Cover Sheet: Request 10339

GLY 4822 Groundwater Geology

Info

Process	Course|New|Ugrad/Pro
Status	Pending
Submitter	Screaton,Elizabeth Jane screaton@ufl.edu
Created	8/10/2015 5:06:01 PM
Updated	11/16/2015 3:36:25 PM
Description	Introduction to the concepts of groundwater flow and its relationship to subsurface geology. Practice in applying groundwater flow concepts and problem solving.

Actions

Step	Status	Group	User	Comment	Updated
Department	Approved	CLAS - Geological Sciences 011610000	Foster, David A		8/17/2015
Replaced GW_Geology_syl15_4822_v3.docx					8/12/2015
Added uccconsult Civil and Coastal Engineering RJT.pdf					8/10/2015
Replaced Related_syllabus_GLY5827.docx					8/12/2015
Replaced Related_syllabus_GLY4822_UFOnline.docx					8/12/2015
Replaced Related_syllabus_GLY5827.docx					8/12/2015
Deleted Related_syllabus_GLY4822_UFOnline.docx					8/12/2015
Replaced Related_syllabus_GLY5827.docx					8/12/2015
College	Recycled	CLAS - College of Liberal Arts and Sciences	Pharies, David A	Conditionally approved by the CCC. Please proofread entire document, c.f. p. 1 of syllabus: "so it (sic) good to get familiar with you (sic) calculator"	10/1/2015
Replaced Related_syllabus_GLY5827.docx					8/18/2015
Deleted Related_syllabus_GLY5827.docx					8/18/2015
Department	Approved	CLAS - Geological Sciences 011610000	Foster, David A		10/15/2015
Replaced GW_Geology_syl15_4822_v3.docx					10/1/2015
Replaced GW_Geology_syl15_4822_v4.docx					10/15/2015
Replaced Related_syllabus_GLY4822_UFOnline.docx					10/15/2015
Replaced Related_syllabus_GLY5827.docx					10/15/2015
Added GW_Geology_syl15_4822.docx					10/15/2015
Added Related_syllabus_GLY4822_UFOnline.docx					10/15/2015
Added Related_syllabus_GLY5827.docx					10/15/2015
College	Approved	CLAS - College of Liberal Arts and Sciences	Pharies, David A		10/15/2015
No document changes					
University Curriculum Committee	Comment	PV - University Curriculum Committee (UCC)	Baker, Brandi N	Added to November agenda.	10/26/2015
No document changes					

Step	Status	Group	User	Comment	Updated
University Curriculum Committee	Pending	PV - University Curriculum Committee (UCC)			10/26/2015
No document changes					
Statewide Course Numbering System					
No document changes					
Office of the Registrar					
No document changes					
Student Academic Support System					
No document changes					
Catalog					
No document changes					
College Notified					
No document changes					

Course|New for request 10339

Info

Request: GLY 4822 Groundwater Geology
Submitter: Screaton,Elizabeth Jane screaton@ufl.edu
Created: 8/10/2015 5:18:43 PM
Form version: 2

Responses

Recommended Prefix: GLY
Course Level : 4
Number : 822
Lab Code : None
Course Title: Groundwater Geology
Transcript Title: Groundwater Geology
Effective Term : Earliest Available
Effective Year: Earliest Available
Rotating Topic?: No
Amount of Credit: 3
Repeatable Credit?: No
S/U Only?: No
Contact Type : Regularly Scheduled
Degree Type: Baccalaureate
Weekly Contact Hours : 3
Category of Instruction : Advanced
Delivery Method(s): On-Campus
Course Description : Introduction to the concepts of groundwater flow and its relationship to subsurface geology. Practice in applying groundwater flow concepts and problem solving.
Prerequisites : A GLY 2000-level or higher & (MAC 1147 or 2311)
Co-requisites : None
Rationale and Placement in Curriculum : A graduate course (GLY 5827) has been taught at UF for decades, but has increasingly been requested by undergraduates. GLY 4822 is taught at FIU, USF, and FAU. The course will be taught on campus and for UF Online. The UF Online syllabus is also provided.

The course should be co-listed with GLY 5827. The graduate course has additional effort required on student presentations, student reports, and student exams. A syllabus for the graduate class is also provided.

An external consultation form has been filled out by Dr. Robert Thieke of Civil and Coastal Engineering.

Course Objectives : Apply the basic concepts of groundwater flow.
Integrate groundwater flow concepts with characterization of subsurface geology.

Course Textbook(s) and/or Other Assigned Reading: Groundwater Science C.R. Fitts,2nd edition, 2012
Weekly Schedule of Topics : Week 1 Introduction and review of geology basics most relevant to groundwater flow.
Week 2: Basic Principles, including Darcy's Law

Week 3: Hydraulic Conductivity and Permeability
Week 4: Geologic Information for Groundwater Studies
Week 5: Geology of Groundwater and Florida’s Hydrogeology
Week 6: First Report and Exam 1
Week 7: Storage and Groundwater Flow equations
Week 8: Potentiometric surface maps and Surface Water/Groundwater exchange
Week 9: Recharge and Groundwater Flow Pattern
Week 10: Second Report, Exam 2
Week 11 and 12: Flow to Wells
Week 13: Freshwater/Saltwater and Groundwater Modeling
Week 14: Groundwater Contamination
Week 15: Third Report, Exam 3

Grading Scheme : Exams 35%
Reports 15.3%
Quizzes 13.1 %
Assignments 26.3%
Class Participation 7.3%
Presentations 2.9%

Instructor(s) : Elizabeth Screaton

GLY 4822: Groundwater Geology
Prof. Liz Screaton, screaton@ufl.edu
Office Hours: TBA
TA: TBA

Course Objectives

- Students will understand the basic concepts of groundwater flow and the relationship between groundwater flow and subsurface geology.
- Students will be able to apply these concepts to solve groundwater problems.

Textbook: *Groundwater Science (Fitts)*

Class Organization

The class is organized in 10 modules. In each module, there will be:

- A background reading assignment to introduce the concepts, terms, and skills. This reading will generally be from the text but will sometimes include outside reading.
- A quiz which consists of 10 multiple choice questions. Quizzes are not timed, are open book and open notes, and you can seek help from classmates and the prof/TA. Quizzes will be scored immediately and you can take a second attempt. The highest grade will be counted. Quiz questions are randomly drawn from pools of questions of similar topic and difficulty.
- A 20-point assignment in each module will provide practice with the concepts and skills**.** The assignment will often include calculations and drawings. For calculations, you will "show your work" on paper and submit. If you submit online, take a clear photo and add to your word document. Unless otherwise specified, working with other students on assignments is encouraged, but **all answers must be written in your own words, all shown work must be yours, and all figures must be created by you.**
- The class meetings are an important part of your learning, and participation is ~7% of your class total grade. During the class meetings, we will pose questions for you to answer. This is also your opportunity to ask questions of the Prof/TA and your classmates. To prepare for the class, you will need to have read the background reading and begun the quiz and assignment. Bring a calculator for to class for practice problems.
- Texting, email checking, and web browsing are not part of class participation or learning. Furthermore, these activities are distracting for those sitting nearby or behind you. If your behavior is distracting to others (including the TA or professor), you will be warned and may not be allowed any use of electronic devices during the remaining classes. A second incident may result in you being asked to leave the class and loss of all class participation points.

During the semester, there will also be:

- Two 3-5 minute **presentations** for your classmates during a class meeting. We'll provide some topic ideas before each class meeting, but you are also welcome to suggest your own. You should notify us by the Friday before the class meeting that you plan to present.

- Three **reports** in which you will apply the skills that you've learned. The reports will also provide experience in technical writing. The reports will be evaluated using Turnitin to determine the originality of your work. Turnitin is an online service to help prevent and identify student plagiarism.
- Three 90-minute **exams**. During the exam, you will be allowed to use a calculator (but not one on your phone) and scratch paper. As you proceed through the modules, you will be alerted as to which equations should be memorized and which will be provided on the exams. If you have any questions, just ask!

This course is co-listed and may be co-taught with GLY 5827. The differences between the two courses are as follows:

- The undergraduate presentations are shorter (3-5 minutes) and can be based on USGS fact sheets or similar-level material. The graduate presentations are longer (7-10 minutes) and must be based on scientific research publications.
- For the three reports, additional analyses are required at the graduate level. Interpretation and written communication will be assessed at a higher level.
- The three exams are shorter (80 pts each) for the undergraduate course than for the graduate course (90 pts each).

Grading (685 pts total):

- Presentations (2@10 pts): 20 pts
- Quizzes (best 9 of 10@10 pts): 90 pts
- Participation/Discussion (best 10@5 pts): 50 pts
- Exams 240 pts (3@80 pts)
- Reports 105 pts (3@35 pts)
- Assignments (best 9 of 10@20 pts): 180 pts

Grades. These grade criteria are firm. A: ≥93%; A- 90.0-92.9%; B+ 87– 89.9%, B: 83 – 86.9 %, B-: 80.0 – 82.9%, C+ 77 – 79.9 %; C: 73 – 76.9%, C-: 70.0 – 72.9 %, D+: 67 – 69.9%, D: 63 – 66.9%, D- 60.0 – 62.9%; E 59.9% and below**.**

Information on how UF calculates GPA based on letter grades can be found at: https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx.

Course Schedule

	Topic	Reading
Week 1	**Introduction** provides class logistics and reviews geologic concepts most relevant to groundwater flow.	Syllabus Outside reading
Week 2	**Module 1 Basic Principles** introduces Darcy's Law and the basics of groundwater flow.	Ch 2 and 3.1-3.4
Week 3	**Module 2 Hydraulic Conductivity and Hydraulic Head** examines controls on hydraulic conductivity and how it is measured. Mapping of hydraulic head is introduced.	Ch. 3.5 to 3.9 Outside reading
Week 4	**Module 3 Geologic Information for Groundwater Studies** covers how geologic information is obtained and interpreted as well as how geophysics can be applied to groundwater studies.	Ch. 4
Week 5	**Module 4 Geology of Groundwater and Florida's Hydrogeology** examines how major aquifer characteristics are controlled by their geologic setting and explores the current state of knowledge about Florida's aquifers.	Ch 5.3-5.6 Outside reading
Week 6	**Report 1 due** **Exam 1**	
Week 7	**Module 5 Storage and Groundwater Flow Equations** focuses on how water is stored in confined and unconfined aquifers and develops groundwater flow equations from Darcy's law and conservation of mass.	Ch. 6.1-6.3, 6.7-6.9.2
Week 8	**Module 6 Potentiometric surface maps and Groundwater/surface water exchange** covers how water levels measured in wells are interpreted to understand groundwater flow directions and exchange of water between surface water and groundwater.	Ch. 5.1.1, 5.1.3, 5.2.1 to 5.2.3
Week 9	**Module 7 Recharge and Groundwater Flow Patterns** examines how recharge occurs and is quantified and how topography and heterogeneity impact groundwater flow directions.	Ch. 1.4.1, 1.4.2, 3.10, 5.1.2, 5.1.4, 5.2.5, 5.2.6, and 10.10.2
Week 10	**Report 2 Due** **Exam 2**	
Week 11/12	**Module 8: Flow to Wells** introduces the prediction of drawdown due to pumping and the use of aquifer tests to determine aquifer properties.	Ch 7.2.2, Ch. 8.2-8.5
Week 13	**Module 9: Freshwater/Saltwater and Groundwater Modeling** covers two topics: 1) How density differences and mixing affect groundwater at the coast and 2) how numerical models are used for groundwater flow problems.	Ch 3.11, 9.1-9.3, 9.5-9.6
Week 14	**Module 10: Groundwater Contamination** focuses on the movement of solutes and non-aqueous phase liquids in groundwater and how contaminated sites are investigated.	Ch 11
Week 15	**Report 3 Due** **Exam 3**	

Academic Honor Code: As a student at the University of Florida, you have committed yourself to uphold the Honor Code, which includes the following pledge: "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honesty and integrity. " You are expected to exhibit behavior consistent with this commitment to the UF academic community, and on all work submitted for credit at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." It is assumed that you will complete all work independently in each course unless the instructor provides explicit permission for you to collaborate on course tasks (e.g. assignments, papers, quizzes, exams). Furthermore, as part of your obligation to uphold the Honor Code, you should report any condition that facilitates academic misconduct to appropriate personnel. It is your individual responsibility to know and comply with all university policies and procedures regarding academic integrity and the Student Honor Code. Violations of the Honor Code at the University of Florida will not be tolerated. Violations will be reported to the Dean of Students Office for consideration of disciplinary action. For more information regarding the Student Honor Code, please see: http://www.dso.ufl.edu/SCCR/honorcodes/honorcode.php

Getting answers to your questions: This class is at a 4000 level, which means it is aimed at senior-level students (although open to others). **Expect to have questions** as you read the course notes, work through the assignments, and prepare for the exams. Questions are part of the learning process! Therefore it is very important to complete assignments well before the deadline.

- For content questions on each module, bring your questions to the class meeting. If you need an answer sooner, go is to the module's Discussion board. First check whether other students have asked the same question and, if not, pose the question to the class. Help your classmates, increase your learning, and keep the discussion moving by answering questions. Discussion posts will be reviewed by the TA/professor daily M-F and additional information may be added.
- For problems with Canvas: call 352-392-4357 or via e-mail at helpdesk@ufl.edu.
- To report course-specific errors (a typo in an assignment or a bad link), notify both the TA (TBA@ufl.edu) and professor (screaton@ufl.edu).
- An email to the TA or the prof is the best way to ask questions that are specific to you, such as about your grade or an upcoming conflict with a deadline.

Course announcements and email: When you log in to Canvas, please ensure that your Notification Preferences are set to "ASAP" for Announcements and for Conversation Messages. These tools will be used to inform you of any updates or changes in the course.

Attendance and conflicts: *Requirements for class attendance and make-up exams, assignments, and other work in this course are consistent with university policies that can be found in the online catalog at: https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx*

Exams:

- For pre-existing conflicts (e.g., athletic, religious, academic), you are responsible for providing notification no later than 1 week in advance, and making arrangements for an alternate date within one week of the exam date.

- With documentation of sudden illness or other unexpected major event, you may make up the exam if you notify TA/prof prior to exam time (or as soon as you are physically able) and arrange a makeup within a reasonable time frame (generally 1 week).
- Without documentation of sudden illness or other unexpected major event, exams can only be made up within 1 day and 20% will be deducted.

Quizzes and Assignments:

Because quizzes and assignments are available for at least 1 week and you can drop the lowest grade of each, only very major and lengthy conflicts will be considered to allow deadline extensions or make-ups.

- For *pre-existing conflicts* (e.g., athletic, religious, academic), **you are responsible** for providing me with email or written notification and making arrangements with me (screaton@ufl.edu) for an alternate date as soon as you are aware of the conflict, **but no later than 1 week before a deadline.**
- For *sudden, unexpected **major** issues that cause you to need additional time* **you are responsible** for providing me (screaton@ufl.edu) with written notification and making arrangements. Documentation will be requested.
- **Deadlines** on quizzes and assignments are firm and are your responsibility. Assignment and quizzes are due **at 1 pm on the due dates**. **We *strongly* recommend you aim to complete these at least a day ahead of time.** This leaves you time to ask questions and for unexpected computer/network problems. ***Problems encountered during the last 2 hours before a deadline are not considered valid reasons for incomplete work.***

Accommodations for Disabilities: Students with disabilities requesting accommodations should first register with the Disability Resource Center (352-392-8565, www.dso.ufl.edu/drc/) by providing appropriate documentation. Once registered, students will receive an accommodation letter which must be provided to the instructor when requesting accommodation. Students with disabilities should follow this procedure as early as possible in the semester.

Course Evaluations: Students are expected to provide feedback on the quality of instruction in this course by completing online evaluations at http://evaluations.ufl.edu. Evaluations are typically open during the last two or three weeks of the semester, but students will be given specific times when they are open. Summary results of these assessments are available to students at https://evaluations.ufl.edu/results

NOTE: The syllabus below is for the online version of the course. It is the same as the residential course syllabus with these major differences: 1) the class meetings are replaced by video lecture and online discussions and 2) ProctorU is required for the exams.

UFOnline GLY 4822: Groundwater Geology
Prof. Liz Screaton, screaton@ufl.edu
Office Hours: TBA
TA: TBA

Course Objectives

- Students will understand the basic concepts of groundwater flow and the relationship between groundwater flow and subsurface geology.
- Students will be able to apply these concepts to solve groundwater problems.

Textbook: *Groundwater Science (Fitts)*

Class Organization

The class is organized in 10 modules. In each module, there will be:

- A background reading assignment to introduce the concepts, terms, and skills. This reading will generally be from the text but will sometimes include outside reading.
- One to two 10-15 minute video lectures which will reinforce written material.
- A quiz which consists of 10 multiple choice questions. Quizzes are not timed, are open book and open notes, and you can seek help from classmates and the prof/TA. Quizzes will be scored immediately and you can take a second attempt. The highest grade will be counted. Quiz questions are randomly drawn from pools of questions of similar topic and difficult.
- A 20-point assignment in each module will provide practice with the concepts and skills**.** The assignment will often include calculations and drawings. For calculations, you will "show your work". If you work on paper, take a clear photo to submit. Unless otherwise specified, working with other students on assignments is encouraged, but **all answers must be written in your own words, all shown work must be yours, and all figures must be created by you.**
- The online class discussions are an important part of your learning, and participation is ~7% of your class total grade. During the class discussions, we will pose questions for you to answer. This is also your opportunity to ask questions of the Prof/TA and your classmates. To prepare for the discussion, you will need to have read the background reading, viewed the videos, and begun the quiz and assignment. Use of Word or similar word-processor and checking grammar and spelling before posting is recommended.

During the semester, there will also be:

- Two 3-5 minute **presentations** for your classmates during a module discussion. We'll provide some topic ideas during each module, but you are also welcome to suggest your own. You should notify class members as soon as you decide on a topic, to prevent overlap. Presentations should be posted **at least 2 days** before the discussion closes.

- Three **reports** in which you will apply the skills that you've learned. The reports will also provide experience in technical writing. The reports will be evaluated using Turnitin to determine the originality of your work. Turnitin is an online service to help prevent and identify student plagiarism.
- Three 90-minute **exams**. Your three exams in this course will be proctored using ProctorU. ProctorU is a service that allows students to complete their assessment at any location while still ensuring the academic integrity of the exam for the institution. Using almost any web cam and computer, you can take exams at home, at work, or anywhere you have internet access. During the exam, you will be allowed to use a calculator (not on your phone) and scratch paper. As you proceed through the modules, you will be alerted as to which equations should be memorized and which will be provided on the exam. If you have any questions, just ask! Exam questions are randomly drawn from pools of questions of similar topic and difficulty level.

This course is co-listed and may be co-taught with GLY 5827. The differences between the two courses are as follows:

- The undergraduate presentations are shorter (3-5 minutes) and can be based on USGS fact sheets or similar-level material. The graduate presentations are longer (7-10 minutes) and must be based on scientific research publications.
- For the three reports, additional analyses are required at the graduate level. Interpretation and written communication will be assessed at a higher level.
- The three exams are shorter (80 pts each) for the undergraduate course than for the graduate course (90 pts each).

Grading (685 pts total):

- Presentations (2@10 pts): 20 pts
- Quizzes (best 9 of 10@10 pts): 90 pts
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- Reports 105 pts (3@35 pts)
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Course Schedule

	Topic	Reading
Week 1	**Introduction** provides class logistics and reviews geologic concepts most relevant to groundwater flow.	Syllabus Outside reading
Week 2	**Module 1 Basic Principles** introduces Darcy's Law and the basics of groundwater flow.	Ch 2 and 3.1-3.4
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Week 8	**Module 6 Potentiometric surface maps and Groundwater/surface water exchange** covers how water levels measured in wells are interpreted to understand groundwater flow directions and exchange of water between surface water and groundwater.	Ch. 5.1.1, 5.1.3, 5.2.1 to 5.2.3
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Week 11/12	**Module 8: Flow to Wells** introduces the prediction of drawdown due to pumping and the use of aquifer tests to determine aquifer properties.	Ch 7.2.2, Ch. 8.2-8.5
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Getting answers to your questions: This class is at a 4000 level, which means it is aimed at senior-level students (although open to others). **Expect to have questions** as you read the course notes, work through the assignments, and prepare for the exams. Questions are part of the learning process! Therefore it is very important to begin assignments well before the deadline.

- For content questions on each module, post your questions to the module's Discussion board. First check whether other students have asked the same question and, if not, pose the question to the class. Help your classmates, increase your learning, and keep the discussion moving by answering questions. Discussion posts will be reviewed by the TA/professor daily M-F and additional information may be added.
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Exams:

- For pre-existing conflicts (e.g., athletic, religious, academic), you are responsible for providing notification no later than 1 week in advance, and making arrangements for an alternate date within one week of the exam date.

- With documentation of sudden illness or other unexpected major event, you may make up the exam if you notify TA/prof prior to exam time (or as soon as you are physically able) and arrange a makeup within a reasonable time frame (generally 1 week).

Quizzes and Assignments:

Because quizzes and assignments are available for at least 2 weeks and you can drop the lowest grade of each, only very major and lengthy conflicts will be considered to allow deadline extensions or make-ups.

- For *pre-existing conflicts* (e.g., athletic, religious, academic), **you are responsible** for providing me with email or written notification and making arrangements with me (screaton@ufl.edu) for an alternate date as soon as you are aware of the conflict, **but no later than 1 week before a deadline.**
- For *sudden, unexpected* ***major*** *issues that cause you to need additional time* **you are responsible** for providing me (screaton@ufl.edu) with written notification and making arrangements. Documentation will be requested.
- **Deadlines** are firm and are your responsibility. Assignment and quizzes are due **at 11:59 pm on Tuesdays (quizzes) and Thursdays (assignments and discussion). We *strongly* recommend you aim to complete these at least a day ahead of time.** This leaves you time to ask questions and for unexpected computer/network problems. ***Problems encountered after 3 pm on the due date are not considered valid reasons for incomplete work.***

Accommodations for Disabilities: Students with disabilities requesting accommodations should first register with the Disability Resource Center (352-392-8565, www.dso.ufl.edu/drc/) by providing appropriate documentation. Once registered, students will receive an accommodation letter which must be provided to the instructor when requesting accommodation. Students with disabilities should follow this procedure as early as possible in the semester.

Course Evaluations: Students are expected to provide feedback on the quality of instruction in this course by completing online evaluations at http://evaluations.ufl.edu. Evaluations are typically open during the last two or three weeks of the semester, but students will be given specific times when they are open. Summary results of these assessments are available to students at https://evaluations.ufl.edu/results

NOTE: This syllabus is for GLY 5827, which will be co-listed with GLY 4822. Differences between GLY 5827 and GLY 4822 are described on page 2 of both syllabi.

GLY 5827: Groundwater Geology
Prof. Liz Screaton, screaton@ufl.edu
Office Hours: TBA
TA: TBA

Course Objectives

- Students will understand the basic concepts of groundwater flow and the relationship between groundwater flow and subsurface geology.
- Students will be able to apply these concepts to solve groundwater problems.

Textbook: *Groundwater Science (Fitts)*

Class Organization

The class is organized in 10 modules. In each module, there will be:

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- A quiz which consists of 10 multiple choice questions. Quizzes are not timed, are open book and open notes, and you can seek help from classmates and the prof/TA. Quizzes will be scored immediately and you can take a second attempt. The highest grade will be counted. Quiz questions are randomly drawn from pools of questions of similar topic and difficulty.
- A 20-point assignment in each module will provide practice with the concepts and skills**.** The assignment will often include calculations and drawings. For calculations, you will "show your work" on paper and submit. If you submit online, take a clear photo and add to your word document. Unless otherwise specified, working with other students on assignments is encouraged, but **all answers must be written in your own words, all shown work must be yours, and all figures must be created by you.**
- The class meetings are an important part of your learning, and participation is ~7% of your class total grade. During the class meetings, we will pose questions for you to answer. This is also your opportunity to ask questions of the Prof/TA and your classmates. To prepare for the class, you will need to have read the background reading and begun the quiz and assignment. Bring a calculator for practice problems.
- Texting, email checking, and web browsing are not part of class participation or learning. Furthermore, these activities are distracting for those sitting nearby or behind you. If your behavior is distracting to others (including TA or prof), you will be warned and may not be allowed any use of electronic devices during the remaining classes. A second incident may result in you being asked to leave the class and loss of all class participation points.

During the semester, there will also be:

- Two 7-10 minute **presentations** for your classmates during a class meeting. We'll provide some topic ideas before each class meeting, but you are also welcome to suggest your own. You should notify us by the Friday before the class meeting that you plan to present.
- Three **reports** in which you will apply the skills that you've learned. The reports will also provide experience in technical writing.
- Three 90-minute **exams**. During the exam, you will be allowed to use a calculator (but not one on your phone) and scratch paper. As you proceed through the modules, you will be alerted as to which equations should be memorized and which will be provided on the exams. If you have any questions, just ask!

This course is co-listed and may be co-taught with GLY 4822. The differences between the two courses are as follows:

- The undergraduate presentations are shorter (3-5 minutes) and can be based on USGS fact sheets or similar-level material. The graduate presentations are longer (7-10 minutes) and must be based on scientific research publications.
- For the three reports, additional analyses are required at the graduate level. Interpretation and written communication will be assessed at a higher level.
- The three exams are shorter (80 pts each) for the undergraduate course than for the graduate course (90 pts each).

Grading (730 pts total):

- Presentations (2@10 pts): 20 pts
- Quizzes (best 9 of 10@10 pts): 90 pts
- Participation/Discussion (best 10@5 pts): 50 pts
- Exams 270 pts (3@90 pts)
- Reports 120 pts (3@40 pts)
- Assignments (best 9 of 10@20 pts): 180 pts

Grades. These grade criteria are firm. A: ≥93%; A- 90.0-92.9%; B+ 87– 89.9%, B: 83 – 86.9 %, B-: 80.0 – 82.9%, C+ 77 – 79.9 %; C: 73 – 76.9%, C-: 70.0 – 72.9 %, D+: 67 – 69.9%, D: 63 – 66.9%, D- 60.0 – 62.9%; E 59.9% and below**.**

Information on how UF calculates GPA based on letter grades can be found at: https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx.

Course Schedule

	Topic	Reading
Week 1	**Introduction** provides class logistics and reviews geologic concepts most relevant to groundwater flow.	Syllabus Outside reading
Week 2	**Module 1 Basic Principles** introduces Darcy's Law and the basics of groundwater flow.	Ch 2 and 3.1-3.4
Week 3	**Module 2 Hydraulic Conductivity and Hydraulic Head** examines controls on hydraulic conductivity and how it is measured. Mapping of hydraulic head is introduced.	Ch. 3.5 to 3.9 Outside reading
Week 4	**Module 3 Geologic Information for Groundwater Studies** covers how geologic information is obtained and interpreted as well as how geophysics can be applied to groundwater studies.	Ch. 4
Week 5	**Module 4 Geology of Groundwater and Florida's Hydrogeology** examines how major aquifer characteristics are controlled by their geologic setting and explores the current state of knowledge about Florida's aquifers.	Ch 5.3-5.6 Outside reading
Week 6	**Report 1 due** **Exam 1**	
Week 7	**Module 5 Storage and Groundwater Flow Equations** focuses on how water is stored in confined and unconfined aquifers and develops groundwater flow equations from Darcy's law and conservation of mass.	Ch. 6.1-6.3, 6.7-6.9.2
Week 8	**Module 6 Potentiometric surface maps and Groundwater/surface water exchange** covers how water levels measured in wells are interpreted to understand groundwater flow directions and exchange of water between surface water and groundwater.	Ch. 5.1.1, 5.1.3, 5.2.1 to 5.2.3
Week 9	**Module 7 Recharge and Groundwater Flow Patterns** examines how recharge occurs and is quantified and how topography and heterogeneity impact groundwater flow directions.	Ch. 1.4.1, 1.4.2, 3.10, 5.1.2, 5.1.4, 5.2.5, 5.2.6, and 10.10.2
Week 10	**Report 2 Due** **Exam 2**	
Week 11/12	**Module 8: Flow to Wells** introduces the prediction of drawdown due to pumping and the use of aquifer tests to determine aquifer properties.	Ch 7.2.2, Ch. 8.2-8.5
Week 13	**Module 9: Freshwater/Saltwater and Groundwater Modeling** covers two topics: 1) How density differences and mixing affect groundwater at the coast and 2) how numerical models are used for groundwater flow problems.	Ch 3.11, 9.1-9.3, 9.5-9.6
Week 14	**Module 10: Groundwater Contamination** focuses on the movement of solutes and non-aqueous phase liquids in groundwater and how contaminated sites are investigated.	Ch 11
Week 15	**Report 3 Due** **Exam 3**	

Academic Honor Code: As a student at the University of Florida, you have committed yourself to uphold the Honor Code, which includes the following pledge: "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honesty and integrity. " You are expected to exhibit behavior consistent with this commitment to the UF academic community, and on all work submitted for credit at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." It is assumed that you will complete all work independently in each course unless the instructor provides explicit permission for you to collaborate on course tasks (e.g. assignments, papers, quizzes, exams). Furthermore, as part of your obligation to uphold the Honor Code, you should report any condition that facilitates academic misconduct to appropriate personnel. It is your individual responsibility to know and comply with all university policies and procedures regarding academic integrity and the Student Honor Code. Violations of the Honor Code at the University of Florida will not be tolerated. Violations will be reported to the Dean of Students Office for consideration of disciplinary action. For more information regarding the Student Honor Code, please see: http://www.dso.ufl.edu/SCCR/honorcodes/honorcode.php

Getting answers to your questions: This class is at a 5000 level, which means it is aimed at graduate students (although open to upper level undergraduates). **Expect to have questions** as you read the course notes, work through the assignments, and prepare for the exams. Questions are part of the learning process! Therefore it is very important to complete assignments well before the deadline.

- For content questions on each module, bring your questions to the class meeting. If you need an answer sooner, go is to the module's online discussion board. First check whether other students have asked the same question and, if not, pose the question to the class. Help your classmates, increase your learning, and keep the discussion moving by answering questions. Discussion posts will be reviewed by the TA/professor daily M-F and additional information may be added.
- For problems with Canvas: call 352-392-4357 or via e-mail at helpdesk@ufl.edu.
- To report course-specific errors (a typo in an assignment or a bad link), notify both the TA (TBA@ufl.edu) and professor (screaton@ufl.edu).
- An email to the TA or the prof is the best way to ask questions that are specific to you, such as about your grade or an upcoming conflict with a deadline.

Course announcements and email: When you log in to Canvas, please ensure that your Notification Preferences are set to "ASAP" for Announcements and for Conversation Messages. These tools will be used to inform you of any updates or changes in the course.

Attendance and conflicts: *Requirements for class attendance and make-up exams, assignments, and other work in this course are consistent with university policies that can be found in the online catalog at: https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx*

Exams:

- For pre-existing conflicts (e.g., athletic, religious, academic), you are responsible for providing notification no later than 1 week in advance, and making arrangements for an alternate date within one week of the exam date.

- With documentation of sudden illness or other unexpected major event, you may make up the exam if you notify TA/prof prior to exam time (or as soon as you are physically able) and arrange a makeup within a reasonable time frame (generally 1 week).
- Without documentation of sudden illness or other unexpected major event, exams can only be made up within 1 day and 20% will be deducted.

Quizzes and Assignments:

Because quizzes and assignments are available for at least 1 week and you can drop the lowest grade of each, only very major and lengthy conflicts will be considered to allow deadline extensions or make-ups.

- For *pre-existing conflicts* (e.g., athletic, religious, academic), **you are responsible** for providing me with email or written notification and making arrangements with me (screaton@ufl.edu) for an alternate date as soon as you are aware of the conflict, **but no later than 1 week before a deadline.**
- For *sudden, unexpected **major** issues that cause you to need additional time* **you are responsible** for providing me (screaton@ufl.edu) with written notification and making arrangements. Documentation will be requested.
- **Deadlines** on quizzes and assignments are firm and are your responsibility. Assignment and quizzes are due **at 1 pm on the due dates**. **We *strongly* recommend you aim to complete these at least a day ahead of time.** This leaves you time to ask questions and for unexpected computer/network problems. ***Problems encountered during the last 2 hours before a deadline are not considered valid reasons for incomplete work.***

Accommodations for Disabilities: Students with disabilities requesting accommodations should first register with the Disability Resource Center (352-392-8565, www.dso.ufl.edu/drc/) by providing appropriate documentation. Once registered, students will receive an accommodation letter which must be provided to the instructor when requesting accommodation. Students with disabilities should follow this procedure as early as possible in the semester.

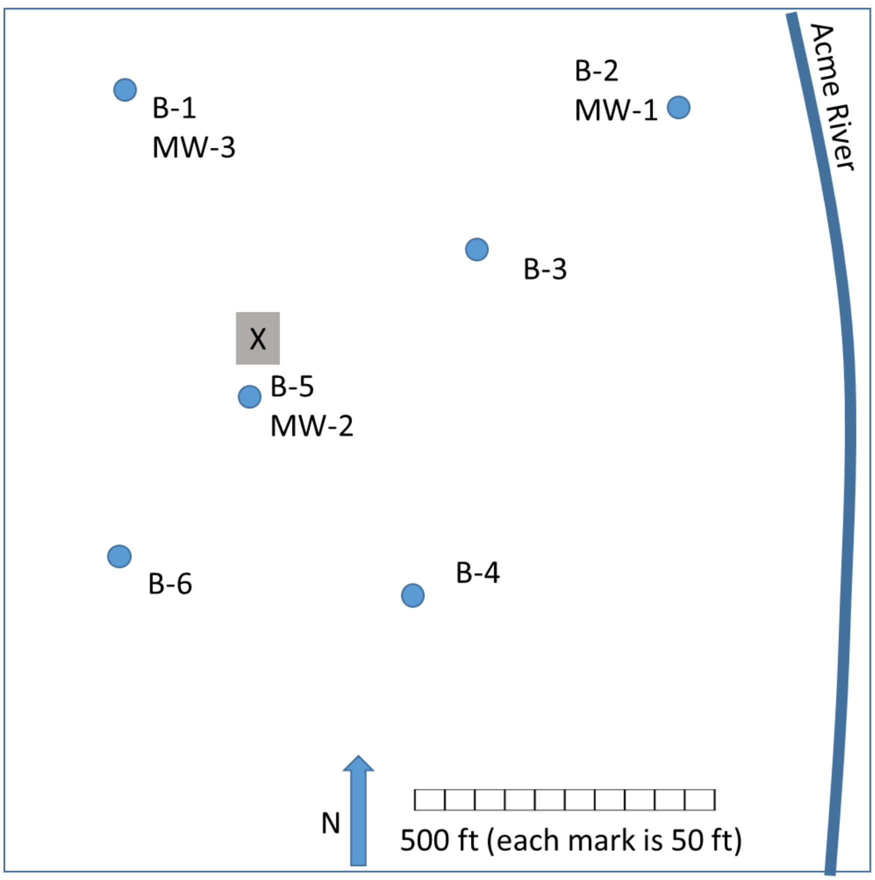
Course Evaluations: Students are expected to provide feedback on the quality of instruction in this course by completing online evaluations at http://evaluations.ufl.edu. Evaluations are typically open during the last two or three weeks of the semester, but students will be given specific times when they are open. Summary results of these assessments are available to students at https://evaluations.ufl.edu/results

GLY 5827/4930 Groundwater Report I: Acmeville

Graduate Students (GLY 5827): 40 pts. Complete all parts.
Undergraduate Student (GLY 4930): 35 pts. Omit any instructions in italics.

Two miles south of the town of Acmeville, there is a site (shown by the "x" on the map) where hazardous waste was buried during the 1960s and 1970s. The town and the waste site are located in the Acme river valley. The Acme River is shown on the map below and flows from south to north.

Initial investigations confirmed that: a) hazardous chemicals were present at the site, b) the valley's sediments are alluvial with some possible glacial till above limestone, c) groundwater contamination was likely, and d) regional flow mapping suggests that groundwater flows to the northeast and discharges into the Acme River (Worker Company, 2014). Your company has been hired to investigate the extent of groundwater contamination.



During the first phase of your company's investigations, 6 borings were drilled using a hollow-stem auger rig (locations are marked B-1 to B-6 on the map). Because regional-scale studies suggest that groundwater flows to the NE, the boreholes were designed to investigate a transect in the flow direction (Boreholes B-6, B-5, B-3, and B-2) and perpendicular to the flow direction (Boreholes B-1, B-5, and B-4). The borings were continuously cored. At each of three marked monitoring well locations (MW-1, MW-2, and MW-3), a shallow well and a deep monitoring well were installed. The well top of casing (TOC) elevations were surveyed, and water depths below TOC were measured at two different times (May and Nov, 2014).

To determine porosity, your company had bulk density of saturated samples of each lithology measured in the laboratory. Permeability was also measured in the laboratory using cores from the site. Groundwater temperatures have not been directly measured. Based on information from the previous report (Worker Company, 2014), the average air temperature is 10° C and this can be assumed to be similar to the shallow groundwater temperatures.

Chemical analyses of sediment samples from the borings were conducted but will be presented in a separate report. No groundwater samples have yet been collected. You do not need to be concerned about properties of the contaminants or processes such as dispersion, diffusion, or reaction.

You will analyze the available data by:

- Constructing a hydrogeologic cross section that includes both geologic and hydraulic head information from B-6, B-5, B-3 and B-2 and hydraulic head information from MW-1 and MW-2. *A second cross-section through B-1, B-5, and B-4 (using Wells MW-2 and MW-3) is required for grads.*
- Determining horizontal hydraulic gradients (direction and magnitude) in the shallow and deep aquifers using MW-1, -2, and -3, and vertical hydraulic gradient at the well pair closest to the site (MW-2). *Grads will conduct calculations for both the May and Nov data (so 6 total gradient calculations, May shallow wells, May deep wells, May vertical gradient at MW-2, Nov shallow wells, Nov deep wells, Nov vertical gradient at MW-2)*, Undergrads will calculate gradients for May (shallow wells, deep wells, and vertical gradient at MW-2).
- Calculating vertical and horizontal groundwater flow velocities using the calculated gradients. *Grads will conduct calculations using both May and Nov data.* Undergrads will conduct velocity calculations for May. These velocity calculations will be used to estimate migration distances since the 1960s to 1970s.

Your report will include:

- The results of your analysis (including figures of the cross section, and hydraulic gradient directions and magnitude). Example calculations should be included in an appendix.
- Your description of the site geology and groundwater flow based on the cross-sections and calculations.
- Your predictions of past and future migration of any dissolved contaminants that reached the aquifer from the dump.
- Your recommendations for future phases of investigation, including important data gaps that should be filled, plans for additional monitoring wells and groundwater sampling, and a recommendation concerning what geophysical investigations would be useful in future phases.

Report Outline:

1) Executive Summary or Abstract
2) Introduction and Site History
3) Methods
4) Site Geology and Groundwater Flow Directions
5) Predictions of Contaminant Migration
6) Limitations of this Work
7) Recommendations for Future Investigations
    - Data gaps
    - Plan for installation of additional wells and sampling
    - The possible role of geophysical investigations in future phases.
8) Appendices:
    - Data (from this handout)
    - Calculations (as a photo of your hand-written example calculations. Repeated calculations can be conducted in Excel).

Report Expectations:

The report should have correct spelling and grammar, and the writing style should be professional. All figures and tables should be captioned. Because you have limited information on this site, some of your sections will be extremely brief. That is OK. In a typical report, you would have a lot more detail on the methods of drilling, sample collection, well installation, and water level measurement protocols. This report will focus on the results. Any sources used should be properly cited. In this case, your only source for previous site information is the Worker Company (2014) report (Full Citation: Worker Company, 2014, Investigation of Acme Dump Site, 302 pp). Typically you would not cite a report that you haven't read yourself. However, in this case, it is OK (since the report is fictitious).

** Hand-drawn/colored cross-sections are fine. All information should be readable and should include vertical scales, horizontal scales, and legends.

Examples of Groundwater Reports are linked below (Note: These are much lengthier than your report should be):

- http://honeywell.com/sites/campus_redevelopment/SiteCollectionDocuments/Final_MTO_SWMU_Investigation_Report_2011-10-06_no_Appen.pdf
- https://fortress.wa.gov/ecy/publications/publications/0903056.pdf
- http://www.michigan.gov/documents/deq/deq-rrd-GS-DowngradientGWInvestigationPhase_216276_7.pdf . Note that this linked report does not include an abstract/executive summary, which your report will include.

Table 1. Boring and Well Information. All lithologic information is in feet below ground surface (ft bgs) and depth to water is measured in ft below top of casing (TOC).

Boring 1: Ground Surface Elevation: 29.0 ft asl 0-4 ft: SM silty sand, loose 4-8 ft: CH high-plasticity clay, soft 8-12 ft: GW sandy gravel with trace silt, loose 12-13 ft: CL gravelly clay, very dense. 13 ft: fractured limestone TD=14 ft	Boring 2: Ground Surface Elevation: 29.0 ft asl 0-7.5 ft: SM silty sand, loose 7.5-8 ft: CH high-plasticity clay, soft 8-12 ft: GW sandy gravel with trace silt, loose 12 -14 ft: CL gravelly clay, very dense. 14 ft: limestone TD=15 ft	Boring 3: Ground Surface Elevation: 30.5 ft asl 0-6 ft: SM silty sand, loose 6-7 ft: CH: high-plasticity clay, soft 7-9 ft: GW sandy gravel with trace silt, loose 9 ft: CL gravelly clay, very dense. TD=10 ft
Boring 4: Ground Surface Elevation: 31.5 ft asl 0-6 ft: SW well-graded sand, loose 6-8 ft CH high-plasticity clay, soft 8-10 ft: GW sandy gravel with trace silt, loose 10 ft: CL gravelly clay, very dense. TD=12 ft	Boring 5: Ground Surface Elevation: 30.5 ft asl 0-7 ft: SM silty sand, loose 7-8 ft: CH high-plasticity clay, soft 8-12 ft: GW sandy gravel with trace silt, loose 12 ft: CL gravelly clay, very dense. TD=14 ft	Boring 6: Ground Surface Elevation: 32.0 ft asl 0-8 ft: SM silty sand, loose 8-13 ft: CH high-plasticity clay, soft 13-15 ft: GW sandy gravel with trace silt, loose 15 ft: CL gravelly clay, very dense. TD=15.5 ft
MW-1S Screen depth: 5-7 ft bgs Well TOC elevation: 31.02 ft asl Depth to water 5/6/2014: 7.25 ft 11/6/2014: 5.32 ft	MW-2S Screen depth: 5-7 ft bgs Well TOC elevation: 33.45 ft asl Depth to water 5/6/2014: 7.23 ft 11/6/2014: 5.44 ft	MW-3S Screen depth: 2-4 ft bgs Well TOC elevation: 30.20 ft asl Depth to water 5/6/2014: 3.32 ft 11/6/2014: 3.25 ft
MW-1D Screen depth: 10-12 ft bgs Well TOC elevation: 31.02 ft asl Depth to water 5/6/2014: 9.11 ft 11/6/2014: 8.32 ft	MW-2D Screen depth: 10-12 ft bgs Well TOC elevation: 33.45 ft asl Depth to water 5/6/2014: 10.98 ft 11/6/2014: 8.44 ft	MW-3D Screen depth: 10-12 ft bgs Well TOC elevation: 30.25 ft asl Depth to water 5/6/2014: 9.38 ft 11/6/2014: 7.25 ft
Laboratory Analyses: k Soft clay: 1×10^{-16} m^2 Dense gravelly clay: 1×10^{-18} m^2 Sand: 1×10^{-13} m^2 Gravel: 1×10^{-10} m^2	Laboratory Analyses: Bulk Density (saturated) Soft clay: 1660 kg/m^3 Dense gravelly clay: 1930 kg/m^3 Sand: 1650 kg/m^3 Gravel: 1650 kg/m^3	

Rubric used for grading of all three reports.

4930 Report Rubric

You've already rated students with this rubric. Any major changes could affect their assessment results.

Criteria	Ratings	Pts
Maps and Calculations: Correctly completed all cross sections and calculations	*This area will be used by the assessor to leave comments related to this criterion.*	15 pts
Content: Included all requested description/discussion components. Discussion was thorough and thoughtful.	*This area will be used by the assessor to leave comments related to this criterion.*	10 pts
Report was well-organized. The writing style was clear, professional, and free of typos. Figures were clear and relevant.	*This area will be used by the assessor to leave comments related to this criterion.*	10 pts
		Total Points: 35

Report 2: Recharge and groundwater flow in the Blue Sandstone

GLY 4930: 35 points. *Omit instructions in italics*

GLY 5827: 40 points. Follow all instructions.

The city of Greensville has been pumping their water supply from an unconfined aquifer consisting of alluvial sediments. Due to concerns about contamination, the city would like to instead use groundwater from the Blue Sandstone aquifer, which is partially confined (Figure 1). The city has hired you to examine the recharge and groundwater flow of the Blue Sandstone aquifer.

A previous group of researchers has already drilled borings, created a cross section (Figure 2), and installed monitoring wells. They have also analyzed previous slug test data and cores. For the Blue Sandstone aquifer, transmissivity values average 120 ft^2/day and effective porosity averages 0.15 (Researcher et al., 2012).

Your field work included: 1) water level (hydraulic head) measurements and 2) sampling and analyses for tritium and carbon-14.

Hydraulic head measurements were taken in Sept 2014, during a period of no precipitation. During that time, the average discharge at Gaging Station A on the Green River was 4.2 cubic feet per seconds (cfs) and at Gaging Station B was 9.4 cfs.

Groundwater hydraulic heads and ages are plotted (Figures 3 to 6).

For this report, you will:

- Contour potentiometric surface maps for both the Green River and Alluvial aquifers. Use a **20 ft contour interval**. Use the Green River water levels for the Alluvial aquifer but not for the Blue Sandstone aquifer.
- Use the potentiometric surface maps and ages to interpret and discuss flow patterns. In particular discuss: a) the exchange of water between the alluvial and Blue Sandstone aquifers (is flow downward or upward), b) the effects of the inferred fault and the Greensville pumping well, and c) the relationship between the Blue Sandstone aquifer and the Green River.
- Calculate recharge rates (specific discharge) for the Blue Sandstone aquifer based on **both** the age measurements and the **potentiometric surface map/Darcy's law**. Discuss the discrepancy between the two estimates. **Because the fault might affect the groundwater flow, use only information from west of the fault for your specific discharge calculations.**
- *(GLY 5827 or XC for GLY 4930) Using your estimated specific discharge from the potentiometric surface maps and the age estimates, calculate baseflow* ***(in cfs)*** *to the Green River from the Blue Sandstone aquifer (e.g., the discharge rate through the aquifer). This will only include the western side of the river between Gaging stations A and B. Compare this estimated baseflow to the total baseflow calculated from the Green River gaging station measurements to discuss a) the proportion of the Green River's baseflow provided by the Blue Sandstone aquifer and b) whether the stream data are more consistent with the estimates from the potentiometric surface map or the age data.*

- Your recommendations for future phases of investigation. GLY 4930 should describe and justify one recommendation for additional data collection or analysis of existing data. *GLY 5827 (or XC for GLY 4930) should describe at least **three** detailed and well-justified recommendations for future field data collection or analyses of existing data.*

Report Outline:
1) Executive Summary or Abstract
2) Introduction
3) Site Geology
4) Methods
5) Results: Groundwater Potentiometric Surface Maps and Ages
6) Recharge Estimates
7) Groundwater flow and discharge
    b) Effects of the fault and Greensville pumping on the Blue Sandstone aquifer
    b) Baseflow to the Green River from the Blue Sandstone aquifer (Qualitative discussion for GLY 4930; Quantitative baseflow estimate and discussion for GLY 5827)
8) Limitations of this Work
9) Recommendations for Future Investigations
10) Conclusions
Appendix: Calculations (as a photo of your hand-written example calculations. Repeated calculations can be conducted in Excel).

Report Expectations:

The report should have correct spelling and grammar, and the writing style should be professional. All figures and tables should be captioned. **Prior to completing Report 2, you should review comments on your submission of Report 1 as well as look through the** "Example Report" **.**

In this case, your only source for previous site information is the Researchers et al (2012) report (Full Citation: Researcher, A., B. Researcher, C. Researcher (2012), Geology and Results of Hydrogeologic Testing of the Blue Sandstone aquifer near Green River, 72 pp). Present Figure 1 and 2 as if they came from Researcher et al (2012). Present Figures 3-6 as if you created them.

** **Hand-drawn potentiometric surface maps are fine.** The contours should be **carefully** sketched, rather than measured. Please make the photo as clear as possible.

Figure 1. Map of the study area showing the cross-section location and the location of the pumping wells for the City of Greensville. Locations of Green River gaging stations A and B are shown. The area of the Blue Sandstone subcrop (area where it directly contacts the alluvium) is shown with shading, and the trace of the inferred fault is shown by a dashed line.

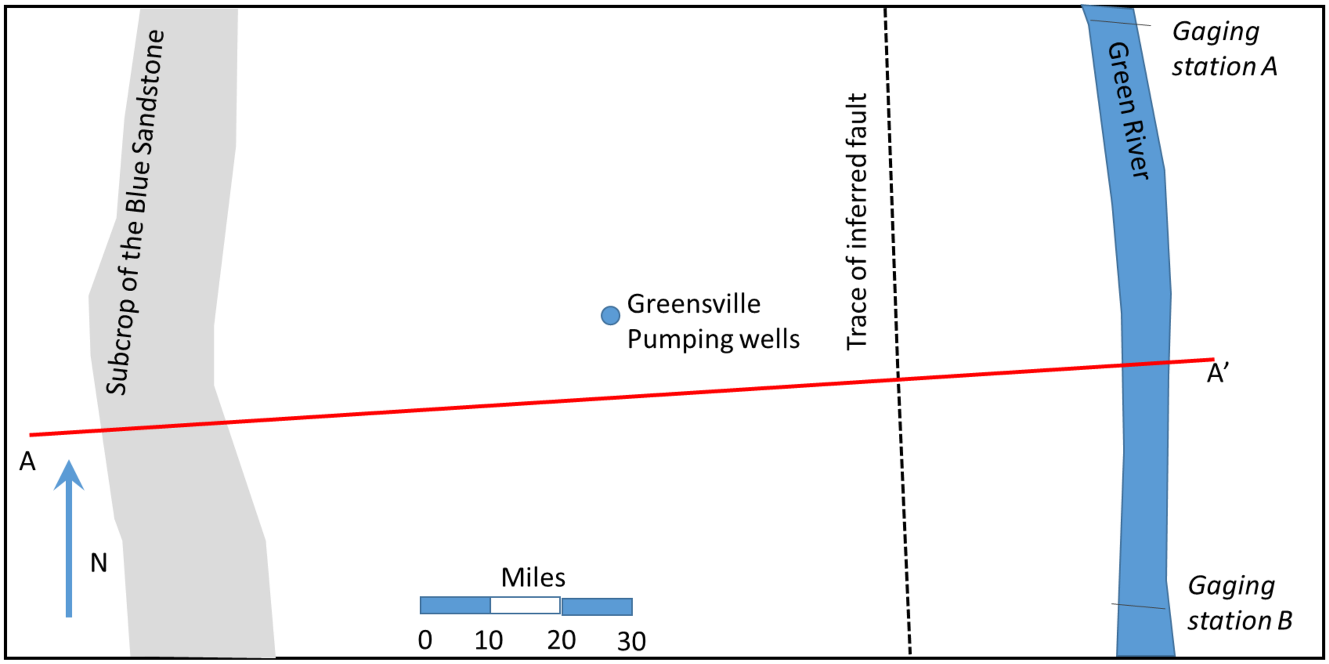


Figure 2. Cross Section A-A'. Inferred fault location is shown by the black line through the Red Shale and Blue Sandstone.

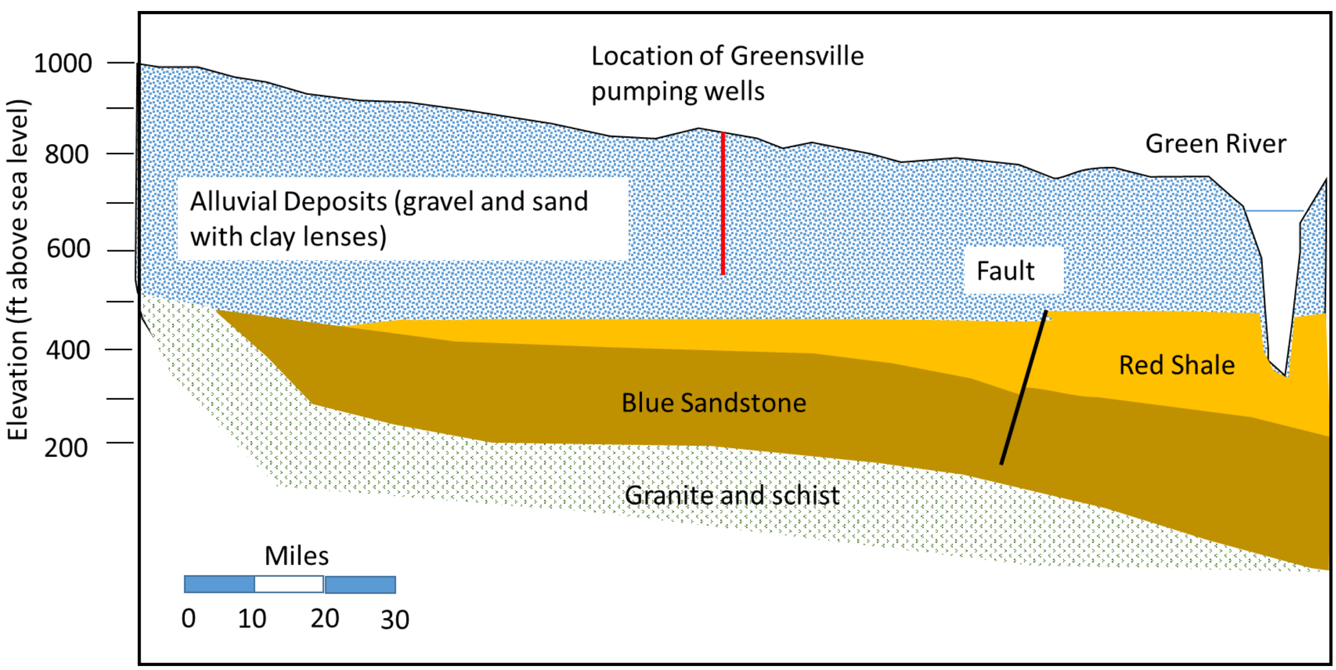


Figure 3. Hydraulic head (ft) in the alluvial aquifer. Green River stage shown in italics. The well with the hydraulic head of 745 ft is located near the Greensville pumping wells.

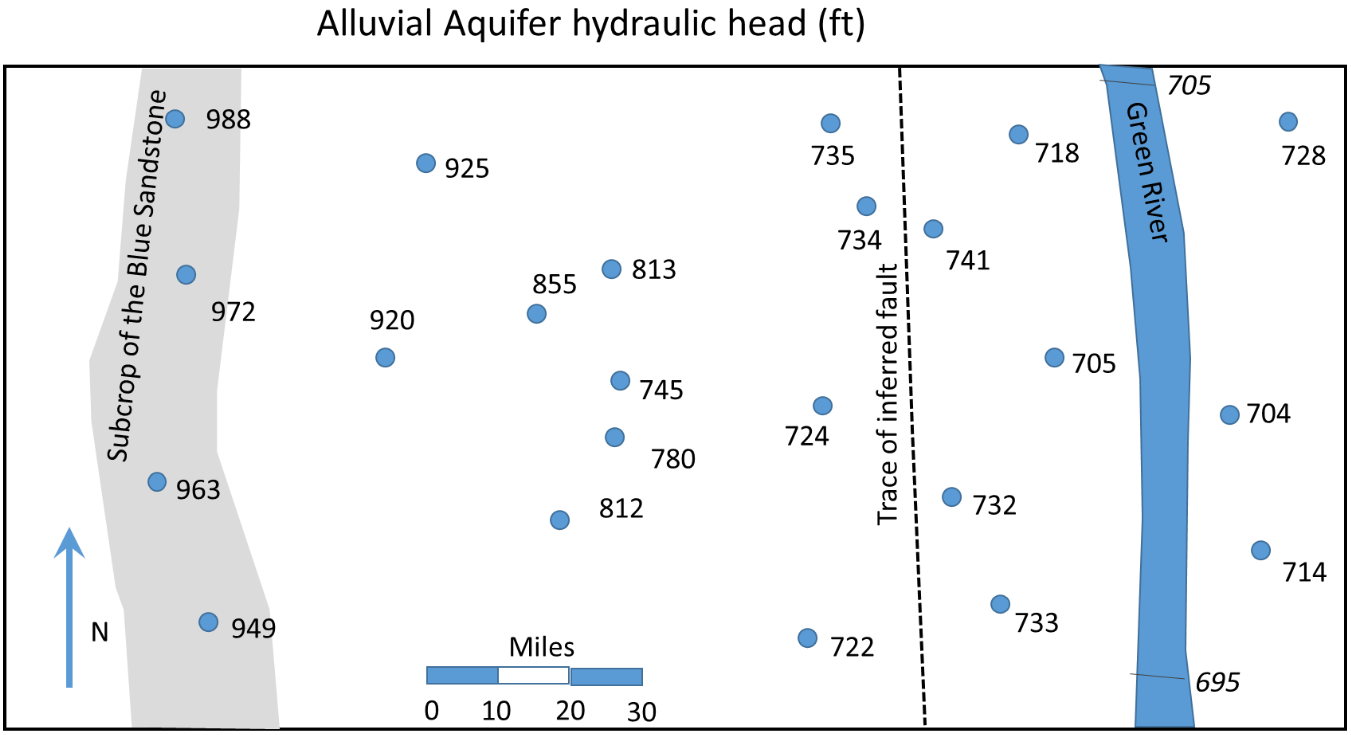


Figure 4. Hydraulic head (ft) in the Blue Sandstone aquifer.

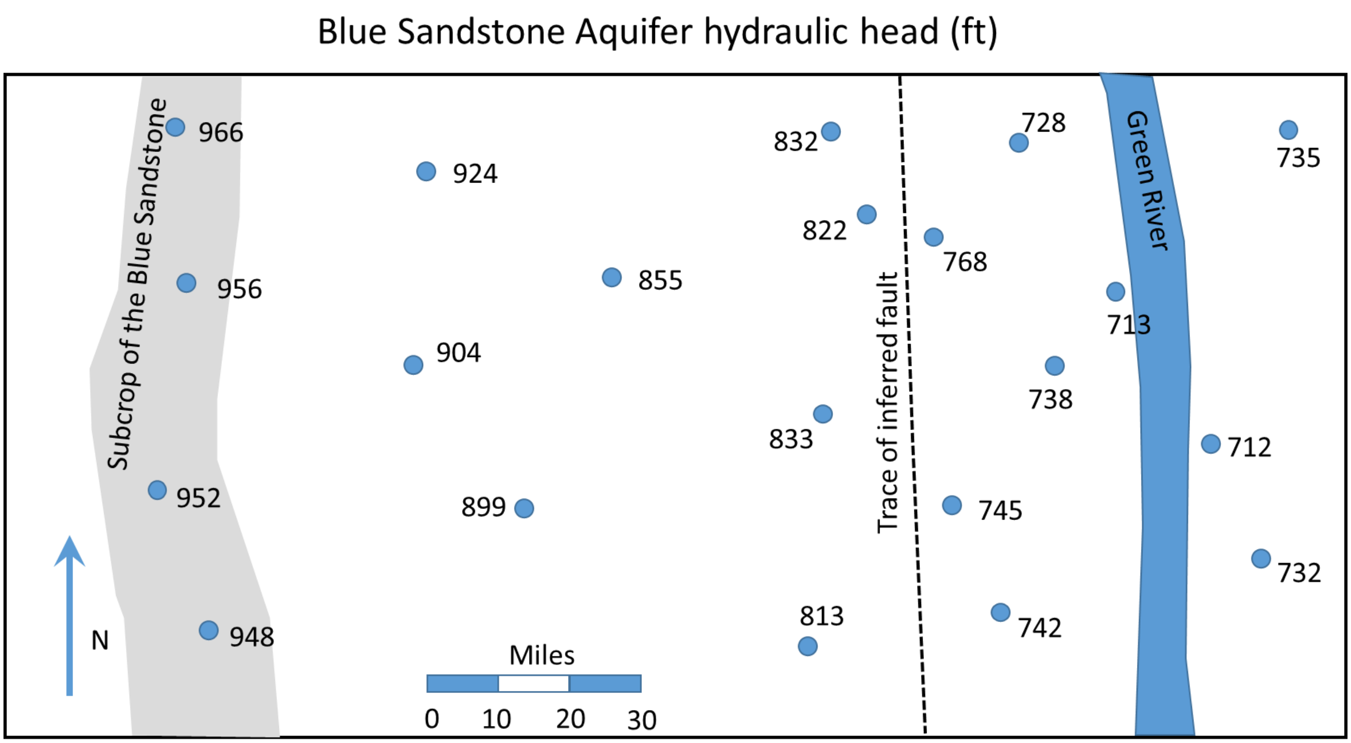


Figure 5. Inferred groundwater ages (+-20%) in the Alluvial aquifer.

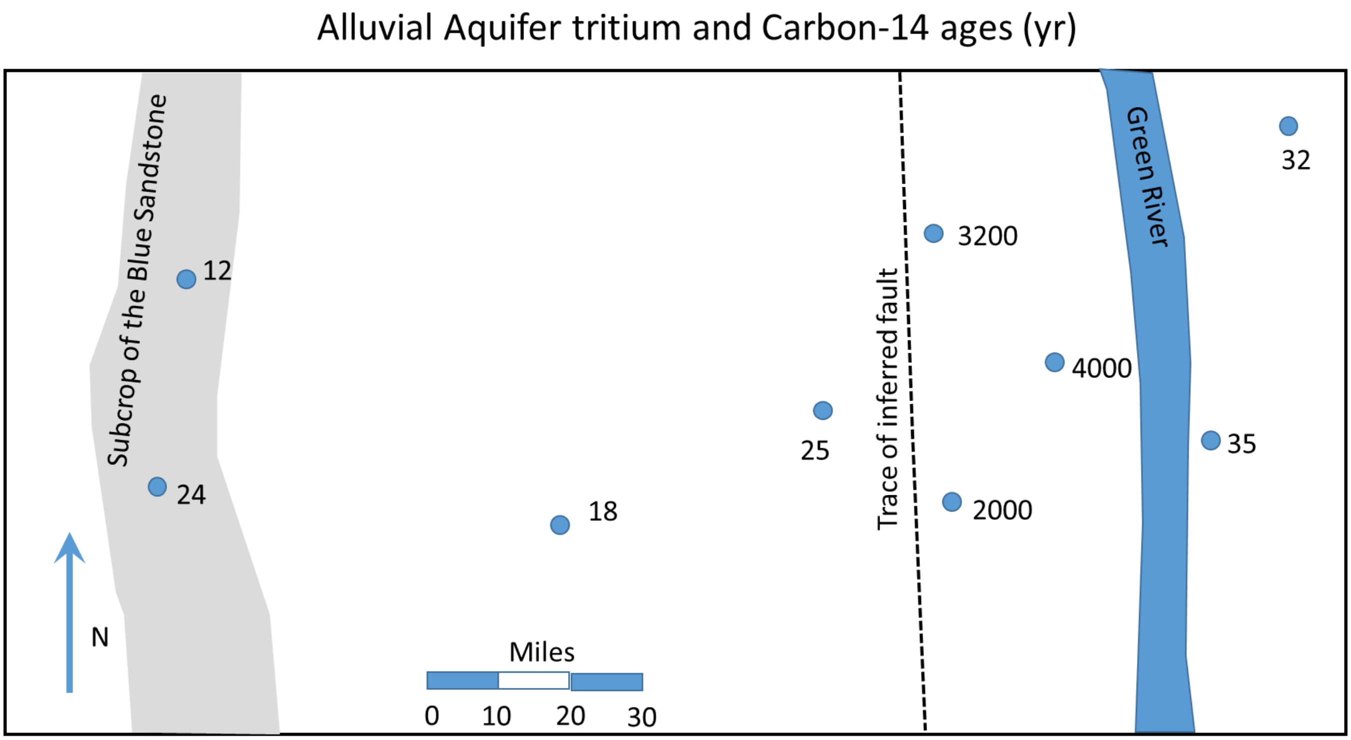
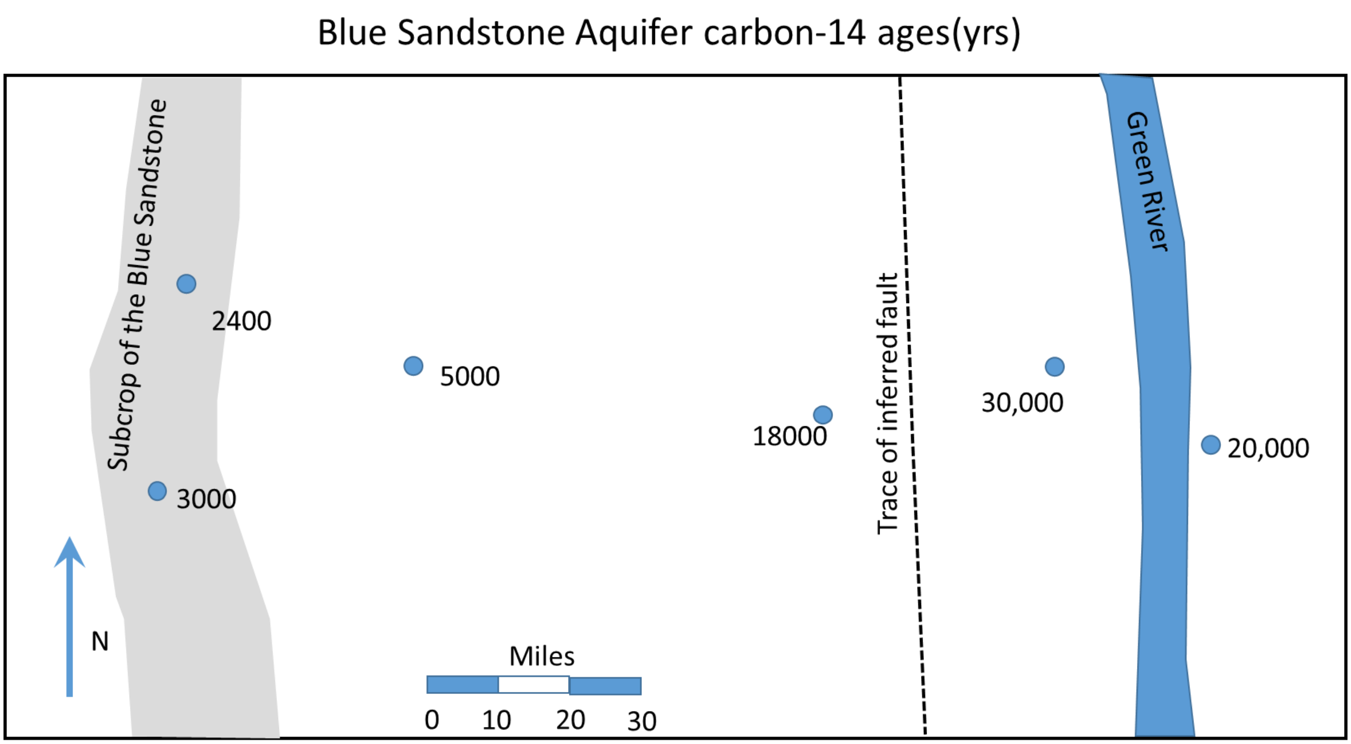


Figure 6. Groundwater ages in the Blue Sandstone aquifer.



Report 3: Fluid Pressures during Aquifer Storage in Swampsville, Florida

GLY 4930: 35 points. Omit instructions in italics

GLY 5827: 40 points. Follow all instructions.

The city of Swampsville, Florida is evaluating the feasibility of Aquifer Storage and Recovery (ASR) in the lower Floridan aquifer (LFA). During wet periods, excess surface water would be pumped into the LFA. It would reside in the aquifer and be extracted during dry periods to supplement the water supply from the upper Floridan aquifer (UFA). The city would like to inject 5 million gallons per day (gpd).

At the site (Fig 1), the Surficial Aquifer System (SAS) ~80 ft thick, unconfined and consists mainly of sand with some shells and clay. The underlying Hawthorn Group is 100 ft thick. The Hawthorn Group contains clays that confine the Floridan aquifer system as well as sand and limestone layers that form intermediate aquifers. The Floridan aquifer system consists of carbonate rock (limestone and dolostone) and is separated into the 300 ft thick upper Floridan aquifer (UFA) and lower Floridan aquifer by a confining unit. This confining unit consists of less permeable dolostone and is ~160 ft thick.

There are a number of concerns with this plan, but one is the pressures created by injection may exceed the capabilities of the available pump. The pump can withstand 100 psi, but is limited to 66 psi to allow a margin of safety. Accidental fracturing of the dolostones of the overlying confining unit is also a concern, but this would require a pressure >66 psi. There are also concerns that injected water may leak upwards into the upper Floridan aquifer, intermediate, and surficial aquifers.

A pumping test has been conducted by a previous consulting company (FHC 2002) and you will analyze the results. The pumping well (Well 4) was in the LFA and the test had one observation well in the LFA (Well 3). In addition, there were observation wells in the UFA, Intermediate and surficial aquifers to monitor whether any drawdown occurred during the pumping test. Figure 2 shows the location of the pumping and observation wells). Figure 3 shows the background monitoring prior to the test, and Figure 4 shows the drawdown at the observation wells.

You will:

- Analyze the Well 3 data using the Cooper-Jacob method and confirm your results using the Theis analysis. The UFA, Intermediate and surficial aquifer data should be described qualitatively in terms of evidence for leakage. Well 3 data also should be discussed in terms of evidence for leakiness of the confining layer.
- Predict the increase in hydraulic head (negative drawdown) due to injection at 5 million gallons per day for 3 months. If the pressure increase at the end of 3 months exceeds 66 psi, the maximum allowable injection rate should be estimated. Use a radius of 1 ft for this calculation. Note that we are ignoring turbulent flow near the well screen. You should discuss this simplification.
- *Provide recommendations for future work on:*
  - *the possible effects of density differences between the injected freshwater and the native groundwater which is brackish (density of 1010 kg/m^3).*
  - *Field investigations and analyses to assess the migration of the injected water between injection and withdrawal.*

Report format

1) Executive Summary
2) Introduction
    a) Objectives
    b) Site descriptions
3) Methods
4) Results
    a) Pumping test description and analyses
    b) Predictions concerning maximum pumping rate
5) Discussion of Results
    a) Test problems or concerns
    b) Evidence for/against leakage between the LFA and other aquifers
6) Limitations of this study
7) *Recommendations for future investigations*
8) Conclusions

Appendix 1: Calculations

Report Expectations

There are not many calculations for this report, so the analysis should be very well done and clearly written. Be sure to use the feedback and examples from your previous two reports. The report format should be followed closely, and the report should address all components of the investigation. The report should have correct spelling and grammar, and the writing style should be professional. All figures and tables should be captioned.

In this case, your only source for previous site information is the FHC (2002) report (Full Citation: Florida Hydrogeology Consultants (2002), Hydrogeology of Swampsville, Florida, 204 pp). Present Figure 1 and 2 as if they came from FHC (2002).

Appendix: Information and Figures (from FHC, 2002)

Well 4 was pumped at a constant rate of 1530 gpm for 48 hours. The drawdown data are linked here. During the pumping, 1.1 inches of rain fell. This timing will be noted in the data.

Well information for the pumping test

Well Name	Description	Screen Depth or Open Interval (ft below ground surface)	Horizontal Distance from Pumping Well
Well 4	LFA Pumping Well	680-950	NA
Well 3	LFA Observation Well	680-963	3015
FO-1	UFA Observation Well	181-300	100
HO-1	Intermediate Observation Well	181-300	100
WT-1	Surficial Observation Well	69-79	100

Figure 1. Site geology and hydrogeology (from FHC, 2002).

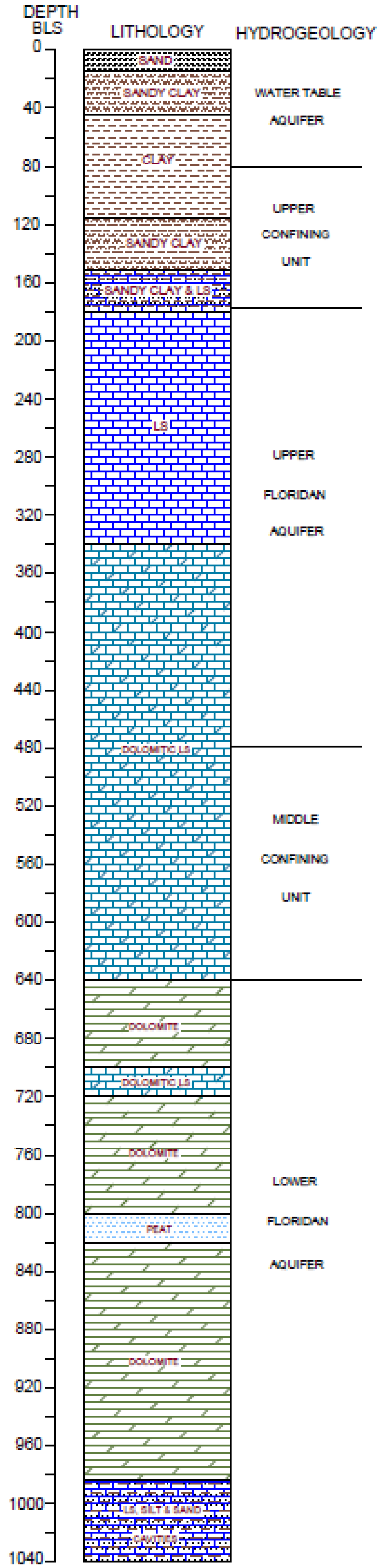


Figure 2. Site map showing locations of pumping wells, observation wells, and other production wells in the region. The location of the discharge pipe for the pumping test is also shown.

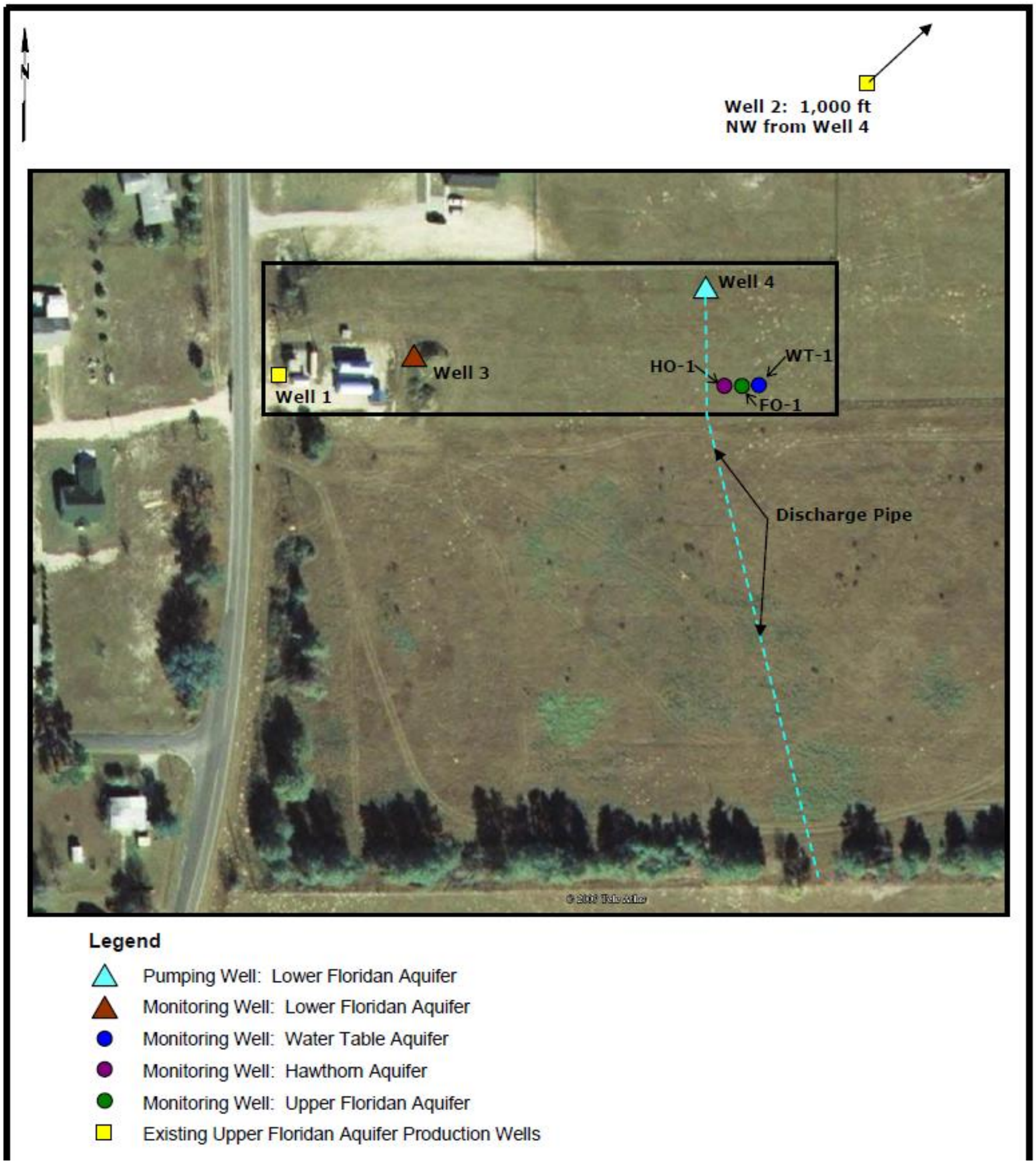


Figure 3. Background monitoring prior to the pumping test.

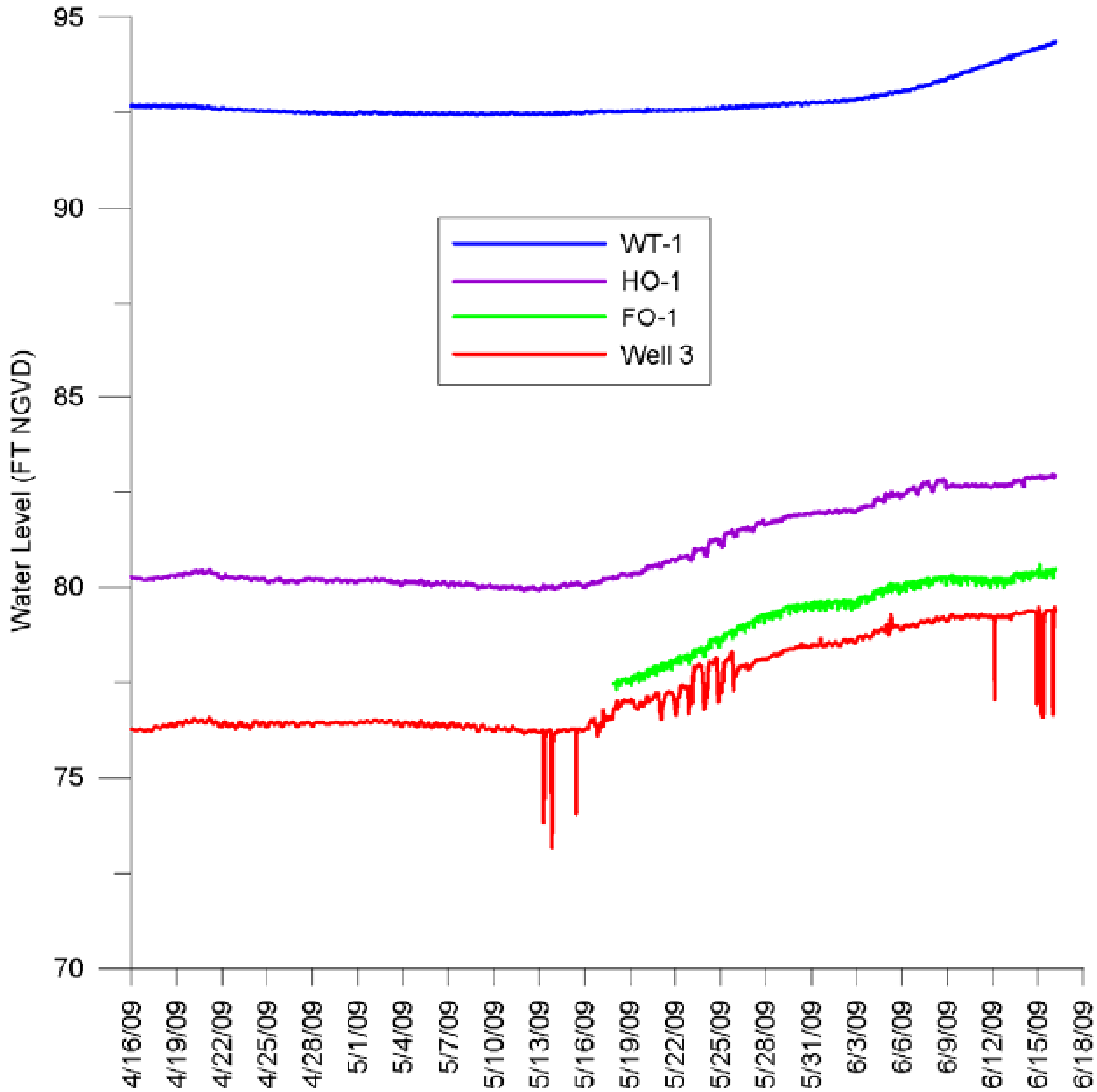
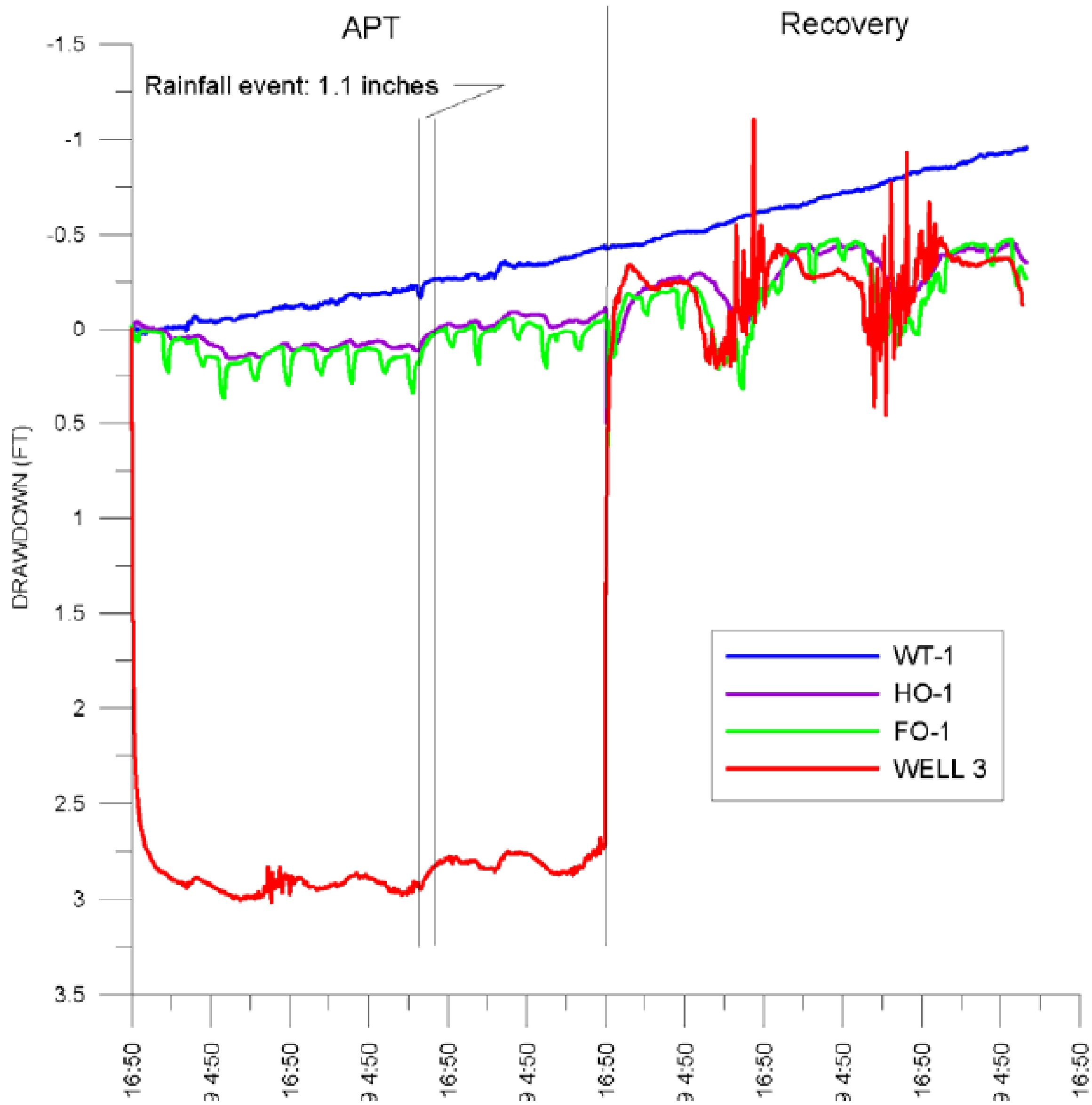


Figure 4. Observation well data during the pumping test at Well 4.



Assignment 1: Darcy's Law and Hydraulic Conductivity 20 points.

Part A: Sediment Description Using the Unified Soil Classification System

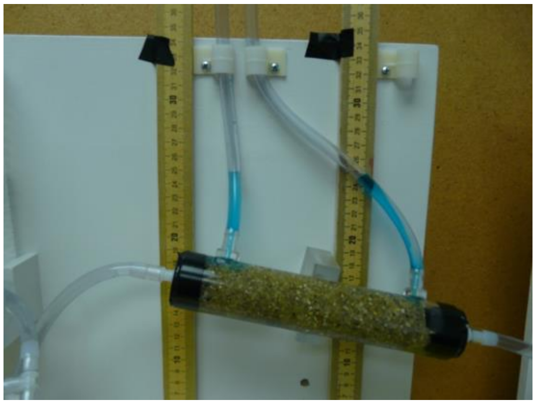
Throughout this semester, we'll use the USCS system to classify sediments. It is very commonly used in groundwater studies. In this assignment, you'll examine only one sample. We'll return to the USCS in later classes. A chart is provided on the last page.

1. Use a ruler to measure the average size of the grains and provide a sample description. The sample description should include the grain size distribution (for sand: fine-grained, medium-grained, coarse-grained, see the table on page 4), whether grains are angular or rounded (or in-between: subangular or subrounded), the consolidation state of the sample (common terms for sands/silts are loose and dense, for clays: soft and firm). Often the description will note the clast type if sands are not primarily quartz.

2. Use the USCS chart to determine the correct two-letter code.

Part B. Hydraulic head and flow direction

Before starting any flow experiments, you'll examine the static case to better understand how elevation head and pressure head contribute to hydraulic head. For this experiment, we have two reservoirs. One is on each end of the cylinder of sand. The water levels in the two reservoirs should equal each other, so there is no flow through the cylinder. If they are not equal, you carefully add/remove water to equalize. They will eventually equalize through flow, but that takes time.



Two piezometers tap into the cylinder. **The cylinder diameter is 1.25 inches and the distance between the two piezometers is 13.5 cm.**

3. Use a ruler to determine the elevation head, pressure head, and hydraulic head in the two piezometers (in **cm**). **Use the wooden base of the stand as your datum.** Assume that the piezometer screen (the location where it is open to the sediment) is at the bottom of the tubing where it attaches to the cylinder.

4. Calculate the fluid pressure (in Pa) at each piezometer screen. Assume a fluid density of 1.0 g/cm^3.

5. Rotate the cylinder slightly (see figure). The hydraulic heads in each piezometer should adjust and return to the same values as previously because the water levels in the reservoirs were not changed. What are the new elevation and pressure heads?

To start flow: Add or very carefully remove water from the reservoir on the left side of the cylinder to raise/lower the water level several cm.

6. What are the hydraulic heads in Well A and Well B and which direction is water flowing? (Note: It's not fast, but you should see the water level rise on one side and drop on the other).

7. Use your understanding of hydraulic head, elevation head, and pressure head to briefly explain how groundwater can flow "uphill" in the cylinder.

Part C. Measurements and calculations of hydraulic conductivity

At this station, the tubing from the Darcy experiment is open on one end so that you can measure discharge. The material in the cylinder is the same as you described (or will describe) at Station A.

Ensure that you have water in the fluid reservoir on the left. Place a beaker to catch the outflow. Open the hose clamps and remove the lid (if on) of the fluid reservoir to allow flow to begin. Allow the hydraulic heads in the two wells to stabilize and then measure the hydraulic head in both of the wells. **Use the wooden base as your datum.** Use a beaker or graduated cylinder and a stopwatch to measure discharge (volume per time).

Conduct two additional runs using different hydraulic gradients. Try to have one at least one run with a small (<0.5 cm) head difference.

During Run 2, you will carefully add dye to the tubing using the syringe. **Start timing the dye as it enters the sediments and stop timing as the dye emerges from the sediments on the downgradient end. If you prefer, you can choose a different distance.** Be sure to run the dye trace using the same hydraulic head difference as your discharge measurement.

If your dye trace during Run 2 doesn't work out (you forget to start or stop timing, etc), you can try again during Run 3.

8. (2 pts) Complete the following table of measurements

Run	h1 (cm)	h2 (cm)	Volume (cm^3)	Time (s)	Dye distance (cm)	Time for dye movement (s)
1						
2						
3						

9. (4 pts) Data from previous experiments using the Darcy cylinder with the same sediment are shown on the next page. Add your data to the table. For all of the runs, calculate discharge (Q), hydraulic gradient (i), specific discharge (q), hydraulic conductivity (K), and the Reynold's number (Re). For the Reynolds number, use a viscosity of 0.001 kg/(s m) and be careful to convert all other values to consistent units. Show your work for one of each calculation and use Excel for the remainder. For Run 2 (or whichever run was your dye trace), you will also calculate velocity and effective porosity. *Notes: you can copy and paste the previous data from the Word version of this handout (online) into Excel. The calculated results for the data on the first line are provided for you as a check on your calculations.*

10. (3 pts) Using Excel, plot specific discharge as a function of hydraulic gradient and fit a linear trendline with a zero intercept. Be sure to label your axes and show the equation. Discuss whether or not the data are well fit by the line. The R^2-value should be considered as well as any qualitative description (e.g., does it fit well at low hydraulic gradients and poorly at higher gradients, is the fit good except for one or two suspicious values? Do your data plot differently from previous results?).

11. Use the slope of the line to determine the hydraulic conductivity. *NOTE: If your results were drastically different than previous results, please average your results them rather than using the slope of all measurements.* Using Figure 3.2 in your text (copied below), discuss how the measured K compares to the expected range for its sediment type.

12. Calculate the permeability of the sand (in m^2) for the hydraulic conductivity from #11.

13. The threshold for turbulent flow is at a Reynold's number somewhere between 1 and 10. Do your Reynold's number calculations suggest that flow is likely to be turbulent during any of the runs? Explain.

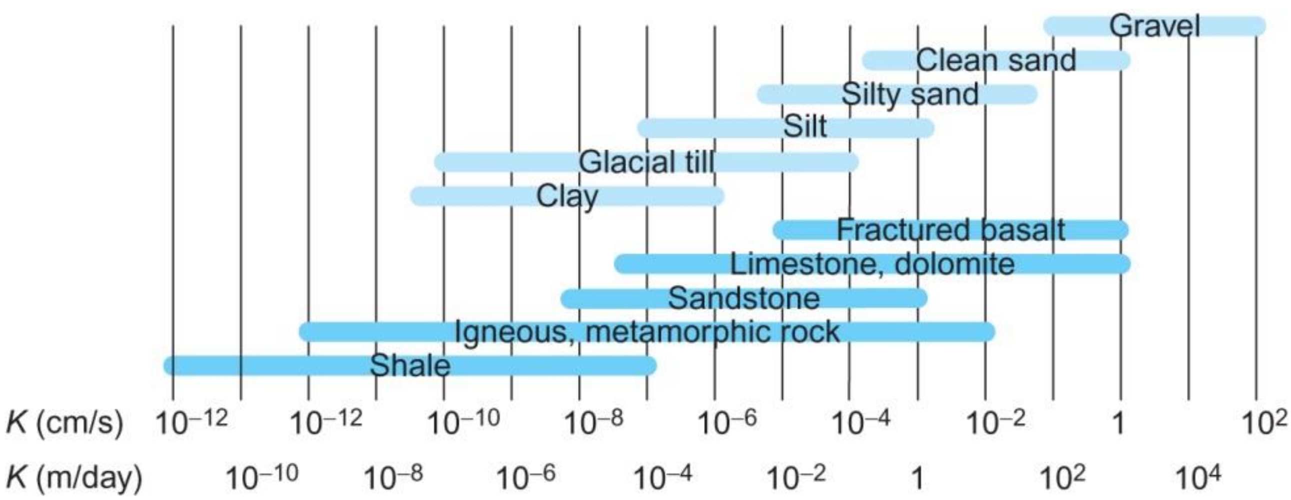
14. Does your plot of specific discharge versus head gradient indicate that the flow during the experiments was laminar or turbulent? Explain. What would you expect the plot to look like if the flow becomes turbulent at high specific discharge values?

H1 (cm)	H2 (cm)	Volume (ml)	time (s)	dye trace time (s)	dye trace distance (cm)	Q (cm^3/s)	i (cm/cm)	q (cm/s)	K (cm/s)	Re	v (cm/s)	n_e
24.6	24.3	9	47	210	15.5	*0.19*	*0.022*	*0.024*	*1.1*	*0.36*	*0.074*	*0.33*
25.8	25	18	30									
25.5	24.8	20	35									
25.2	24.4	17	30									
27.4	26.8	18	42									
25.1	24.7	11.5	44									
27	26.7	8	43									

	grain size
Boulders	>300 mm
Cobbles	75 to 300 mm
Coarse gravel	19 to 75 mm
Fine gravel	4.75 to 19 mm
Coarse sand	2 to 4.75 mm
Medium sand	0.425 to 2 mm
Fine sand	0.075 to 0.425 mm
Silt and Clay	<0.075 mm

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES	FIELD IDENTIFICATION PROCEDURES (EXCLUDING PARTICLES LARGER THAN 3 IN. AND BASING FRACTIONS ON ESTIMATED WEIGHTS)			INFORMATION REQUIRED FOR DESCRIBING SOILS
1	2		3	4	5			6
Coarse-grained Soils More than half of material is larger than No. 200 sieve size. The No. 200 sieve size is about the smallest visible to the naked eye.	Gravels More than half of coarse fraction is larger than No. 4 sieve size. (For visual classification, the $^1/_4$-in. size may be used as equivalent to the No. 4 sieve size.)	Clean Gravels (Little or no fines)	GW	Well-graded gravels, gravel-sand mixture, little or no fines.	Wide range in grain size and substantial amounts of all intermediate particle sizes.			For undisturbed soils add information on stratification, degree of compactness, cementation, moisture condition, and drainage characteristics.
			GP	Poorly graded gravels or gravel-sand mixture, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.			
		Gravels with Fines (Appreciable amount of fines)	GM	Silty gravels, gravel and silt mixtures.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).			Give typical name; indicate approximate percentages of sand and gravel, maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbol in parentheses.
			GC	Clayey gravels, gravel and clay mixtures.	Plastic fines (for identification procedures see CL below).			
	Sands More than half of coarse fraction is smaller than No. 4 sieve size.	Clean Sand (Little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines.	Wide range in grain size and substantial amounts of all intermediate particle sizes.			
			SP	Poorly graded sands or gravelly sands, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.			Example: Silty sand, gravelly; about 20% hard, angular gravel particles $^1/_2$-in. maximum size; rounded and subangular sand grains, coarse to fine; about 15% nonplastic fines with low dry strength; well compacted and moist in place; alluvial sand; (SM).
		Sands with Fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).			
			SC	Clayey sands, sand-clay mixtures.	Plastic fines (for identification procedures see CL below).			
Fine-grained Soils More than half of material is smaller than No. 200 sieve size.					Identification Procedure on Fraction Smaller than No. 40 Sieve Size.			
					Dry Strength (Crushing Characteristics)	Dilatancy (Reaction to shaking)	Toughness (Consistency near PL)	
	Silts and Clays Liquid limit is less than 50		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.	None to slight	Quick to slow	None	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Medium to high	None to very slow	Medium	
	Silts and Clays Liquid limit is greater than 50		OL	Organic silts and organic silty clays of low plasticity.	Slight to medium	Slow	Slight	Give typical name; indicate degree and character of plasticity; amount and maximum size of coarse grains; color in wet condition; odor, if any; local or geologic name and other pertinent descriptive information; and symbol in parentheses.
			MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	Slight to medium	Slow to none	Slight to medium	
			CH	Inorganic clays of high plasticity, fat clays.	High to very high	None	High	
			OH	Organic clays of medium to high plasticity, organic silts.	Medium to high	None to very slow	Slight to medium	Example: Clayey silt, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (ML)
Highly Organic Soils			Pt	Peat and other highly organic soils.	Readily identified by color, odor, spongy feel and frequently by fibrous texture			

1. Boundary classifications: Soils possessing characteristics of two groups are designed by combinations of group symbols. For example GM-GC, well-graded gravel-sand mixture with clay binder.
2. All sieve sizes on this chart are U.S. standard.
3. Adopted by Corps of Engineers and Bureau of Reclamation, January 1952.



Assignment 2: Hydraulic Conductivity 20 points

1. (2 pts) In the previous (Module 1) assignment, you calculated the hydraulic conductivity of the sand in the Darcy experiment. Return to that assignment to find your estimated K and the average grain size.
   a. Use the Kozeny-Carman equation to calculate the permeability and hydraulic conductivity of the sand. Use a porosity of 0.33.
   b. Discuss how the hydraulic conductivity calculated using the Kozeny-Carman equation compares to that estimated in the experiment.

Questions 2 to 5 are based on the Cabot/Koppers Superfund in Gainesville, Florida. At this site, the Hawthorn Group of sediments acts as a confining unit to the upper Floridan aquifer (below) and separates the upper Floridan aquifer from the contaminated surficial aquifer (above). The upper Floridan aquifer consists of limestone and dolostone and the surficial aquifer in this region is primarily sand.

The upper Floridan aquifer is an important water source. The well field for Gainesville Florida is just a few miles from of the Cabot/Koppers site. Unfortunately, contamination has been found in the upper Floridan aquifer. This was not expected, because it was assumed that the contamination would travel very slowly through the Hawthorn Group. To better understand, you will use calculations to estimate travel times across the Hawthorn Group.

2. (3 pts) The Hawthorn Group of sediments consists of layers of clay, limestone, and clayey sand. Thicknesses are variable across the site, so ranges are provided below.

From the top down, the Hawthorn Group consists of:

clay 1 to 5 ft thick,
clayey sand 25 to 30 ft thick
limestone: 5 to 10 ft thick
clay 20 to 25 ft thick
clayey sand 40 to 55 ft thick
clay 14 to 30 ft thick

Clay vertical hydraulic conductivity has been measured in the laboratory and is 6.7×10^{-8} cm/s. The clayey sand vertical hydraulic conductivity is 1×10^{-5} cm/s, and the limestone hydraulic conductivity is 1×10^{-3} cm/s.

What is the equivalent vertical hydraulic conductivity (in ft/day) in the Hawthorn Group? Conduct the calculation twice, first using the maximum clay/minimum sand and limestone thicknesses and second using the minimum clay/maximum sand and limestone thicknesses.

Hints:

a. Be efficient and add up the total clay, sand, and limestone thicknesses so you can simplify to three layers (rather than 6).
b. After your first "by hand" calculation, create a formula in Excel. You will be repeating the calculation below.
c. Be careful about units!

3. (3 pts) To test whether your calculated equivalent vertical hydraulic conductivities are sensitive to the laboratory-measured value of hydraulic conductivities:

    a. increase and decrease the clayey sand hydraulic conductivity by an order of magnitude. Use the calculation with the thinnest clay/thickest clayey sand and limestone for this test.
    b. increase and decrease the limestone hydraulic conductivity by an order of magnitude. Use the calculation with the thinnest clay/thickest clayey sand and limestone for this test.
    c. increase and decrease the clay hydraulic conductivity by an order of magnitude. Use the calculation with the thinnest clay/thickest clayey sand and limestone for this test.
    d. Discuss your results and the implications. Which hydraulic conductivity value has the greatest impact? If you have a limited budget for laboratory testing, which sediment type would be most important to test? Would you expect the results to be the same for equivalent horizontal hydraulic conductivity?

4. (3 pts) Hydraulic heads are higher in the surficial aquifer (above the Hawthorn Group) than in the upper Floridan aquifer (below the Hawthorn Group). The vertical head difference across the Hawthorn Group is 130 ft and its thickness is 130 ft. Estimated effective porosity is 0.3. Calculate the following for both your upper- and lower-end estimates of equivalent vertical K (from #2):

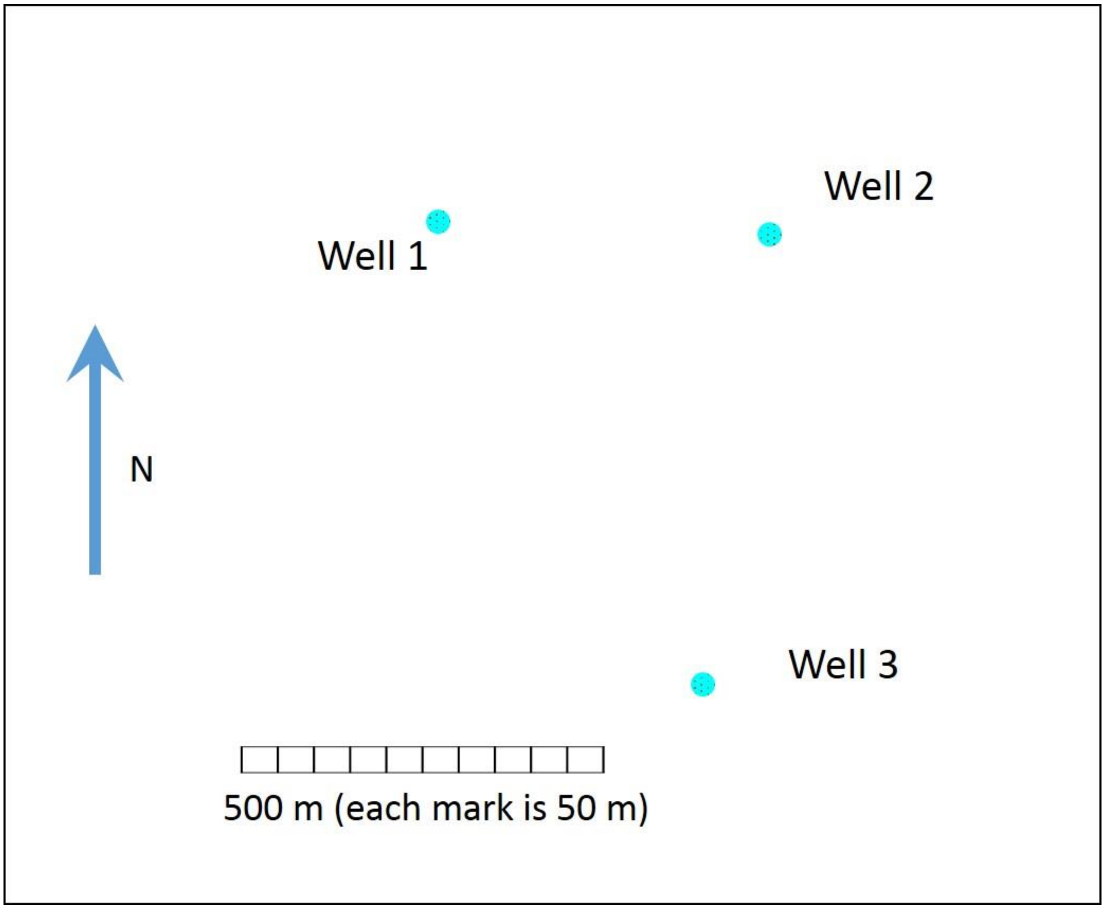
    a) vertical specific discharge (in ft/day)
    b) vertical velocity (in ft/day)
    c) travel time across the Hawthorn Group (in years)

5. (2 pts) The hydraulic conductivity of the upper Floridan aquifer in the area is ~150 ft/day. Assume the groundwater moves downward almost vertically (an angle of 89°) in the lowermost clay layer (K=6.7 x 10^{-8} cm/s). Based on the tangent law of refraction, what would the angle of flow be in the upper Floridan aquifer?

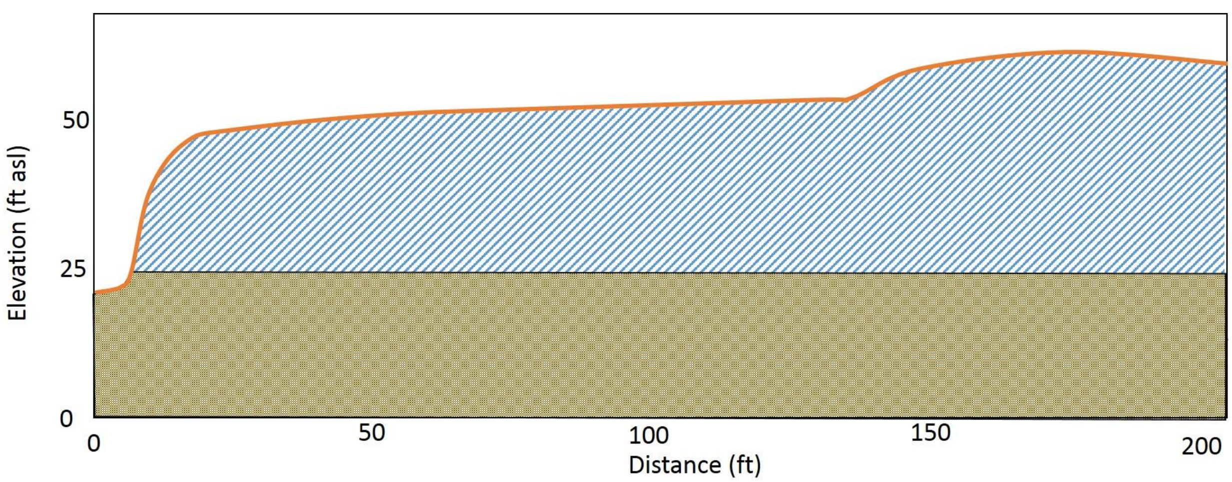
6. (3 pts) Hydraulic head has been measured at 3 wells shown on the map. All are within the same aquifer.

Well	Top of well elevation (m asl)	Depth to water (m)	Hydraulic head (m)
1	32.6	5.2	
2	33.5	5.5	
3	32.4	5.3	

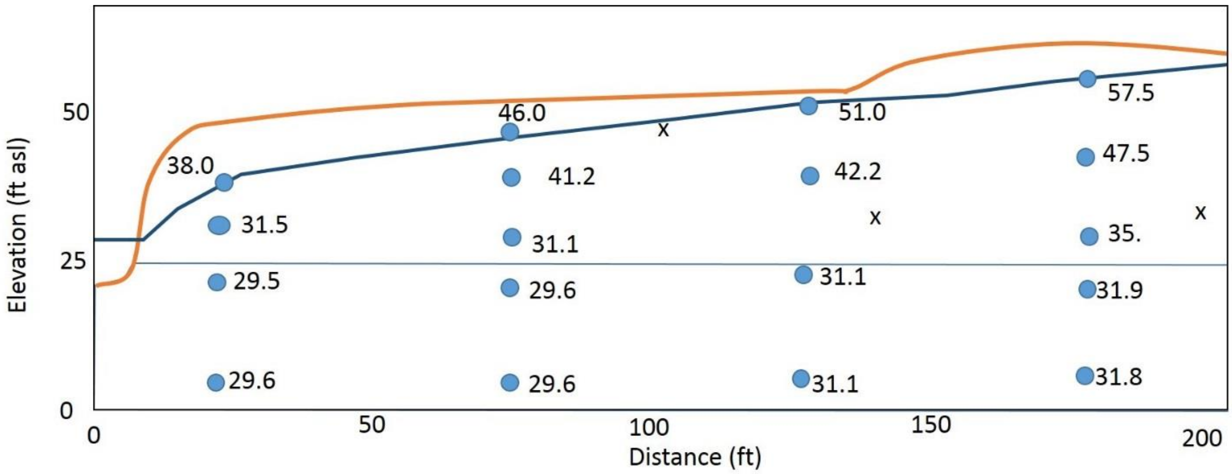
a. Calculate the magnitude of the hydraulic gradient. Show the **flow** direction on the map, assuming the aquifer is isotropic.
b. Calculate specific discharge (in m/day) for a hydraulic conductivity of 0.24 **ft**/day.



7. (4 pts) Based on drilling investigations, it has been found that the subsurface at a site consists of a clay layer (diagonal pattern) overlaying a sand layer.



Piezometer nests were installed, and hydraulic head values are shown on the cross-section below.



a) Contour the cross-section, using a contour interval of 2 ft.
b) Draw three flow lines starting at the three “x” marks. Assume the clay and the sand are both isotropic.
c) Describe the refraction shown by the equipotentials and the flow lines and explain whether or not the observed refraction is consistent with your expectations.
d) The hydraulic conductivity of the sand is 30 ft/day. Calculate the specific discharge through the sand layer between the 32 and 30 ft contours.

Assignment 3: Boring logs and Cross Sections 20 pts

Hydrogeologic cross sections are used to interpret and present the distribution of aquifers and confining units. Hydraulic heads can also be shown on cross sections to help interpret flow directions.

Part I. Your first cross section will be based on 4 borings. At each of the boring locations, 2 wells – a shallow well and a deep well, were later installed. The top of each well casing was surveyed to find elevation in ft above sea level (ft asl) and the depth to water was measured on June 21, 2015.

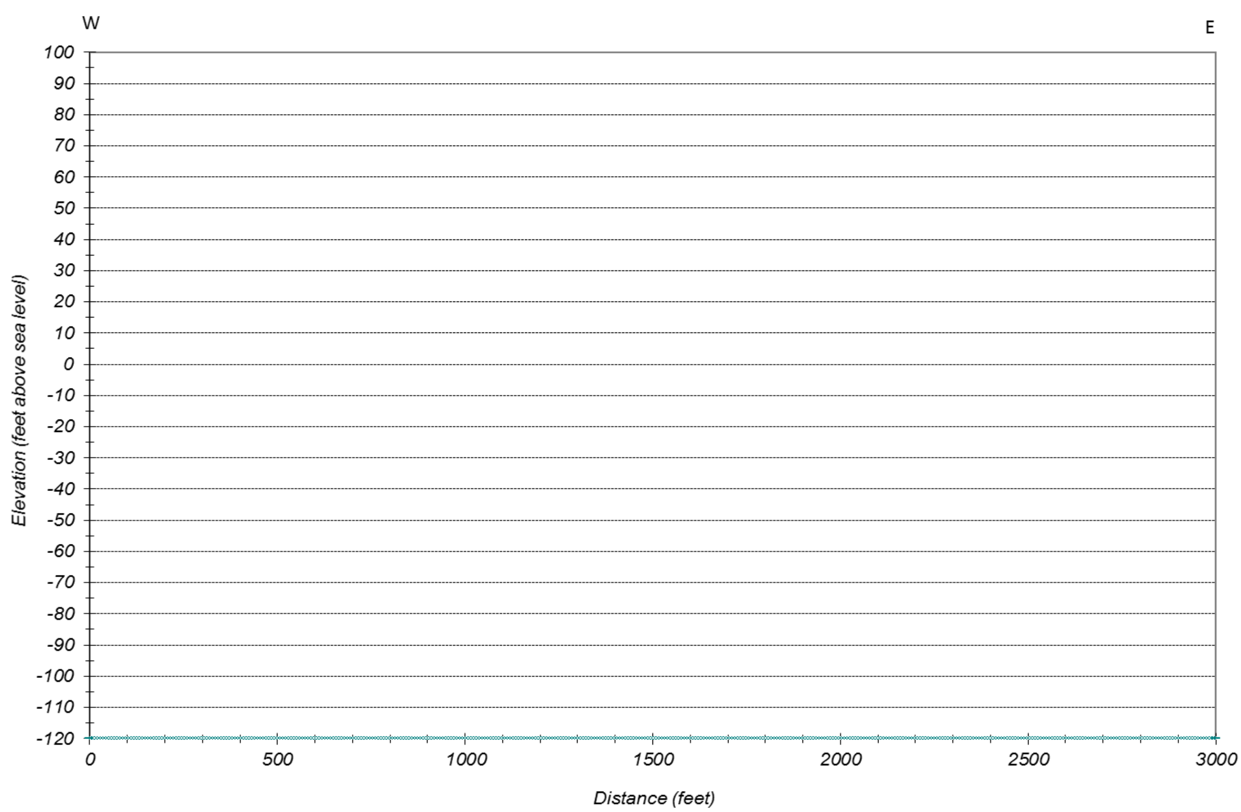
1. (6 pts) Complete the cross section, following these steps.
   - Mark the ground surface elevation and connect. *In real-life cross sections, you could supplement this with topographic information from the study area.*
   - Mark the contacts in, measuring down from the ground surface at each well.
   - Mark the total depth of each boring, but keep in mind that it is not a contact, just the vertical extend of your information.
   - Decide how detailed your cross-section needs to be for your purpose. For this cross-section, we are grouping by "aquifer" material and "confining unit" material and will not mark changes from silty sand to sand (for example).
   - Connect similar materials. *When sediments are deposited they are often in layers, but not always. It is possible for a "lens" of sediment to exist either due to how it was deposited or later erosion.*
   - Label aquifers and confining units. For aquifers, label whether they are confined or unconfined.
   - Mark in screen locations at each boring (one for the shallow well and one for the deep well. You may want to color-code the shallow and deep.
   - Calculate and mark in water-level elevations for each well using an upside-down triangle with a line underneath. You may want to color-code the shallow and deep.
   - Create a legend for your cross section showing all symbols used.
   - Connect water levels to show potentiometric surface, being careful to only connect water levels screen in the same aquifer.
   - Draw a flow arrow for the shallow wells and for the deep wells indicating the direction water is flowing for both.

2. (4 pts) Based on the cross section:
   A) Calculate the vertical hydraulic gradient at B-2 as well at B-4. Assume the vertical distance is the thickness of the confining unit. In other words, assume there are no vertical gradients in the aquifers.
   B) Calculate the horizontal hydraulic gradient between:

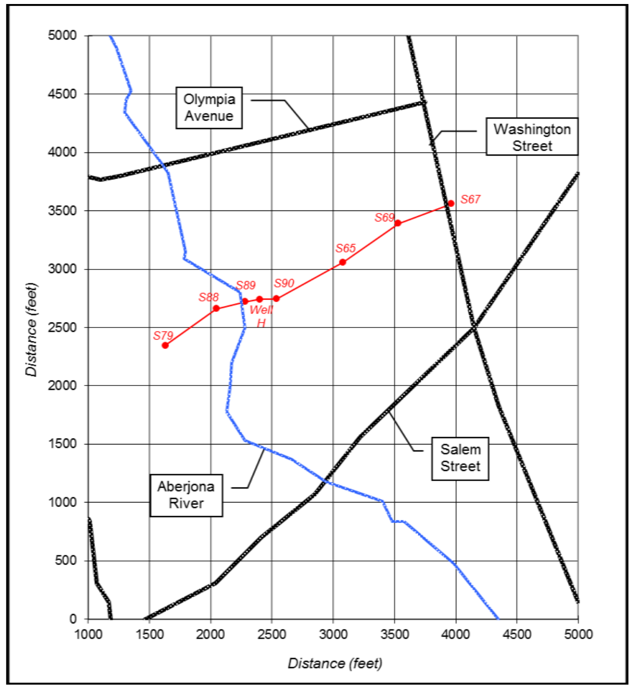
      a) the shallow wells of B-2 and B-3
      b) the deep wells of B-2 and B-3.

Boring and Well Information (Distance relative to the west side of the cross section). Lithologic descriptions given using USCS abbreviations.

	B-1	B-2	B-3	B-4
Distance	500	1000	2000	2900
Ground surface elevation (ft asl)	60	60	40	30
Total depth (TD) ft	100	90	80	90
Lithologic Description (ft below ground surface)	0-TD SC	0-40 SC 40-60 ML 60-TD SM	0-40 SC 40-50 CL 50-TD SP	0-20 SC 20-40 CL 40-TD SP
Depth of deep monitoring well screen (ft bgs)	80-90	70-80	50-60	40-50
Depth of shallow monitoring well (ft bgs)	20-30	20-30	10-20	10-20
Elevation of top of well casing for both shallow and deep wells (ft asl)	61	61	41	31
Deep wells (DW) depth to water (ft)	26	29	14	11
DW water level elevation (ft asl)				
Shallow wells depth to water (ft)	25	28	10	5
SW WL elev (ft asl)				



Part II. Your second cross section will be based on the geology of a Superfund site in the Aberjona River valley near Woburn, Massachusetts. In this region, Wells G&H were used for water supply starting in 1964 (Well G) and 1967 (Well H). In 1979, contamination was found in Wells G & H and both wells were shut down. During this time, a number of leukemia deaths occurred in the area supplied by Well G&H.



Subsequent lawsuits attempted to attribute responsibility for the Well G&H contamination. Understanding the geology of the Aberjona River valley was an important part of the investigation. The bedrock of the river valley has been eroded by glaciation and glacial till was deposited on the bottom and sides of the valley. After the last glacial maximum, alluvial sediments filled the valley.

Many borings were drilled and cores were collected. Your cross section will use the information from drilling to better understand the aquifer's geometry and its heterogeneity.

The cross section location is shown in red on the map.

3. (2 pts) Using the boring logs from Well H and Boring S67 (below), find the land surface elevation and summarize the lithology similar to the wells shown below.

This is a more challenging cross section than the previous one because there are no distinct confining units here. You are looking at more subtle differences in material. Therefore you will not be grouping sediments as "aquifer material" or "confining material" as you did in Part I. Instead, you will be trying to connect similar geologic material. Use your best judgment (ask for advice where unsure) as to what sediments should be grouped.

Well H **Land Surface Elevation =**

Depth (feet)			***Lithologic Description***
	to		
	to		
	to		
	to		
	to		
	to		
	to		
	to		

Well S67 **Land Surface Elevation =**

Depth (feet)			***Lithologic Description***
	to		
	to		
	to		
	to		
	to		
	to		
	to		
	to		

4. (5 pts) Construct the cross-section by drawing in the ground surface and the contacts between geologic materials.
5. (3 pts) Using the information from the cross section, describe the geometry of the aquifer and how the hydraulic conductivity would be expected to vary, both laterally and vertically.

Well S65 **Land Surface Elevation = 77**

Depth (feet)			***Lithologic Description***	***Top Elev.***
0	*to*	2	*Peat*	77
2	*to*	10	*Sand and gravel*	75
10	*to*	27	*Silty sand with some cobbles*	67
27	*to*	37	*Gravel*	50
37			*Bedrock*	40

Well S69 **Land Surface Elevation = 75**

Depth (feet)			***Lithologic Description***	***Top Elev.***
0	*to*	*10*	*Sand and gravel*	*75*
10	*to*	*21*	*Silt **(dense)***	*65*
21	*to*	*35*	*Sand **(dense)***	*54*
35			*Bedrock*	*40*

Well S79 **Land Surface Elevation = 48**

Depth (feet)			***Lithologic Description***	***Top Elev.***
0	*to*	*9*	*Artificial fill*	*48*
9	*to*	*14*	*Silty sand*	*39*
14	*to*	*60*	*Sand*	*34*
60	*to*	*69*	*Silty sand*	*-12*
69	*to*	*80*	*Sand and gravel and silt **(dense)***	*-21*
80	*to*	*107*	*Sand and gravel **(dense)***	*-32*
107			*Bedrock*	*-59*

Well S88 **Land Surface Elevation = 44**

Depth (feet)			***Lithologic Description***	***Top Elev.***
0	*to*	2	*Peat*	*44*
2	*to*	42	*Sand and gravel*	*42*
42	*to*	52	*Sand*	*2*
52	*to*	82	*Sand and gravel*	*-8*

Well S89 **Land Surface Elevation = 44**

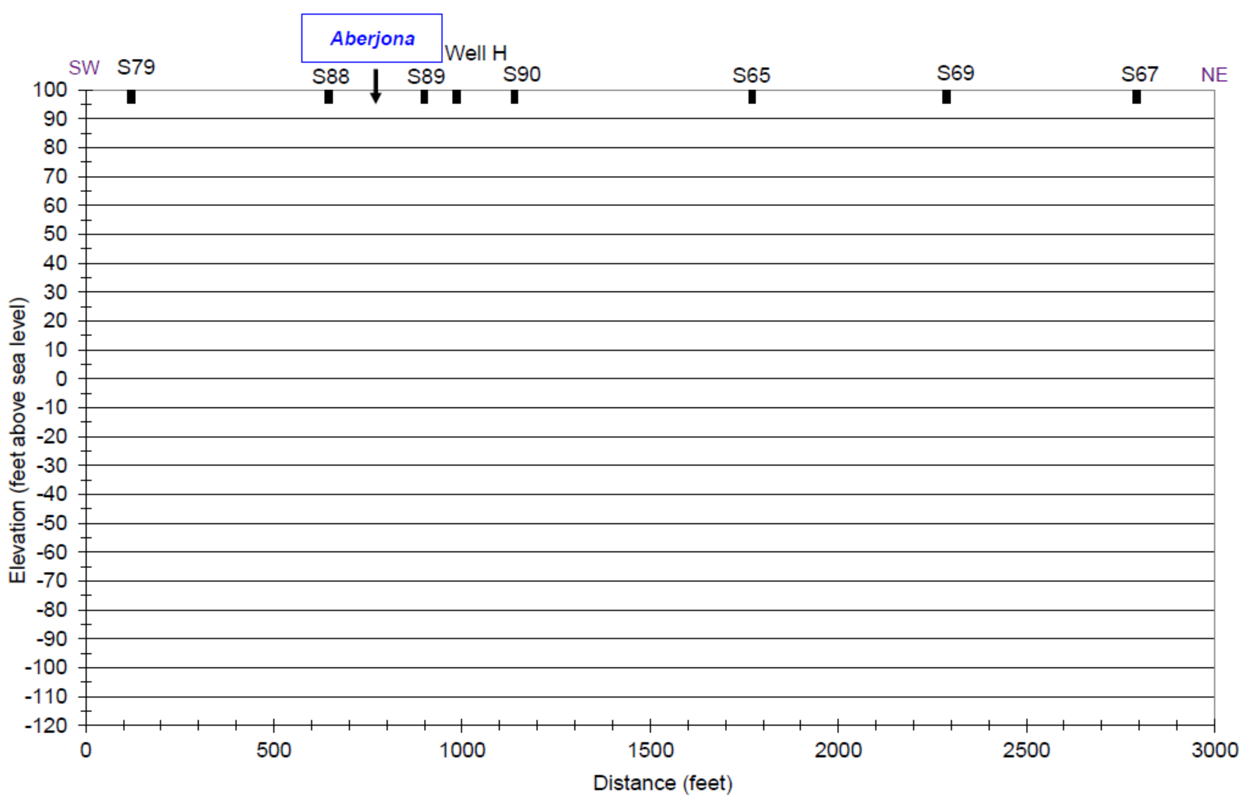
Depth (feet)			***Lithologic Description***	***Top Elev.***
0	*to*	5	*Peat*	*44*
5	*to*	40	*Sandy, organic silt*	*39*
40	*to*	50	*Sand*	*4*
50	*to*	55	*Silty sand*	*-6*

55	*to*	100	*Sand*	*-11*
100	*to*	105	*Sand and gravel and silt*	*-56*
105	*to*	115	*Sand*	*-61*
115	*to*	122	*Sand and gravel **(dense)***	*-71*

Well S90 **Land Surface Elevation = 47**

Depth (feet)			***Lithologic Description***	***Top Elev.***
0	*to*	15	*Sand*	*47*
15	*to*	30	*Sand and gravel*	*32*
30	*to*	35	*Sand*	*17*
35	*to*	66	*Sand and gravel with some boulders **(dense)***	*12*
66			*Bedrock*	*-19*

Cross-section for Part II:

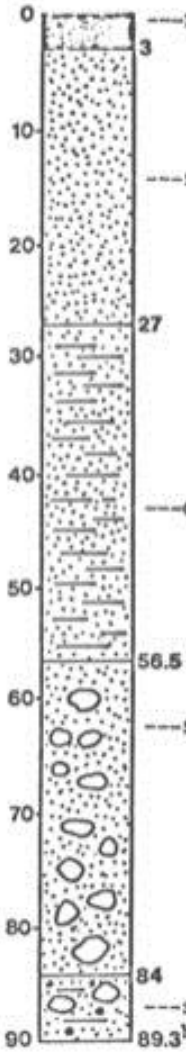


Well H boring log:

ECOLOGY AND ENVIRONMENT, INC.
30 East Cummings Park
Woburn, MA 01801

Well Log # 106
Project Name Woburn Well Survey
Project # TDD F1-8010-03A
Date Prepared 3/11/81
Prepared By R. DiNitto

Depth, Ft. (M)	Description
0 – 3	---Peat
3 – 27	---Sand, fine to med, gray
27 – 56.5	---Clay & Sand (fine to med.,brown)
56.5 – 84	---Sand (brown) & gravel
84 – 89.3	---Sand (fine to coarse, gray to brown) and gravel, trace of clay



Well No. (W 420) S39
Location North of Salem Street East of Aberjona River
Owner City of Woburn "H"
Ground Elev. 45 ft.
Driller Maher
Drilling Completed 1964
Type of Rig

----------- WELL DATA -----------

Hole Diam. 24 in.
Depth 89.3 ft.
Casing Diam.
Casing Depth
Screen Diam.
Screen Setting
Screen Type
Well Type Water withdrawel

----------- TEST DATA -----------

Static Water Level 1 ft.
Date Measured
Pumping Depth
Test Duration
Pumping Rate 700 GPM
Test Date
Test Type
Pump Setting
Specific Gravity
Final Pump Capacity
Final Pump Setting
Average Pumpage

-------- WATER QUALITY --------

Samples Taken Yes x No
No. of Samples 6
Type of Samples Priority Scan

Date Sampled 1/29/81
Samplers R. Palermo, J. Panaro
Will be Analyzed for 129 Priority Pollutants

Split Samples to

Comments

--------- REMARKS ---------

From Delaney and Gay (1980)

S67 boring log (2 pages).

NUS CORPORATION
A Halliburton Company

Project	TDD No.	Sheet	Hole No.
Wells G & H Remedial Investigation	F1-8409-01	1 of 2	S67

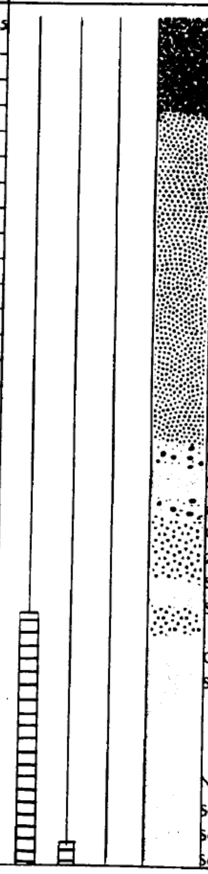
Location	Angle from Horiz.
Directly across Washington St. East Cummings/From 200 W. Cummings Park	Vertical

Begun	Completed	Driller	Drill Make & Model	Hole Dia.	Overburden (ft)	Rock (ft)	Total Depth
5 Dec 84	10 DEC 85	NEBC	Mobile B-47	3.5"	54	21	75'

Core Recovery (ft)	Core Bxs	Samples	El. Top of Casing	Ground El.	Depth to Top of Rock
20	2	7		S67S 83.23, S67M 83.28, S67D 83.35	54'

Sample Hammer Weight/Fall	Casing	NUS Inspector
140 lbs/30"	Solid: Sch 80 PVC 1.5" I.D. Screen: 0.010 slot	Baldyga

Depth	Sample No.	ROCK Core/Rec (in)	ROCK RQD	SOIL Pen/Rec (in)	SOIL Depth Interval (ft)	SOIL Blows/6"	Well Construction	Stratum Description	Notes
	01			18/18	0-1.5	12/11/12/15		Cover Fill-Sandy loam underlain by coarse Gravel	
5	02			15/11	5-6.25	100/110.5		BR F/M SAND, LI M Gravel, LI Silt	
10	03			18/18	10-11.5	43/69/92		BR M/C SAND, LI M/C Gravel, TR Silt, very compact, Cobbles at 12.7'	
15	04			24/12	15-17	47/52/30/21		Differentiated spoon sample. 3" GR-BN C SAND, LI M Gravel, TR Clay 2" clayey SILT 1" C GRAVEL very angular 6" GREEN BN C SAND	
20	05			12/12	20-21	106/100/R		C SAND, SO SILT and F Gravel 2" layer highly angular GRAVEL S67S Top of Ottawa SAND 22'	1
								S67S Top of screen 24'	
25	06			14/14	25-26.2	41/52/120.3		Green-GR SILT and F SAND, SO C Gravel	
30	07			14/0	30-31.2	20/100/100.		No recovery S67M Top of Ottawa Sand 31' S67M Top of screen 33' S67S Bottom of screen 34'	2



GRANULAR SOILS

Blows/Ft	Density
0-4	V. Loose
4-10	Loose
10-30	M. Dense
30-50	Dense
>50	V. Dense

PROPORTIONS USED

Trace (TR)	0-10%
Little (LI)	10-20%
Some (SO)	20-35%
And	35-50%

ABBREVIATIONS

F-Fine
M-Medium
C-Coarse
F/M-Fine to Medium
F/C-Fine to Coarse
V-Very
GR-Gray
BN-Brown
YEL-Yellow

1. S67S sealed with 2 foot thick layer of bentonite pellets from 18' to 22', Natural backfill to GS.
2. S67M sealed with cement/bentonite slurry from 31' to GS.

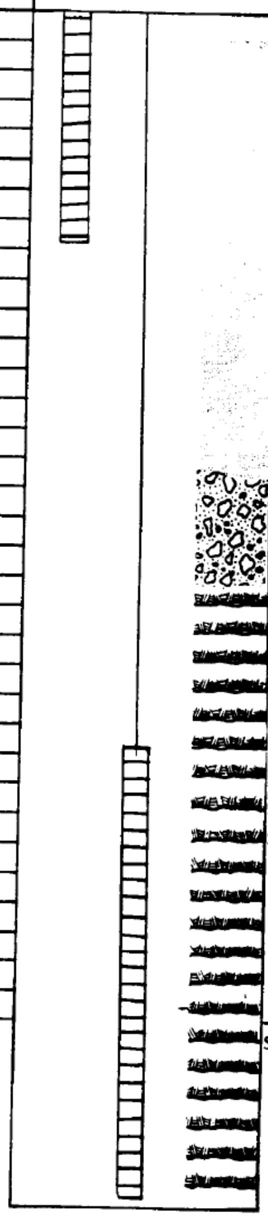
NUS CORPORATION
A Halliburton Company

Project	TDD No.	Sheet	Hole No.
Wells G & H Remedial Investigation	F1-8409-01	2 of 2	S67

Location: East Cummings/from 200 W. Cummings Park

Depth	ROCK Sample No.	ROCK Core/Rec (in)	ROCK RQD	SOIL Pen/Rec (in)	SOIL Depth Interval (ft)	SOIL Blows/6"	Stratum Description	Notes
				0/0	35	100,R	No recovery. Refusal at 35'- boulder	
40							Roller bitted to 45'	
							S67M Bottom of Screen 43'	
45				1/0	45	130,1	No recovery	
50				4/0	50	140,4 R	Basal Till Green-GR CLAY and Silt; SO C angular Gravel Roller bitted 1' into bedrock 54'- 55' coring begins at 55'	
55		60/60					Highly fractured Salem Gabbrodiorite w/inclusions of Granodiorite	
60		60/60					Becoming more ganitic and and competent w/depth S67D Top of Ottawa Sand 58' S67D Top of screen 60'	
65		60/60						
70								

Well Construction



REMARKS: 60/60

S67D Bottom of screen 75'

EOB - 75'

S67D sealed with cement/bentonite slurry from 58' to GS

Assignment 4: Florida's hydrostratigraphy

Natural gamma ray (NGR or "Gamma") logs are commonly used in Florida to differentiate lithologic formations within boreholes. Gamma logs are sensitive to vertical changes in radioactive material with depth.

- Phosphate grains within sediments of the Hawthorn Group have a high radioactive signature.
- Clay minerals and organic material are moderately radioactive.
- Calcite and dolomite generally have low radioactivity

Electric geophysical logs measure differences in electrical potential and the flow of electrical current through the adjacent formation material. In Florida, resistivity logs are commonly used. A high porosity rock will be able to conduct an electrical current through the water in the interconnected pores, and therefore will register a low resistivity. On the other hand, rocks with low porosity (limited water filled pore-space) will have more resistance to an electrical current and thus register a high resistivity.
In Florida:

- Low porosity evaporite deposits exhibit the highest resistivity values
- Low porosity limestones and dolostones show moderate to high resistivities.
- High porosity limestones and dolostones typically exhibit low resistivity values.

Fluid salinity will affect electrical response. In the logs you will look at in this assignment, groundwater is generally fresh and you can assume salinity variations are not a factor.

1. (3 pts) Figures 9 & 10 (linked here) are examples of the relationships between gamma logs, electric logs, and the geologic formations of Florida. Based on the geophysical logs, discuss how you would identify the boundary between the following. (*Note: In some cases, logs might not be helpful)*:

    A. The bottom of the Hawthorn Group and the top of the Ocala Limestone?
    B. The bottom of the Ocala Limestone and the top of the Avon Park Formation (Fm)?
    C. The bottom of the Avon Park Fm and the top of the Oldsmar Fm?

2. (2 pts) A geophysical log from borehole M-0650 is linked here. This borehole is from the the Silver Springs region in Ocala, FL (~40 miles south of Gainesville).

    A. The top of the Avon Park Formation is marked on the geophysical log. As you learned from the reading, the Avon Park Formation is limestone and dolostone, and part of the Floridan aquifer system. The cross section shows the Surficial Aquifer System (SAS) but doesn't mark in the Hawthorn Group (known as the upper or Intermediate confining unit). Which log suggests that the Hawthorn Group exists at this site? Explain. Based on that log, at what depth is the boundary between the Hawthorn Group and the top of the Floridan aquifer system (Ocala Fm)?

    B. The Hawthorn Group is much thinner at this site that at the Cabot-Koppers site in Gainesville. What must have occurred to "thin" the Hawthorn Group? What must have occurred to the Suwannee Limestone, which does not appear at this site?

3. (4 pts) As shown in the cross-section included with the reading, the “Middle Confining Unit” or “Middle Composite Unit” separates the upper and lower Floridan aquifers. But its hydraulic conductivity is variable and poorly mapped in northern Florida. Recent investigations by the St John’s Water Management District (SJWMD) have focused on drilling this interval at locations where it previously was not mapped.

   A. Discuss why the middle confining unit of the Floridan aquifer system is particularly difficult to characterize (as opposed to the upper confining unit).
   B. There is discussion of using more water from the lower portions of the Floridan aquifer system because the upper portions of the Floridan aquifer are over used. Discuss why it matters whether or not the middle confining unit exists in north Florida.
   C. Explain which borehole geophysical logs might be most helpful in identifying the middle confining unit and predict how these logs would indicate the presence of a confining unit.
   D. Return to the M-0650 log. The middle confining unit is marked with “MCU”. Describe the gamma, caliper, and electric resistivity (Normal Electric) log responses and discuss whether they agree with your predictions from “C”.

4. (4 pts) We’ve previously described sediments in class and used lithologic logs from sediments. Lithologic logs in carbonate aquifers rely on a lot of specialized information. The linked Excel spreadsheet from the SRWMD provides a view of the detailed information collected from core descriptions. These are from a boring M-0738, which is located in Marion County near M-0650.

   A. Sheet M-0738_Litho_Unit_Picks has a table with the depths chosen for the contacts between geologic formations. Make note of the depth for the top of the Avon Park Fm (which is the boundary between the Ocala Limestone and the Avon Park Fm), then switch to the lithologic description sheet and find that depth. Answer the following questions based on the columns of main properties (primary rock type, primary porosity, limestone grain type, dolomite alteration, induration, cement type, and index fossils), looking immediately above and below the top depth marked for the Avon Park Fm.

      -What properties change across this contact?

      -What properties remain the same across this contact?

   B. Examine the primary rock types and their respective primary porosities. Is there any obvious relationship between primary rock type (limestone vs dolostone) and porosity type?

5. (2 pts) Inspect the geophysical logs for M-0738. (linked here)

   A. There are multiple spikes in the natural gamma log within the FAS. Similar spikes were observed at M-0650. Predict what could cause high gamma values in a carbonate sequence?
   B. Examine the lithologic log descriptions for the depths of the gamma spikes at M-0738. Does the lithologic information support your prediction?

6. (2 pts) The middle confining unit was observed at a depth of 190 ft at M-0650. Does the character of the resistivity spike from M-0650 better match the M-0738 spike at 160 or the spike at ~200 ft? Explain.

7. (2 pts) Examine the core descriptions on the Excel spreadsheet for M-0738 for either 160 ft or ~200 ft (whichever your pick was for the confining unit). Do the lithologic descriptions support the interpretation that this interval acts as confining unit relative to the overlying rock? Explain.

8. (1 pt) Suggest two distinct tests or data collection that could be used to determine whether this interval tentatively identified as a confining unit is lower permeability than the overlying and underlying rock.

Assignment 5 Groundwater Storage and Flow Equations

Part I

The first six questions examine storage in the northern portion of the Gulf Coast aquifer system. This coastal plain aquifer consists of sands and clays, ranging from unconsolidated near the surface to semi-consolidated at depth. The aquifer system has an area of ~68,000 square kilometers, and groundwater is under semi-confined to confined conditions. The aquifer is ~2000 feet thick. Between 1970 and 1980, the average reduction in storage was 0.6 million acre-feet per year. An average hydraulic head drop of 10 feet and an average subsidence of 0.5 feet were observed over the aquifer area. Note: This might not sound like much subsidence, but keep in mind that the subsidence will be much greater than average in the active pumping areas.

For the calculations, assume a porosity of 0.05, a fluid density of 1000 kg/m^3 and a fluid compressibility of 4.4 x 10^{-10} Pa^{-1}.

1 acre-foot=1234 m^3
1 m= 3.2808 ft

1. Calculate the volume of water (in **m^3**) removed from storage in the 1970s.
2. Use the volume of water removed, the aquifer area, and the hydraulic head change to calculate the apparent storativity (unitless) of the aquifer system. Use Eq 6.29.
3. Hydrogeologic studies that examined seasonal changes in hydraulic head due to changes in pumping and recharge found storativity values averaging 0.001. Why is it reasonable that this value is less than the storativity estimated from the decade-long hydraulic head change?
4. Calculate the specific storage of the aquifer system (in 1/m) based on the storativity and the aquifer thickness.
5. Calculate the matrix compressibility of the aquifer system (in 1/Pa) using Equation 6.27 in your text.
6. Equation 6.27 is only valid if $\alpha >> n\beta$. Calculate $n\beta$ to confirm

Part II

The following three questions refer to the High Plains aquifer. In parts of Texas, the High Plains aquifer saturated thickness has decreased from 100 feet to 50 feet due to pumping. The aquifer is unconfined and the specific yield is estimated to be 0.15. Estimated specific storage is 1 x 10^{-7} 1/ft.

7. Your text states that for an unconfined aquifer, $S=S_y$, or storativity equals specific yield. Yet, elastic storage due to compression still occurs in unconfined aquifers. More accurately, $S=Sy + S_s$ x b (where b is aquifer thickness). Use this equation to calculate the storativity of the High Plains aquifer.

8. How much has the volume of water stored in the aquifer decreased (in ft^3 per square foot of aquifer area)?

9. If hydraulic conductivity is 50 ft/day, how much would transmissivity decrease (in **m^2/min**) as the saturated thickness decreased from 100 to 50 feet?

Part III (11 pts) consists of a simplified approach to the groundwater flow equations. This will be worked through in class, and graded on a completion basis.

Assignment 6: Potentiometric Surface Maps

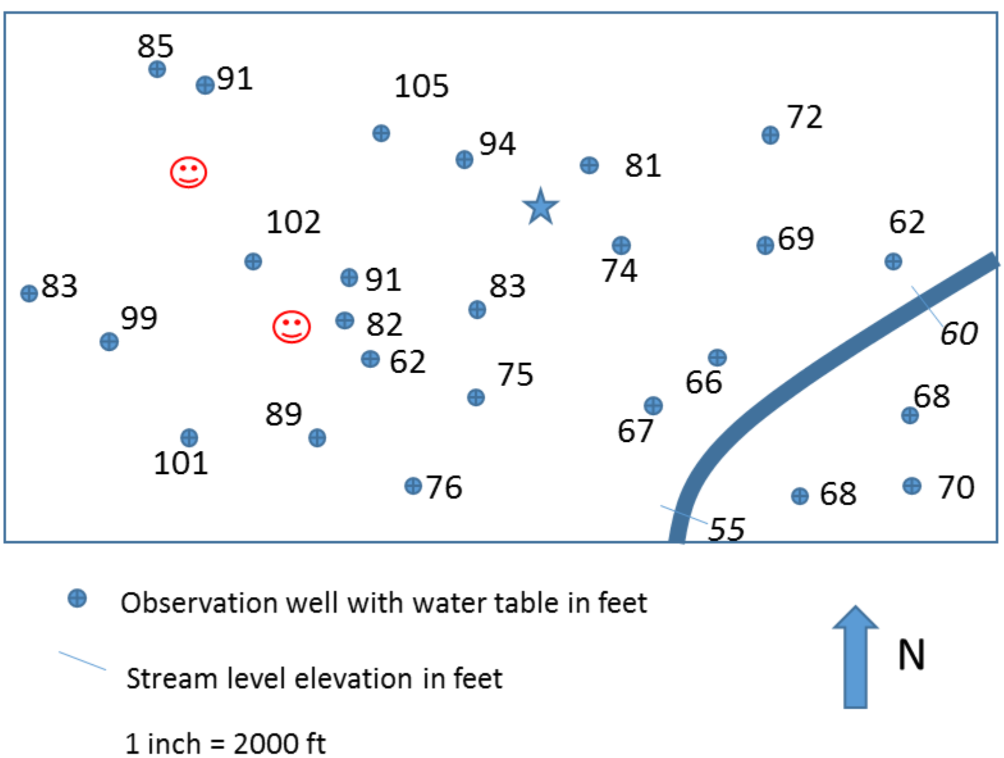
Please complete contours and calculations on paper and submit in class next Weds.

Objectives:

- Learn to draw and interpret potentiometric surface maps.
- Practice calculations of equivalent horizontal and vertical hydraulic conductivity
- Evaluate whether several industrial sites could have contributed to contamination at water-supply wells by drawing flow lines and calculating travel times.

Part I: Warm-up map. It's a really good idea to have us look over your map and calculations before you start on Part II.

1. The map below shows hydraulic head data (in ft) from an unconfined isotropic aquifer and a stream (shown as a solid line) that is hydraulically connected to the aquifer.
   A. (2 pts) Contour the data using a 10 foot contour interval. Label your contours and be sure to use the stream levels in addition to the monitoring well hydraulic heads.
   B. (1 pt) Draw in the groundwater divide on your contour map as a dashed line.
   C. (1 pt) Draw 3 flow lines starting at the star, and at each of the 2 "happy faces".
   D. (1 pt) Calculate the hydraulic gradient between the "star" and the stream.
   Note: You do not need to estimate the hydraulic head at the star and the stream. You can calculate hydraulic gradient between two contours.
   E. (1 pts) Assuming K=15 ft/day and n_e=0.12, calculate the travel time between the "star" and the stream.



Part II

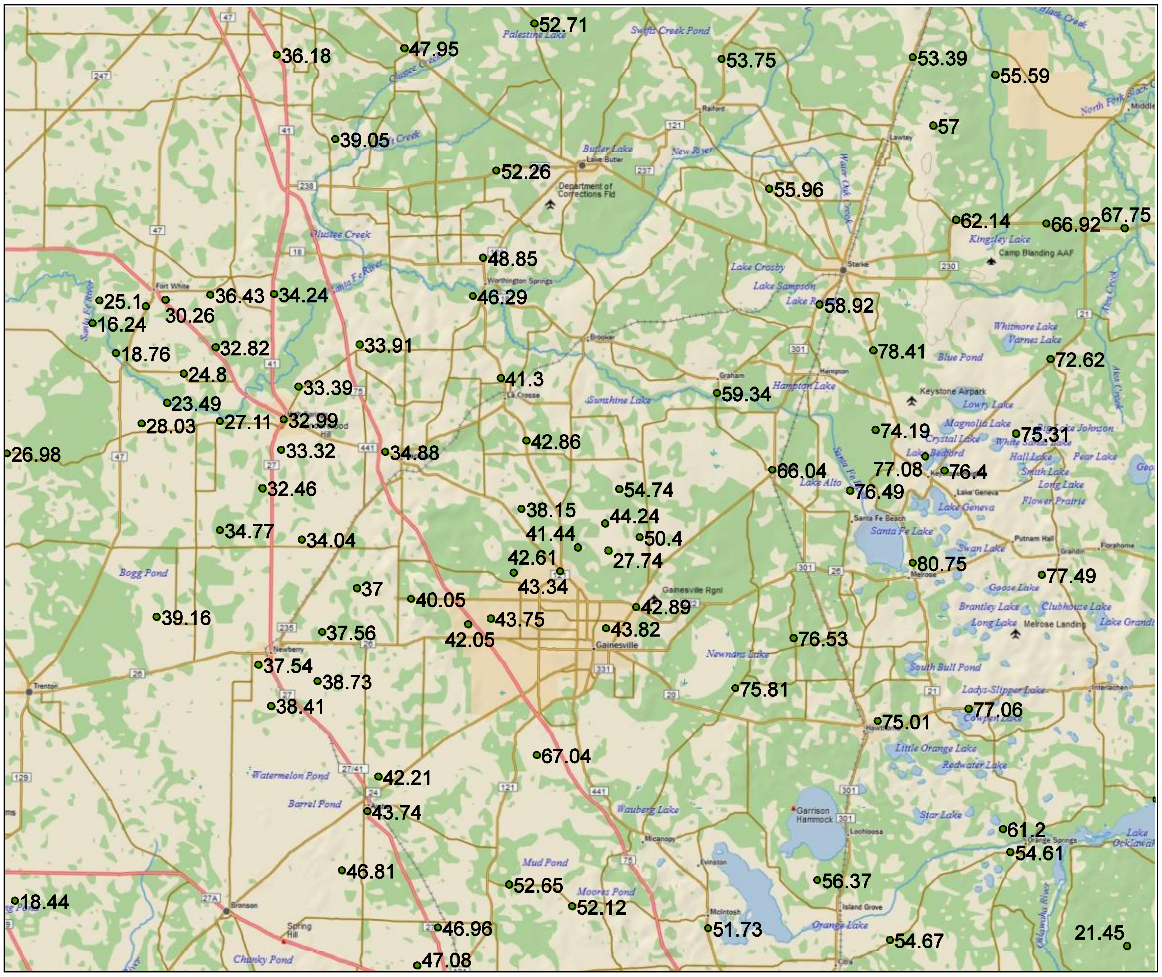
The attached map shows hydraulic heads (in feet above mean sea level, or asl) from 2008 for the upper Floridan aquifer (UFA) in the Gainesville, FL area. Two versions are provided because the hydraulic head values are easier to read and contour without the background map. It is suggested that you first contour the version without the background map and then transfer your contours.

In the map area, the upper Floridan aquifer transitions from unconfined in the south and west to confined conditions in the north and east. Gainesville's water is pumped from the upper Floridan aquifer, just north of 53rd Ave (~ where you see the 27.74 ft asl water level).

1. (5 pts) Sketch a potentiometric surface map for the upper Floridan aquifer. **Use a 5 foot contour interval.** *Draw the 10 foot intervals (80,70,60 ft, etc) first, and then fill in the "5"s. Label your contours.*
2. (1 pt) The Cabot-Koppers hazardous waste sites are located in Gainesville approximately where the 43.82 ft reading is located. Assume that the aquifer is isotropic, and draw a flowline from this location. Does the groundwater from this site flow to the well field's cone of depression?
3. (4 pt) Find and justify reasonable values for the hydraulic conductivity and effective porosity of the upper Floridan aquifer. Use these values to calculate travel time (in years) from the Cabot-Koppers site to the Gainesville well field. Because the hydraulic gradient changes drastically as you approach the cone of depression, break the calculation into two segments. First calculate the hydraulic gradient and travel time for the segment from the location of the well with a hydraulic head of 43.82 ft to the 40 ft contour. Next calculate the hydraulic gradient and travel time from the 40 ft contour to the well with a hydraulic head of 27.74 ft. Add the two travel times to find the total.

   Other features to observe on the potentiometric surface map:

4. (1 pts) Use a dashed line to sketch the location of the groundwater divide south (to southeast) of Gainesville. There is a ridge that separates groundwater that flows roughly north (and to the well field from groundwater that flows south to Payne's Prairie.
5. (1 pt) What is the relationship between the equipotential lines and surface water north and east of Gainesville? For example, look at the Santa Fe River near Hampton Lake to see if there are any indications that it is gaining or losing water. Explain – why does this make sense for an area where the aquifer is confined?
6. (1 pt) Examine the relationship between the equipotential lines and the Santa Fe River on the west side of your map (near Fort White). Is the Santa Fe River gaining or losing water from the UFA at this location?



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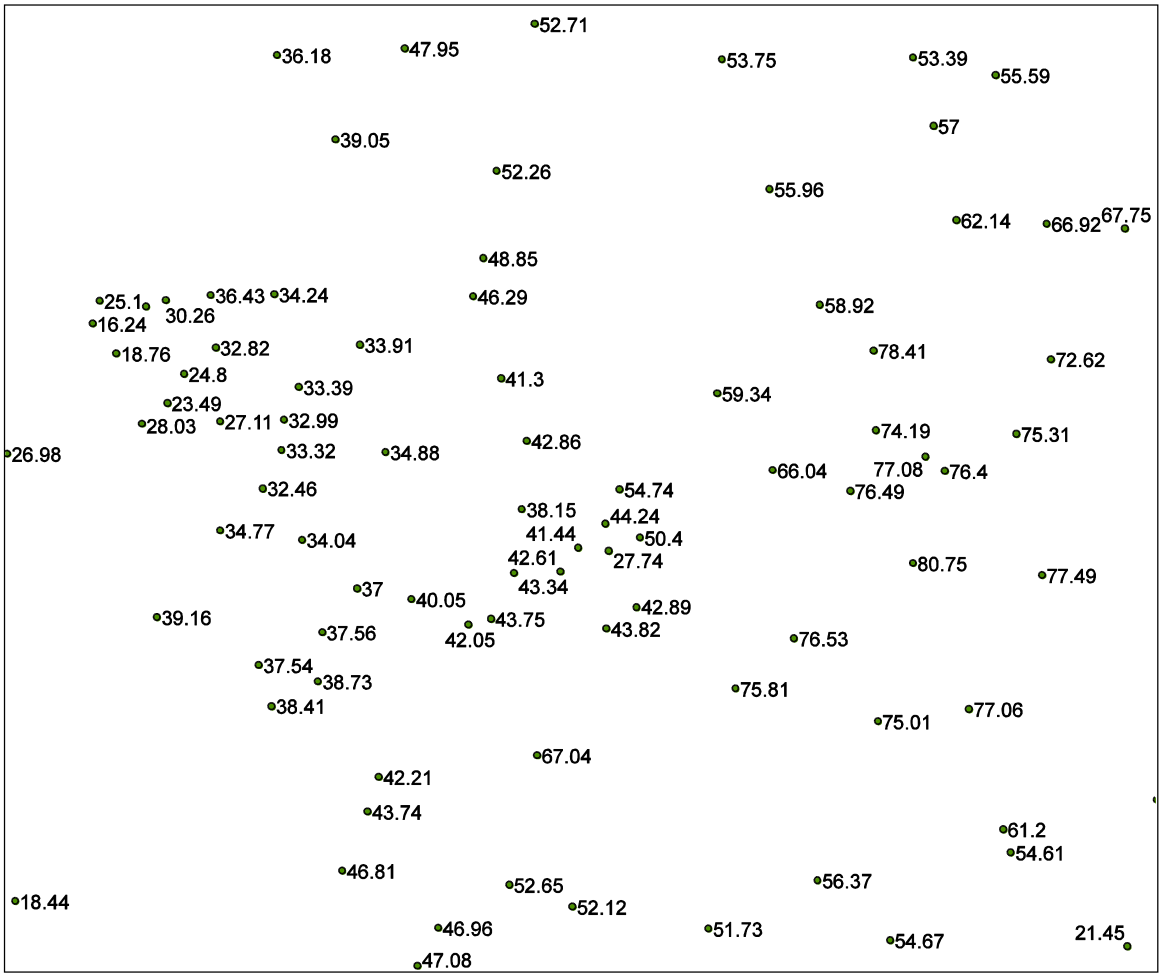

52.71
36.18
47.95
53.75
53.39
55.59
57
39.05
52.26
55.96
62.14
66.92
67.75
48.85
25.1
30.26
36.43
34.24
46.29
58.92
16.24
18.76
32.82
33.91
78.41
72.62
24.8
33.39
41.3
59.34
23.49
28.03
27.11
32.99
74.19
75.31
26.98
33.32
34.88
42.86
77.08
66.04
76.4
32.46
54.74
76.49
38.15
44.24
34.77
41.44
34.04
50.4
42.61
27.74
80.75
77.49
43.34
37
40.05
42.89
39.16
43.75
37.56
42.05
43.82
76.53
37.54
38.73
75.81
38.41
77.06
75.01
67.04
42.21
43.74
61.2
54.61
46.81
56.37
52.65
18.44
52.12
46.96
51.73
21.45
54.67
47.08

Assignment 7 Recharge and the Hydrologic Cycle

In this assignment, you'll examine recharge estimates and groundwater ages at two locations: 1) Great Artesian Basin in Australia; and 2) Silver Springs group springshed near Ocala Florida.

Part I: Great Artesian Basin in Australia

The Great Artesian Basin is a structural basin, which means that it is lower in the center than at the sides. The aquifers in the basin are sandstones and the confining units are mostly shales.

There are some similarities to the Dakota Sandstone aquifer (Figure 5.3.9 in your text). Both aquifer systems consist of more than one sandstone layer that is recharged where exposed, and confined by shales elsewhere. There is also a shallower unconfined aquifer above the sandstone. Differences are that recharge of the Dakota sandstone generally occurs on the western side only (with discharge on the eastern side). Another view of the GAB can be found at [this link](). Data and the potentiometric surface map are from [Bethke et al (1999).]()

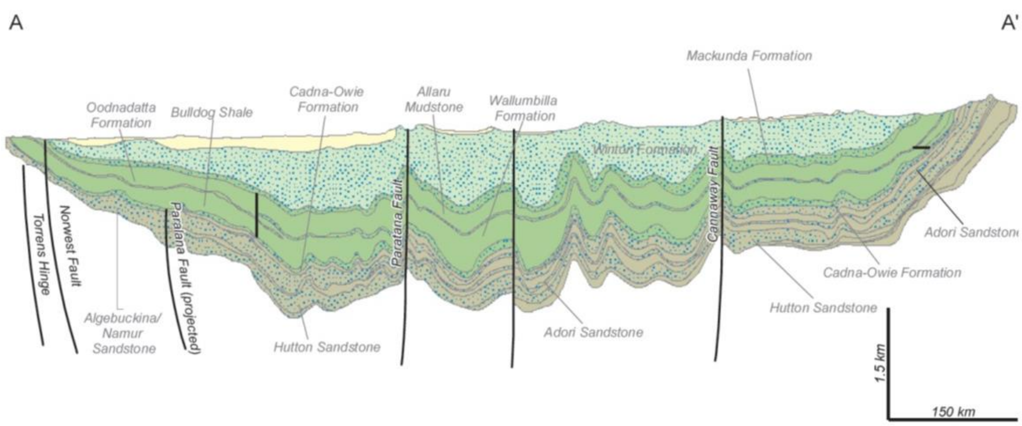
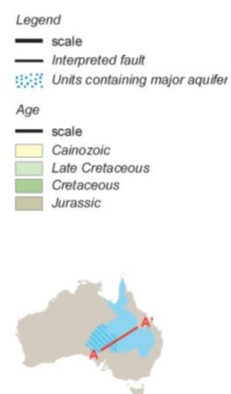


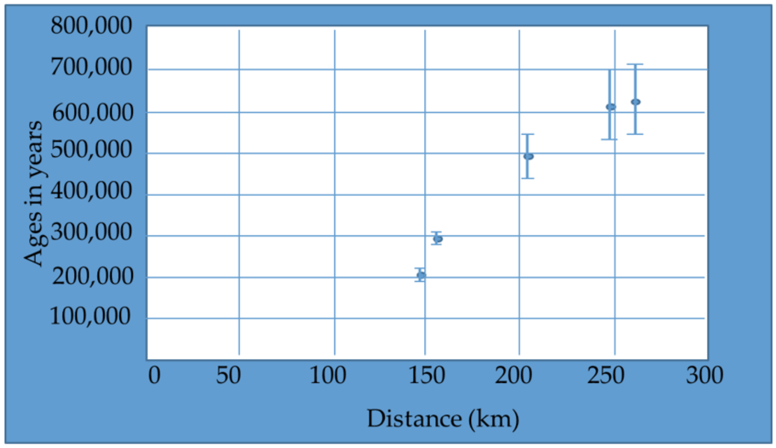
Figure 3.1: Regional cross-section from eastern recharge zone (Queensland) to Lake Eyre (South Australia)

Adapted from Habermehl and Lau (1997) and Radke *et al.* (2000).



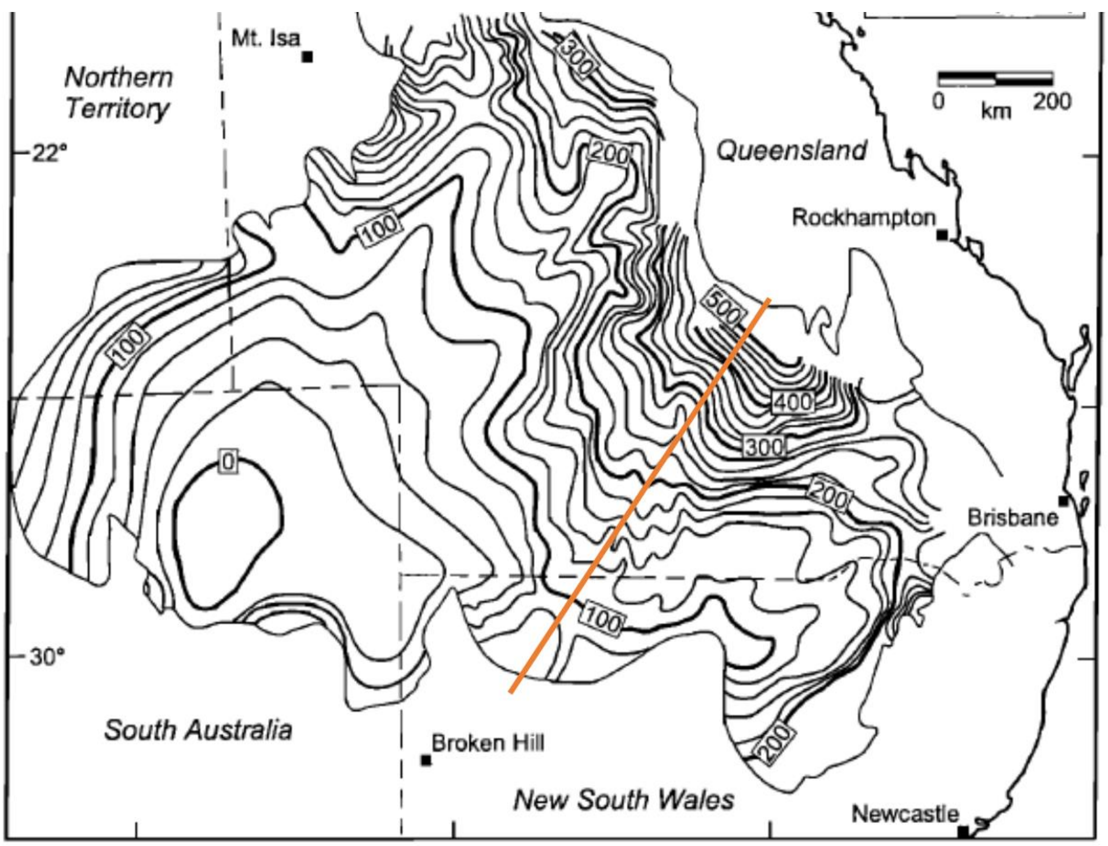
1. Groundwater in the confined Great Artesian Basin in Australia has been dated and ages up to 2 million years have been determined. What radioactive tracer could have been used for these ages?

2. To the right, ages are plotted at various distances from the northeastern recharge area (see the map for the location). You'll notice that the error bars get larger for the older ages. Use the ages and distances to calculate average velocity (in m/year).



3. The long-term average recharge rate will be the same as specific discharge. If the effective porosity of the sandstone in the Great Artesian Basin is 0.23, what is the long-term average recharge rate in **m/year** and in **m/day**?

4. (4 pts) Next you will use Darcy's law, estimated hydraulic conductivity and effective porosity, and the potentiometric surface map (contours are in m) to calculate a second estimate of recharge rate.



a. Calculate hydraulic gradient between the 500 and 100 m contours along the cross-section line. Note that this is not an exact flowline, but sufficient for this rough calculation.

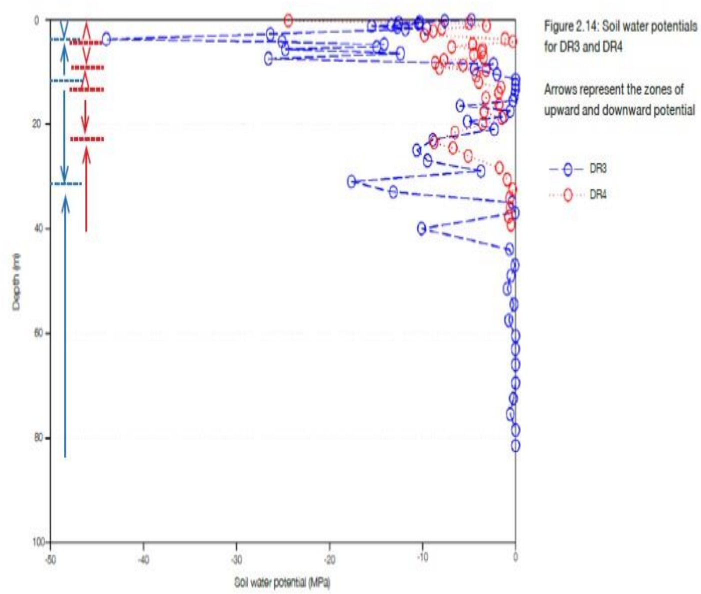
b. Average hydraulic conductivity is 2.0 m/day. Estimate the specific discharge (in m/day).

c. Effective porosity is 0.23. Calculate velocity.

d. Briefly discuss how the velocity result compares to the velocity estimated from the age estimates (Question 2). One explanation for the difference is the faults observed in the cross section. How might faults reduce horizontal hydraulic conductivity in the sandstone layers?

5. (3 pts) In the western recharge area for the Great Artesian Basin aquifer, two boreholes (DR-3 and DR-4) were drilled in the unsaturated zone. The pressure (tension) was measured, and can be converted to pressure head by multiplying by water density of 1000 kg/m^3 and gravitational acceleration). You'll notice that: 1) the unsaturated zone is quite thick (80 m) and 2) the pressure heads are very low (extremely negative). As a result of the extremely low pressure heads, changes in elevation are small compared to changes in pressure head. Inferred flow directions (upward or downward) are shown with arrows.

a. What do the flow directions indicated by the pressure heads suggest about groundwater recharge at the present time?



b. Carbon-14 dating of recharge indicates ages up to 30,000 years at the water table. What does this suggest about recharge? Is that conclusion consistent with the results from the studies of the unsaturated zone? Is it consistent with the conclusions from age dating within the aquifer?

c. Why might the long-term average (100,000s of years) indicated by the age dating be significantly greater than the current recharge?

Part II: Silver Springs Group springshed near Ocala Florida

The Silver Springs group discharges groundwater from the upper Floridan aquifer to begin the Silver River. You examined cores and geophysical data from this region in Module 4. The figure below is from Phelps (2004) and shows the location as well as the potentiometric surface. The groundwater basin (or springshed) has an area of 2 x 10^{10} ft^2. In the 1960s, pumping was minimal in the springshed and the discharge from the springs averaged 820 cubic feet per second (cfs). The basin has no other groundwater or surface water inflows/outflow. Due to the aquifer's high permeability, runoff is negligible.

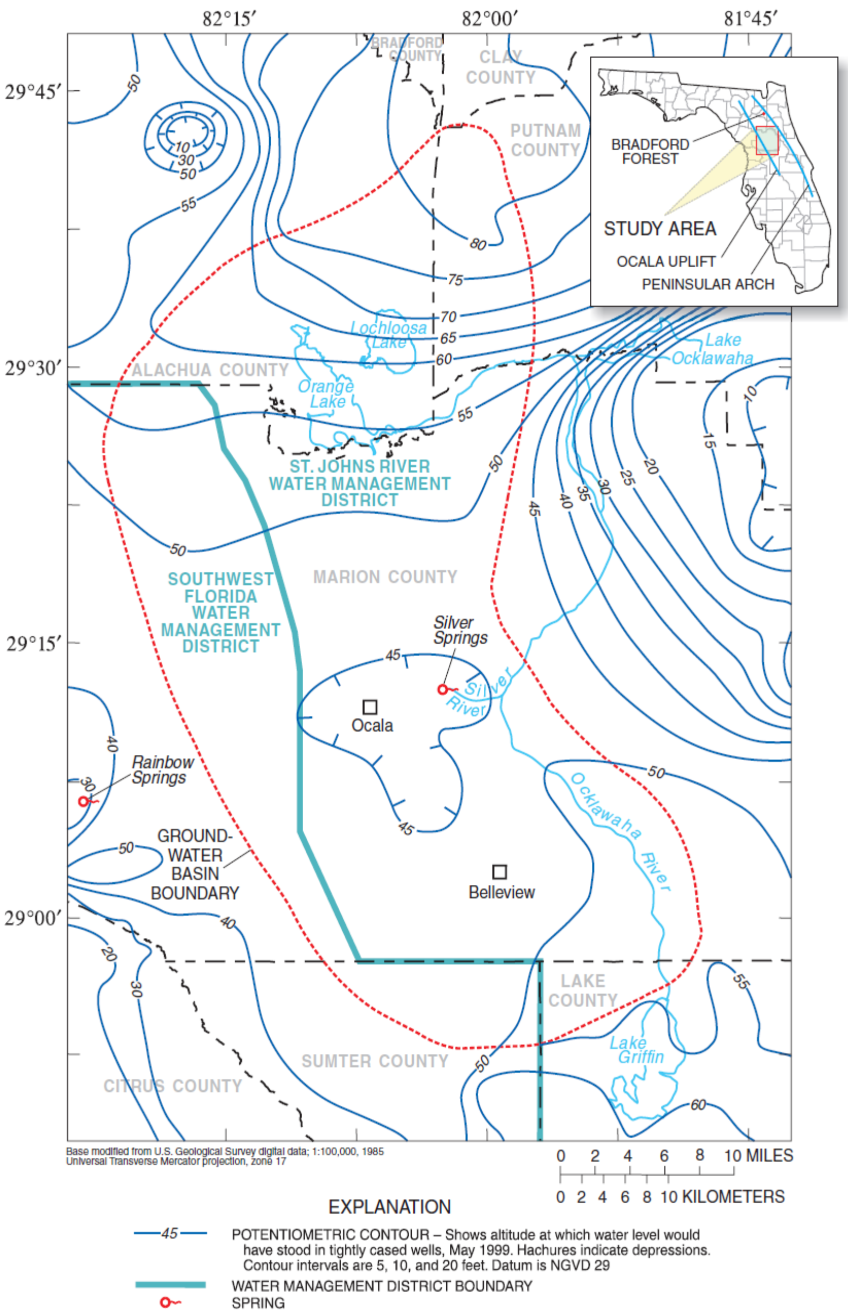


Figure 1. Approximate extent of Silver Springs basin and potentiometric surface of the Upper Floridan aquifer, May 1999 (from Bradner and Knowles, 1999).

1. Recharge calculation (2 pts)

   A) Use a steady-state water budget to calculate the aquifer's recharge in ft^3/day.

   B) Calculate the recharge rate (per unit area) in inches/year.

2.The average rainfall in the Ocala Florida region is 53 in/year. Using the recharge rate calculated in the previous problem, calculate the percentage of rainfall lost to ET.

2. (5 pts). Calculating

groundwater ages from the potentiometric surface map.

a. Using the potentiometric surface map, calculate the average hydraulic gradient (in ft/mile) from the 80 ft contour near the northern end of the springshed to the 45 foot contour marking the spring group.

b. Transmissivity of the upper Floridan aquifer is extremely variable, but estimates for the region are 2 x 10^6 ft^2/day. Recall from Assignment 4 that the top of the middle confining unit is at ~190 to 200 ft below land surface. Assume that the water table is approximately at the land surface and calculate hydraulic conductivity (ft/day) from the transmissivity.

c. Calculate specific discharge (in ft/day) based on the hydraulic conductivity and hydraulic gradient.

d. Effective porosity is estimated to be 0.20. Calculate the velocity (in ft/day).

e. Calculate the travel time (in years) from the 80 ft contour to the 45 ft contour.

f. Based on your predicted age, what tracers would be best used to determine age?

3. (2 pts) Because the UFA is unconfined in much of the springshed, recharge of young water can occur throughout the basin. Because the unsaturated zone is very thin, this recharge is expected to be rapid (days). It is also possible that water from the lower Floridan aquifer could contribute to the discharge at the Silver Springs group. How would each of these factors impact the inferred ages (based on tracer analyses) of Silver Springs water?

Assignment 8 Flow to Wells (20 pts)

Each part has two questions. For the first of each type, the answer will be linked from the online discussion. Check your answer with the solution example. Work through the second on your own. Because the answers are given on the odd questions (first of each type) you must show your work on all questions.

Part I. Thiem Solution

1. (2 pts) A well in a 20 m thick confined aquifer was pumped at 100 m^3/day until it reached steady state conditions, and hydraulic heads were measured at two observation wells. The drawdown at a well located 10 m from the pumping well was 2 m and the drawdown at a well located 100 m from the pumping well was 1 m. Use the Thiem solution to calculate the transmissivity (T) in m^2/day and K in m/day.

2. (3 pts) A well in a 100 m thick confined aquifer was pumped at 700 m^3/day until it reached steady state conditions, and hydraulic heads were measured at two observation wells. The drawdown at a well located 5 m from the pumping well was 2.5 m and the drawdown at a well located 50 m from the pumping well was 0.75 m. Use the Thiem solution to calculate the transmissivity (T) in m^2/day and the hydraulic conductivity (K) in m/day.

Part II. Theis Forward Solutions

3. (2 pts) For a transmissivity, T, of 2500 m^2/day, storativity, S, of 0.00015, and pumping rate, Q, of 950 m^3/day, calculate drawdown in a confined aquifer for r =75 m at t=450 min using the Theis solution. Use the table in the reading to find W(u).

4. (3 pts) For a transmissivity of 1000 m^2/day, storativity, S, of 0.0010, and pumping rate, Q, of 1000 m^3/day, calculate drawdown in a confined aquifer for r =20 m at t=300 min using the Theis solution. Use the table in the reading to find W(u).

Part III. Theis Inverse Solution

The linked spreadsheet should be used for the Theis inverse solution. Download the spreadsheet and open in Excel. To use the spreadsheet:

a. Make sure your units are consistent.
b. Enter the pumping rate and radius on the spreadsheet.
c. Copy and paste the observation data into the spreadsheet.
d. By trial and error, adjust transmissivity and storativity until the Theis curve matches the data as best as possible. Decreasing the transmissivity will shift the Theis curve up (and slightly over). Increasing the storativity will shift the Theis curve to the right.

5. (2 pts) The linked time-drawdown data are from a test where a well was pumped at a rate of 5760. ft^3/ day. Drawdown was measured in an observation well 300 ft away from the pumped well. Assume that the pumping and observation well were both screened over the entire thickness of the **confined aquifer.** The geologist's log of the pumping well is in ft below ground surface (bgs):

   0 - 23 ft bgs Silty sand
   23 - 77 ft bgs Clay
   77 - 82 ft bgs Poorly sorted gravel
   82 - 117 ft bgs Unfractured granite

Find the transmissivity, storativity, hydraulic conductivity, and specific storage of the aquifer. You don't need to submit the spreadsheet. Show your transmissivity and storativity values below and show calculations for K and S_s.

6. Values of drawdown and time from a constant-rate pumping test are linked here. Both the pumped well and the observation well screen the entire aquifer thickness, and the observation well is 35 ft from the pumping well. A pumping rate of 100 ft^3/day was used for the test.

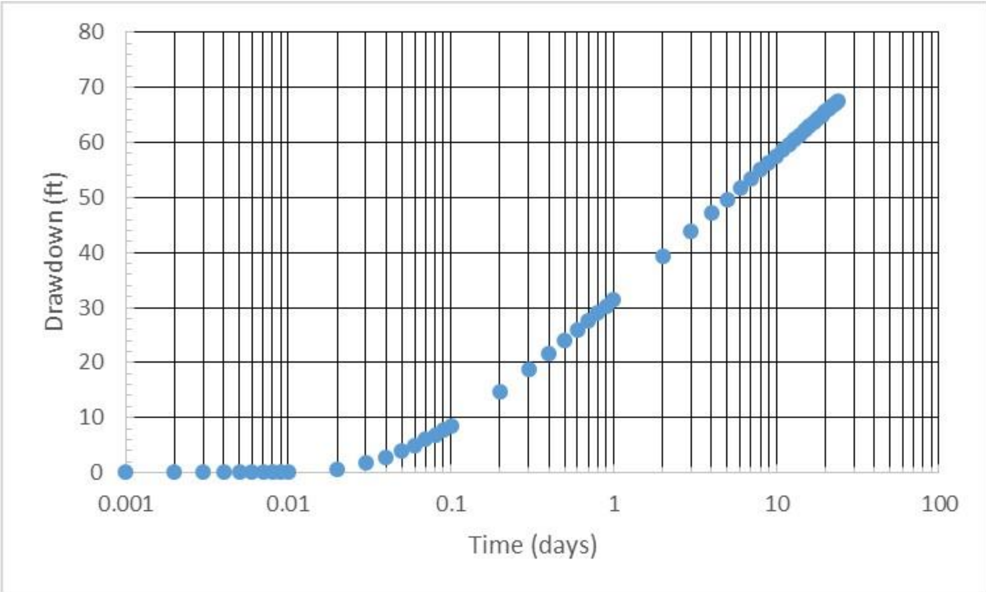
The geologist's log of the pumping well is

0 - 120 ft bgs Clay
120-160 ft bgs Limestone, high porosity, some dissolution
160-200 ft bgs Shale

Determine the transmissivity, storativity, hydraulic conductivity and specific storage of the aquifer.

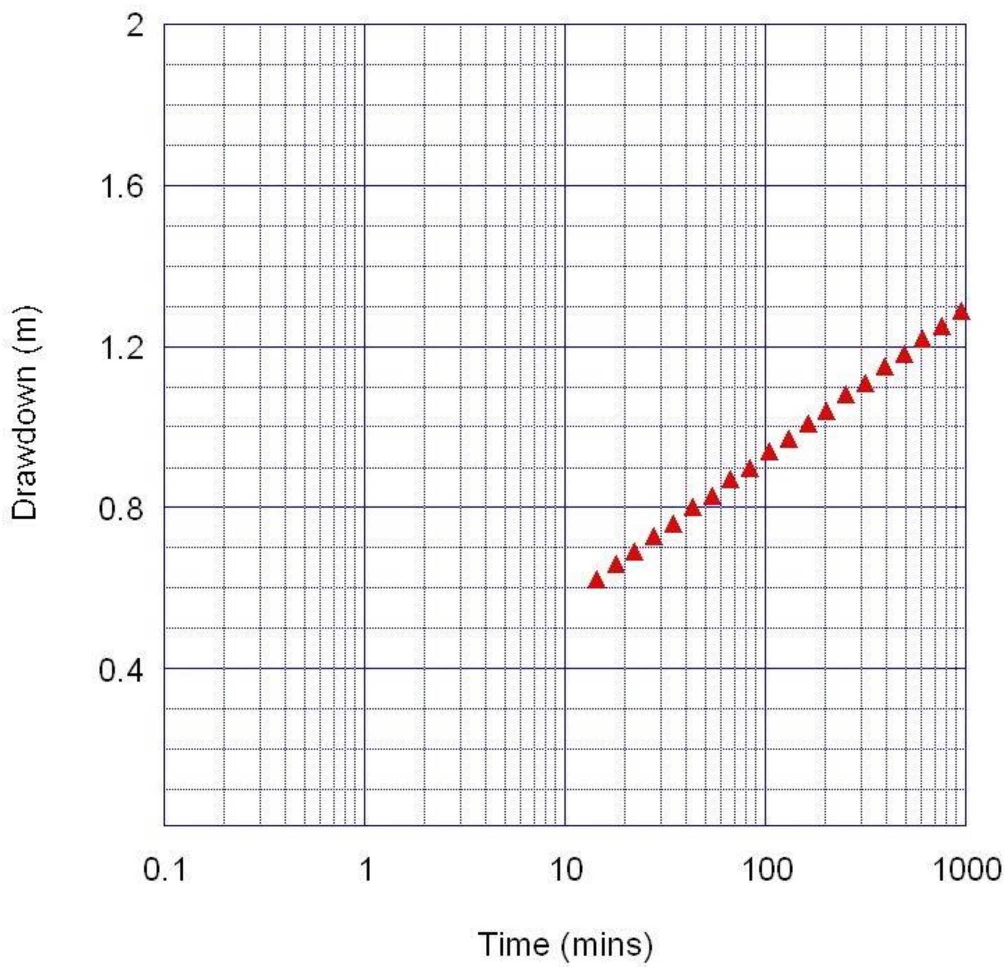
Part IV. Cooper-Jacob Solution

7. (2 pts) A well in a confined aquifer was pumped at a rate of 7.5 ft^3/min. Time-drawdown data from an observation well located 80 feet away are plotted on a semi-log plot. Use the Cooper-Jacob method to calculate the transmissivity (in ft^2/min) and storativity of the aquifer. Show your line, your location where you measure Δs and your t_o location, as well as calculations.



8. (3 pts) Values of drawdown and time from a constant-rate pumping test are plotted. Both the pumped well and the observation well are fully penetrating, and the observation well is 150 m from the pumping well. A pumping rate of 10,000 m^3/day was used in the test.

   Determine the transmissivity (in m^2/day) and storativity of the aquifer using the Cooper Jacob solution. Show your line, your location where you measure Δs and your t_o location, as well as calculations.



Assignment 9: A spreadsheet groundwater model (20 pts)

In this assignment, you will work with an Excel spreadsheet that is a very simplified steady-state model of an aquifer. The model will be used to predict the maximum rate at which a new pumping well can extract water without causing stream water to enter the aquifer. Prior to using the model for prediction, you'll calibrate the model using data from observation wells.

Study Area

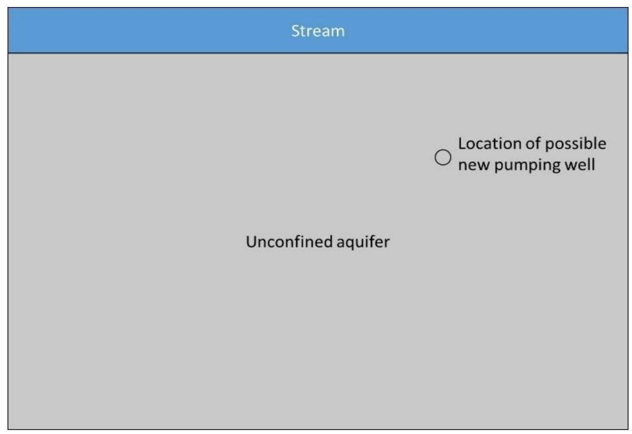
The 50 ft thick unconfined aquifer consists of mostly sand with some thin clay layers, and receives 20 inches a year of recharge (per unit area). Slug tests and pumping tests have been conducted and found that the hydraulic conductivity is between 1 and 20 ft/day.

For the modeling, it is assumed that the aquifer is at a steady-state over the long term and that it is homogeneous and isotropic.

The stream is on the north end of the aquifer and has a water level of 110 ft above sea level on the west side and 101 feet on the east side.

There is a groundwater divide to the south (so no flow crosses the boundary). The east and west boundaries also have no flow, and represent the physical limits of the aquifer. The aquifer dimensions are 900 ft (N-S) x 1800 ft (W-E).

The location of the proposed new pumping well is shown on the map.

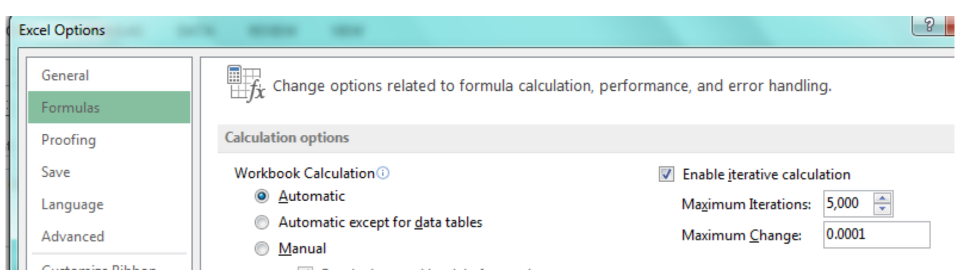


The Spreadsheet Model

The spreadsheet model discretizes the aquifer (breaks the aquifer into grid cells) and solves for hydraulic head in the center of every cell simultaneously. Each Excel cell represents a 50 ft x 50 ft area of the aquifer.

Because the hydraulic head in each cell is affected by the neighboring cells, the model will need to "iterate", or repeatedly calculate hydraulic head at every one of the cells until the hydraulic heads satisfy both Darcy's law and conservation of volume (the amount coming into each cell has to equal the amount going out).

Download and open the [Excel file](). When you first open the excel spreadsheet, it might give you a warning about a circular reference. That is expected, because the solution requires iteration (as described above). To enable iterations in Excel 2013 for PC: Go to the File pulldown menu and choose options, then Formulas. Click on the checkbox to Enable Iterative Calculations, Change the maximum number of iterations to 5000 and maximum change to 0.0001 then say OK. *If you are using a different version of Excel, you can use the Excel help menu and search for "iterations".*



Calibrating the Model

Before you can use the model for prediction, the hydraulic conductivity must be **calibrated** by comparison to observations. Right now, the model is calculating the hydraulic heads for a hydraulic conductivity of 1 ft/day. The pumping well rate is zero ft^3/day because the well has not yet started pumping.

There are five observation wells where water levels have been measured over several years and you will use the average values to calibrate the steady-state model. The measured hydraulic head values are shown in the spreadsheet just to the right of the shaded region. The spreadsheet also shows the simulated values. If the model is well calibrated, the simulated values should match the observed values.

1. Enter the known recharge rate of 20 inches/yr (if it is not already entered). Compare the simulated and observed hydraulic heads. Are the simulated hydraulic heads too high or too low?

01.8	101.5	101.3	101.0	aquifer thickness	50	ft
06.1	106.0	105.8	105.7	hydraulic conductivity	1	ft/day
10.3	110.2	110.0	110.0	recharge	20	in/yr
14.2	114.1	114.0	114.0	pumping Q	0	ft^3/day
17.9	117.8	117.7	117.7			
21.2	121.2	121.1	121.1		Hydraulic head in feet above sea level	
24.4	124.3	124.2	124.2		Observed	Simulated
27.3	127.2	127.1	127.1	Observation Well #1 (H15)	111.2	142.236
29.9	129.9	129.8	129.7	Observation Well #2 (AE17)	108.8	142.135
32.4	132.3	132.2	132.1	Observation Well #3 (K7)	109.1	125.227
34.5	134.5	134.4	134.3	Observation Well #4 (W6)	106.7	119.8
36.5	136.4	136.3	136.3	Observation Well #5 (AH5)	103.8	114.2

2. Our simulated hydraulic gradient is too high, causing the hydraulic heads to be too high. To lower the observed hydraulic heads in the aquifer, should we increase or decrease the hydraulic conductivity in the model? **Explain your answer using Darcy's Law.**

3. Change the hydraulic conductivity to 20 ft/day by replacing the "1" by a "20" and hit enter. What happens to the hydraulic head values in the aquifer? Does this agree with your expectations?

J	AK	AL	AM	AN	AO
1.3	101.0		aquifer thickness	50	ft
1.9	101.8		hydraulic conductivity	20	ft/day
2.5	102.4		recharge	20	in/yr
3.0	103.0		pumping Q	0	ft^3/day

4. (3 pts) Vary hydraulic conductivity between 1 and 20 ft/day to find the K (to the nearest ft/day) that provides the best match between the simulated and observed hydraulic heads. *If you are strategic, you do not have to try every possible K value.*

A) Which hydraulic conductivity value yields the best match to the observed hydraulic heads?

B) Is it a “perfect” match? Explain.

C) In real life, what characteristics of an aquifer, the recharge, and the hydraulic head measurements would contribute to an imperfect match?

The Current Potentiometric Surface and Water Budget

The color shading on the results should show red for the highest calculated hydraulic heads in the aquifer and yellow for the lowest. So you can look at it as if you were looking at a potentiometric surface map. The calculated hydraulic head values are shown in the center of each cell.

5. Describe where hydraulic head is highest and where it is lowest. Which direction is flow going? Where does the flow enter the aquifer?

6. (3 pts) As noted above, the aquifer dimensions are 900 ft (N-S) x 1800 ft (W-E).

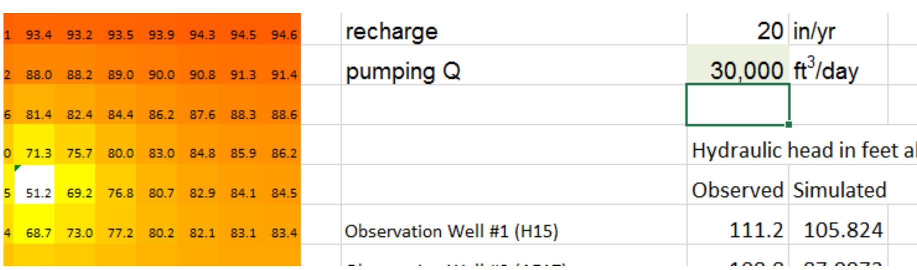
   A) If recharge is 20 inches/year, what is the total recharge (in ft^3/year) over the entire aquifer?

   B) What is the recharge in ft^3/day?

   C) Based on a steady-state water budget, what is the discharge to the stream in ft^3/day?

Now that the model is calibrated, you can simulate the effect of a new well with a pumping rate of 30,000 ft^3/day per day. Change the pumping rate in the spreadsheet and hit enter.

The pumping well is located in the white cell. You should see the hydraulic head decrease. *Note that observed and simulated values will no longer be expected to be similar. You have introduced a major change to the hydraulic heads by adding pumping.*



7. Based on the model results, would a pumping rate of 30,000 ft^3/day cause stream water to flow toward the well?

8. (4 pts) Drawdown and budget changes:
   A) How much drawdown occurs at the pumping well? (You might have to change the pumping rate back to zero to determine the hydraulic head before pumping).

   B) Given that the aquifer thickness is 50 feet, why might that amount of drawdown be unrealistic? (What would happen to your pump?)

   C) Even if this much drawdown were possible, what negative impacts could this much drawdown have on the aquifer?

   D) Look back at your steady-state water budget for the aquifer. Is a pumping rate of 30,000 ft^3/day possible without pulling stream water into the aquifer or removing water from groundwater storage?

9. Use trial and error to find the highest pumping rate (to the nearest 1,000 cubic feet per day) that can be pumped without water flowing from the stream to the well. *There should be a "groundwater divide" in between the stream and the well. On the north side of the divide, groundwater flows to the stream. South of the divide, groundwater flows to the well.*

   Highest pumping rate: ________________

10. Write a new quantitative groundwater budget for the aquifer with pumping at the rate that you determined. To balance the budget, what budget term must change?

11. This simulation was for steady-state conditions (e.g., long-term averages of recharge and pre-pumping hydraulic heads). In real life, streams have water levels that vary through time and recharge changes through time. How might those changes affect your conclusions?

12. What additional data or parameters would be needed for a transient simulation? (Hint: What information is needed to solve any transient groundwater flow problem that is not needed for steady-state groundwater flow problems?)

13. The model can help you get a general feel for the relationship between hydraulic conductivity and the shape of the cone of depression. For your optimal pumping rate, increase and decrease the hydraulic conductivity and describe how the cone of depression is affected. Does this result agree with your expectations based on Module 8?

Assignment 10: Contaminant Transport

In this assignment, you'll return to the Woburn Well G&H Superfund site where contamination was found in the water supply for Woburn Massachusetts. Following leukemia deaths and discovery of some abandoned drums, investigations attempted to determine the source(s) of the contamination.

The first part of the assignment focuses on creating contour maps showing the distribution of dissolved TCE in the Aberjona River Valley area. The second part of the assignment uses an Excel spreadsheet to calculate the rate of transport of dissolved TCE in the Aberjona River Valley aquifer. *TCE refers to trichloroethylene, which is a man-made solvent. It often acts as a DNAPL. Although there are likely TCE DNAPLs in the Aberjona River valley, the assignment will focus only on migration of* ***dissolved*** *TCE.*

Maps of concentrations from 3 different time periods are included below. The dimensions on the side are distance in feet.

1. (1 pt) Carefully review the potentiometric surface during pumping of Wells G & H shown on the next page. Discuss the flow patterns relative to the pumping Wells G & H, the Aberjona River, the Riley Well, and the three potential source sites (A, B, and C). A larger version of the map is linked here).
2. (1 pt) Wells G&H were only pumped during the summer months. How would variation of the potentiometric surface through time be expected to affect the migration of the contaminant plumes?
3. (1 pts) In Assignment 3 you constructed a geologic cross-section through the Aberjona River Valley near Wells G&H. Refer back to your completed cross-section. Discuss how you'd expect the geology of the site to influence contaminant transport. Keep in mind the role of heterogeneity in mechanical dispersion.
4. (4 pts) For each of the three maps, contour the concentrations for 10 micrograms per liter (μg/L), 50 μg/L, 100 μg/L and depending on which map is being used, possibly 500 μg/L and 1000 μg/L. When contouring, start with the highest concentrations and work downward. If you are not certain whether or not to connect two regions with high concentrations, consider groundwater flow directions.

   Many of the monitoring wells were not drilled until after 1984. The absence of monitoring well data (labeled as an NA on the 1979 through 1984 map) should be considered when interpreting the distribution of TCE and answering the questions below.

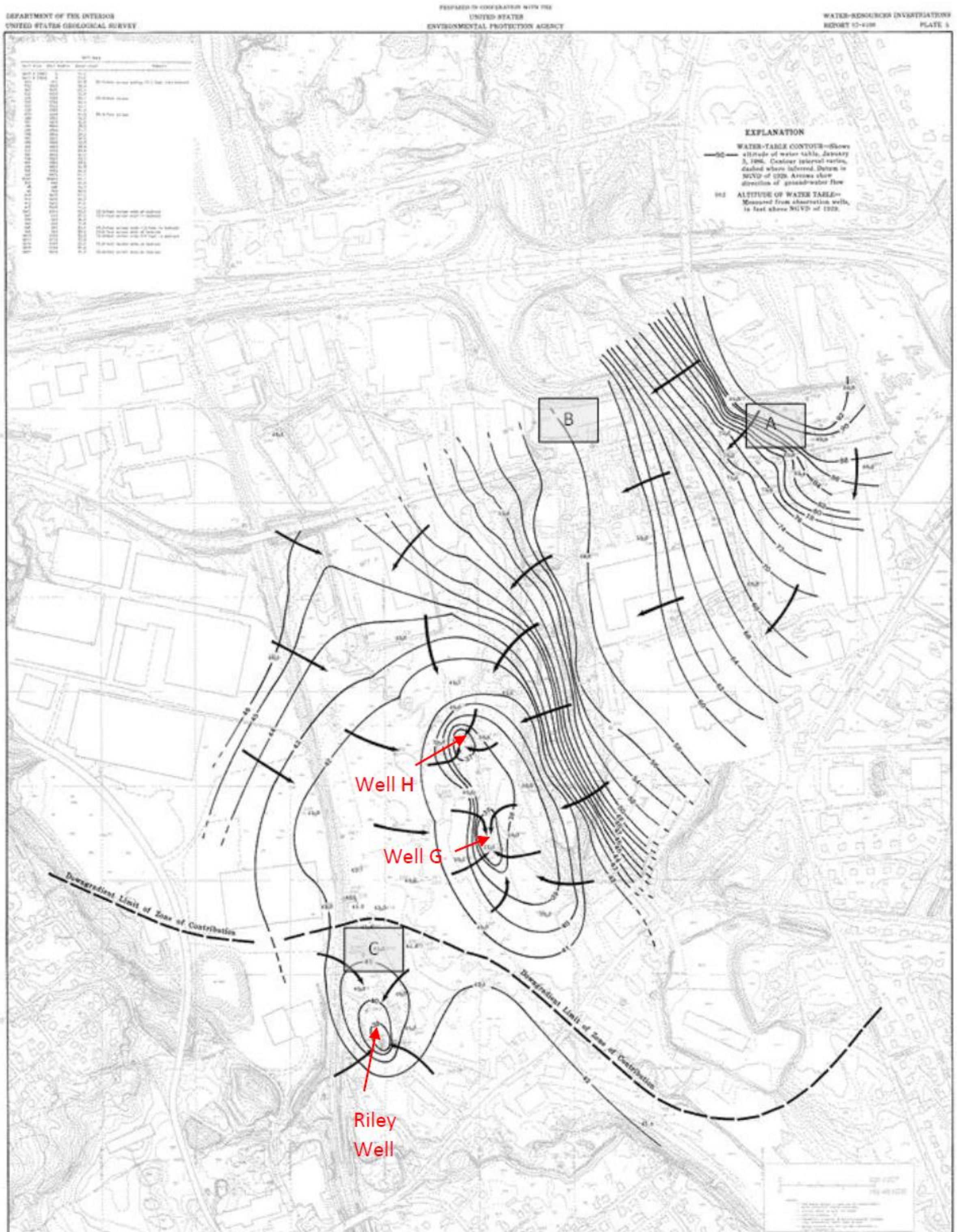
5. (4 pts) Using the contour maps, answer the following questions.

   A. Describe the locations of the highest concentrations and the distribution of TCE for each map.

   B. In early investigations and the legal trial, 3 potential groundwater sources were identified (marked A, B, and C on the map). **Based on the concentration contours**, do you agree that these are probable contamination sources? Are there other likely sources?

   C. Can you make any conclusions as to which of the three potential sources identified (A, B, and C) is most likely responsible for the contamination of Wells G&H? Can any of the three potential sources be ruled out as not at fault for contamination of Wells G&H? Explain your reasoning.

   D. If it were possible to go into the past and sample more wells, where would additional samples be most helpful? Mark the locations on the 1985-89 map and explain your reasoning.



Altitude of the water table after 30 days of pumpage from wells G and H, January 3, 1986

Part II.

This second part of the assignment demonstrates how advection, diffusion, and dispersion influence the travel velocity and concentration of a TCE plume at Woburn, Massachusetts. It is an analytical solution worksheet in EXCEL format for one-dimensional advective transport with dispersion considered. The Ogata-Banks solution (Ogata and Banks, 1961; see page 557 in your text) is embedded into the linked Excel spreadsheet to calculate concentration at a specific time.

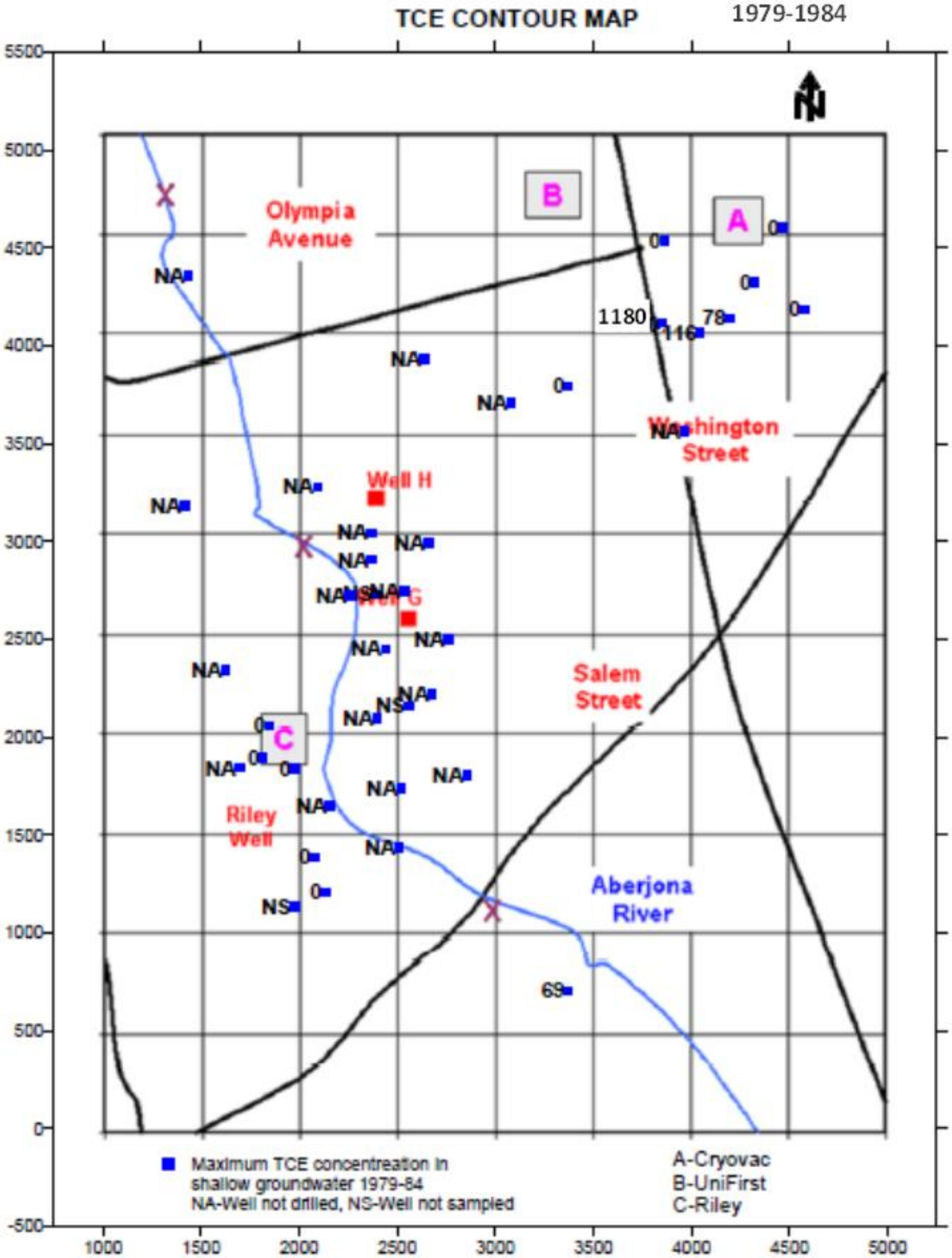
The worksheet calculates the movement of the dissolved TCE plume at 800, 1000, and 1200 feet and assumes no retardation of TCE movement (related to absorption or degradation) within the aquifer.

Download the spreadsheet.

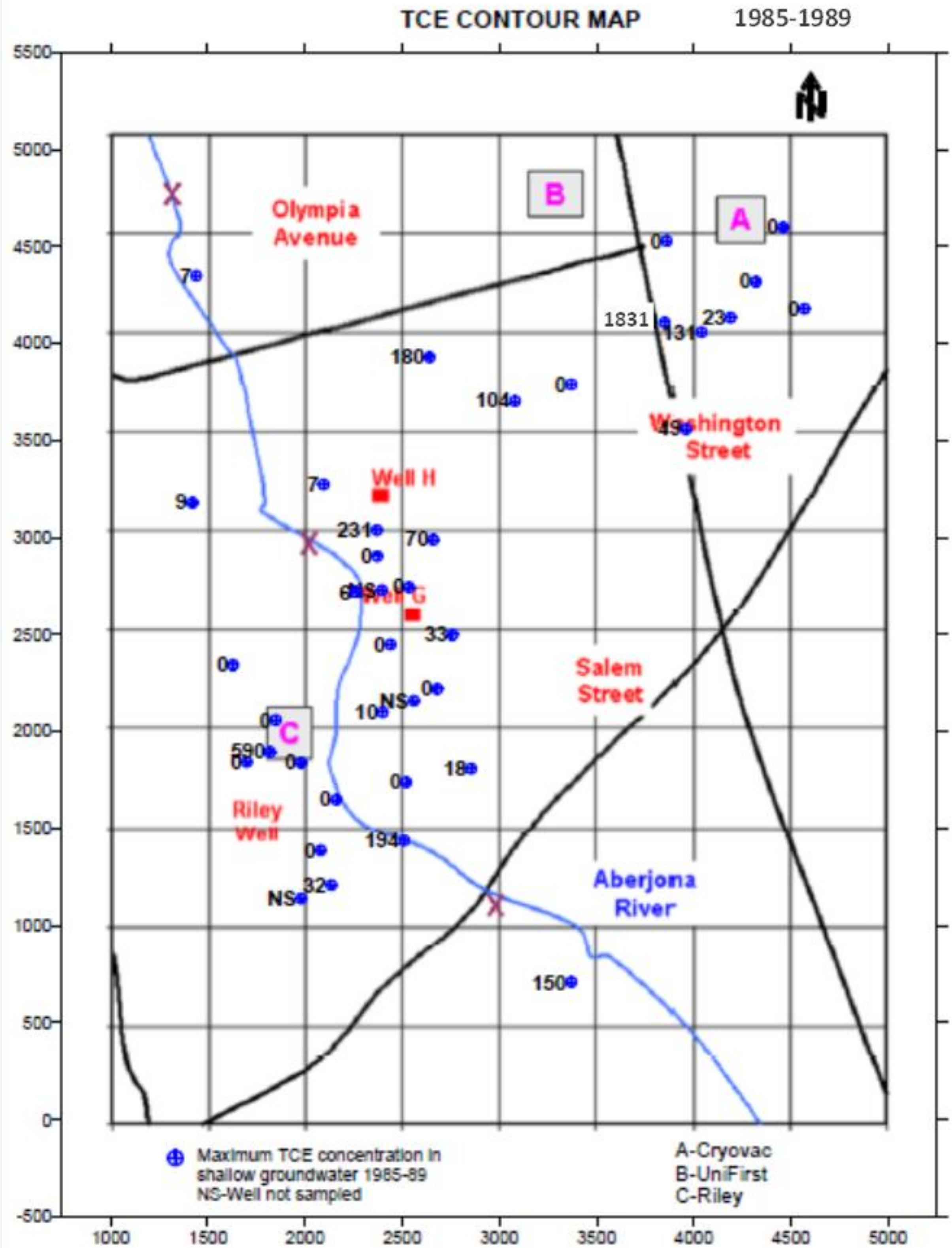
When the data are entered, the table below the input parameters will populate showing time intervals (column t), the calculated ratio for the concentration at time t per initial concentration (C/C_0) at a defined distance from the source, the concentration for a specific time t (C) at a defined distance from the source. The complementary error function is part of the calculation of the analytical solution, and is also shown. The table is repeated in three sets of columns with each set of columns representing the distances of 800 feet, 1000 feet and 1200 feet from the source. This type of calculation is valuable in estimating the time of arrival of a contamination plume from a given source. The accuracy of this time is dependent on the homogeneity of the aquifer media and how well the velocity and mechanical dispersion are known.

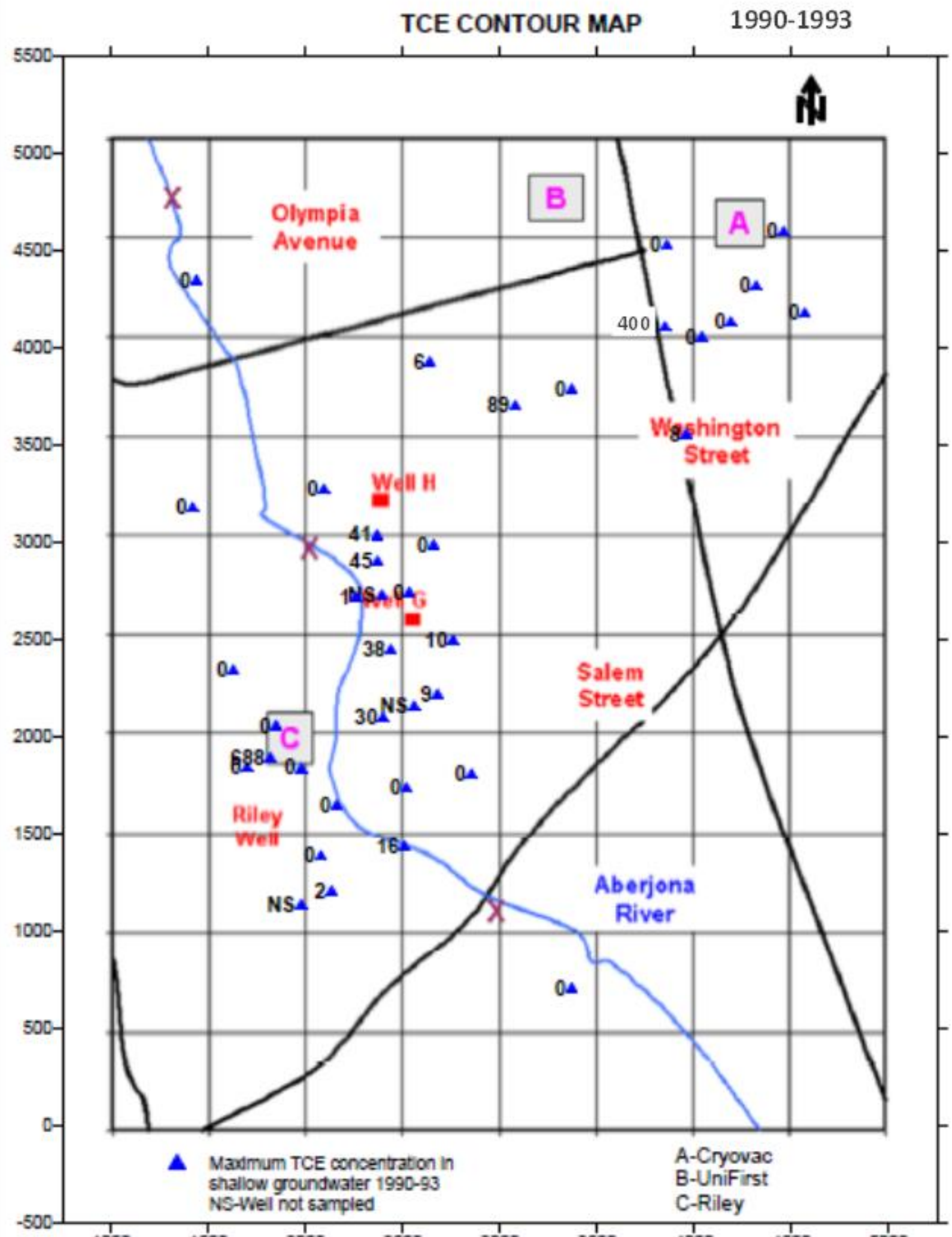
Hydrogeologic data from the unconfined aquifer underlying the Aberjona River valley at Woburn indicate that the aquifer has a hydraulic conductivity of 400 ft/d, an effective porosity of 30% (Metheny, 2004), and an average hydraulic gradient of 0.001 (Myette et al., 1982). The longitudinal dispersivity is assumed to be 25 ft. and the coefficient of molecular diffusion is assumed to be 1×10^{-6} ft^2/day. For initial concentration, use the highest concentration measured during the sampling.

6. (2 pt) According to drinking water standards, the maximum contaminant level (MCL) for TCE is 5 μg/l. How many days would it take before the MCL was exceeded at the 800 feet location, the 1000 feet location, and the 1200 feet location?
7. (2 pts) How would you expect longitudinal dispersivity, the coefficient of molecular diffusion, hydraulic conductivity, effective porosity, and hydraulic gradient to affect the shape of the concentration-time curve arrival times?
8. (2 pts) Test the effects of each, by entering different parameter values and viewing the plot. Do results agree with your expectations?
9. (2 pts) Return to the original parameters and change the distance of “x3” from 1200 ft to the horizontal distance from Source Site “A” to Well H. The scales on the sides and bottom of the maps are in feet. How long it would take concentrations near Well H to exceed the MCL after contamination was introduced at Source Site “A”?
10. (1 pts) The actual transport is 3-dimensional. Discuss how the concentration-time plots would be affected by 3D dispersion and diffusion.



TCE CONTOUR MAP
1979-1984
N
Olympia Avenue
B
A
Washington Street
Well H
Well G
Salem Street
C
Riley Well
Aberjona River
1180
116
78
69
Maximum TCE concentreation in shallow groundwater 1979-84
NA-Well not drilled, NS-Well not sampled
A-Cryovac
B-UniFirst
C-Riley


TCE CONTOUR MAP
1985-1989
Olympia Avenue
Washington Street
Salem Street
Aberjona River
Well H
Well G
Riley Well
Maximum TCE concentration in shallow groundwater 1985-89
NS-Well not sampled
A-Cryovac
B-UniFirst
C-Riley



TCE CONTOUR MAP
1990-1993
N
Olympia Avenue
Washington Street
Well H
Well G
Salem Street
Riley Well
Aberjona River
A
B
C
Maximum TCE concentration in shallow groundwater 1990-93
NS-Well not sampled
A-Cryovac
B-UniFirst
C-Riley

UNIVERSITY of FLORIDA

UCC: External Consultations

External Consultation Results (departments with potential overlap or interest in proposed course, if any)

Department
Civil and Coastal Engineering

Name and Title
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Comments

The Civil Engineering Water Resources Group faculty did not find any significant conflict between the proposed GLY 4822 Groundwater Geology and the existing Civil Engineering course CWR 4120 (Groundwater). The general consensus is that the proposed course and geological perspective will provide a useful out-of-department elective for Civil Engineering seniors.

Department

Name and Title

Phone Number

E-mail

Comments

Department

Name and Title

Phone Number

E-mail

Comments