UMBC
Department of Chemical, Biochemical, and Environmental Engineering
ENCE 489/ENCE 621 Groundwater Hydrology

Spring 2015
Course Syllabus

Instructor
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Office Hours: T, Th 5:15 – 6 PM, or by appointment

Teaching Assistant
Alimatou Seck, Ph.D. Candidate, Environmental Engineering
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Office Hours: T, Th 2:30 – 4 PM, or by appointment

Class Meeting Time and Place: T Th 4:00 – 5:15 PM; TRC 122

Required Text
Freeze and Cherry, *Groundwater,* Prentice Hall, 1979.

Reference Text
Kruseman, and deRidder. Analysis and Evaluation of Pumping Test Data, 2nd Edition, International Institute for Land Reclamation and Improvement, 1990.

Class Notes must be printed out from BB and brought to class in a 3-ring binder unless you can demonstrate to me that you can take notes electronically on the posted pdfs in class. This practice is to begin on Day 1 of the course.

Grading 5% participation, 10% quizzes, 25% problem sets, 30% midterm, 30% final

Problem Sets
Due in class per deadlines; 10% off per day late.

Problem sets should be done on 8-1/2 x11" (preferably engineering) paper with pages stapled together. (Alternatively, work can be typed and e-mailed as an attachment.) No partial credit will be given for wrong answers if calculations are not shown.
See sample solved problem posted in BlackBoard for level of detail expected.

Rules regarding significant digits are to be followed. Points will be taken off of homework and exams if rules are not followed. (See http://en.wikipedia.org/wiki/Significant_figures or http://www.physics.uoguelph.ca/tutorials/sig_fig/SIG_dig.htm).

Because this is a combined undergraduate and graduate class, there will be additional work for graduate students for the purpose of differentiating the two levels.

Quizzes NEW In 2015, a new method for administering quizzes will be implemented. Quizzes will be "pop-up" in nature. On random days, not selected in advance, one student will be called on by the instructor to pose a quiz question and all students will then write down the answer for grading. Quiz material must be relevant to lectures and readings since the prior quiz.

Exams Midterm: 7th week; Final exam: 15th week. Closed book exams; formula sheets provided by instructor.

Plagiarism Policy Problem sets submitted for grading are to be each student's own work. Plagiarism will not be tolerated. Students turning in plagiarized work will receive a grade of zero on such work and reported to the appropriate dean for disciplinary action.

Attendance Policy Class attendance is required. Students needing to attend academic conferences or job interviews must inform C. Welty well in advance. Illness is to be reported to C. Welty by telephone (leave voice mail if phone is not picked up). Unexcused absences will be considered in assigning final grades.

Cell phones are to be switched off in class.

Objectives of Course The learning objectives for this course are: (1) to understand the use and occurrence of groundwater in the U.S.; (2) to be able to quantify flow of groundwater in aquifers and in unsaturated soils; (3) to be able to design and evaluate laboratory tests to determine porous media parameters (permeability, hydraulic conductivity, total porosity, effective porosity); and (4) to be able to design and evaluate field tests to determine aquifer parameters (permeability, hydraulic conductivity, total porosity, effective porosity, specific yield, storage coefficient); (5) to be able to utilize stochastic approaches to modeling subsurface heterogeneity; (6) to understand the physical basis, and its relationship to mathematical modeling, of contaminant transport in aquifers; (7) to learn how to use analytical mathematical solutions to the advection-dispersion equation to model aquifer contamination under various simplified 1D, 2D, and 3D scenarios; (8) to understand how to calculate from the literature and/or conduct appropriate tests to determine input parameters needed for laboratory and field-scale contaminant transport models. NEW **for 2015: A new objective for 2015 is to learn to use the USGS groundwater modeling software MODFLOW at a basic/introductory level to complement the analytical methods presented in class.**

Course Synopsis

I. Introduction (F&C: Chapters 1, 2, 4)
Hydrologic cycle; occurrence and use of groundwater in the U.S.; NJ, PA, MD, VA and DE examples; subsurface moisture zones; concept of piezometric head; aquifer types; specific yield, total porosity, effective porosity

II. Flow Dynamics (F&C: Chapters 2, 5, 6)
Darcy's law for saturated flow; hydraulic conductivity and permeability; limitations of Darcy's law and nonlinear flow effects; heterogeneity and anisotropy of hydraulic conductivity; spatial variability and variogram analysis; Darcy's law for 3D flow systems; conceptualization of unsaturated flow; flow in fractured media; mass balance in 3D porous media; field equations for groundwater flow; piezometric or phreatic surface maps; construction and use of flownets; regional groundwater flow systems; vertical flow effects; regional circulation; storage coefficient, transmissivity, and specific storativity

III. Groundwater Hydraulics (F&C: Chapter 8; Kruseman and deRidder selected chapters)
Steady and unsteady radial flow to fully-screened wells with constant discharge in homogeneous, isotropic, confined, infinite domain aquifers; effects of nonidealities on radial flow: non-constant Q; heterogeneity and anisotropy; constant head and impermeable boundaries; phreatic aquifers; leaky aquifers; partially penetrating and/or partially screened wells. Design and analysis of pumping tests for determining aquifer hydraulic properties; slug tests; well losses; specific capacity; superposition of radial flow on natural flow fields; calculation of capture zones and stagnation points.

IV. Contaminant Transport (F&C: Chapter 9 and journal articles)
Mass balance for transport of an ideal tracer; advection, dispersion, and diffusion; non-ideal processes as sources and sinks. 1D, 2D and 3D solute transport; pulse and step inputs; solutions

to the advection dispersion equation. Applications to lab data; use of CXTFIT. Field-scale considerations; scale-dependent dispersivity; uniform and nonuniform flow tracer tests. Natural gradient tests with application to the USGS Cape Cod site; radial and doublet tracer tests with applications. Considerations for reactive tracer transport.

Detailed Course Outline

I. Introduction/Occurrence and Use of Groundwater

A. Hydrologic Cycle
B. Motivation for Studying
C. Distribution of Groundwater
D. Subsurface Moisture Zones
E. Concept of Hydraulic Head
F. Aquifer Types

II. Flow Dynamics

A. Darcy's Law
B. Hydraulic Conductivity and Permeability
C. Limitations of Darcy's Law
D. Heterogeneity and Anisotropy of Hydraulic Conductivity
    1. Definitions
    2. Evidence for heterogeneity
    3. Geostatistical quantification of spatial variability
    4. Relationship between layered heterogeneity and anisotropy
E. Generalization of Darcy's Law to 3-D
    1. Isotropic case
    2. Anisotropic case
    3. Concept of hydraulic conductivity ellipse
F. Mass balance in porous media
G. Development of 3D field equations
    1. 3D general form
    2. Some example simplifications
H. 2D application: flownets
    1. Purpose
    2. General terminology/"rules"
    3. Determining total flows
    4. Estimating transmissivity along a streamtube
    5. Determining travel times
    6. Heterogeneous systems and the tangent law
    7. Anisotropic systems
    8. Use of the inverse hydraulic conductivity ellipse to determine the direction of flow
I. Regional groundwater flow systems
    1. Recharge, discharge, groundwater divides
    2. Effect of topography on groundwater flow systems
    3. Effect of geology on groundwater flow systems
J. Applications of 2D and 3D aquifer equations
    1. 2D confined
    2. 2D unconfined
    3. 3D aquifer equation and aquifer compressibility
K. Concepts in unsaturated flow
    1. Tension head
    2. Relationship among ψ, h, and θ
    3. Nonlinear flow behavior
    4. Field equations for unsaturated flow

L. Darcy’s Law and Field equations for Variable-Density Fluids
M. Flow in Fractured Media

III. Groundwater Hydraulics

A. Radial Flow to a Well in a Confined Aquifer -- Constant Q
   1. Steady Flow
   2. Unsteady Flow
   3. Applications

B. Radial Flow to a Well in a Confined Aquifer -- Nonconstant Q
C. Boundary Effects
D. Leaky Aquifers
E. Phreatic Aquifers
F. Other effects to consider in well hydraulics
G. Piezometer Tests
H. Superposition of a pumping well on a uniform flow field
I. Ghyben-Herzberg relation
J. Barometric efficiency and tidal efficiency

IV. Contaminant Transport

A. Classical equation for transport of an ideal tracer
B. Transport processes
   1. Advection
   2. Dispersion and diffusion
   3. Nonideal processes

C. 1D solute transport (lab scale; limited field scale)
   1. Governing eqn.
   2. Continuous or step input
   3. Pulse input

D. 2D, 3D Solute transport
E. Field-scale considerations
   1. Heterogeneity and scale-dependent dispersion
   2. Uniform vs non uniform flow