemaker, W.B., and Guo, Weixing, 2003, MODFLOW-2000, the U.S. Geological Survey Modular Ground-Water Model–Documentation of the SEAWAT-2000 Version with the Variable-Density Flow Process (VDF) and the Integrated MT3DMS Transport Process (IMT): U.S. Geological Survey Open-File Report 03-426, 43 p.

3. Langevin, C.D., Thorne, D.T., Jr., Dausman, A.M., Sukop, M.C., and Guo, Weixing, 2007, SEAWAT Version 4: A Computer Program for Simulation of Multi-Species Solute and Heat Transport: U.S. Geological Survey Techniques and Methods Book 6, Chapter A22, 39 p.