Final Report

Environmental Data Science

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Abstract

Understanding the relationship between tidal dynamics and aquifer behavior is crucial for effective land and water management in coastal regions. This study will investigate the drawdown within the surficial aquifer of the Estero Bay Watershed and model the interaction using the package FloPy with in Jupyter Notebook of Python. I will do this by following the process outlines in the course “Modflow6 and Flopy” presented by the Australian Water School. By understanding how these influences of the aquifer we can be better prepared to manage events such as flooding and saltwater intrusion with the rising sea level. This project is very feasible due to the availability of data and information on this subject and remains manageable due to the small scale of the single watershed of the study area. Overall, this project hopes to deliver a data-driven model for sustainable resource management in this rapidly developing urban area, showing the rise and fall of the water table as well as the overall water table elevation of the Estero Bay Watershed.

Introduction

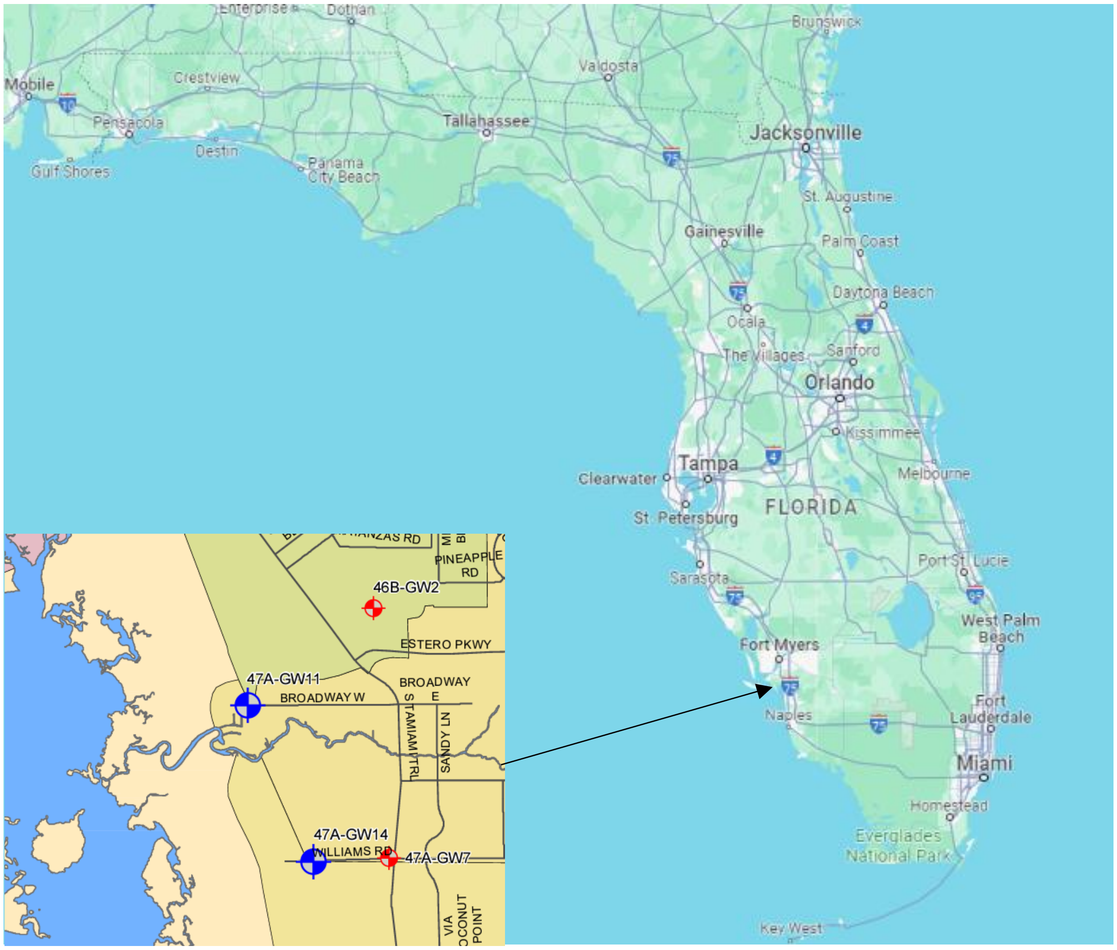
Groundwater resource management is a vital part of sustainable development and environmental protection. The key is effective management of groundwater systems, one way that we can do that is by using hydrogeologic models. For this project I will be using multiple packages within Python including: numpy, matplotlib, & flopy. I will be using these packages to create a basic contour array of the surficial aquifer using two monitor wells on either side of Estero River. The Lee County Utilities has a large amount of surficial monitor wells located throughout the county. This data is publicly available from their website, for the head of Estero River I used data from the US Geological Survey stage height monitors. I have watched instructional videos on using flopy, that were previously webinars hosted by the Australian Water School (AWS).

Objectives

I aim to follow the process the was given by the AWS to create grid views of the well locations in reference to the Estero River and then create a basic contour map. I will be executing this using the following steps: first I will import all necessary packages, then add grid properties, once the properties are correct the simulation gets created the following components are added. Time Discretization (Tdis), this breaks up the simulation period into time steps. Next is the Iterative Model Solution, this computes the groundwater heads for each time step until they reach an acceptable level of accuracy. The GWF (ground water flow model) simulates the movement of groundwater through the aquifer. We then add the initial conditions, constant head boundary and recharge. Once these are input and ran without errors, we can then generate a top view and cross section of our model. We then run the simulation to create the contour model.

Case Study

The map below shows the location for this study, Estero Bay is in Lee County Florida. The county has abundant resources and has a large well field with monitor wells that cover the entire county. I used the data to input the well locations into the parameters. I then went to the USGS stage height data base to calculate the hydraulic head of the Estero River to be 3.15 feet. I then used the average yearly rainfall to calculate the water table recharge rate of 0.126 in/day. I calculated the hydraulic conductivity using a tool from the University of Iowa for 85% Sand and 15% Clay surficial aquifers. And calculated the porosity of the aquifer to be 0.106 inches.



Methods

The first thing that I did was import all packages that were needed to run this code. Once this was done, I created a pathway where all newly written files would end up. After this step I set up all model parameters such as the grid size and shape, the hydraulic conductivity, porosity, head, well draw and recharge rate. After these parameters were defined, I then had to create the simulation. We needed to add the period length the complexity of the simulation and note that it was groundwater. Since it is groundwater, I needed to define the aquifer as unconfined, since I am modeling the water table aquifer, the initial conditions, and head. I also needed to add the four wells to the simulation. To confirm that all this data worked together we needed to solve the models, I did this by creating top and cross section views of the grid. Once this all came back with no errors it was time to run the simulation, and then read the simulation. After this was completed, I went ahead and created a contour map of the grid and calculated the input and output of the simulation.

Visualization, Analysis and Results:

Figure 1 Below gives us the water budget for the created simulation

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VOLUME BUDGET FOR ENTIRE MODEL AT END OF TIME STEP    1, STRESS PERIOD   1
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  CUMULATIVE VOLUME      L**3       RATES FOR THIS TIME STEP      L**3/T          PACKAGE NAME
  -----------------                 ------------------------                      ----------------

        IN:                                    IN:
        ---                                    ---
              WEL =          0.4000                  WEL =          0.4000     WEL_0
             RCHA =       1247.4000                 RCHA =       1247.4000     RCH
              CHD =          0.0000                  CHD =          0.0000     CHD_0

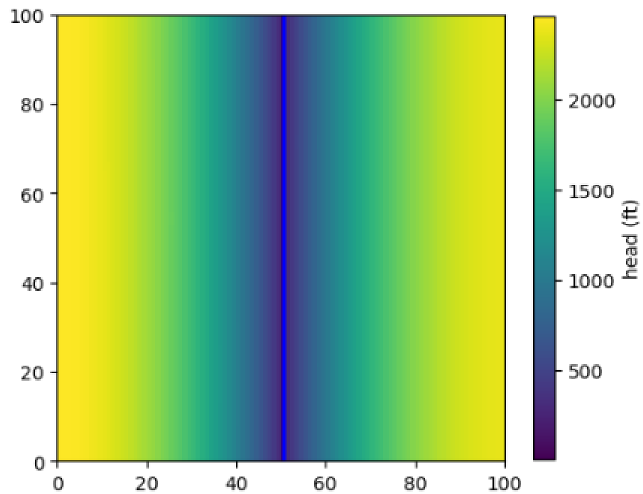
         TOTAL IN =       1247.8000             TOTAL IN =       1247.8000

       OUT:                                   OUT:
       ----                                   ----
              WEL =          0.0000                  WEL =          0.0000     WEL_0
             RCHA =          0.0000                 RCHA =          0.0000     RCH
              CHD =       1247.8011                  CHD =       1247.8011     CHD_0

        TOTAL OUT =       1247.8011            TOTAL OUT =       1247.8011

         IN - OUT =     -1.0983E-03             IN - OUT =     -1.0983E-03

PERCENT DISCREPANCY =         -0.00     PERCENT DISCREPANCY =         -0.00
```



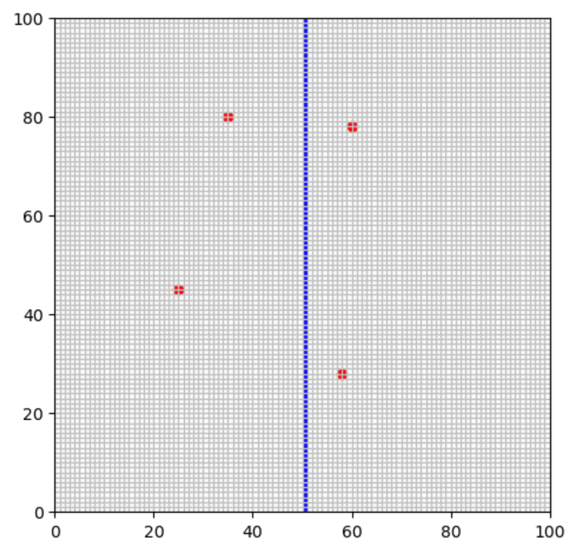
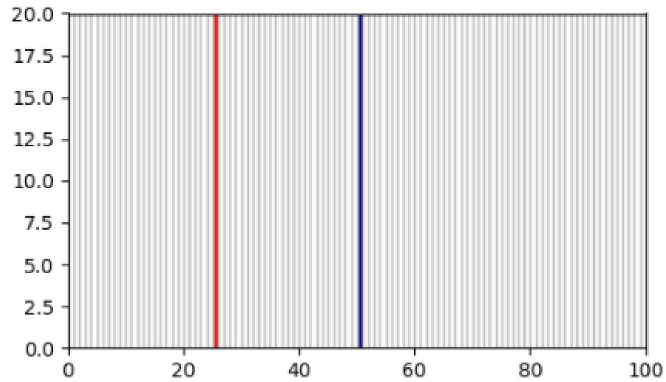


Figure 2 above left show us the contour model of our simulation. Figure 3 above right is the top view of our site showing the four well locations and the Estero River. Figure 4 below shows us the cross-section view of one of our wells in near the river.



Conclusion:

I learned a lot of new skills throughout this course and was able to apply them to this project. As I was working through the course from the Australian Water School, I had a good base understanding of how Jupyter Notebook operated and was able to follow along with only two major issues in at the end. However, I was able to understand how Flopy works within python and how all the parameters work together to create the simulation to get the precent of input and output into the Estero River. This project can be used to further my knowledge and understanding of groundwater modeling by adding additional variables and other well types.

Data Availability:

Data and Code are available at https://github.com/hgrimm27/flopy_eds

References:

Australian Water School. (2022, October 13). *MODFLOW 6 and flopy*. YouTube. https://www.youtube.com/watch?v=xDgWjArrHNY&t=1806s

Leaf, A. T., & Fienen, M. N. (2022). Flopy: The python interface for modflow. *Groundwater*, *60*(6), 710–712. https://doi.org/10.1111/gwat.13259