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Portfolio for GEOL 488/888: Groundwater Geology

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PORTFOLIO FOR GEOL 488/888: GROUNDWATER GEOLOGY

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ABSTRACT

Groundwater Geology is a course that draws undergraduate and graduate students from multiple units, including the College of Arts and Sciences, Institute for Agriculture and Natural Resources, and Civil and Environmental Engineering. The course material focuses on groundwater as a resource, and includes the use of computer programming (Python programming language) to analyze groundwater data. Many students who enroll in the course are new to either geosciences or Python, despite the fact that it is an advanced course. The course has been redesigned recently to include materials suitable for a groundwater engineering course, because it is newly offered with sections listed by the Department of Civil and Environmental Engineering. This has provided opportunities for course updates, but also challenges due to the hybrid nature of engineering classes, since the department is split between two campuses. By focusing on course objectives and using backward design for assignments and assessments, the Spring 2023 student cohort was successful in mastering the course materials and made excellent strides in applying Python programming to groundwater applications.

Keywords: Hydrogeology, Environmental engineering, Applied science, Upper division, STEM

Contents

Objectives of Peer Review Course Portfolio

Key goals for course portfolio.

This portfolio is designed to demonstrate the academic rigor of Groundwater Geology across the majors and disciplines that the course serves, which include not only geosciences, but also natural resources and environmental engineering. I have also used this opportunity to connect course assignments more explicitly with course objectives and goals.

The completion of this portfolio has helped me to reorient the course for students from Civil and Environmental Engineering, for whom the class is newly available as a CIVE section at the 400 and 800 levels. This document also demonstrates my efforts in improving my teaching prior to my application for tenure and promotion.

Type of course portfolio.

This portfolio pertains to the entirety of GEOL 488/888 and crosslisted sections, providing a broad overview of the course rather than focusing on any particular aspect. There is some additional detail with respect to assessments, specifically programming and data analytics assignments and exam questions. This portfolio is not part of a larger departmental effort; however, the geology program has been discussing curriculum reforms, and has an academic program review in Fall 2023. Some findings from this portfolio are relevant to these exploits, for example to the possibility of redeveloping the water emphasis area for students interested in environmental geology, and also the possibility of making Groundwater Geology part of a menu of electives rather than a free elective.

Course Overview

Rationale for choosing this course.

My regular teaching load includes GEOL 488/888 Groundwater Geology and GEOL 106 Environmental Geology, both taught every spring, and three courses that rotate in fall semesters: GEOL 988 Groundwater Modeling, GEOL 455/855 Computational Methods for Modeling Earth Systems (co-taught with Lynne Elkins), and GEOL 372 Water in Geosciences. I selected Groundwater Geology as a portfolio focus because of the planned crosslisting with Civil and Environmental Engineering (CIVE). With the influx of engineering students to a course that previously catered to students in geology and natural resources, it is appropriate to revisit the goals and objectives for the course, to ensure that all students are getting what they need. The methods portion of the course, which focuses on programming in Python, is especially important, and relevant across disciplines. This course often draws students with a range of programming expertise, which makes it difficult to balance between challenging experienced students and bringing new programmers up to speed.

When I first designed the course in Spring 2020, there was an established Groundwater Engineering course taught in Civil and Environmental Engineering. Because of this course, I avoided some topics that are typically covered in detail in introductory hydrogeology courses, particularly analytical models. Instead, I focused almost exclusively on real-world applications, since analytical models are rarely used in practice now that advanced numerical and statistical models have become feasible. However, the Groundwater Engineering course is no longer being taught due to the professor, Yusong Li, moving into a primarily administrative position. I was asked to bring engineering students into my course in order to fill this gap, and so I have redesigned several assignments and weeks of lectures to integrate the material that I had avoided when Dr. Li was teaching her course.

This portfolio explicitly addresses two challenges. The first is that it is challenging to simultaneously teach programming and water resources. I am working to build those two proficiencies together. The second is that most students are proficient at pencil-and-paper number crunching, but have limited programming experience. I went into the semester with the intention to write more assessments that combine Python with concepts from the class, rather than being “pure” programming or hydrogeology exercises.

Description of the course.

According to the course catalog, Groundwater Geology is about the “[o]ccurrence, movement, and development of water in the geologic environment.” This course focuses on water as a resource. I teach students computer programming skills using Python for calculating natural subsurface fluxes and groundwater flow to wells. We also cover some career skills, such as introducing students to job posting sites for water management.

The class includes upper division undergraduates, master's, and PhD students. Most of the students come from outside the Earth and Atmospheric Sciences (EAS) department, especially the graduate students. Many of them have a strong background in water resources, but haven't taken many (if any) geology classes. Students are usually highly motivated for this course. Many plan to enter the workforce within the next two years, and a large proportion indicate that they plan to pursue a career in water resources. Students come from the School of Natural Resources, Environmental Studies, and increasingly from Civil and Environmental Engineering, as well as from geology. By drawing students from outside of EAS, it is a favorable offering for the department in light of the university's potential new budget model.

This course is an upper division undergraduate elective. It is part of the Hydrogeology graduate student track, so all my graduate students take it. This is also an unofficial capstone course for undergraduates who are interested in a career in water. Since water resources account for a large share of geology jobs, it is a popular course despite being an elective, attracting 11-12 students per year before being listed with a CIVE option, and 20 students with the CIVE option available in Spring 2023. It is very career-oriented in its focus on scientific applications, emphasis on programming (an important job skill), and the needs of the student population.

This course is meant to stand alone from the geology curriculum, because so many students have very little geology background. For many students it is one of the last courses they ever take before graduating. Therefore, it is very encapsulated, even from other courses that I teach.

General aims of Groundwater Geology.

Ideally, students enrolled in Groundwater Geology will have a career-oriented mindset and a focus on scientific applications to real aquifer systems. It is important for students to recognize that there are many jobs available in water resources, and that this is a common career pathway for students in geoscience, natural resources, and environmental engineering. Different disciplines and sectors have different relationships with water conservation, and tend to serve different roles in aquifer management; students should consider how their disciplinary background affects their attitudes toward groundwater as a resource. Programming and data science are increasingly important for water management in all disciplines.

Since this class focuses on water as a resource, students should leave with an understanding of how to withdraw water most efficiently from an aquifer while also grasping the potential impacts on surface water flow and quality. They should explicitly recognize tradeoffs in groundwater use both at a personal level and at a societal level; for example, the nuances of saving water through shorter showers, which saves a small amount of water at a local level, versus eating less meat, which (in the United States) saves a much larger amount of water, but in a more abstract and dislocated way. To structure the course content, I already use backward design to start with course goals and work toward assessments and lessons.

Many students in this course will be entering the workforce within the next 2 years. They need to master these goals in order to get a job and be successful in the field of water resource management, whether they go on to work in consulting, management agencies, research facilities, nonprofit organizations, or a further degree program. Students' proximity to the workforce makes them very invested in practical goals, both for getting their next job position and for the kinds of work they are likely to do in water resources jobs.

In this course, students practice skills such as writing a project scope and finding job openings in water resources, and think about how they would tailor their resume for these job openings. When we cover something that they can put on their resume (like Python), I point it out explicitly. When other professors send me openings for jobs and graduate school positions, I announce it to the class and connect the work that we are doing in class to the ways they could demonstrate proficiency in the skills that are asked for in the job advertisement. I invite guest speakers from public and private sector positions in water resources, to give a non-academic perspective on careers.

Summary of course goals.

The main goals and learning objectives for this course are as follows:

- Goal 1. Gain an understanding of how water moves in the subsurface.
  - Calculate discharge using Darcy's Law.
  - Identify the direction of flow based on head gradients.
- Goal 2. Connect geologic history of an area with distribution of water resources.
  - Connect depositional environments and rock types with aquifer distributions.
- Goal 3. Recognize tools and data sources used by the discipline.
  - Program algorithms in Python to solve analytical solutions to groundwater flow to wells.
  - Given problem parameters such as confined/unconfined, transient/steady flow, select the appropriate formula for calculating flow of water to a well.
- Goal 4. Be conversant about the role of water as an agricultural resource.
  - Articulate the importance of groundwater for irrigation.
  - Predict the impact of irrigation well withdrawals on groundwater head and surface water flux.
- Goal 5. Prepare for a career in water resources.
  - Locate job postings, including graduate school openings, in water resources.
  - Demonstrate career skills, such as structuring a resume, requesting a letter of recommendation, and reaching out to a potential advisor or supervisor.
  - Reflect on the role of project management in water resources careers.

Since this course is catering to engineering students, I have also added ABET outcomes to the syllabus. ABET is used for engineering accreditation, and includes a list of six overarching goals for training in engineering.

- ABET student outcomes addressed by the course:
  - (1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.

- (3) an ability to communicate effectively with a range of audiences.
- (6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

After taking this course, I want students to understand the utility of computer programming and the data life cycle (in the USGS sense; https://www.usgs.gov/data-management/data-lifecycle). They should be able to articulate the role of aquifer categories and parameters on the appropriateness of analytical solutions to groundwater flow to wells. Students should understand the assumptions of analytical problems, and their limitations (e.g. aquifers of infinite lateral extent). As a geology class, it is also important that students grasp the link between depositional environments and the ability of earth materials to store and transmit water. In the realm of scientific applications, students should understand the role of irrigation water demand in aquifer decline, as well as the role of aquifer decline in surface water flow. Students should also recognize opportunities to get a job in water resources.

In the long term, students should retain their knowledge of the role of project management in water resource careers. They should also recall the importance of programming for data science, even if they enter a position that does not require them to use Python. Students should remember why some types of earth materials are more suitable for water storage and transmission than others, the fact that water flows according to a gradient that is determined by elevation and pressure, and the fact that groundwater and surface water are connected. Former students should also be able to articulate the role of irrigation water demand in aquifer decline.

Teaching Methods

Pedagogical methods, course materials, and outside activities.

The primary teaching method for this class is lecture. This is largely due to constraints of hybrid teaching, first during the pandemic, and then as this class is taught synchronously at the Lincoln and Omaha campuses to accommodate engineering students from the split Civil Engineering department. By delivering traditional PowerPoint-based lectures, I am able to cover material quickly, and reinforce spoken information with visual aids. This is primarily assessed through regular assignments, the midterm, and the final exam, which all focus on the material covered in class.

There is a particular module that students complete during class time. This module, which I co-wrote, is from an online learning platform called HydroLearn. The module introduces several important concepts that are built on throughout the rest of the course. Students work together to complete the problem set that is embedded in the module. We devote two weeks to this module before Spring Break. This was originally because of an agreement as part of writing the module – the HydroLearn principle investigators were conducting Scholarship of Teaching and Learning efforts related to student learning from the modules, so module authors were required to include their modules in their courses. I have continued to use this module because I feel that it breaks up the semester and does a good job challenging the students with introductory materials.

Outside of class, students are expected to complete one group project and one solo project. The group project comes after the in-class group work, so students already have each other's contact information and a sense of who they work well with. I feel that interaction with other students is an important aspect of classroom experience. Group projects are also more authentic to the field of hydrogeology – in a professional role, students will never need exam skills, but working with groups is an essential part of day-to-day projects. For the HydroLearn module and the second group project, I hope students will learn to recognize the need for planning and communication. The logistics of group assignments are very important. I tell my students that a larger group will require more administrative effort, and I allow them to self-organize into groups so that they get practice navigating teams.

My final project assignment is a solo assignment in two stages. Mid-semester, I assign a project scope, with requirements such as a timeline and estimated time to complete each task; a summary of how their project is related to the course; and a summary of how this project will support the student's own goals. I provide detailed feedback on this scoping document, and allow students to adjust their scope – one part of the final report is a reflection on how the scope had to change once they started their project work. The scope is worth the same amount as the final project. The feedback on their project scope is the point of this entire final project assignment. Many of my students are current or future graduate students, and they usually get tasks with an implied 'scoping' step that is rarely taught or critiqued. This is a relatively low-stakes opportunity to practice this skill, unlike a thesis proposal or grant proposal. It is an incredibly valuable skill that I hope will give my students an edge when they reach the workforce.

Our regular course assignments are conducted using Python programming, because that is a skill that can go on students' resumes and translate outside of the course. I have struggled with integrating course topical information with Python, because most introductory materials in hydrogeology do not have a coding component, and it can be difficult to find an authentic problem that can be solved with a very simple beginner-level script. I am working to develop my own materials for this purpose.

Rationale for teaching methods.

I want students to focus on learning and not worry about their grades. To that end, I allow students to resubmit assignments to earn any points they miss in their first attempt, and I also give students two chances to take their exams, with their wrong answers marked in their first attempt. For some students, this is taken as a free pass to blow off my class, but most students understand my approach and appreciate the prioritization of learning, especially from their mistakes. For qualitative assignments I offer detailed feedback through Canvas, so that students can improve – even students who are already performing above my baseline expectations, since those students rarely receive in-depth comments on their work. If my classes were small, these student-centric practices would be untenable, but I am fortunate to have classes with enrolments between 10 and 30.

I have three suggested textbooks for this course. Two of them – a beginning Python programming book and a classic hydrogeology textbook – are free online. I give recommendations for chapters to read from these books, but I do not require them for Spring 2023. The third is a recommendation for students who are interested in a career in groundwater engineering, but this book is too expensive to be worthwhile for students who would not refer to it after the course. There are many free tutorials and classroom activities for hydrogeology, and as I have mentioned I also use the Groundwater Flow module from HydroLearn. I try to make my course self-contained. All PowerPoints are posted to Canvas, and lecture recordings are also available.

I expect my methods, materials, and assignments to assist students in meeting course goals in the following ways:

- The same information is accessible in a number of formats
- All course materials are available online
- I prioritize skills that are useful in hydrology careers, which helps students stay engaged
- I prioritize learning over grades, and encourage students to identify and learn from their mistakes

Illustration of changes from previous years.

Hydrogeology and engineering are very quantitative fields, with lots of job opportunities for students who major in geology or civil engineering. Since this is often the first water-focused class that a geology major takes, and many geologists end up in water-related jobs, I find the career preparation aspects to be especially important. My students tend to be very good at straightforward math tasks, but they often struggle with more open-ended assignments, so I ask them to do things like critique aquifer diagrams that we find online, to try to get them to approach materials critically. I expect that the career-mindedness of my students is very much in line with my teaching approach, and students seem to appreciate that.

I have a lot of students enroll in this course who are new to water resources, and others who have a background in water resources and are new to geology. For undergraduates, this is not a required course, so most of the students – graduate or undergraduate – are there because they are interested in a career in water resources. Since this is a 400/800 level class, most students are within a few semesters of graduating, so I try to focus on their needs for workforce preparation.

Analysis of Student Learning

Analysis of particular students and assignments.

This analysis of student data focuses on the midterm from Groundwater Geology, a course that brings together advanced undergraduates, master's, and PhD students from geology, civil engineering, and allied fields. Students may take the midterm twice, and they have the opportunity to see what they got wrong the first time they took the exam, although the correct answers are not shown. Questions are a mix of multiple choice, true/false, and select-all-that-apply; all are machine graded. The exam is worth 20% of students' final grades.

Data was downloaded for all students' exam attempts using the Canvas "Student Analysis" report generator. Student identities were anonymized. Two of the 20 students were excluded from the analysis, because one student took the exam only once, and the other got a lower score on the second attempt. These happened to be the two lowest-scoring students, and it is likely that they did not fully read the instructions for the exam. Test items that the Canvas analytics identified with a discrimination score of 0.25 or greater were highlighted in yellow (this takes into account both the initial and second attempts); then incorrect answers were highlighted in blue if students were able to improve their score in the second attempt, and orange if the score for the second attempt was the same or lower. The resulting spreadsheet is in the file "Haacker_GEOL488888MidtermData.xlsx."

This exam is open-book, open-resource, untimed, and administered via Canvas. Students are given one class period 'off' to ensure time to complete the exam. Several students remarked that they enjoyed the exam, which has many 'lateral thinking' questions and plausible distractors. For the most plausible distractors, I added comments to try to help students in their second attempt – for example, in a question where students were asked to determine the gradient in the water table, a failure in unit conversion would lead to a very unrealistic gradient of -0.6. The correct answer was -0.01. If students selected this answer in their first exam attempt (as did seven of the 18 students analyzed), they received the message "It's the world's steepest water table! But seriously, you needed to convert discharge from cubic meters per minute to cubic meters per second." All of these students were able to find the correct answer in their second exam attempt. Unit conversions were highlighted in their last homework assignment prior to the exam, since it is a practice that students struggle to remember.

Analysis of grades and grade trends.

The midterm did not assess all of the course objectives, since we still have more than half of the semester to cover additional material. I have analyzed selected objectives using targeted midterm questions below.

****

Objective 1a. Calculate discharge using Darcy's Law.

Question 17 1 pts

True or false: According to Darcy's Law, all else being equal, mercury flowing through a porous medium will have less discharge than water flowing through a porous medium. Hint: look up the viscosity and density of mercury.

○ True

○ False

11 out of 18 students got this question wrong on their first attempt, which is slightly worse than chance. Unsurprisingly, all of them got it right on their second attempt. This question did not have a discrimination factor greater than the cutoff, which indicates that the students who missed this question were not necessarily the students who performed poorly on the overall exam, which is surprising.

Students are supposed to look up the viscosity and density of mercury, calculate the fluid component of Darcy's Law: (density*acceleration due to gravity)/(dynamic viscosity), and compare with water. Mercury has a low viscosity but a *very* high density. I suspect that students attempted to answer this question using their gut feelings, which were wrong. The density and viscosity of mercury are readily available online in any units one would care to use, and students calculated the corresponding value for water in a previous assignment. Contrast Question 6, which was very similar except that it asked about whole milk rather than mercury, and, crucially, the relevant values were provided; only two students got this question wrong on their first attempt. From this I believe students have the capacity to answer this kind of question, but are unwilling to bring in outside information, even in an open-book exam.

Objective 1b. Identify the direction of flow based on head gradients.

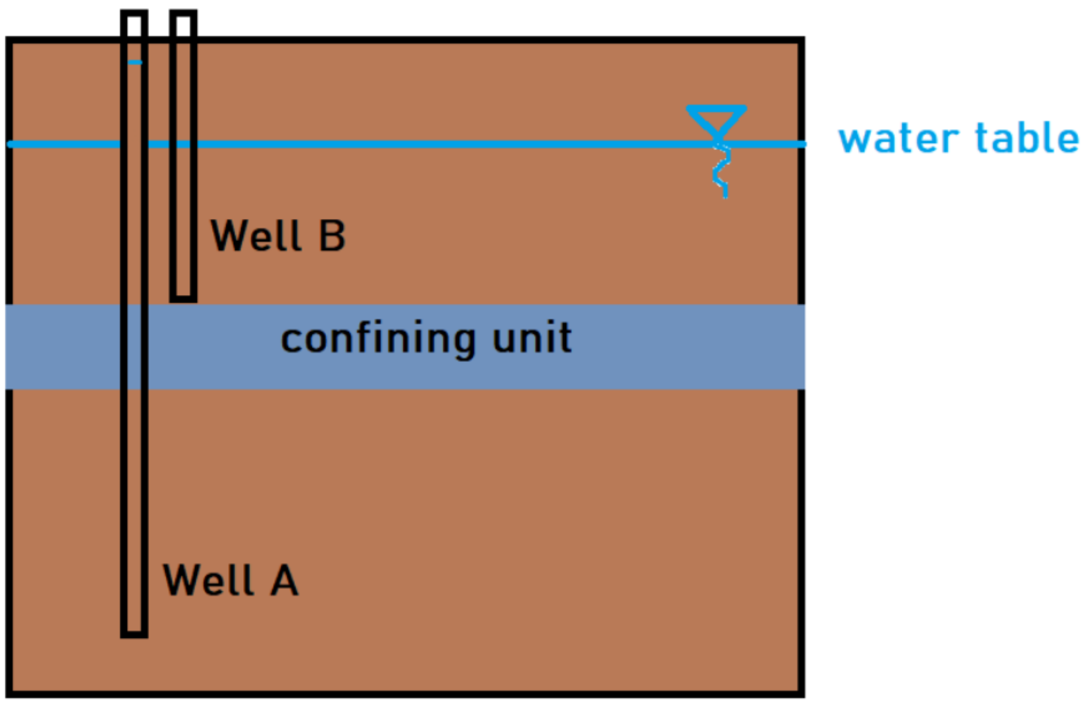
Question 32 1 pts

Well A and Well B are two piezometers that were installed very close together, but that terminate in different geologic units separated by a confining bed. Well A is deeper than Well B.

The elevation head in Well A is 75 meters, and the pressure head in Well A is 29 meters.

The elevation head in Well B is 92 meters, and the pressure head in Well B is 8 meters.

Which of the following statements is true?



- ○ Well A terminates in the saturated zone, whereas Well B terminates in the unsaturated zone.
- ○ There is an upward flow gradient from the confined to the unconfined aquifer.
- ○ The total head in Well A can't be determined because it doesn't terminate at the base of the aquifer.
- ○ Contamination in the unconfined aquifer will pose an immediate threat to the quality of the confined aquifer.

This question was identified as having a high discrimination score. The image in the question depicts a set of heads that corresponds with the question statement (i.e. higher head in the piezometer that terminates in the lower confined aquifer, which indicates a gradient from the confined aquifer to the upper unconfined aquifer). 5 students got this question wrong on their first attempt; three of those students were able to identify the correct answer on their second attempt. Thus, 16 out of 18 students ultimately arrived at the correct answer.

Flow direction in the subsurface can be unintuitive. Students must internalize the fact that groundwater flows from high head to low head, which can very well mean that water is flowing upward. This question indicates that the students who performed well on the overall exam were able to apply course information to an unintuitive (but very common) scenario; other students are still 'going with their gut' and being led astray by analogies to surface processes. A classroom demonstration might help students get a better sense of groundwater behavior.

Objective 3a. Program algorithms in Python to solve analytical solutions to groundwater flow to wells.

Question 9 — 1 pts

What does the following script do? (You can test it out using this file: new3.txt and this code, because sometimes Python is unhappy about copying and pasting into Spyder: test_.py)

```
intext = 'new3.txt'
outtext = 'AdventuresOfTheBanana.txt'

with open (intext, 'r') as f, open(outtext, 'w') as fo:
  for line in f:
    fo.write(line.replace("Robin Hood", 'The Banana'))


print('done!')
```

Hint - this will work if you save new3.txt and test_.py in the same directory, otherwise you will need to update the file paths.

- ○ Replaces all instances of "Robin Hood" in a text file with "The Banana" and saves a new file
- ○ Replaces all instances of "Robin Hood" in a text file with "The Banana" and saves over the original
- ○ Replaces all instances of "The Banana" or "the banana" with "Robin Hood" and saves a new file
- ○ The script doesn't work because "Robin Hood" is in double quotes and 'The Banana' is in single quotes

Canvas analytics identified this question as having a high discrimination score. The students who performed better on the overall exam were more able to determine the purpose of a code, either by examining the code or downloading the files and running the script. In theory, all students should have been able to get this question right – they have used Python in their assignments, and the instructions and files are in the question, so they were able to test the script and examine the cause and effect. Five students got this question wrong in their first attempt, and two persisted in choosing an incorrect answer in their second attempt.

A number of students in this course are new to programming, and several have expressed a sense of intimidation. I have tried to demystify Python, but I have moved more quickly than in previous iterations of this course, because there are also many experienced coders. Instead of spending a few weeks covering Python in class, I asked students to brush up on coding themselves if they felt they needed it, and provided a number of suggested free tutorials in different formats: a workbook, a few websites, a mobile app, and embedded tutorials in software. I interpret this as students having low bandwidth, either for doing work that won't contribute directly to their course grade, or for going out on a limb and actually downloading the files from the question and testing it themselves if they couldn't figure out what the script is doing just from looking at it. I think I should have more in-class Python practice, and perhaps a larger number of simple or extra-credit assignments that occur frequently so that students can build their competency and comfort with programming in small steps.

Goal 4a. Articulate the importance of groundwater for irrigation.

Question 30 1 pts

Which of the following is a statement of Jevons' Paradox as it applies to water resources?

- ○ Non-consumptive water use can affect water quality parameters such as temperature
- ○ Increased irrigation efficiency leads to reductions in water level decline
- ○ When you can extract water more efficiently, you will tend to use more water to produce more goods/crops, rather than saving water
- ○ Pumping technology continues improving while water resources continue disappearing

All students were able to select the correct answer for this question on their first attempt, and so there is no discrimination score for this question. The application of Jevons' Paradox to water resources is fairly new, making it more difficult for students to find this information online compared with some questions. There are other questions that came primarily from course materials that students were less successful with. I have tended to assume that students in this class are more comfortable with quantitative rather than qualitative information, but the high performance on this question suggests that they are readily grasping concepts that relate to general water management and sustainability. They are performing less well when it comes to practical calculations and groundwater behavior. It would be a good idea to include more classroom activities and demonstrations, and it looks like it will be OK to cut time from the more qualitative case studies that are more similar to the material that students are grasping very readily.

Reflection on the Course

Overall, the Spring 2023 instance of Groundwater Geology, with a mixed cohort of engineering, geoscience, and natural resources students, was a success. The logistical support from the College of Engineering was essential for the split campus setup. It was great to have students from different disciplinary backgrounds, although most of the engineers were based in Omaha and all non-engineering students were based in Lincoln; since they tended to form groups based on location, there was less interaction than I expected during group work, but they were able to see each others' presentations, and there were consistent differences in the types of information they tended to focus on.

A less successful aspect of this class was the introduction of new materials, particularly new assignments. I experienced a lot of challenging demands on my time this semester, making it difficult to design new assignments and lectures and grade student work in a timely way. I ended up removing a few of my planned assignments, which gave students less frequent coding practice. This reduced my workload, allowing me to focus on the lectures, but it meant that students were not getting as much hands-on experience and feedback. Next spring, I plan to introduce additional assignments, and possibly break the existing assignments into smaller chunks and find ways to incorporate more in-class exercises despite having more material to teach. I will assign more readings to make up for the reduction in lecture time, and possibly cut a few case studies that are less pertinent based on backward design principles. "First drafts" of assignments are generally less successful than assessments that have been modified based on trial runs, so it is not surprising that the new material was the roughest for teaching and learning; I expect to be able to integrate it smoothly into the course in Spring 2024.

The hybrid format was also a challenge, even though I have had experience before in hybrid classrooms. I have requested support to move the class to a computer lab for some class periods, which may be possible next spring. Several students had Apple computers, which are fine for the earlier programming assignments, but problematic when we reach the end of the course and start using MODFLOW. Since I teach MODFLOW in my GEOL 988 Groundwater Modeling course, I may cut that material; students struggled a great deal with the final coding assignment, despite having time in class, because so many students were unable to get their software set up to run the executable, and I wasn't able to troubleshoot the Apple operating systems. Other than that assignment, it worked fine for students to bring their own computers for in-class work.

This was the first semester in which I asked graduate students to do a project I call "Site the Well." This is a team project, although I assigned it as an individual project during the pandemic from 2020-2022. Until this semester, it was the final project for undergraduate students. This semester, I asked two teams of students to do this project during class. The project consists of a narrative and several datasets, and students are given instructions to come up with a preferred site for either an irrigation or a domestic well. This assignment brings together many aspects of the course – the application of data to a realistic problem, understanding of the important factors for well performance, teamwork, and the ability to communicate their findings in a presentation. Despite including graduate students on the teams, students still made some basic mistakes, such as giving a lot of weight to soil type, or attempting to site an irrigation well on land that is not owned by the irrigator. This suggests that students need more hands-on practice in applying basic principles to real-world situations, even though I had thought this was adequately covered in other case studies.

Overall, the suite of assignments and assessments indicate that students need more time with the course material. This will involve more hours of work for students, but also more in-class activities that provide opportunities for immediate feedback. One successful aspect of my assessments was to allow students to resubmit their work for full credit early in the semester; however, I eventually struggled to return assignments quickly, and the final assignment, which was the biggest challenge for many students, was not due until the week before finals week. I will restructure the later assignments to enable students to continue acting on their assignment feedback. This assessment-of-assessments has led to valuable insights that will improve student experience for subsequent cohorts.

The portfolio process has enabled me to incorporate big-picture goals into the day-to-day activities of the course, and help implement backward design at multiple scales (course, unit, assessment, lecture). I have also looked more critically at the formative assessments as tools for investigating student learning. This process has helped me update the course to reflect the needs of engineering students, and to think about how the assignments and exams can help verify whether student needs are met. I plan to implement these practices in this and other courses in future semesters.

Appendix: Syllabus for Groundwater Geology, GEOL 488/888 – CIVE 491/891, Spring 2023

Logistics
Tues/Thurs 9:00 AM - 10:15 AM
Dr. Erin M. K. Haacker, haacker@unl.edu
Lincoln: Nebraska Hall W213 Omaha: Peter Kiewit Institute 160

Week	Topic	Assignment	Notes
1/23	Introduction	Intro to Python	
1/30	Aquifer characteristics	Pseudocode	
2/6	Water budgets and users	Darcy's Law	
2/13	Groundwater flux & discharge		HydroLearn Module
2/20	Groundwater flux & discharge II		HydroLearn Module
2/27	Groundwater flow to wells	HydroLearn	
3/6	Guest Lecture and Review	Exam 1	March 7: Guest lecture from Mikaela Cherry
3/13	***Spring Break***		No Class
3/20	Unsaturated flow & recharge	Project Scope	
3/27	Groundwater flow to wells		
4/3	Coastal, desert aquifers; Nebraska		
4/10	Site the Well in-class challenge	Homework 4	Site the Well - in-class
4/17	Aquifer Problems and Solutions		
4/24	Groundwater models		
5/1	MODFLOW	Homework 5	
5/8	Grad presentations & review	Final Project	Presentations
5/15	Finals Week	Take-home Final Exam	Official exam time: Wed 5/17 7:30-9:30 AM

Dates planned in-person in Omaha: Jan 26; Feb 9; Feb 28; Mar 9; Mar 28; Apr 6; Apr 18; May 4

Office Hours
Ask Me Anything: TUESDAYS 12:00 Zoom, 2:30 Bessey 330

Course Description
Occurrence, movement, and development of water in the geologic environment.

Grade Breakdown
40% Homework
20% Project (different for grad students vs undergraduates)
20% Midterm
20% Final Exam

Letter grade cutoffs:

92-100% A	80-82%: B-	68-70%: D+
90-92%: A-	78-80%: C+	62-68%: D
88-90%: B+	72-78%: C	60-62%: D-
82-88%: B	70-72%: C-	>60%: F

<u>Specific goals for the course</u>
Students will:
Gain an understanding of how water moves in the subsurface.
Connect geologic history of an area with distribution of water resources.
Recognize tools and data sources used in groundwater research and management.
Be conversant about the role of water as an agricultural resource.
Prepare for a career in water resources.
ABET student outcomes addressed by the course:
(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
(3) an ability to communicate effectively with a range of audiences.
(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
Brief list of topics to be covered: Aquifer characteristics; water budgets and users; groundwater flux and discharge; groundwater flow to wells; recharge; unsaturated flow; aquifers in environments such as coastal, desert, karst; aquifers of Nebraska; Python programming and data visualization; groundwater sustainability; computational modeling of aquifer systems.

Other Course Policies
There is no assigned textbook for this course. Some readings and examples will be taken from Freeze & Cherry, available free online at fc79.gw-project.org/english, as well as other sources. Links to course readings will be provided via Canvas. Homework submission and exams, as well as course updates and announcements, will also happen through Canvas. If it's not on Canvas, does it really exist?
Class Format: This is an in-person class. Please follow university and county guidelines with respect to masks. If you can't attend in person, on request you may attend synchronously via Zoom at the usual Zoom link for the lectures (listed in the first section of this very syllabus). Asynchronous attendance may be permitted on a case-by-case basis.
Instructional Continuity Plan: By default, if in-person classes are canceled or if your instructor is sick, class will be held at the regular time at the usual Zoom link for lectures. If other changes need to be made, you will be notified via Canvas as soon as possible.
Late Work: If you request an extended deadline for an assignment, a one-week extension will be granted with no questions asked. Other circumstances will be considered on a case-by-case basis. If you are late on an assignment and you did not request a deadline extension, or if you hit the new deadline without turning in an assignment, you will lose 1 point per business day. Exams will be available on Canvas for one week; late exams will not be accepted without extenuating circumstances (talk to me). If you have a group project or presentation, synchronous participation will be expected.
Course Goals, in order of importance: 1. Support your mental and physical health; 2. Cram as many awesome groundwater facts into your brain as possible. If you have suggestions to help support these goals, please let me know.

UNL Course Policies and Resources: Students are responsible for knowing the university policies and resources found at go.unl.edu/coursepolicies:
University-wide Attendance Policy
Academic Honesty Policy
Services for Students with Disabilities
Mental Health and Well-Being Resources
Final Exam Schedule
Fifteenth Week Policy
Emergency Procedures
Diversity & Inclusiveness
Title IX Policy
Other Relevant University-Wide Policies

One last parting thought from Tom Lehrer: “Life is like a sewer. What you get out of it depends on what you put into it.”