

# Groundwater Modeling

8:00-8:30 a.m.		<b>Welcome and Introduction (Course Goals)</b>
8:30-9:45 a.m.	1.1 Lecture	<b>Occurrence and Movement of Groundwater</b>
	A.	Hydrologic Cycle
	B.	Subsurface Distribution
	C.	Geology and the Occurrence of Groundwater
	D.	Hydraulic Conductivity
	E.	Flow and Transmissivity
	F.	Homogeneity and Isotropy
	G.	Storage
	H.	Groundwater Flow Velocity
	I.	Groundwater Flow Equations
9:45-10:00 a.m.	Break	
10:00-11:20 a.m.	1.2 Lecture	<b>Numerical Modeling</b>
	A.	Numerical and Analytical Methods
	B.	Appropriate Use of Models
	C.	Review of General Flow Equations
	D.	Solution Techniques/Numerical Methods
	1.	Finite Difference
	2.	Finite Element
	E.	Available Groundwater Flow Models
	1.	Finite Difference (MODFLOW)
	2.	Finite Element (FEMWATER)
	3.	Applications
	4.	Advantages/Disadvantages
11:30-noon	1.3 Lecture	<b>Aquifer Characterization- An Integrated Approach</b>
	A.	Conceptual Model Development
	B.	Literature Search
	C.	Geologic Information
	D.	Hydrologic Data
	E.	Geophysical Data
	F.	Cone Penetrometers

12:00-1:00 p.m.	Lunch	
1:00-1:45 p.m.	1.4 Lecture	<b>The Development and Application of Numerical Groundwater Flow Models</b>
	A.	Development of Conceptual Model
	B.	Code Selection
	C.	Grid Design
	D.	Boundary and Initial Conditions
	E.	Model Calibration/Parameter Estimation
	F.	Sensitivity Analysis
	G.	Execution and Interpretation of Results
	H.	History Matching and Post-Audits
1:45-2:30 p.m.	1.5 Workshop	<b>Finite-Difference Methods</b>
2:30-2:45 p.m.	Break	
2:45-3:30 p.m.	1.6 Lecture	<b>The United States Geological Survey Finite-Difference Modular Flow Model (MODFLOW)</b>
	A.	History of Development
	B.	Advantages/Disadvantages
	C.	Options
	D.	Data Requirements
	E.	MODFLOW Packages
3:30-4:30 p.m.	1.7 Workshop	<b>Approaches to Conceptual and Numerical Model Development</b>

\*\*\* idea here is to give geologic/hydrologic information on site and have class (in small groups) develop a conceptual model, construct a model grid, and select boundary conditions which best represent site conditions. For continuity, the same site location/general conditions will be used for Workshops 1.7, 2.6, 2.8, 3.5.

8:00-9:00 a.m.	2.1 Lecture	<b>MODFLOW BAS, BCF, SIP, OC Packages</b>
9:00-10:15 a.m.	2.2 Workshop	<b>Darcy's Law, Steady-State Applications (Probs. 1, 2)</b>
	A. Darcy's Law	
	B. Specified (or Constant) Head Boundaries	
	C. LAYCON Values	
10:15-10:30 a.m.	Break	
10:30-11:00 a.m.	2.3 Lecture	<b>MODFLOW Format</b>
	A. Input/Output Format	
	B. Name File Format (MODFLOW '96)	
	C. Assigning Constant Values over an Array	
	D. Calling in Arrays from a Separate File	
11:00-12:00 noon	2.4 Workshop	<b>MODFLOW Format (Prob. 3)</b>
12:00-1:00 p.m.	Lunch	
1:00-2:00 p.m.	2.5 Lecture	<b>MODFLOW WEL, RCH Packages</b>
2:00-3:15 p.m.	2.6 Workshop	<b>MODFLOW WEL, RCH Packages (Probs. 4, 5, 6, 7)</b>
3:15-3:30 p.m.	Break	
3:30-4:00 p.m.	2.7 Lecture	<b>Head (or Value) Dependent Flux Boundaries (Fenske)</b>
4:00-5:00 p.m.	2.8 Workshop	<b>MODFLOW GHB and RIV Packages (Probs. 8, 9)</b>
8:00-8:50 a.m.	3.1 Lecture	<b>Additional MODFLOW Packages</b>

- A. Drain Package
- B. EVT Package
- C. Stream Package
- D. Reservoir Package
- E. CHD Package
- F. GFD Package
- G. HFB Package

9:00 -10:00 a.m. 3.2 Lecture **Contaminant Transport in Groundwater**

- 1. Types of Contaminants
- 2. Advection
- 3. Dispersion
- 4. Diffusion
- 5. Sorption
- 6. Degradation
- 7. NAPLS
- 8. Modeling Contaminant Transport

10:00-10:15 a.m. Break

10:15-11:00 a.m. 3.3 Lecture **Particle Tracking with MODFLOW**

- 1. Purpose/Use
- 2. Applications
- 3. Theory
- 4. Model Input/Output

11:00-12:00 p.m. 3.4 Lecture **Field Example: Development and Application of a Groundwater Flow Model for Design of Pump-and-Treat System**

12:00-1:00 p.m. Lunch

1:00-5:00 p.m. 3.5 Workshop **Class Exercise: Development and Application of a Computer Model which Simulates the Effects of Aquifer Pumping on Stream/Wetlands Hydrologic System**

Day 4

8:00-9:00 a.m.	4.1 Lect./Workshop	<b>Pre- and Post-Processing</b>
	A.	Theory
	B.	Challenges/Pitfalls
	C.	Pre-Processing Options
	4.	Post-Processing Options
9:00-9:15	Break	
9:15-10:30 a.m.	4.2 Lecture	<b>Introduction to the Department of Defense Groundwater Modeling System (GMS)</b>
10:30-10:45	Break	
10:45-12:00 p.m.	4.3 Lecture	<b>Application of GMS Pre/Post-processor</b>
12:00-1:00 p.m.	Lunch	
1:30-5:30 p.m.	4.4 Workshop	<b>Class Exercise: Development of Simple Conceptual Model and Numerical Application using the GMS Pre/post-processor</b>
	A.	Conceptual Model Development
	B.	MODFLOW Application
	C.	MODPATH Application
	D.	MT3D Application

Day 5

8:00-9:00	5.1 Lecture	<b>Reviewing Groundwater Modeling Projects</b>
	1. Types of Reviews	
	2. Things to Consider	
	3. Top 10 Ways to Misuse a Model	
	4. Model Evaluation Checklist	
9:00-9:45 a.m.	5.2 Lecture	<b>Recent Trends/Developments in Groundwater Modeling</b>
	1. Computational Power	
	B. User Interfaces	
	3. Model Optimization	
	D. Integrated Models of Hydrologic Cycle	
9:45-10:00 a.m.	Break	
10:00-11:00 a.m.	5.3 Lecture	<b>Course Post-Test/Review/Final Comments</b>