CEE 266G Water Resource Systems Analysis

Course Syllabus
Fall 2021

Course Description

Water resources planners use computational systems engineering models to inform decisions about operations, infrastructure development, and policy. Systems models evaluate alternative decisions against performance metrics like water reliability, access, cost, electricity production, and ecosystem services under a range of hydrological and social conditions. This course will introduce computational methods used in decision-support and common applications in water resources. Focus is on applied optimization methods such as linear programming, dynamic programming, and evolutionary algorithms as well as stochastic simulation. Application areas may include: reservoir operation, environmental flow alteration, hydropower, and flood control. Attention will be given to multi-objective analysis, climate change adaptation, and equity. Assignments will involve programming in Python; some Python tutorials will be provided, but prior programming experience is recommended.

Prerequisites

CEE 166A or equivalent and some prior programming experience

Learning Objectives

After successful completion of this course, students will be able to:

- Explain the importance and limitations of systems modeling in decision support for water resources management
- Formulate conceptual water resource systems models
- Apply common simulation, optimization, and uncertainty analysis methods to common water resources management decisions
- Evaluate the adequacy and appropriateness of modeling choices
- Identify some open research areas in water resource systems analysis

Contact Information

Primary Instructor:
Prof. Sarah Fletcher (she/her): sfletcher@stanford.edu

Teaching Assistants (TA):
Ali Kashefi – kashefi@stanford.edu
Samarpreet Singh – samar89@stanford.edu

Preferred communication methods:

We will use Ed Discussion as the primary venue for questions about course logistics or asynchronous help with assignments, so that all students can benefit from the responses. Help with assignments or course material can also be addressed in office hours.

For individual questions (e.g. extension requests, class conflicts, etc.) feel free to contact the teaching team by email for individual questions or concerns. We aim to respond within 48 hours except on weekends. If you ask a general question that other students would benefit from hearing, you will be directed to post your question on Ed Discussions instead.

Office Hours

Office hours are times you can meet with your instructors to: discuss the material being covered in class, get help with assignments, ask questions, or raise concerns you might have. They are scheduled:

Jacob Castaneda – TBD
Samarpreet Singh – TBD
Prof. Fletcher – TBD

COVID Safety

All university requirements for classroom safety precautions regarding COVID-19 will be strictly enforced. This includes:

- All students and instructors are required to **wear a mask at all times**. If you need to take a sip of water, please step outside.
- **Do not come to class if you feel sick**, even with minor symptoms. All the lectures are recorded and available online, and we will be summarizing in class discussions and problem-solving activities on Canvas so you can easily make them up. I will be grading your participation, which can be virtual or in person, not attendance.
- We will check your **health check badge for entrance** to the classroom to ensure you are up to date on your weekly testing. You will not be allowed to enter if your badge is not green.
- We will be assigning fixed seating areas to reduce the number of students you are in close contact with and to enable contact tracing in the event it becomes necessary.

Compassion during Crisis

The past 18 months have been tremendously difficult. We are all doing the best we can to navigate our professional and personal obligations during an unprecedented crisis. You may be stressed about friends or family impacted by COVID, increased work or family care responsibilities, and/or financial concerns. Your health and well-being are the most important thing, now and always. This class should challenge you to grow as scientists and engineers, but never at the expense of your well-being.

I am fully committed to supporting you. I will make whatever accommodations I can to help you finish your exercises, do well on your projects, and learn and understand the class material. Under ordinary conditions, I am flexible and lenient with grading and course expectations when students face difficult challenges. Under pandemic conditions, that flexibility and leniency is intensified. If you tell me you're having trouble or feeling behind, I will not judge you or think less of you. I hope you'll extend me the same grace.

If you or someone you know is feeling overwhelmed, depressed, and/or in need of support, services are available. You can learn more about the broad range of confidential mental health services available on campus here: https://vaden.stanford.edu/caps-and-wellness/counseling-and-psychological-services-caps

Course Structure

This course is scheduled from 3:15 – 4:45 pm on Tuesdays and Thursdays. We will be using a ***flipped classroom approach***.

Asynchronous lectures:
Lectures will be recorded and posted on Canvas in advance of class to watch at your convenience. Lectures will total approximately 1.5 hours each week, broken into 20-30 min segments. Students are expected to watch the lectures and do required reading ***before class on Tuesday*.**

In person class time:
Class time will be used for: Q&A from the lectures, interactive coding demonstrations, discussion questions, and problem solving in small groups. Additionally, about half of the in-person class time will be reserved for student to start working on homework assignments, with the instructor team available for support.

Why a flipped classroom?
A flipped classroom allows us to focus our time together on learning methods where interaction is most beneficial. Because lectures are a one-way teaching strategy, we don't need to be together when you watch them. This approach has been widely demonstrated in the scientific literature to improve learning outcomes. By reserving class time for homework assignments, watching lectures in advance will not increase the total time students spend on the class.

Additionally, given the uncertainties of the pandemic, there is a real possibility that the class will need to move online mid quarter or that some participants will need to quarantine. The flipped classroom approach will ensure that the class is accessible remotely if necessary.

Course Materials

In order to ensure class material are accessible to all students without posing a financial burden, all of the readings and software tools used in this class are available free of charge.

Required Texts:
The following textbook is required reading for this class. It is available online for free.

Loucks, D.P., & Van Beek, E. (2017). Water Resources Systems Planning and Management: An Introduction to Methods, Models and Applications. https://link.springer.com/book/10.1007/978-3-319-44234-1

Additional required readings will be posted on Canvas.

Required Computing Software:
In this course, coding examples and support will be provided in Python. Students are welcome to use R or MATLAB to complete assignments if they prefer, but the teaching team will not provide programming support for languages other than Python.

If you do not have Python installed on your computer, we recommend you install it from anaconda: https://www.anaconda.com/download/

Course Management Systems

Canvas: This course will be facilitated online through Canvas. All readings, lectures, assignments, and other course material will be posted on Canvas and organized into weekly modules. Our course Canvas page is here.

Ed Discussions: We will use Ed Discussions, a discussion board integrated with Canvas, for asynchronous Q&A and discussion. You can access our Ed Discussion page directly from our class Canvas page.

Gradescope: We will be using Gradescope, which allows us to provide fast, consistent, and accurate feedback on your work. Homework will be submitted through our Gradescope page. As soon as grades are posted, you will be notified immediately so that you can log in and see your feedback. You may also submit regrade requests within two weeks of receiving your grade if you feel we have made a mistake.

Course Schedule

This schedule is a guide for the course and is subject to change with advance notice. This is a new class, so it is likely some changes will be necessary over the course of the quarter.

Week	Topics	Assignments
9/20	**Motivation**: Why model water resource systems? **Class Policies** **Python Tutorial**	
9/27	**Systems Modeling Concepts**: Role in decision-making; simulation vs. optimization; performance metrics and objectives; conceptual model development; calibration and validation; parsimony; uncertainty	HW 1: Python tutorial due 9/27
10/4	**River Basin Simulation 1**: Water balance; discrete event simulation; water supply and allocation applications	HW 2: Modeling Concepts Reflection due 10/4
10/11	**River Basin Simulation 2**: Model evaluation; applications in hydropower, flooding, environmental flows **Intro to Optimization:** Origins in calculus; local vs. global minima; problem formulation	
10/18	**Linear programming:** Problem formulation; Lagrange multipliers; simplex algorithm; examples in allocation, crop choice, groundwater	HW 3: River Basin Simulation due 10/18
10/25	**Dynamic programming:** Planning vs. management; closed loop vs. open loop; Bellman equation; backwards recursion; applications in reservoir operations	Quiz 1: 10/26 HW 4: Linear programming due 10/29
11/1	**Evolutionary algorithms:** Simulation-based optimization; multi- vs. single objective; search algorithm basics	Project Proposal due 11/4
11/8	**Uncertainty Analysis:** scenarios, Monte Carlo simulation; sensitivity analysis; stochastic and robust optimization	HW 5: DP and EAs due 11/11
11/15	**Equity:** Value-laden nature of model design; participatory modeling; equity metric design; examples in river basin planning, urban water affordability	Quiz 2: Optimization 11/16
11/22	**Thanksgiving Break – No Classes**	
11/29	**Project Presentations**	Projects due 12/3

Course Policies

Grade Breakdown

Participation/Attendance	10%
Problem Sets	40%
Quiz (higher score)	13%
Quiz (lower score)	7%
Group Project	30%

Quizzes

There are two quizzes that together comprise 20% of your grade. I will weight whichever one you score higher on twice as much as the lower grade. The problems will be very similar to homework questions. I am including them as a form of individual assessment since I encourage you to work in groups for problem sets.

Both quizzes are take-home. You will have 1.5 hours to complete each quiz, but you will have a window of two days in which you can open the exam and complete it within the 1.5 hours. I expect you will only need 30 min. The time starts when you open the quiz in Gradescope. If you foresee or encounter extenuating circumstances that would not allow you to complete the exam within the limit or before the deadline, please contact me as soon as possible.

Late Policy

I understand that you are all adults balancing many responsibilities and issues come up. Please reach out to me by email if you anticipate needing an extension for an assignment. Requests should be made before the assignment due date. Unless you receive permission for an extension, you will be docked 20% of the maximum possible points for each late day.

Group Project

The group project is an opportunity to apply methods we learn in class to a real-world water resources management problem. Details about the project expectations will be posted on Canvas.

Participation

Your participation grade will be based on your attendance, engagement in class discussions and problem-solving sessions during in-person class sessions, and participation on our class discussion board. You are expected to participate in discussion at least once a week; this can be in person or on the discussion board as

suits you. Remember that engagement means not only sharing your ideas but also listening and responding to what others have to say.

Expectations

You are expected to treat your classmates, the teaching team, and yourself with respect at all times, both in and out of the classroom, and in writing (over email, on discussion boards). Your success in this course will be enhanced if you: are prepared for active participation, having watched the pre-recoded lectures and read the assigned readings; ask questions about any material you don't understand (in-class or on the course Discussion Board); contribute your ideas to discussions and problem-solving sessions.

You can expect that we, the teaching team, will facilitate a respectful and inclusive learning environment, both in and out of the classroom. You can expect that we will post course materials in a timely fashion and be available for consultation during office hours and over email (we will respond within 48 hours). You can expect that we will provide opportunities for you to give us (anonymous) feedback during and at the end of term.

Justice, Equity, Diversity, and Inclusion

Justice, equity, diversity, and inclusion are central to our work in the classroom and beyond. I echo the Civil and Environmental Engineering department's statements on diversity and inclusion https://cee.stanford.edu/our-culture/diversity-equity-inclusion :

> *As a Civil & Environmental Engineering community, our mission to advance education and research in engineering the built and natural environment is inextricably tied with environmental issues, and therefore, racial and social issues. We want to encourage each member of the CEE community to continue to grow, listen, learn, and reflect. We must also recognize how the field of engineering has historically failed to prioritize the value of diversity in experience, and work to change that.*

Diversity is a source of strength, creativity, and innovation for Stanford. We value the contributions of each person and respect the profound ways their identity, culture, background, experience, status, abilities, and opinion enrich the university community. We commit ourselves to the pursuit of excellence in teaching, research, outreach, and diversity as inextricably linked goals.

It should go without saying that in this classroom Black Lives Matter. For resources on dismantling anti-Black racism in academia, please see: https://www.particlesforjustice.org and https://shutdownstem.com.

Land Acknowledgment

We acknowledge that Stanford sits on the ancestral and unceded land of the Muwekma Ohlone Tribe comprised of all known surviving American Indian lineages of the San

Francisco Bay region traced through Missions Dolores, Santa Clara, and San Jose and that were also members of the historic Federally Recognized Verona Band of Alameda County. Consistent with our values of community and diversity, we have a responsibility to acknowledge benefit from use and occupation of this land and to honor and make visible the university's historic and ongoing relationships to Native peoples.

The field of stochastic hydrology and its use in water resources engineering is inextricably linked to infrastructure development that has displaced Indigenous peoples and harmed endangered fish species of importance to Indigenous communities. As one example, you can learn more about the impacts of California's Shasta Dam on the Winnemem Wintu Tribe here: https://mavensnotebook.com/2020/04/08/the-shasta-dam-raise-project-history/

To learn about other places of significance to you or land acknowledgements in general, please see: https://native-land.ca.

Academic Integrity

It is expected that you and I will follow Stanford's Honor Code in all matters relating to this online course. You are encouraged to virtually meet and exchange ideas with your classmates while studying and working on homework assignments, but you are individually responsible for your own work and for understanding the material. You are not permitted to copy or otherwise reference another student's homework or computer code. Compromising your academic integrity may lead to serious consequences, including (but not limited to) one or more of the following: failure of the assignment, failure of the course, disciplinary probation, suspension from the university, or dismissal from the university.

You, as students, are responsible for understanding the University's Honor Code policy and must make proper use of citations of sources for writing papers, creating, presenting, and performing their work, taking examinations, and doing research. For tips on how to uphold the honor code in an online learning environment, read these recommendations. If you have any questions regarding this policy, please contact me.

Academic Accommodation

I am committed to making this class accessible for all students, including upholding all university disability policies:

> *Students who may need an academic accommodation based on the impact of a disability must initiate the request with the Office of Accessible Education (OAE). Professional staff will evaluate the request with required documentation, recommend reasonable accommodations, and prepare an Accommodation Letter for faculty dated in the current quarter in which the request is being made.*

Students should contact the OAE as soon as possible since timely notice is needed to coordinate accommodations. The OAE is located at 563 Salvatierra Walk (phone: 723-1066, URL: http://oae.stanford.edu).

Additionally, I recognize that accessibility needs may arise that are not explicitly covered by these policies. You are invited to contact me directly to discuss any situation that impacts your ability to engage with this course and how I can best support you and your learning.

Course Material Copyrights

I share with you Stanford's statement on copyright of course materials:

The materials provided to you for this course are copyrighted or licensed to Stanford University. Stanford grants you a limited license to use the materials solely in connection with the course for your own personal educational purposes. Any use of the materials outside of the course may be in violation of copyright law. You agree that you will not post, share or copy the materials. You agree that you will only save the materials for the duration of the course.

Penalties for copyright infringement can be harsh. Fines of up to $150,000 in civil statutory damages may apply for each separate willful infringement, regardless of the actual damages involved. Stanford may also take administrative action against copyright infringement, including loss of networking privileges and SUNet ID, or disciplinary action up to and including termination for faculty and staff, and expulsion for students.

Proceeding with this course indicates that you have read the above statement, agree to be bound by its terms and you agree to delete course materials on the earlier date of 14 days from the conclusion of the course or 14 days after withdrawing from the course.