# Advanced PYTHON Programming
# for MODFLOW Modelers

## *Webinar*

### *Instructors:*
**Jim Rumbaugh**
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### *Location:*
**Your Home or Office!**

### *Cost*
**Individual: $950**
**Office: $1,900**

Contact Jim Rumbaugh (see above) to Register

## Instructor Bio:

**Jim Rumbaugh**, hydrogeologist and groundwater modeler, has over 35 years of experience in application of groundwater models and in development of groundwater modeling software tools. He is the co-author of the Groundwater Vistas software and is President of Environmental Simulations, Inc., a company that specializes in groundwater modeling. Jim was a past Chairman of ASTM Subcommittee D18.21 on Groundwater and Vadose Zone Investigations. Subcommittee D18.21 was funded by U.S. EPA to develop standards for groundwater modeling practice. Jim was honored by the National Ground Water Association with the 1999 John Hem Excellence in Science and Engineering Award by NGWA. This award is given to those who have made a significant, recent scientific or engineering contribution to the understanding of groundwater.  NGWA also presented Jim with the 2014 Technology Award, which is given to those who have made a significant contribution to the groundwater industry in the development of ideas and tools, along with exemplary service to colleagues throughout the industry in sharing these ideas.  Jim teaches groundwater modeling seminars throughout the USA, Europe, Australia, and New Zealand. Jim has an active consulting practice and has worked on hundreds of groundwater modeling projects throughout the world.

**Rodrigo Herrera**, is a civil engineer with over 17 years of consulting experience in hydrogeology/hydrology for mining companies in Chile, specializing in groundwater modelling. He has worked for local and international consulting firms as project engineer, technical lead, and senior consultant, leading up to his role as group/discipline leader of the groundwater modelling group of GeoHidrología/Arcadis Chile from 2012 to 2016. Currently, he provides services as a groundwater modelling consultant through his company SGM Co, based in Santiago, Chile.  During his professional career, he has developed numerous conceptual and numerical groundwater flow/transport models for environmental assessment purposes and operational scopes. His work has primarily been in basins located in northern and central Chile where natural water resources are limited. Mining operations there typically develop open pits or underground mines, and often deposit mine residues in large waste rock dumps and large tailings storage facilities. His main expertise lies in numerical modeling where he has continuously specialized in saturated, unsaturated, integrated surface-groundwater flow and solute transport modelling using codes such as MODFLOW-USG (flow and transport), SEEP/W, MODFLOW-SURFACT, MODFLOW 6, MT3D-USGS, among others. Currently, his interests are focused on seepage estimation for large tailings storage facilities using different approaches through inverse modelling (calibration) and other methods assisting the designing of seepage control systems using numerical modelling.

## Registration:

To register for this seminar, simply send Jim an email at **JRumbaugh@GroundwaterModels.com,** give us a call at (610) 670-3400, or pay by credit card on our web site at www.groundwatermodels.com and click Online Store.  Registration is not confirmed until we receive payment for the Webinar.  Cost is $950 for an individual or $1,900 for an office (purchase 2 webinars at the online store for the office registration).  Note that "office" means one physical location.

## Webinar Information:

- The Webinar is divided into 6 lectures lasting between 1 and 2 hours.  There are also 2 question and answer sessions.  After each lecture, there will be computer exercises that you may work on at your own pace.  Help with exercises is provided by email (support@groundwatermodels.com).

- Lectures are live **but will be recorded** in case you cannot attend all of them. You will call into the Webinar using either VoIP or telephone.

- Computer exercises are based on the Anaconda python development environment. All python-related software for the course is free. Detailed installation instructions will be provided before the webinar so you can get your computer set up for the course. Some references will be made to Groundwater Vistas Version 8 as well so a license to the advanced, professional, or premium versions would be advisable, but not required.

- ESI reserves the right to cancel the Webinar if there are less than 6 participants

- Each lecture will start at **1:00 pm Eastern Time**. **<u>Note that this time is not our usual webinar starting time!</u>** Webinar Lectures will be on Monday, Tuesday, and Wednesday for 2 consecutive weeks. Question & Answer sessions will be held on Thursdays. Consult our webinar schedule for exact dates.

# Course Description:

### Advanced PYTHON Programming for MODFLOW Modelers

There will be 6 lectures and 2 question/answer sessions.  Each lecture will use a brief powerpoint presentation introducing the topics to be covered, followed by a Jupyter Notebook to show the step-by-step development of the topic (e.g. building a model in flopy).

We will assume that attendees already have the necessary python modules installed (we will post these before the webinar starts) and have a working knowledge of python.

The following is an outline for the six lectures:

### Session 1: Designing a MODFLOW6 Model in Flopy

In the Introduction to Python webinar we built a Modflow2005 model.  In this first session of the Advanced webinar we will use MODFLOW6 on a similar model, but with more complexities.  MODFLOW6 is the latest version of MODFLOW from the USGS.  The flopy interface is different in some ways from MODFLOW2005 and we will illustrate those differences.  We will also show how to assign boundary conditions from shapefiles and the use of raster files for properties such as the top of layer 1.

### Session 2: Advanced Post-Processing of MODFLOW-USG Models

Flopy does not have very good support for MODFLOW-USG, even though it is the most popular version of MODFLOW at the moment.  We will show how to read and plot budget data from a MODFLOW-USG run.  We will show how to add a python script to a batch file to automatically make plots after a run.  A script that plots hydrographs from multiple runs will be presented.  In addition, Groundwater Vistas 8 has been modified to automatically run a python script after importing model results and this procedure will be described.

### Session 3: Designing Unstructured Grids in Flopy

This session will use flopy, gridgen, and triangle to build unstructured grids.  These will include quadtree, triangular, and Voronoi mesh types.  Each mesh type will then be exported to a grid specification file (gsf) that can be imported into Groundwater Vistas.  Flopy cannot export a gsf file so we will provide source code to do it in python without using flopy.  We will use a real-world example to illustrate the complexities of this type of operation.

## Session 4: Advanced Post-Processing of MODFLOW-USG Models – Part 2

Post-Processing of both flow and transport MODFLOW-USG results will be presented, along with loading a gsf file to plot the mesh, and importing parts of a MODFLOW-USG simulation into flopy. Not all MODFLOW-USG packages can be imported into flopy and we will show how to exclude the unsupported ones. Python scripts will be created to plot head and concentration contours for multiple time steps. Mass flux calculations will also be presented.


## Session 5: Workflows for Integrating Python into Groundwater Vistas

Python offers a lot of flexibility in pre- and post-processing of groundwater models created in Groundwater Vistas. We have added several features in recent updates to Groundwater Vistas to facilitate the use of flopy and python in general. GV will automatically export a series of files for calibration and monitoring well data that can be plotted in python. GV now also can run a python script after importing results. Examples of this will be presented to plot hydrographs of all wells and write them to a pdf file automatically after importing the results of a simulation. We will also show how to work with property matrices and zones in python and import those back into Groundwater Vistas. Reading and writing of MODFLOW and MODFLOW-USG binary files will also be covered.


## Session 6: Introduction to Using Pest with Pyemu

Pyemu will be used to enhance an existing Pest calibration. Pyemu could form the basis for an entire course because of its complexity. We will focus on using existing Pest calibrations created by Groundwater Vistas (or created manually) to show how to obtain detailed information from the pest run and make associated plots of run results.