



Course overview

The course covers the most advanced calibration and uncertainty analysis techniques through the [PEST](#) and [PEST++](#) suites. The course includes practical workshops. It targets those who develop, calibrate, deploy and rely on models to support environmental decision-making, as well as water resources managers, stakeholders and anyone who wishes to better understand what groundwater modelling can, and cannot, offer to the decision-making process.

Pre-course online session is dedicated to introduce the course, know each-other and solve any software installation issue.

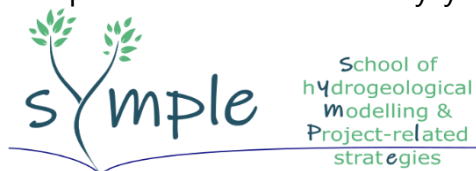
Day 1 deals with preliminary data processing and the basics of modelling with [MODFLOW 6](#), introducing the free Graphical User Interface [ModelMuse](#) with simple exercises.

Day 2 and 3 focus on model calibration and linear uncertainty/sensitivity analysis. These will be implemented using PEST and its utility support programs – from both the command line and from the graphical user interface. Usage options and theory will be explained.

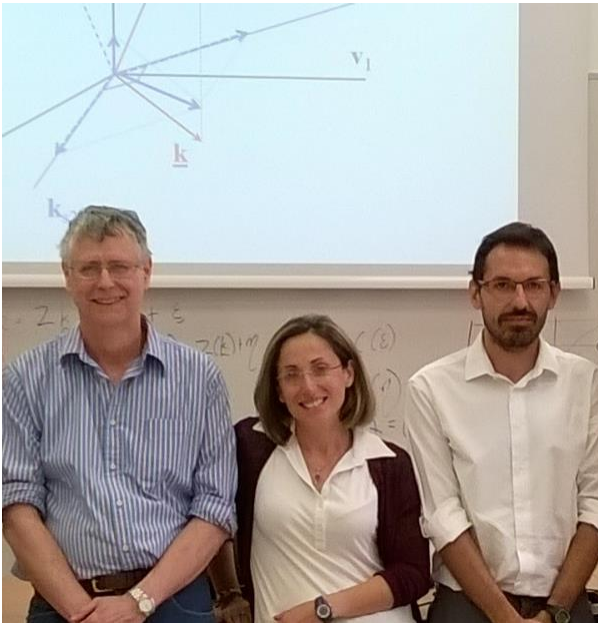
Day 4 discusses and demonstrates nonlinear uncertainty analysis, including ensemble methods such as PESTPP-IES and data space inversion.

Day 5 is dedicated to critical reflections and discussions on the use of modelling in decision-making.

Post-course online session: most of the doubts and questions are likely to arise *after* rather than *along* the course. The session is aimed at discussing the “matured” doubts and practical issues of the “try-yourself” process.



Trainers



John Doherty, Ph.D, is the author of **PEST** and its supporting utility software suites. He is a self-employed consultant, who has also held positions with the National Centre for Groundwater Research and Training, Flinders University, Australia, and with University of Queensland, where he has undertaken research and supervised PhD students. He started his career as an exploration geophysicist, then moved to environmental modelling. He has since worked in the government, private and tertiary sectors. His research interests include the continued development of software and methodologies for solution of inverse problems using environmental models, quantification of model predictive uncertainty, and appropriate use of models in the decision-making context.

Francesca Lotti, Ph.D, is a consultant hydrogeologist and partner at Kataclima srl Società Benefit. In 2021 she started SYMPLE, an Innovative Start-Up, together with 4 other partners. She has nearly 20 years of experience in field investigations and numerical modeling with MODFLOW and FEFLOW of contaminated sites, mines, geothermal plants, coastal aquifers, dewatering projects and more. She collaborates with national and international research institutions and companies. From 2001 to 2014 she carried out research at the University of Tuscia; since 2008 she is professor at the University of Camerino, where she has followed numerous MSc and PhD theses.

Giovanni Formentin is an environmental engineer graduated at Politecnico di Milano. He is a founding partner of Tethys srl, which is a consultancy firm specialized in hydrogeology, and he is president of IT2E srl, an isotope laboratory providing services to the environmental and oil&gas sectors. He has been working since 2002 as a consultant and researcher in the fields of hydrogeology and water management. In particular, he applies flow and transport models to the management of water resources and contaminated sites, aimed at qualitative and quantitative characterization, planning of remediation, and saltwater intrusion. With regard to contaminated sites, it has carried out activities and built models for the main Italian petrochemical sites and refineries. He has also carried out water management studies and numerical models on regional aquifers, in Italy and abroad, including the Bekaa valley in Lebanon and the Central Dry Zone in Myanmar. Other studies were aimed at stochastic forecasting of the effect generated by the interventions on aquifer systems, assessing the interaction between groundwater and infrastructures and designing dewatering interventions. Formentin held groundwater modeling courses using Modflow and FEFLOW at the Politecnico di Milano and Federico II University of Naples, as well as modeling and uncertainty analysis courses with PEST together with John Doherty and Francesca Lotti. Since January 2021 he is part of the Scientific Committee of SYMPLE.

Course Programme

March 1 (9 am – 1 pm) On-line preliminary session

- Presentations
- Introduction of the course
- Instructions for installing the software and access the e-learning platform
- A test model is provided to check that everything runs fine
- Suggested readings to "foretaste" PEST
- Assignment: a tutorial is provided that explains how to build a simple model with ModelMuse

March 20 (9 am -1 pm; 2-6 pm)

Introduction to history matching

- An overview of decision-support modelling and how it differs from explanatory modelling.
- Overview of MODFLOW 6 and usage of MODFLOW 6 through the ModelMuse graphical user interface.

Workshop 1

Model building in ModelMuse

March 21 (9 am -1 pm; 2-6 pm)

Model Calibration

- The difference between model calibration and history-matching.
- How regularization achieves uniqueness.
- Short introduction to geostatistics
- Tikhonov regularization and singular value decomposition
- The advantages of highly parameterized inversion.
- Pilot points as a parameterization device.
- Use of PEST in model calibration.

Workshop 2

MODFLOW 6 settings in ModelMuse. Getting familiar with the command line. Preparing for calibration.

March 22 (9 am -1 pm; 2-6 pm)

Linear Sensitivity/Uncertainty Analysis

- Difference between sensitivity analysis and uncertainty analysis
- Is sensitivity analysis really necessary?
- Bayes equation and its linearized form
- Analysis of data worth
- Parameter contributions to predictive uncertainty

Workshop 3 Post-calibration linear analysis.

March 23 (9 am -1 pm; 2-6 pm)

Nonlinear uncertainty Analysis

- Principles of nonlinear uncertainty analysis
- Rejection sampling
- Pseudo-nonlinear methods
- Ensemble methods (PESTPP-IES)
- Data space inversion

Workshop 4

Nonlinear analysis of predictive uncertainty.

March 24 (9 am -1 pm; 2-6 pm)

Workshop 5

Completion of previous exercises. Examples from the real world.

Practicalities, examples and discussion

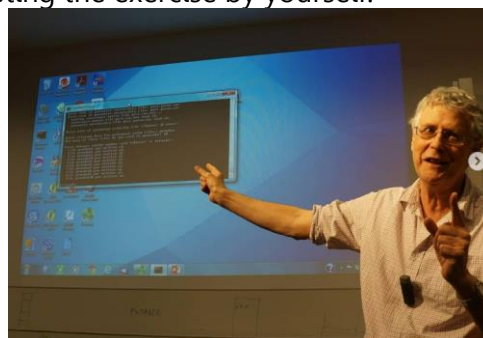
- The effect of model defects
- Formulation of an appropriate objective function
- Direct predictive hypothesis testing
- When to be simple and when to be complex
- When to calibrate and when not to calibrate
- Examples
- Getting the most out of PEST and PEST++

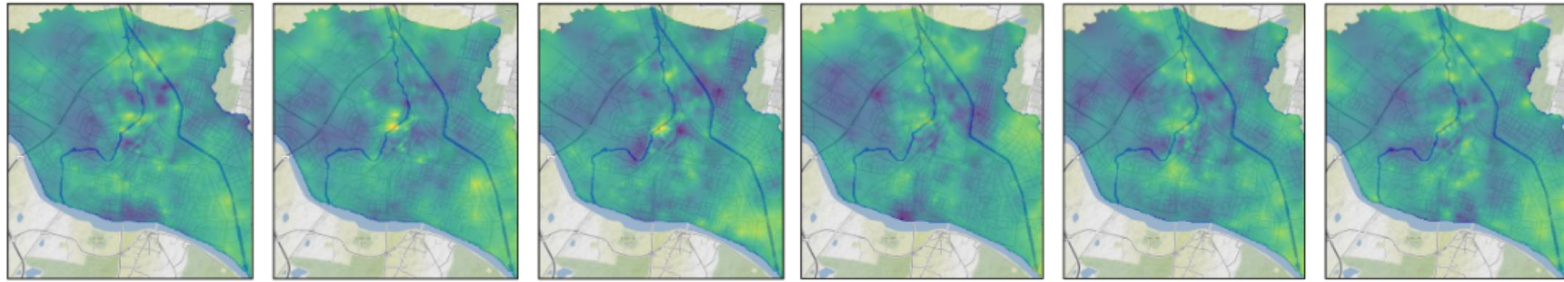
Assignment

An optional exercise will be proposed as homework. This would test the assimilation of the course contents and allow to encounter the most common obstacles for beginners. Assistance is provided in case you get totally stuck.

On-line Q&A session (schedule to be agreed)

Aim of the last session is to evaluate the assignment delivery, to discuss the issues encountered and answer the questions that have arisen after completing the exercise by yourself.





What is included

- Access to live lessons (both in the on-site classroom and remotely)
- Software and installation instructions provided 1 month before the course
- Material to carry out the exercises
- Access to our [e-learning platform](#) to watch again the recorded lessons until June 30, 2023
- *APC credits* for Italian Geologists
- Coffee breaks

Remote/Live Attendance

The course can be attended remotely or on site. The venue is located in [Vetralla \(VT\)](#), Italy (60 km from Rome).

Costs

SYMPLE is an Accredited Training Organization, VAT is not due (art. 10 DPR 633/72).

- Regular: 900 €
- IAH/SGL: 800 €
- Students/ECHN: 400 €
- Discounts available for the attendees of the 2nd ed. of the [SYMPLE School](#)
- Installments available

We live in a wonderful place, surrounded by wild woods and nearby the Volcanic Lake Vico... For accommodation suggestions and "how to get there" advises, just ask us!



Other opportunities to "meet" PEST

- See [roadmaps](#), [videos](#), [webinars](#), [tutorials](#) and [frequently asked questions](#) that are accessible for free through the [PEST web pages](#).
- Further training material is available on the [GMDSI](#) web pages.
- Training in PEST is also included in the Second [PEST conference](#), La Jolla, CA.
- A PEST course will also be held in [France in April, 2023](#).



Registration form

Seats are limited to 20 participants

Register preferably before January 23rd, 2023



SYMPLE is an Innovative Start-up founded by Francesca Lotti in 2021 that intends to **promote and facilitate the understanding, use and evaluation of hydrogeological numerical models through a multidisciplinary program associated with the use of strategies aimed at solving specific problems.**