Internship: Generating variable-density groundwater benchmarks in 2D using iMOD-SEAWAT

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Content

Introduction

This report contains the most important characteristics of the internship "Generating variable-density groundwater benchmarks in 2D using iMOD SEAWAT". The task of this assignment was to transfer existing 2D models of variable-density groundwater flow and coupled salt transport which are in the computer code MOCDENS3D to SEAWAT, in an iMOD-SEAWAT format. Different geometries and boundary conditions were tested. The tools used included iMOD-SEAWAT, iMOD, Python and Tecplot.

Methodology

The first task of this assignment was to become familiarized with MODFLOW, SEAWAT and iMOD codes. Manuals of these tools were read and analyzed in order to understand the theory of groundwater flow and transport and how this is represented by programming tools.

In total, 6 benchmark models were converted to iMOD-SEAWAT format. The values and location of the boundary conditions used were obtained from the manual “Density Dependent Groundwater Flow - (Salt Water Intrusion and Heat Transport)” (2001) by Oude Essink, G. H. P.

At the beginning, the creation of the input data was done manually by creating ASCII files and later transforming them to IDF/IPF files using iMOD graphical user interface (GUI). New runfiles were also created based of the modification of previously existing ones. Later on, a Python tool in Jupyter Notebook was provided by Deltares to simplify this task. Nonetheless, some parameters still were modified directly in the runfile after its creation with the Python tool (for example: the DSP properties, the number and length of stress periods, flags to indicate that the boundary conditions should be applied for many stress periods). One important thing to mention is that iMOD-SEAWAT runfiles are easy to modify because with just one file all the boundary conditions parameters can be controlled.

iMOD GUI, was used to visualize IDF and IPF files obtained from the Python code and check that they were correctly created.

The main tool for running the models was the iMOD-SEAWAT executable. The final version used was imod-wq_svn270_x64r.exe, which had to be modified by the developers in order to be able to work with small grid dimensions (around 0.05 m), which was not possible with the previous versions of the code.

Tecplot, which is a visualization software, was used to evaluate the final results in a more simple way. It transformed the text results obtained from iMOD-SEAWAT to a *.avi format file, as well as *.png.

Results

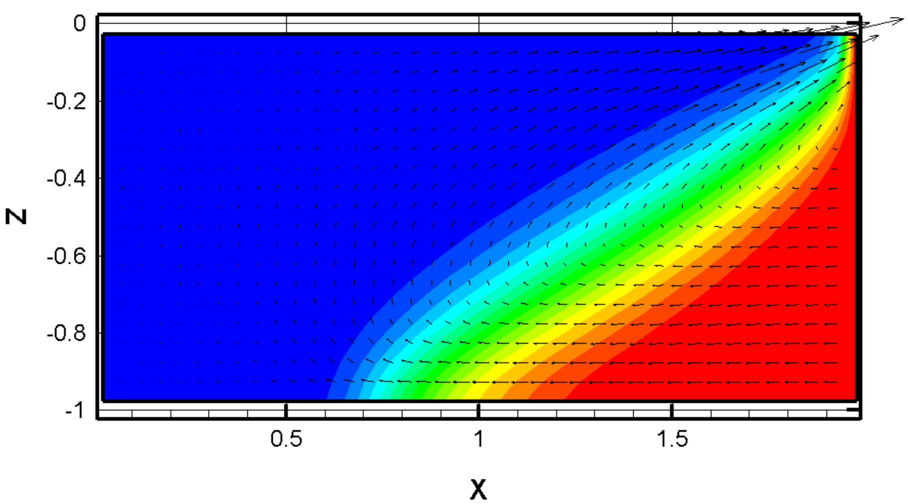
The following section shows the results obtained from the transformation of the models to 2D using iMOD-SEAWAT. All the graphs were obtained from the animations created in Tecplot.

1. Henry's problem

The first case to be created was Henry's problem. Here it was dealt with values of dx and layer thicknesses of 0.05 m. Because of this, there were issues when using previous iMOD-SEAWAT executables, however, they were modified by Deltares team to fix this problem.

For the model parameters considered, the system will reach a steady state after around 400 minutes, time when maximum intrusion occurs, as seen in Figure 1.

Figure 1
Henry´s case – Final simulation



2. Vertical interface between fresh and saline groundwater

For this case, the solver used for the advection solution was the Method of Characteristics (MOC), since when using TVD the results were not accurate and the system would not reach the steady state.

Due to the difference in density, the interface will start rotating as it is seen in Figure 2, until it reaches a steady state which is shown in Figure 3.

Figure 2
Vertical interface

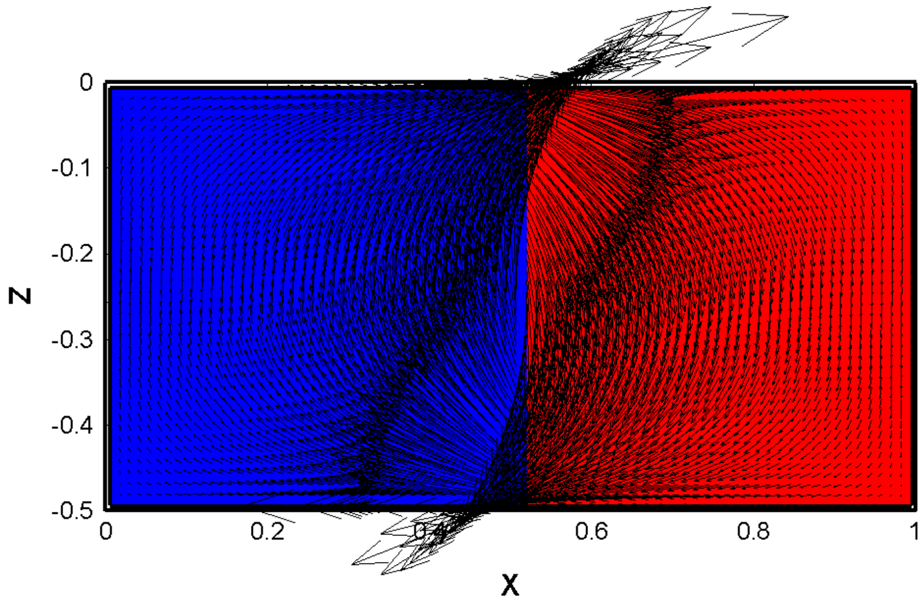
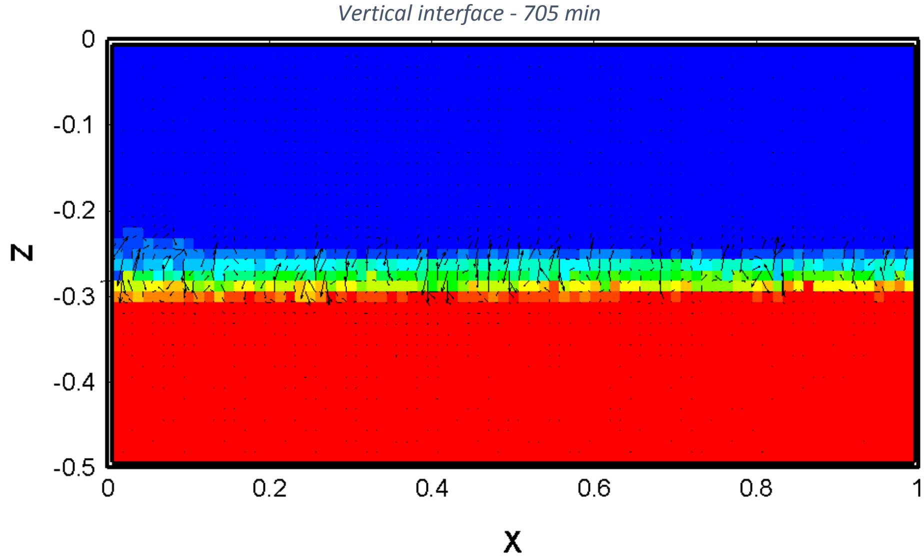


Figure 3
Vertical interface - 705 min



3. Elder problem

The variation in concentration in these two zones of the model caused the distribution of concentration to vary from the initial moments (Figure 4) to the dispersion distribution seen in Figure 5.

Figure 4
Elder problem – Concentration (g/l) during the initial moments

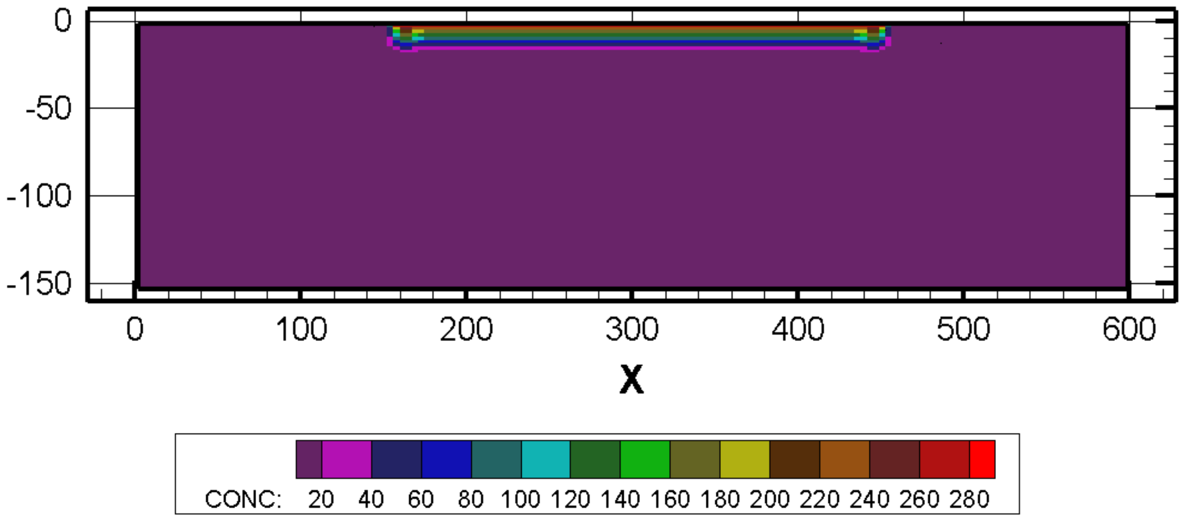
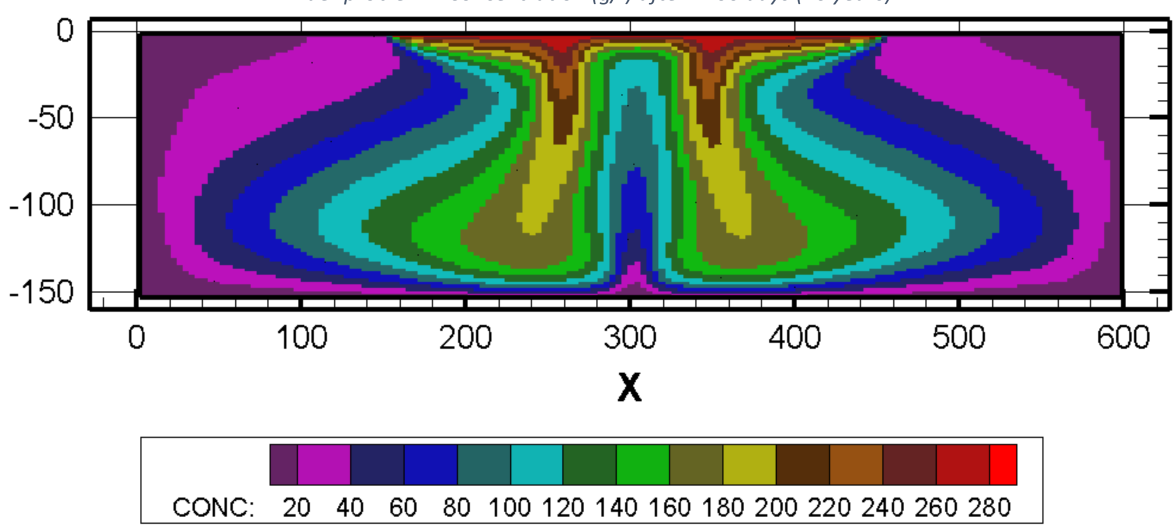


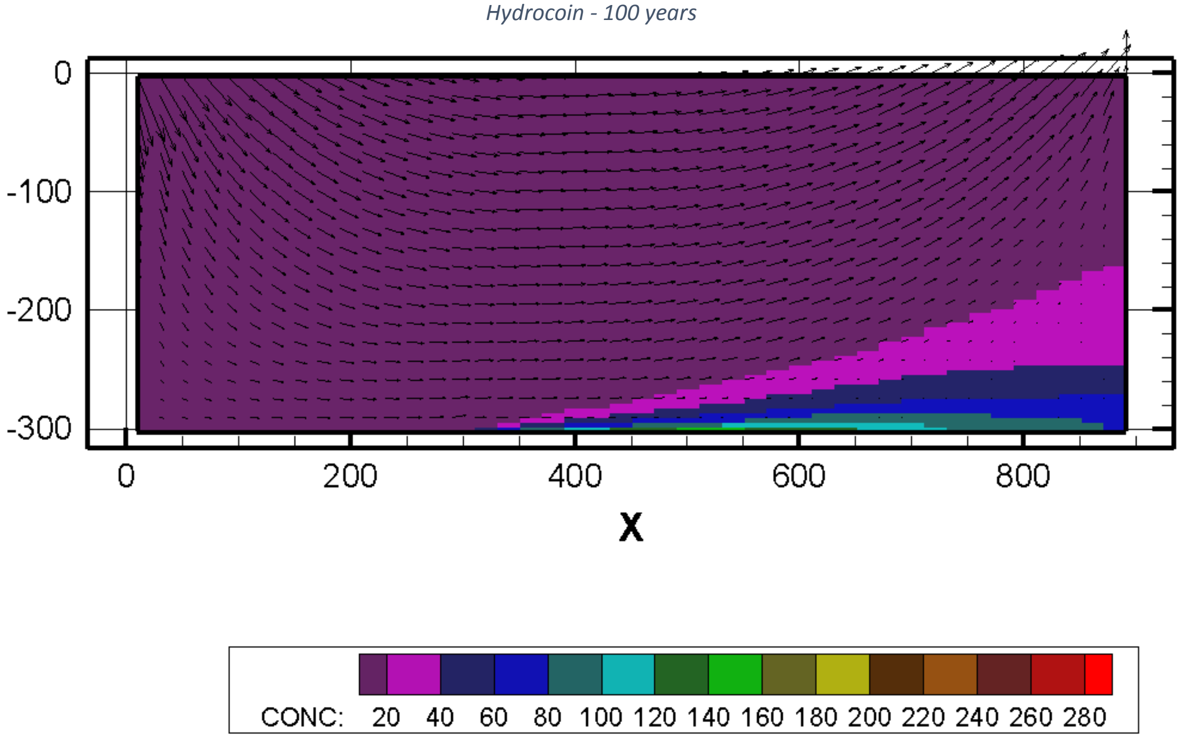
Figure 5
Elder problem – Concentration (g/l) after 7100 days (20 years)



4. Hydrocoin, level 1, case 5

Hydrocoin case boundary conditions were a bit more complex to insert than the rest of the cases, nonetheless, they were successfully represented as seen in Figure 6.

Figure 6
Hydrocoin - 100 years



5. Saltwater pocket in a fresh groundwater environment

Figure 7 shows the early moments of the saltwater pocket case, where a vortex is formed as the high concentration zone starts going downwards. After 3585 minutes, it has reached an almost flat state as observed in Figure 8.

Figure 7
Saltwater pocket

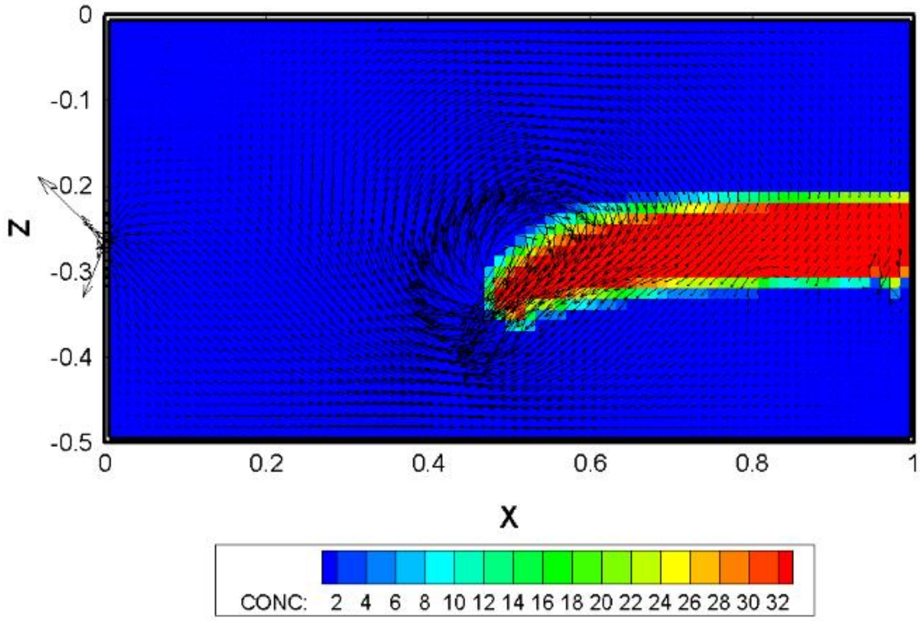
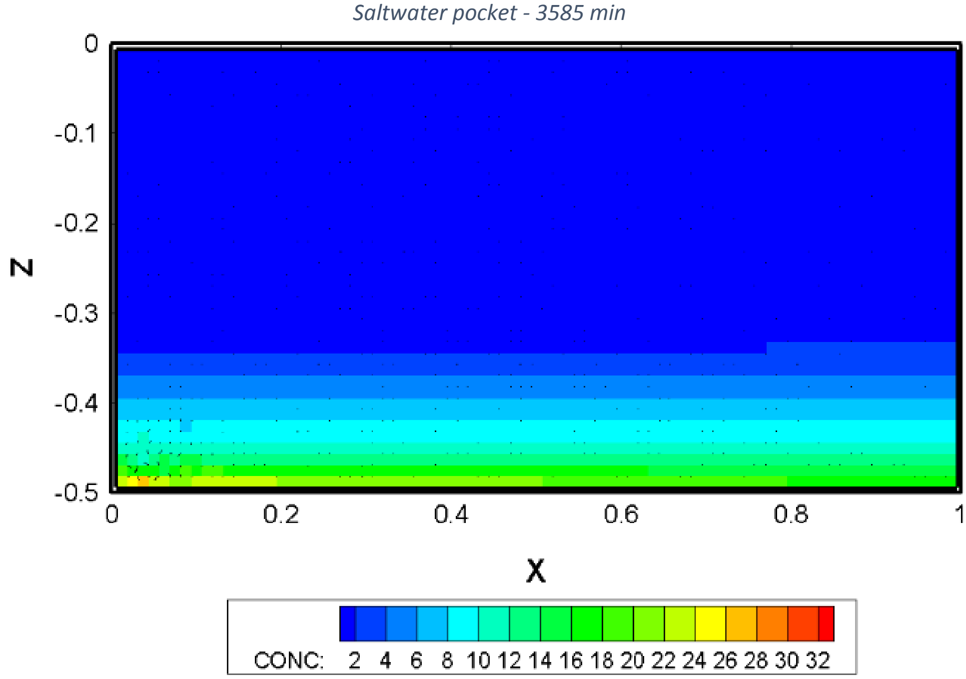


Figure 8
Saltwater pocket - 3585 min



6. Evolution of a freshwater lens

The freshwater lens case had larger geometry settings than the previous models because this is representing the conditions of an island where a freshwater recharge is occurring. Figure 9 shows the initial moments of the simulation, while Figure 10 depicts how the lens has increased its dimensions over time.

Figure 9
Freshwater lens - Initial

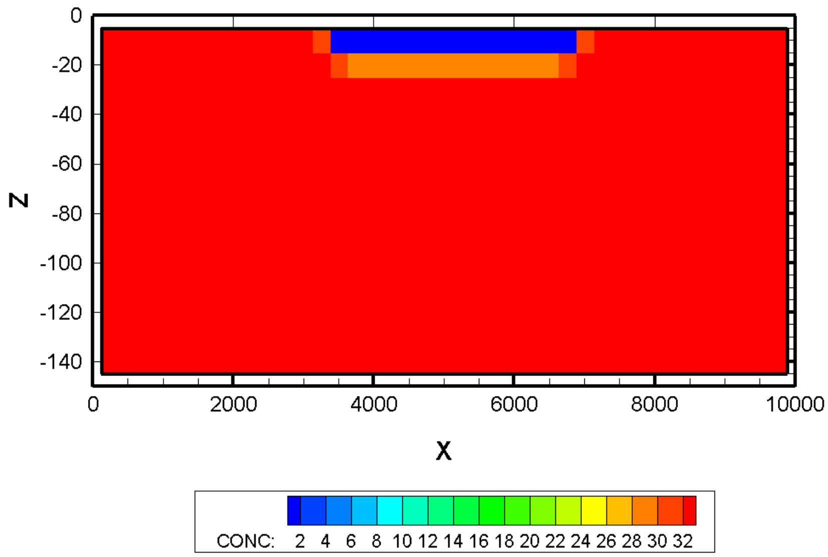
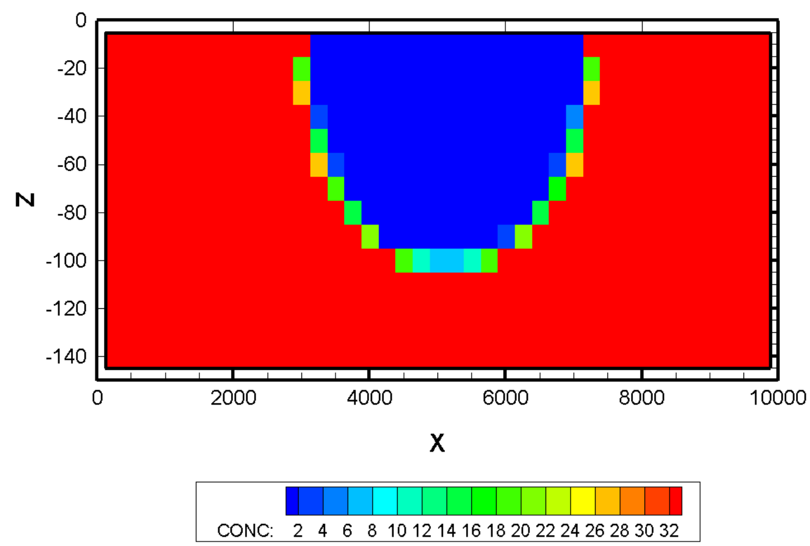


Figure 10
Freshwater lens – 400 years



Conclusions

The main objective of this internship, which was to transform six existing 2D models of variable-density groundwater flow and coupled salt transport which were in the MOCDENS3D code to iMOD-SEAWAT format, was successfully accomplished.

The initial literature review was extremely important, as it was necessary to understand the theory of groundwater flow and transport and how MODFLOW, SEAWAT and iMOD-SEAWAT represent these processes using certain parameters and packages.

The use of Python tools for the creation of input files was extremely helpful because it simplified this task and, at the same time, reduced the errors that could happen because of the manual modification of files.

One of iMOD-SEAWAT's advantages is that the runfile contains all the boundary conditions and parameters, making it easier to make modifications by just accessing this file. Another advantage is that iMOD-SEAWAT is supported by Deltares, so the executable could be checked and modified by their team when needed (in this case, for small grid cell dimensions).

The visualization of the results in an *.avi format (animation) provided by Tecplot, was an easy way to check the results, see if they were actually representing the case and understand the dynamics of these processes.