**Earth Sciences 146: Groundwater, Spring 2019**

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| **Instructor** | **Teaching Assistant** |
| Andy Fisher  | Jenny Pensky |
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| Office hours: E&MS A209Mon 11-12, Tue 11-12 | Office hours: E&MS A170Mon 3-4, Tue 9-10 |

Course hours: MWF, 1:20-2:25

Course location: E&MS D250

Laboratory hours: (1) Tue 12:30-15:30 \*or\* (2) Weds 9:00-12:00

Laboratory location: E&MS D250 (and occasionally in the field or Kresge 317 - computer lab)

Field trip: Scott Creek (or Waddell Creek): **Saturday 5/18**, 0800 - 1700 (more or less…)

 ***Saturday 5/25 is a rain date, so please keep this open if possible…***

 (Lab on Campus Hydrogeology – week of 4/29 – will also take us into the field)

Assignments: nine lab exercises, nine problem sets, technical report

Exams (both closed-book): Midterm – **Weds, 5/8, 1:20-2:25 (regular time)**

 Final - **cumulative, Thurs 6/13, 8:00-11:00**

Grades/Evaluations are to be based on the tests, labs, class participation, and assignments:

 25% Labs and technical report

 25% Problems sets

 20% Midterm

 25% Final

 5% Class participation/demonstration of PMA and ROV

Required text: Hiscock and Bense, 2014, *Hydrogeology: Principles and Practice*, 2nd ed.

Supplementary reading: Freeze and Cherry, 1979, *Groundwater* (on website)

 Fetter, 2001, *Applied Hydrogeology*, 4th ed. (on website)

More reading: at the course website in a "virtual reader" **es.ucsc.edu/~afisher/Courses/Eart146**, login required

***Notes about reading and other assignments:***

Please complete reading *prior* to class discussion, ask questions in class, visit during office hours. Please read assigned materials more carefully a second time after topic is discussed in detail or used in lab.

Labs and problem sets normally due one week after being handed out. Late assignments may be accepted, but points will be deducted. Chronic lateness is not acceptable.

All work turned in for grading should be neat and easy to read, stapled at upper left, with answers boxed in and labeled with appropriate units. Copy calculations to a clean page, if necessary. Working together is encouraged, but the work you turn in should be your own. All plots are to be generated using a computer (with Excel, Kaleidagraph, Matlab, R, etc.). Please see instructor, TA, and/or your colleagues for help with plotting.

**Lecture, Lab, Assignment and Reading List**

Subject to revision as the quarter progresses

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| **Date** | **Presentation/Lab topic(s)** | **Readings/Problem sets** |
| **Week 1**M 4/1 – F 4/5***First class: M 4/1*** | 1. Introduction, motivation, overview, terminology | Fetter 1.1-1.10, 2.1-2.9Freeze & Cherry 1.1-1.3Stephens, 2009 (GW careers)Davis, 1994 and Focht, 1995 (GW careers) |
|  | ***First week, no lab meetings*** |  |
|  | 2. Terminology, water and soil properties  | Fetter 3.1-3.3, 6.1-6.2Freeze & Cherry 2.5Nelson, 1997 (units) + conversion table**Hand out PS #1** |
| **Week 2**M 4/8 – F 4/12 | 3. Darcy’s Law, potential and head, aquifers | Fetter 3.4-3.6, 4.1-4.3, 4.5-4.6Freeze & Cherry 2.1-2.3 |
| *Tu 4/9 or W 4/10* | *Lab 1: Darcy’s law and soil properties* | *Fetter 3.4-3.5, 4.6* |
|  | 4. Water table, aquifer properties, measuring head, flow in aquifers | Fetter 3.7-3.9, 3.11-3.12Freeze & Cherry 2.4, 2.7-2.8,2.10Saines, 1981Hand in PS #1, hand out PS #2 |
| **Week 3**M 4/15 – F 4/19 | 5. Limitations of Darcy’s law and the REV, flow refraction, flownets, conservation of mass equations | Fetter 4.7-4.12Freeze & Cherry 2.11-2.12, 5.1DWR: Fractured aquifers |
| *Tu 4/16 or W 4/17* | *Lab 2*: *Flow nets and seepage* | *Fetter 4.9-4.12* |
|  | 6. Wells: design, hydraulics, testing | Fetter 5.1-5.5, 10.4**Hand in PS #2, hand out PS #3** |
| **Week 4**M 4/22 – F 4/26 | 6. Wells: design, hydraulics, testing (continued)  | Fetter 5.1-5.5, 10.4Freeze & Cherry 8.2 (p.312-314), 8.3, 8.6; DWR: groundwater wells |
| *Tu 4/23 or W 4/24* | *Lab 3: Aquifer test analysis - by hand* | *Fetter 5.1-5.9* |
|  | 7. Wells: multiple pumping, boundaries, aquifer properties, single well tests | Fetter 5.6-5.10Freeze & Cherry 8.5-8.6Rovey and Cherkauer, 1995**Hand in PS#3, hand out PS #4** |
| **Week 5**M 4/29 – F 5/3 | 8. Capture zones, confined vs. unconfined 1-D eqns, regional flow | Fetter 10.10, 4.13-4.14, 7.1-7.7Freeze & Cherry 6.1-6.3 |
| *Tu 4/30 or W 5/1****ON-CAMPUS FIELD TRIP*** | Lab 4: Campus (karst) hydrogeology | *Fetter 8.3.4**Johnson et al., 1989**Freeze & Cherry, 11.4 (p. 513-515)* |
|  | 9. Effective stress, subsidence, groundwater modeling | Fetter 3.10, 13.1-13.4Freeze & Cherry 2.9, 8.8, 8.10, 10.1Bredehoeft and Hall, 1995 **Hand in PS #4, hand out PS #5** |
| **Week 6**M 5/6 – F 5/10 | 10. Unsaturated properties, flow, and infiltration | Fetter 6.1-6.7Freeze & Cherry 6.4, 8.1-8.2Deming, 2002: 6.1-6.2 |
| *Tu 5/7 or W 5/8* | *Lab 5: Aquifer test analysis - by computer* ***(Kresge 317)*** | *Fetter 5.1-5.9, 5.6, 5.9-5.10* |
| **Wednesday, 5/8** | MIDTERM EXAMINATION**1:20-2:35 (regular time), D250** | ***covers material discussed through (and including) Week 5, closed book*** |
|  | 10. Unsaturated properties, flow, and infiltration (continued) | **Hand in PS #5, Hand out PS #6** |

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| **Week 7**M 5/13 – F 5/17 | 11. Unsaturated zone monitoring, groundwater chemistry | Fetter 10.5, 9.1-9.8, 9.13-9.14Freeze & Cherry 3.1-3.3, 3.5 |
| *Tu 5/14 or W 5/15* | *Lab 6: Groundwater modeling I* *(****Kresge 317)*** | *Fetter 13.1-13.4, 13.6-13.8*Bredehoeft and Hall, 1995 |
|  | 12. Groundwater solute transport | Fetter 10.6Freeze & Cherry 2.13, 3.4, 9.2Wood, 1996 **Hand in PS #6, hand out PS #7** |
| SATURDAY 5/18***OFF-CAMPUS FIELD TRIP*** | ***Lab 7: Scott Creek/Waddell Creek*** **8 am – 5 pm, *details to follow*…** | **Lee and Cherry, 1978** |
| **Week 8**M 5/20– F 5/24 | 13. Groundwater contamination, well head protection  | Fetter 10.1-01.4, 10.7Freeze & Cherry 9.1, 9.3-9.5Andrews, 1998 + Stanley, 1998 |
| *Tu 5/21 or W 5/22* | *No lab meeting, work on Lab 7* | *Fetter 13.1-13.4, 13.6-13.8**Bredehoeft and Hall, 1995* |
|  | 14. Groundwater remediation | Fetter 10.8-10.9Bredehoeft, 1994; Dasch et al., 1997; Nyer and Suthersan, 1996; Nyer and Fierro, 1998 **Hand in PS #7, hand out PS #8** |
| **Week 9**Tu 5/28 – F 5/31***No class M 5/27*** | 15. Salt water intrusion | Fetter 4.4; 8.7-8.9Freeze & Cherry 8.13Izbicki, 1996 |
| *Tu 5/28 or W 5/29* | *Lab 8: Tracer experiment* | *Fetter 10.6* |
|  | 16. Groundwater management,groundwater law | Fetter 11.1-11.11Freeze & Cherry 8.10-8.11Dragonetti, 1998; Bredehoeft et al., 1982; Alley, 2004; Devlin, 2005; DWR GW management; DWR GW adjudication**Hand in PS #8, hand out PS #9** |
| **Week 10**M 6/3 – F 6/7 | 17. Special topics in groundwater (I): geology, basins, and convection | Fetter 8.1-8.4, 8.10Freeze & Cherry 4.1-4.6, 11.3 |
| *Tu 6/4 or W 6/5* | *Finish lab report*  | *Fetter 13.1-13.4, 13.6-13.8* |
| **Last week of classes!** | 18. Special topics in groundwater (II): ores and oil, geophysical logging | Freeze & Cherry 11.2 and 11.5Fetter, 12.4 **Hand in PS #9** |
| **Thursday 6/13, 8-11 am** | FINAL EXAMINATION | ***Cumulative, closed book*** |