CEE 5390 Urban Water Sustainability

The Charles E. Via, Jr. Department of Civil and Environmental Engineering
Virginia Polytechnic Institute and State University
Spring Semester, 2021

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Course Description

Catalog Description: Climate change and the supply of freshwater. Coupled socio-hydrologic feedback loops (systems dynamics models) and implications for water systems resilience. Urban water transitions theory and the evolution of water systems through time. Water productivity. Stormwater capture/reuse, green stormwater infrastructure, and ecosystem services. Decentralized water and wastewater treatment systems. Emphasis is placed on the social (equity), environmental, and technological context in which urban water systems operate. Advanced statistical computing is used to quantitatively explore urban water systems challenges. (3H, 3C)

Prerequisites: Graduate standing

Textbook (Required): David Sedlak, *Water 4.0: the Past, Present, and Future of the World's Most Vital Resource*, Yale University Press (2014);

Other reading: Additional reading material (peer reviewed journal articles) will be available for download through Canvas.

Course notes: Lecture notes will be available periodically through Canvas.

Educational Objectives

Having successfully completed this course, the student will be able to:

1. Critique methods to improve urban water system resilience
2. Diagram urban water systems using systems dynamics models and identify common systems configurations
3. Quantitatively evaluate systems dynamics models and interpret their results
4. Debate the relative merits of centralized and distributed water infrastructure
5. Define and calculate urban water productivity at different spatial scales
6. Create causal chain diagrams using ecosystem services principles and quantitatively evaluate them
7. Compare and contrast the historical and present roles of urban water infrastructure in the environmental justice movement
8. Apply advanced statistical computing to evaluate coupled systems of equations, perform network analysis and develop Bayesian Belief Network models

Topics and Reading Assignments (*subject to modification*)

Module 1 - Lectures 1-4: Urban water systems from Ancient Rome to modern-day Los Angeles and Melbourne.

Lecture 1: Overview of the Class and Water 1.0

Lecture 2: Water 2.0
Reading: Water 4.0 (ch 1-4)

Lecture 3: Water 3.0 and 3.1
Reading: Water 4.0 (ch 5 and 6)

Lecture 4: Hydrosocial Contracts and the Water Sensitive City
Reading: Wong, T.H.F. and Brown R.R. (2009) "The Water Sensitive City" Water Science and Technology, 60.3.

Module 2 - Lectures 5-11: Feedback loops, alternative steady states, regime shifts, and coupled human-natural systems.

Lecture 5: Feedback Loops, Alternative Steady States, and Regime Shifts (Conceptual)
Reading: Beisner et al., (2003) "Alternative Stable States in Ecology" Front Ecol Environ; 1(7): 376–382
Reading: Mirchi et al., 2012. Synthesis of System Dynamics Tools for Holistic Conceptualization of Water Resources Problems. *Water Resources Management*. 26: 2421-2442.

Lecture 6: Feedback Loops, Alternative Steady States, and Regime Shifts (Computational)
Reading: May, R. M. Thresholds and breakpoints in ecosystems with a multiplicity of stable states. Nature. 269 471-477.

Lecture 7: Introduction to R as a coding platform for evaluating feedback loops & alternative stable states
Reading: none for this lecture
NO QUIZ

Lecture 8: **In-class coding exercise**: using R to evaluate feedback loops and alternative stable states
Reading: none for this lecture (must download R prior)
NO QUIZ

Lecture 9: Feedback Loops that lead to societal collapse
Reading: Turner, B.L.; Sabloff, J.A. (2012) "Classic Period collapse of the Central Maya Lowlands: Insights about human-environment relationships for sustainability" Proceedings of the National Academy of Sciences, USA, 109(35), 13908-13914;

Lecture 10: Breaking positive feedback loops: the water sensitive city
Reading: Low, K.G. et al. (2015) "Fighting Drought with Innovation: Melbourne's response to the Millennium Drought in Southeast Australia", WIRES Water, doi:10.1002/wat2.1087.

Lecture 11: Socio-Hydrology (Guest Lecture)
Reading: Baldassarre, G.D. et al. (2013) "Socio-hydrology: conceptualizing human-flood interactions" Hydrol. Earth Syst. Sci. 17, 3294-3303.

Module 3 - Lectures 12-18: Challenges facing urban water systems.

Lecture 12: Hydrologic and Water Quality Problems arising from Urbanization
Reading: 112 -163 of Water 4.0 (ch 7 and 8)

Lecture 13: The Urban Stream Syndrome
Reading: Askarizadeh et al. (2015) "From Rain Tanks to Catchments: Use of Low-Impact Development to Address Hydrologic Symptoms of the Urban Stream Syndrome" Environ. Sci. Technol. 49, 11264-11280;

Lecture 14: Water Security Challenges
Reading: Hoekstra et al., 2018. Urban water security – A review. Environmental Research Letters 13, 053002.

Lecture 15: Equity and Urban Water Systems
Reading: Vanderwarker, A. Water and Environmental Justice (ch 3). A 21st Century US Water Policy. pp. 1-39.

Lecture 16: Tools for Assessing Equity in Systems Management: Network analysis (key concepts)
Reading: Ch 2 of Jackson (Social and Economic Networks)

Lecture 17: Network analysis (siting and design archetypes)
Reading: Schifman et al., 2017. Situating Green Infrastructure in Context: A Framework for Adaptive Socio-Hydrology in Cities. Water Resources Research

Lecture 18: **In-class coding exercise:** performing network analysis using R
Reading: none for this lecture
NO QUIZ

Module 4 - Lectures 19-23: Hard Path and Soft Path solutions for satisfying urban water demand. (*Key Concepts: Water productivity; Hard vs Soft path; Green vs Grey*)

Lecture 19: Water Productivity
Reading: Grant, S.B. et al. (2012) "Taking the 'Waste' out of 'Wastewater' for Human Water Security and Ecosystem Sustainability" Science 337, 681-685;
Reading: Water 4.0 pp 187-216 (ch 10)

Lecture 20: Hard vs Soft Path Solutions
Reading: Gleick, P.H. (2003) "Global Freshwater Resources: Soft-Path Solutions for the 21st Century" Science 302, 1524-1528.
Reading: pp 217-237 of Water 4.0 (ch 11)

Lecture 21: Natural Treatment Systems (Constructed Wetlands and Stormwater Bioretention)
Reading: A Handbook of Constructed Wetlands, Volume 5, Stormwater. Ch 3 pp. 13-31
Reading: Payne et al., 2018. Which species? A decision-support tool to guide plant selection in stormwater biofilters. Advances in Water Resources 113 (2018) 86–99

Lecture 22: Economic incentives for urban water reform (the soft path for water)
Reading: pp 164-186 of Water 4.0 (ch 9)

Lecture 23: Rain Garden Walk – (recognizing NTS in-situ)
Reading: none for this lecture
NO QUIZ
Blacksburg walk led by Dr. Rippy; NCR walk led by Dr. Grant

Module 5 - Lectures 24-28: Ecosystem services (co-benefits) and disservices of natural and engineered ecosystems for managing stormwater

Lecture 24: Ecosystem Services Assessment – FEGS, FFES, and Concept Maps
Reading: Final Ecosystem Goods and Services Classification System
FEGS-CS pp. 1-35. https://gispub4.epa.gov/FEGS/FEGS-CS%20FINAL%20V.2.8a.pdf

Lecture 25: From Concept Maps to Bayesian Belief Networks
Reading: Landuyt et al., 2017. Bayesian Belief Networks. Ch 4.5 of Mapping Ecosystem Services.

Lecture 26: **In-class coding exercise**: Bayesian Belief Networks using R
Reading: none for this lecture
NO QUIZ

Lecture 27: The value of urban nature
Reading: Keeler et al., 2019. Social-ecological and technological factors moderate the value of urban nature. Nature Sustainability. https://doi.org/10.1038/s41893-018-0202-1

Lecture 28: Perception and human wellbeing
Reading: Smith et al., 2013. Relating ecosystem services to domains of human well-being: Foundation for a U.S. index. Ecological Indicators

Class Wrap-up
Lecture 29: A different tomorrow
Reading: pp 238 – 281 Water 4.0 (ch 12-13)

GRADING POLICIES

Course Grade:

Take-Home Projects – Module-based (3) 30%
Short Quizzes (daily, except when noted).................... 50%
Final Exam.................... 20%
Participation (in-class coding exercises & lectures) ....up to 2% extra credit

Take-Home Projects (Module-based and Comprehensive)

At the graduate level, three take-home projects will be assigned for the course (e.g., for Modules 2, 3, and 5). Project prompts (and due dates) will be made available on Canvas. Completed projects should be submitted online (through Canvas), and must be turned in by midnight on the due date. Late projects will be penalized by 1/2 letter grade for each day they are late.

You may work with other students on your take-home projects. However, each student must prepare their own diagrams, writing, assessment, and other work for each assignment. You may not copy another student's work. Duplicate assignments will result in an F on the project for both parties.

Quizzes (total of 21: final quiz scores will be calculated from the top 18 quizzes for grad students)

Short quizzes on the required reading (10 multiple choice questions) will be given at the end of each lecture (unless otherwise indicated). These quizzes will be closed book and implemented online in Canvas. You will need to bring a laptop, smartphone or other device through which you can access Canvas in order to take the quizzes. Quizzes will open automatically 15 minutes before class ends and time out automatically when class is over. **The password to access each quiz will be given prior to starting the quiz.** If you miss a quiz or do not finish a quiz in time you will not have the opportunity to make up that quiz. The missed quiz will count towards the 3 quizzes that are not included in your final quiz score.

Final Exam

The final exam will be closed book and comprehensive. It will focus on material covered in lecture, which closely follows the assigned reading. 60% of the exam will be questions pulled directly from quizzes and the remainder will be new questions based on course material. The final will be implemented in Canvas, and therefore you will need to bring a laptop, smartphone, or other device through which you can access Canvas in order to take the Final.

Participation extra credit

Up to 2% extra credit in the course can be obtained through participating in lecture (asking questions, being involved in discussions) and participating in class-coding exercises (participation will be assessed through completed codes turned in at the end of lecture)

COURSE POLICIES

Principles of Community: The Virginia Tech Principles of Community are intended to increase access and inclusion and to create a community that nurtures learning and growth for all of its members. They are defined at: inclusive.vt.edu

Honor Code: All students must adhere to the Honor Code Policies of Virginia Tech. For information about the Graduate Honor System of Virginia tech, please visit graduateschool.vt.edu/academics/expectations/graduate-honor-system.html. Any suspected violations of the Honor Code (plagiarizing published work, copying another student's work, cheating on exams, etc) will be promptly reported to the honor system. Honesty in your academic work will develop into professional integrity. The faculty and students of Virginia Tech will not tolerate any form of academic dishonesty.

Attendance Policy: Daily attendance is expected and required to receive credit for in-class quizzes. Participation during lecture is encouraged, and worth up to 2% extra course credit.

Accommodations: Students are encouraged to address any special needs or accommodations with me during the first two weeks of the semester, or as soon as you become aware of your needs. Those seeking accommodations based on disabilities are required to obtain a Faculty Letter from the Services for Students with Disabilities office in Lavery Hall (www.ssd.vt.edu/).

If you have emergency medical information to share with me, or if you need special arrangements in case the building must be evacuated, please make an appointment with me during the first two weeks of the semester or as soon thereafter as you become aware of the need.