GEOLOGY 551
Hydrogeology
Thorbjarnarson
Fall 2016

<table>
<thead>
<tr>
<th>Mod</th>
<th>Date</th>
<th>Lecture, Reading</th>
<th>Lab</th>
<th>Quiz</th>
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<tr>
<td>1</td>
<td>8/29-31</td>
<td>Introduction, Water Cycle and Budgets, Chpt 1</td>
<td>Salton Sea movie: on-line</td>
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<td>1</td>
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<td>Watersheds &amp; Budgets, Chpt 1, Tale of Two Lakes Reading</td>
<td>San Diego Watershed Hydro Info</td>
<td>Quiz 1</td>
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<td>2</td>
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<td>Sediment Description &amp; Intro to Woburn</td>
<td>Quiz 2 Budgets</td>
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<td>5</td>
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<td>SURFER contouring</td>
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<td>Transient Flow, Chpt 8</td>
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<td>Groundwater Contamination, Chpt 11</td>
<td>Case Study Presentations</td>
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<td>11</td>
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<td>What’s up with Fracking, Chpt 12</td>
<td>Case Study Presentations</td>
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<td>Monday Final Exam 10:30 AM</td>
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Office Hours: W 10-11, Th 10-12 or email for appointment
GMCS-228F, kthorbjarnarson@mail.sdsu.edu

Learning Outcomes: Detailed Learning Outcomes for each module are included in the class Blackboard postings and are listed in the last pages of this syllabus.

Textbook website: http://booksite.academicpress.com/9780123847058/

Geotechnical Gage: Required for sediment description lab and very useful for your future hydrogeological work. The book store should have these.

Class Materials and Blackboard: Most lecture notes, all presentation problems and other materials will be posted on the class Blackboard site. Go to blackboard.sdsu.edu and log in using your Red ID and password.

Class Guidelines and Schedule: The class will be taught as a flipped classroom. Lectures will be taped and posted on the class Blackboard site and are expected to be viewed early in the week. Our class will not meet on Monday (can use this time for viewing lectures!). On Wednesday, we will have an overview of material and address questions. Students will complete a quiz on the previous week’s material. The class will have lab exercises, exams and speakers during the Wednesday laboratory time.
Exams: Quantitative exams based on problem presentations are scheduled during laboratory time. A study card will be provided for students to fill out and bring to the exam.

Labs & Field Trip: In-class participation and completion of activities as listed. Completed lab exercise sheet turned in at end of lab (or before next class) unless otherwise indicated. Missed labs or field trip may not be made up.

Quizzes: Each module has posted quantitative problems and solutions. Students are expected to review and practice solving these problems. The quizzes will allow practice for exam questions.

Case Study Presentation: Each student will select a case study to summarize hydrogeology and possibly contaminant movement. Sites will be selected from USGS reports, Geotracker, etc.

Grading/Evaluation:

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<td></td>
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Grade Scale:

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Learning Outcomes: Detailed learning outcomes are listed in each module’s summary on the class Blackboard site. The following pages provide a summary of learning outcomes and tasks (readings, labs and assignments) for each module.
GEOL551 Hydrogeology Learning Objectives

Module 1: Hydrologic Cycle, Watersheds and Water Budgets

Upon completion of this unit students should be able to:

- Use appropriate significant figures when estimating hydrologic parameters.
- Calculate volumes and estimate storage, given simple water budget parameters.
- List and describe the components of the hydrologic cycle.
- Describe how each component is measured or quantified.
- Analyze input and output variables that affect water storage in a basin.
- Distinguish between overland flow, interflow and baseflow.
- Create a water budget for a basin.
- Compare and contrast the hydrologic issues of Mono Lake and Salton Sea.
- Explain rainfall patterns.
- Accessing available hydrologic data (rainfall, evapotranspiration and streamflow) for a watershed.

More specific learning outcomes are listed in the module’s summary on Blackboard.

Tasks

View On-Line Lectures: Watersheds and Budgets, A Tale of Two Lakes, Significant Figures, Time Averaging

Labs: Salton Sea Movie Question Sheet [5 pts extra credit]
      San Diego River Watershed Hydrologic Data Search Lab

Reading: Fitts Chpt 1
         Tale of Two Lakes Reading

Review and practice Applied Problems
Module 2: Sediment and Aquifer Properties

Upon completion of this unit students should be able to:

- Describe important properties of water such as polarity, incompressibility, viscosity, surface tension
- Distinguish between primary porosity, secondary porosity, and effective porosity
- Distinguish between porosity and permeability
- Explain grain-size distribution curves for sediment samples and uses
- Be able to classify a sediment according to USCS classification system
- Describe the main components of total hydraulic head
- Discuss the forces that act on a fluid
- Distinguish between pressure head and elevation head
- Calculate total hydraulic head
- Convert depth-to-water measurements to total hydraulic head
- Interpret hydraulic head values and water flow directions for differing scenarios
- Describe the general history and hydrogeology of Woburn, Mass. case study (A Civil Action)
- Discuss the difference in the Hinkley, CA case study (Erin Brockovich) from the Woburn, Mass case study

More specific learning outcomes are listed in the module’s summary on Blackboard

Tasks
Labs: Sediment Description Lab  
      Toxic Trials Movie Question Sheet [5 pts extra credit]

Reading: Fitts Chpt 2

Review and practice Applied Problems
Module 3: Groundwater Flow and Darcy’s Law

Upon completion of this unit students should be able to:

- Define aquifers and aquitards and differing types of aquifers (unconfined, confined, perched)
- Describe Henri Darcy’s apparatus and the derivation of Darcy’s Law.
- Analyze the variables that affect flow in a Darcy tube.
- Discuss the difference between hydraulic conductivity and intrinsic permeability.
- Convert hydraulic conductivity values to intrinsic permeability.
- Describe Reynolds number and how it affects validity of Darcy’s Law.
- Discuss homogeneity, heterogeneity and isotropy in aquifers.
- Define and calculate transmissivity.
- Calculate average hydraulic conductivity and transmissivity in complex units with multiple layers.
- Explain laboratory techniques to estimate hydraulic conductivity for a core sample.

More specific learning outcomes are listed in the module’s summary on Blackboard.

Tasks
Labs: Hydrogeologic Cross-Section Lab
Reading: Fitts Chpt3 Sections 1-8
Review and practice Applied Problems
Module 4: Field Methods & Wells

Upon completion of this unit students should be able to:

- Understand differing ways to obtain sediment sample from subsurface and concept of disturbed sample
- Describe hollow-stem auger drilling and other drilling techniques for well installation
- Describe electrical resistivity and how it can provide information on sediment type and water salinity
- Describe differing components of a well: casing, screen, seal, filter pack, etc.
- Understand concept of well efficiency and why we care about it
- Understand concept of development of wells and why it is necessary
- Understand Township and Range mapping and well numbering in California
- Pass the first midterm!!

More specific learning outcomes are listed in the module’s summary on Blackboard

Tasks
Labs: Woburn Water Levels Hand Contouring

Reading: Fitts Chpt4

Review and practice Applied Problems
Module 5: Groundwater Flow Patterns

Upon completion of this unit students should be able to:

- Convert depth-to-water measurements to total hydraulic head
- Calculate horizontal and vertical groundwater gradient
- Use well information to determine total depth of a well and land surface elevation
- Report water levels as elevation above sea level
- Interpret groundwater flow patterns from map view and cross-sectional hydraulic head contour maps
- Discuss general patterns of flow between aquifers and aquitards
- Discuss general patterns of vertical flow from recharge to discharge regions in a basin
- Describe local, intermediate and regional flow scales and patterns
- Calculate hydraulic gradient vector from three hydraulic head values on a map (3 point problem)
- Be able to interpret possible causes of change in hydraulic gradient in a flow system by applying Darcy’s Law
- Describe 3 types of boundary conditions and how flow lines will be oriented with respect to them
- Identify a location as a recharge or discharge region based on nested piezometer data of vertical flow (hydraulic head at differing depths)
- Describe and calculate the behavior of flowlines at K boundaries via the tangent rule
- Describe the general trend (deflection) of flowlines in anisotropic aquifers

More specific learning outcomes are listed in the module’s summary on Blackboard

Tasks

Reading: Fitts Chpt5 Sections 1 & 2

Review and practice Applied Problems
Module 6: Groundwater Geology

Upon completion of this unit students should be able to:

- Describe geology of major aquifers (consolidated vs unconsolidated sediments, sedimentary, metamorphic and igneous rocks)
- Describe relative permeability of crystalline igneous and metamorphic rock, basalt, sandstones, clays, shale, till, alluvium, limestone
- Describe occurrence of basin-fill aquifers and importance in water resources
- Describe differing sediment types (and permeability) going from mountains to valley floor in Basin and Range basin-fill aquifers. Where would water wells be placed?
- Explain the basic differences between the differing basin-fill aquifers (closed, partially drained, etc.)
- Describe the locations of high permeability and low permeability material in a fluvial sediment environment
- Describe and explain the different permeability expected in glacial till sediments vs glacial outwash sediments
- Explain the importance of secondary porosity in crystalline bedrock and carbonate materials
- Explain what geologic materials have been used (or studied for potential use) as nuclear repositories.
- Describe difference between alluvial fill aquifers and sedimentary rock aquifers in San Diego. Which sedimentary rock formation is being utilized as a drinking water source?

More specific learning outcomes are listed in the module’s summary on Blackboard

Tasks
Labs: Woburn Gradients and Velocities Lab
      Civil Action Movie Question Sheet [5 pts extra credit]

Reading: Fitts Chpt5 Sections 3 through 6

Review and practice Applied Problems
Module 7: Groundwater Storage and Flow Equations

Upon completion of this unit students should be able to:

- Describe and calculate storativity in unconfined and confined aquifers
  - Give appropriate ranges of values for storativity of unconfined vs confined aquifers
  - Calculation of volumes of water released from storage using the storage coefficient or storativity, \( S \)
  - Understand difference between storativity or storage coefficient \((S)\), specific yield \((S_y)\) and specific storage \((S_s)\)
- Understand difference between processes of dewatering of pores, expansion of water and compression of aquifer
- Describe the irreversible compression of clays and resulting subsidence of ground surface due to groundwater pumping
- Describe the derivation of the groundwater flow equation from mass balance of a control volume

More specific learning outcomes are listed in the module’s summary on Blackboard

Tasks
Labs: SURFER Contouring Lab

Reading: Fitts Chpt6 sections 6.1-6.3, 6.7-6.7.1, 6.8-6.10

Review and practice Applied Problems
Module 8: Steady-State Groundwater Flow

Upon completion of this unit students should be able to:

- Understand and apply of differing flow equations for various scenarios: confined aquifer, unconfined aquifer
- Explain why the saturated thickness and hydraulic gradient changes in an unconfined flow situation.
- Understand and apply well flow equations for pumping scenarios in confined and unconfined aquifers (Thiem equations)
- Explain concept of superposition in steady-state flow scenarios
- Describe measurement of and application (use) of well-capture zones
- Describe the use of image wells to simulate the impacts of impermeable and recharge boundaries. Explain why necessary in steady flow models with assumption of infinite areal extent.

More specific learning outcomes are listed in the module’s summary on Blackboard

Tasks

Reading: Fitts Chpt7 Sections 1 through 7.2.2, 7.2.5 through 7.2.8

Review and practice Applied Problems
Module 9: Transient Groundwater Flow

Upon completion of this unit students should be able to:

- Utilize transient flow equations/models for calculation of hydraulic head change with time due to pumping an aquifer: Theis equation for confined aquifers
- Explain graphical pattern of aquifer drawdown from pumping a confined aquifer on a log-log graph
- Explain difference in pattern on a log-log graph of aquifer drawdown over time from pumping a leaky confined aquifer and an unconfined aquifer (compare to confined aquifer)
- Utilize transient flow equations for leaky confined aquifer (Hantusch-Jacob) and for unconfined aquifer (Neumann)
- Explain need for aquifer tests (pumping of wells, etc.) to obtain estimates of K, T and S
- Apply type-curve matching technique (manually with graphs and via spreadsheet model) to calculate T and S of a confined aquifer
- Explain difference in pattern on a semilog graph of aquifer drawdown over time from pumping a confined aquifer, leaky aquifer and unconfined aquifer
- Apply Jacob straight-line technique to calculate T and S from the drawdown response of a confined aquifer on a semilog graph
- Explain the impact of various boundaries (recharge or impermeable) on the drawdown response of a confined aquifer on log-log graphs and semilog graphs
- Explain the impacts of not having a well screened through the entire saturated thickness of an aquifer (partial penetration). Assess when the assumption of horizontal flow is appropriate for aquifer test analysis under these conditions.
- Explain the hydraulics of slug tests

**Tasks**

**Labs:**
- Midterm 2 Chpts 5-7
- Aquifer Testing Lab

**Reading:**
- Fitts Chpt8

**Review and practice Applied Problems**
Module 10: Groundwater Contamination

Upon completion of this unit students should be able to:

- Describe natural dissolved solutes in water
- Describe nonpolar organic molecules and aqueous solubility and sorption
- Apply the hydrophobic model of sorption to estimate Kd parameter
- Calculate and use retardation factor, R, to predict slowing of dissolved solute transport
- Explain LNAPLs and DNAPLs differing behavior in the subsurface and be able to classify common organic compounds as light or dense NAPLs
- Describe advection, dispersion/diffusion and retardation on the transport of a plume in groundwater
- Explain the scale effect on dispersivity
- Understand the Safe Drinking Water Act’s contaminant MCLs regulation
- Describe the major groups of contaminants regulated under the SDWA
- Discuss the problems with regulating contaminants which also occur naturally (chromium)
- Explain why certain pesticides have been banned such as DBCP
- Describe the major water-soluble pollutants from petroleum contamination
- Describe the general history of MTBE use and subsequent ban
- Describe the primary chlorinated solvents used and their subsequent breakdown products found in the environment
- Which two organic contaminants are known carcinogens
- Describe POPs and the efforts for global control of their releases
- Apply solute transport concepts to describe and calculate processes (advection, dispersion, retardation, 1st order transformation)
- Understand which redox conditions will favor transformation/breakdown of petroleum hydrocarbons vs chlorinated solvents
- Describe the concept of natural attenuation

Tasks
Labs: Solute Transport Lab
Reading: Fitts Chpt11

Review and practice Applied Problems

Module 11: What’s up with Fracking

Upon completion of this unit students should be able to:

- Discuss environmental impacts on groundwater of hydraulic fracturing in petroleum extraction

Tasks
Labs: Group Poster Presentations
Reading: Fitts Chpt12