Geology 473/573: Ground Water Hydrology

Syllabus and Schedule - Winter 2008
Dr. Robert Mitchell

Text

Applied Hydrogeology, C.W. Fetter, 4th Edition, 2001

Learning Objectives

My objectives for this course are to help you understand (1) how the properties of fluids, porous media and energy influence saturated and unsaturated groundwater flow; (2) the physical and mathematical relationships that integrate these concepts; (3) mathematical modeling approaches for resolving groundwater related problems; and (4) the importance of groundwater in a variety of geologic processes (e.g., slope stability, accretionary prisms, and earthquakes).

Assessment

Problem Sets

An effective way to learn the material in this course is to do problems. Problem sets will be given out each week or so and will be due the following week at the beginning of class. You will be required to use Mathcad to compose your problem-set solutions. Homework will be deducted 10% for each day it is late. Homework will not be accepted after the return of the corrected.

Exams

One midterm exam and a comprehensive final exam will be given. My exams are typically short answer essay with an emphasis on process description. I want you to be able to tell me in words, what controls groundwater processes. I also integrate problems into exams that require equation manipulation and calculations. You will be required to take all exams. Make-up exams will be given only in the case of official emergencies. An excused absence form from the office of Student Affairs is required.

Graduate Student Projects

Graduate students enrolled for graduate credits are required to do an additional research project.

Grading

The grading break down will be as follows:

Undergraduate	Graduate
Homework........35%	Homework.......25% and Research Project…10%
Exam 1.............30%	Exam 1............30%
Final Exam........35%	Final Exam.......35% (Wednesday, March 19, 8-10 am)

A grading scale will be as follows (a curve is possible but not certain):
100-93 = A, 92-90 = A-, 89-88 = B+, 87-83 = B, 82-80 = B-, 79-78 = C+, 77-73 = C, 72-70 = C-, 69-68 = D+, 67-63 = D, 62-60 = D-, 60 or below = F

I reserve the right to change the syllabus as required throughout the term to better meet the instructional needs of the class.

Academic honesty is an important part of every course at WWU. Please refer to Appendix D (p. 389-390) of the 2007-2008 Course Catalog for details.

Ground-Water Hydrology Topics

Introduction (Chapter 1 and pp. 95-98)
1. Ground water--what is it, where is it, and why is it important?
2. Aquifers – definition of an aquifer, depositional environments that form aquifers, scales of aquifers. Whatcom County aquifers. What recharges aquifers?

Fluid Mechanics (Read Handout) – Mathcad Problem Set 1

3. Water in aquifers – introduction to fluid properties and fluid mechanics. Fluid Properties handout. Fluid flow in aquifers requires the knowledge of 3 fluid quantities (density, dynamic viscosity and compressibility).
4. Fluid properties - the importance of the hydrogen bond and properties such as density, compressibility and thermal expansion
5. Fluid statics – pressure, pressure head, buoyancy (effective stress), abnormal fluid pressures in sedimentary basins and accretionary prisms.
6. Fluid dynamics – steady state vs transient, 1-, 2-, 3-D flow, laminar, turbulent, compressible vs incompressible, Reynolds #, dynamic viscosity, and energy.

Properties of Porous Media (Chapter 3) – Mathcad Problem Set 2

7. Properties of Porous media – in general, knowledge of 3 earth-material quantities are required to understand ground-water flow (porosity, intrinsic permeability, matrix compressibility).
8. Porosity – quantitative and qualitative description, range of magnitudes and what controls the magnitude (mainly grain-size distribution and consolidation/compaction), primary vs secondary, effective porosity, and how is it determined? Porosity's relationship to other quantities such as specific yield and water content. Demonstration.
9. Intrinsic Permeability - quantitative and qualitative description, range of magnitudes and what controls the magnitude (mainly grain-size and consolidation/compaction). How is it quantified— empirical relations using sediment characteristics and backing-it-out from hydraulic conductivity values.
10. Hydraulic Conductivity – combination of material properties (intrinsic permeability) and fluid properties (density and dynamic viscosity). Quantitative and qualitative description, range of magnitudes and what controls the magnitude (intrinsic permeability).

Energy, Head, Gradients and Darcy's Law (Chapter 4) – Mathcad Problem Set 3

11. Hydraulic Head – total hydraulic head = elevation head + pressure head. Explain all three in terms of energy. Measurement of each. Make use of a DEMONSTRATION. Emphasize that hydraulic conductivity is a measure of "energy loss" due to friction loss as fluid encounters grain surfaces.
12. Hydraulic Gradient – 1-D (horizontal and vertical) and 2-D using the classic three point problem. Introduce a "regression" technique for estimating a 2-D gradient using many wells.
13. Darcy's Law – combines hydraulic head and hydraulic gradient to describe the flow of water through a cross-sectional area. Demonstration.
14. Heterogeneity – Discuss the inherent heterogeneous nature of most geologic deposits— quantifying aquifer properties for such deposits is the most challenging aspect of assessing ground-water flow in a region. Heterogeneity is "scale" dependent. Effective hydraulic conductivity (parallel and perpendicular to flow).
15. 15. Special Topic – effective stress and the seepage force (quick sand and liquefaction). Seepage Force results from a hydraulic gradient (and buoyancy) across the length of a grain. Quick sand Demonstration.
16. Aquifer Compressibility and Specific Storage.– buoyancy reduces the weight of grains which equates to an "effective stress.

Unsaturated Flow and Recharge (Chapter 6) – Mathcad Problem Set 4

17. Unsaturated Zone – infiltration and water flow in the unsaturated zone.
18. Recharge – rainfall, evapotranspiration, and recharge.

Ground-Water Flow Equations (Chapter 4) – Mathcad Problem Set 5

19. Ground-Water Flow Equations – derivations of PDEs from a mass-balance point of view (coupling Darcy's Law with the Continuity equation). Handouts.
20. Ground-Water Flow Equations – Solution techniques. Examples.
21. Flow nets as a solution technique to PDEs

MIDTERM EXAM

Well Hydraulics (Chapter 5) – Mathcad Problem Set 6

22. Well hydraulics – establish the assumptions of the conceptual picture and Theis solution (mathematical similitude with heat flow).
23. Well hydraulics – Theis solution (pump tests) multiple wells and superposition of W(u)
24. Well hydraulics – Jacob and Thiem pump-test approximations (examples).
25. Pump Tests –Deviations from the Theis solution (bounded and unconfined aquifers)
26. Slug Test – Hvorslev method Sea-Water Intrusions (pp. 327-338)

27. Sea-water Intrusions – theory
28. Sea-water Intrusions – Islands (with examples) Ground-Water Modeling (Chapter 13)
29. Ground-water Modeling – Use the Toth conceptual picture (and analytical solution) to introduce the finite-difference numerical approach.