Tullia Bonomi

Tullia Bonomi is Associate Professor of Hydrogeology at the University of Milano Bicocca, where she teaches Environmental Hydrogeology and Applied Hydrogeology. She graduated with honours in Geological Sciences in 1991 at the Department of Earth Sciences of the University of Milan, where she finished her PhD in 1995, specializing in hydrogeological flow and transport modelling, applied to the problems of quantitative and qualitative evaluation of groundwater. She is the author of about 50 international publications and over 100 articles in national journals and conference proceedings. For the full list of publications, see the UNIMIB archive at this link. Since 2000, she is head of the research group of Environmental Hydrogeology of DISAT, with an average of 4-5 young researchers each year. The research activity is aimed at the application of hydrogeological mathematical models of flow and transport for the evaluation of groundwater (both in plain environments and alpine contexts), the study of the relationships between surface and groundwater according to their hydrochemical and hydrogeological characteristics, the development of hydrogeological and hydrochemical databases for the management of large amounts of data, with development of interchanging procedures among databases, GIS and models. The main research projects connected to model are: Flow modeling of SIN Laghi di Mantova e Polo Chimico (2019-2020), Modelling of the Oglio basin (2018-2020), Flow modelling and transport of Aosta plain (2011-2017), Hydrogeological modeling of torrent Spoel, Livigno (SO) (2012-2017), Hydrogeological modeling of the landfill of Vizzolo Predabizzi (MI) (2017-2018), Modelling of urban area of Saint Petersburg (Russia) (2009-2012), Contamination of arsenic iron and manganese in groundwater (2009-2020), Development of a Hydrogeological database (since 1998) and Hydrochemical database (since 2004), Three-dimensional reconstructions of the characteristics of the subsoil (since 2000).

Walter Dragoni

Walter Dragoni, former Full Professor of Engineering Geology and Hydrogeology, retired in 2015; at present, he is in charge of the Hydrogeology course in the Master Course of “Petroleum Geology” at Perugia University. He graduated in Geological Sciences from the University of Rome “La Sapienza” in 1969. Up until 1977 he worked in the fields of mineral prospecting and applied geology, in Italy and abroad. W. Dragoni carried out visits of study and research in USA, France, Spain, Israel, China, Morocco. From 1977 to 1988 W. Dragoni worked as a researcher at the CNR-IRPI (National Research Council – Institute for Protection against Hydro-Geologic Hazards). In 1988, he obtained a professorship at the University of Perugia, where between 1988 and 2015 he taught various courses in Hydrogeology, Engineering Geology, Geological Hazards. W. Dragoni served as an expert consultant for Italian Civil Protection, dealing with landslides, floods, and groundwater pollution. He has carried out and coordinated research on hydrogeology (Darcy and non-Darcy systems), hydrology, limnology (studies on several lakes in Central Italy), karst (in temperate and arid climates), erosion and landslide phenomena. At present, he mainly works on mathematical modelling of hydrogeologic and hydrologic systems and the problem of the influence of climate variations on the water cycle. He is also interested in the archaeology of water works and management. W. Dragoni was responsible for several public research contracts (ENEL, ENEA, local authorities, etc.). Between 2000 and his retirement, W. Dragoni has been an external reviewer for IPCC. He is a member of the Accademia delle Scienze dell’Umbria and honorary member of the “Watershed Management Society” of Iran. W. Dragoni is author or co-author of more than one hundred publications.

Lucia Mastrorillo

Lucia Mastrorillo is an Assistant Professor at the Sciences Department of the Roma Tre University. She obtained her degree in Geological Sciences at La Sapienza University of Roma, where she completed her PhD in Earth Sciences in the 1994, dealing with the Hydrogeology of the Umbria Marche carbonate ridge. Her initial research field was the hydrostructural study of the carbonate aquifers aimed at the assessment of water resource and definition of the groundwater flowpath, at regional scale. In time, she applied the regional hydrostructural approach to other geological frameworks, collaborating with different Universities to develop the hydrogeological conceptual models of dolomitic, volcanic and coastal aquifers. Since many years, she teaches Hydrogeology (Field and Natural Resources Geology master's degree Roma Tre University) and Applied Geology (Environment and Field Engineering master's degree Tor Vergata University). She is currently elaborating a new line of research in the Earthquake Hydrology field, carrying on the study of the earthquake effects on the Apennine carbonate hydrostructures, after the 2016 seismic events.

Marco Petitta

Marco Petitta is Full Professor of Hydrogeology at the University of Rome Sapienza, where he teaches Hydrogeology, Underground Hydrodynamics and Applied Hydrogeology. He is author of about 80 international publications and over 100 articles in national journals and conference proceedings. He holds a PhD in Earth Sciences on the subject of hydrogeological modelling and carries out researches in the field of groundwater management, influence of human activities on the quality and quantity of groundwater, remediation of contaminated sites, role of hydrogeology in environmental and ecological studies, relationships between hydrogeology and earthquakes. He has been a member of the board of the Italian Geological Society, coordinator of the Group of Experts in Hydrogeology of the European Federation of Geologists, chair of the Italian chapter of the International Hydrogeologists Association (IAH), coordinator of the UNECE Geneva working group for the implementation in the water field of the UNFC classification of natural resources. He currently holds the role of vice-president of IAH for Western and Central Europe and he is a member of the Working Group on Groundwater of the European Commission in Brussels for the Water Directives. He coordinated (2015-18) the European project HORIZON2020 KINDRA on the importance of groundwater for man and the environment. He is currently the national manager of the KARMA project (H2020 PRIMA program) on the evaluation and protection of groundwater resources in the karst environment.

Vincenzo Piscopo

Vincenzo Piscopo obtained his degree in Geological Science at the University of Naples Federico II. From 1992 to 1995, he participated in hydrogeological and hydrogeochemical research programs at the Earth Science Department and Geophysics and Volcanology Department of University of Naples Federico II. From 1995 to 2000, he worked as researcher of Applied Geology at the Geophysics and Volcanology Department of University of Naples Federico II. Since 2000 he is associate professor of Applied Geology at the Faculty of Science of University of Tuscia, Viterbo. Here he developed and conducts several research programs specifically concerning groundwater flow and hydrochemistry of the volcanic aquifers, hydrogeology of carbonate rocks, relationships between lakes and groundwater, definition of sustainable yield, aquifers naturally contaminated by arsenic, new methods for functioning of wells at a constant level, hydraulic and hydrogeological characterization of hard rocks, modeling of aquifer in hydrothermal areas. He held and at present

he holds several courses at University of Tuscia and at the Faculty of Engineering of University of Roma Tor Vergata, such as Hydrology and Hydrogeology, Geopedology, Applied Geology, Applied Hydrogeology and Cartography. Since 2012 he lectures of hydrogeology at the Master "Characterization and technologies for remediation of contaminated sites" of Sapienza University of Rome. During his academic career he supervised about 75 bachelor, master and doctoral dissertations. He is member of the Italian Geological Society, Italian Order of Geologists, International Association of Hydrogeologists (IAH). He is member of the Council of IAH Italian Chapter. He is member of the IAH Commission of Mineral and Thermal Waters and participates in the IAH Network on Fractured Rock Hydrogeology. He has to his credit about 90 scientific and technical publications, including articles in national and international journals, monographs and proceedings of national and international conferences. He has participated in about 40 national and international conferences on hydrogeology and applied geology both with oral and poster presentations and as session chairman.

Session programme

Lesson 1 (W. Dragoni) *(1 hour)*

Introduction

- Water cycle and fundamental qualitative nomenclature
- Definition of hydrological/hydrogeological system
- Conservation of mass, conservative systems
- Real hydrological/hydrogeological systems and their models
- Steady state and transient state

Lesson 2 (W. Dragoni) *(1 hour)*

Hydrological balance

- Hydrological systems and hydrological balance
- Definition. What's the use of it
- General balance equation, with operational variants

Lesson 3 (W. Dragoni) *(1 hour)*

Groundwater

- Flow of fluids in rocks. Darcy equation in elementary terms
- Similarity with other physical laws. Limits of applicability of the Darcy equation
- Hydraulic head, potential energy. Darcy from the point of view of the Bernoulli equation
- Flow lines, equipotential lines, flow nets
- Darcy velocity and effective velocity, specific discharge, kinematic porosity, specific porosity, specific yield
- Applications of the Darcy equation in elementary form, unconfined and confined flow

Lesson 4 (W. Dragoni) *(1 hour)*

Applications of the Darcy equation: elementary analytical solutions

- Parallel flow, confined flow, isotropic and homogeneous media, equipotential lines
- Equivalent hydraulic conductivity
- Parallel flow, confined horizontal aquifer, stratified medium with isotropic and homogeneous layers, constant head boundaries:
  - flow parallel to the stratification
  - flow orthogonal to the stratification
- Parallel flow, unconfined horizontal aquifer, constant head boundaries, isotropic and homogeneous medium
- Dupuit-Forchheimer assumptions: usefulness, consequences and limits

Lesson 5 (W. Dragoni) *(1 hour)*

Other analytical solutions of the Darcy equation

- Parallel flow, isotropic and homogeneous porous medium, zenith recharge:
  - one constant head boundary and one no-flow boundary
  - two constant head boundaries and one no-flow boundary
- Flow in anisotropic media: isotropization techniques and applications

- Radial flow towards a well at constant rate:
  - confined aquifer, steady state, radius of influence
  - unconfined aquifer, transient state, radius of influence
  - confined aquifer, transient state, Theis and Cooper-Jacob equations
- Relation between transient and steady state pumping
- Principle of superposition. Wells in aquifers with non-horizontal hydraulic gradient, capture zone

Lesson 6 (M. Petitta) *(0.5 hrs)*

From Darcy to the field

- Aquifers and confining beds
- Hydraulic conductivity of rocks

Lesson 7 (M. Petitta) *(3 hrs)*

Aquifers I – Carbonate aquifers

- Permeability and potential yield of carbonate aquifers
- The role of tectonic discontinuities in groundwater circulation
- The influence of karst: epikarst, dual-flow, spring regime
- Chemical-physical equilibrium of water circulating in fractured carbonate rocks
- Regional study of fractured/karst carbonate aquifers
- Monitoring of karst springs: tools and analyses
- Scale-of-detail approach for the use, management and protection of resources
- Vulnerability of fractured/karst carbonate aquifers
- Limits of potentiometric maps, numerical models, forecasting tools

Lesson 8 (T. Bonomi) *(3 hrs)*

Aquifers II – Alluvial aquifers

- Genesis of alluvial aquifers
- Instruments for the reconstruction of lateral and vertical heterogeneity
- Parameterization of heterogeneities
- Recharge and discharge areas
- Local and regional flow
- Vulnerability of alluvial aquifers
- Relation between surface water and groundwater in alluvial aquifers
- Hydrogeochemical and hydrogeological relationship in alluvial aquifers

Lesson 9 (V. Piscopo) *(2 hrs)*

Aquifers III – Volcanic and crystalline aquifers

- Hydrogeology of vulcanoes
  - Types of volcanoes
  - Permeability of volcanic and pyroclastic rocks
  - Groundwater flow in volcanic aquifers
  - Recharge and discharge areas
  - Hydraulic properties of volcanic rocks
- Crystalline aquifers
  - Permeability and porosity in crystalline rocks
  - Groundwater flow in crystalline rocks
  - Recharge and discharge areas
  - Pumping response of crystalline rocks

Lesson 10 (M. Petitta) *(4 hrs)*

Springs and rivers

- Relation and interdependence of surface water and groundwater
- Springs: chemical-physical and geological classifications
- River discharge and regime
- Riverbed drainage and linear springs
- Recharge and recession of springs
- Analysis of springs recession
- Examples of river/aquifer interaction in mountain, piedmont and valley contexts
- Quantitative impact of anthropogenic withdrawals on river/aquifer relationships
- Possible consequences on water quality due to the modification of the river/aquifer relationship
- Ecological value of surface water and the contribution of groundwater
- Concept of GDE (Groundwater Dependent Ecosystems) and related applications

Lesson 11 (L. Mastrorillo) *(2 hrs)*

Hydrogeological investigations - Climate data

- Precipitation and temperature
  - national and regional thermo-pluviometric networks
  - hydrological annals
  - precipitation: measuring instruments
  - temperature: measuring instruments
  - temperature-altitude and precipitation-altitude relationships
  - representation of thermo-pluviometric data (graphs and maps)
  - Standard Precipitation Index (basic notions)
- Evapotranspiration
  - Evaporation and transpiration
  - Potential and actual evapotranspiration
  - Measurement and calculation of actual evapotranspiration
  - Turc equation and its applications
  - Thornthwaite method and its applications

Lesson 12 (L. Mastrorillo) *(2 hrs)*

Hydrogeological investigations - Hydrologic data

- Flow discharge
  - hydrological annals
  - hydrometers
  - river discharge measurement
  - discharge calculation
  - rating curve
  - flow hydrographs
  - river hydrograph and spring hydrograph
  - river hydrograph decomposition (graphical and statistical methods)
  - spring hydrograph: recession curve and its applications
- Hydraulic heads
  - phreatic level - phreatimetry
  - piezometric measurements and piezometric survey (phreatmeters and automatic level probes)
  - analysis approach of the piezometric data: point data (groundwater regime, water table fluctuation); areal data (piezometric surface reconstruction)

Lesson 13 (V. Piscopo) *(4 hrs)*

Wells I - Construction

- Drilling methods
- Casing
- Screen
- Development
- Monitoring well

Lesson 14 (V. Piscopo) *(4 hrs)*

Wells II – Aquifer tests

- Basic concepts
- Solution methods
  - Thiem
  - Theis
  - Cooper and Jacob
  - Hantush and Jacob
  - Neuman
- Drawdown and its derivative
- Well performance test
- Slug tests

Lesson 15 (T. Bonomi) *(3 hrs)*

From the conceptual model to the numerical model

- Choose which elements should be modeled: from the field to the grid
- From the hydrogeological reconstruction, anthropic elements, project hypotheses to model layer design
- Grid design: area size versus model focus, cell width, spatial and vertical discretization
- From aquifer test to hydraulic conductivity of the model
- Water balance: what elements to insert into the model?
- Choice of natural and/or artificial boundary conditions
- Real examples from local and regional model