CIVIL AND ENVIRONMENTAL ENGINEERING

Contact Information

Civil and Environmental Engineering
https://cee.rice.edu/
204 Ryon Lab, MS 318
713-348-4949

Jamie Ellen Padgett
Department Chair
jamie.padgett@rice.edu

Civil and Environmental Engineering (CEE) is an exciting field of study in which students build the fundamental knowledge and contextual sensitivity to engineer solutions that address some of the world's most pressing problems—sustainable cities and systems, clean water and air, safe and smart structures, resilient infrastructure, climate risk management, and adaptation. The most flexible degree options are at the bachelor's level, where students can pursue either the Bachelor of Science in Civil Engineering (BSCE) degree, the Bachelor of Science in Environmental Engineering (BSEnvE) degree, or the Bachelor of Arts (BA) degree. The more scientific BSCE and BSEnvE degrees include four areas of specialization while the BA, with its two distinct major concentrations, affords students more flexibility, including the possibility to complete a double major with any other Rice University major. The department also oversees the interdisciplinary minor in Energy and Water Sustainability (https://ga.rice.edu/programs-study/departments-programs/engineering/energy-water-sustainability/).

At the graduate level, the department offers one non-thesis graduate degree, the Master of Civil and Environmental Engineering (MCEE), to students who desire additional education and specialization in the practice of civil engineering or environmental sciences and engineering. Students admitted for graduate study leading to a Master of Science (MS) or Doctor of Philosophy (PhD) degree must complete a rigorous course of study that combines advanced coursework with scholarly research culminating in the public defense of a written thesis. Graduate research is carried out in a range of areas reflecting the interests of the department's faculty. Examples include environmental engineering, data science, sustainable materials, structural engineering and mechanics, infrastructure reliability, hydrology, water resources and water quality management, air pollution and its control, and hazardous waste treatment.

Bachelor's Programs

- Bachelor of Arts (BA) Degree with a Major in Civil and Environmental Engineering
  - and a Major Concentration in Civil Engineering (https://ga.rice.edu/programs-study/departments-programs/engineering/civil-environmental-engineering/civil-environmental-engineering-ba-civil-concentration/)
  - and a Major Concentration in Environmental Engineering (https://ga.rice.edu/programs-study/departments-programs/engineering/civil-environmental-engineering/civil-environmental-engineering-ba-environmental-concentration/)
- Bachelor of Science in Civil Engineering (BSCE) Degree (https://ga.rice.edu/programs-study/departments-programs/engineering/civil-environmental-engineering/civil-engineering-bsce/)
- Bachelor of Science in Environmental Engineering (BSEnvE) Degree (https://ga.rice.edu/programs-study/departments-programs/engineering/civil-environmental-engineering/environmental-engineering-bsenve/)

Minor

- Minor in Energy and Water Sustainability (https://ga.rice.edu/programs-study/departments-programs/engineering/energy-water-sustainability/energy-water-sustainability-minor/)

Master's Programs

- Master of Civil and Environmental Engineering (MCEE) Degree (https://ga.rice.edu/programs-study/departments-programs/engineering/civil-environmental-engineering/civil-environmental-engineering-mcee/)
- Master of Science (MS) Degree in the field of Civil and Environmental Engineering (https://ga.rice.edu/programs-study/departments-programs/engineering/civil-environmental-engineering/civil-environmental-engineering-ms/)

Doctoral Program

- Doctor of Philosophy (PhD) Degree in the field of Civil and Environmental Engineering (https://ga.rice.edu/programs-study/departments-programs/engineering/civil-environmental-engineering/civil-environmental-engineering-phd/)

Department Chair

Jamie Ellen Padgett

Professors

Pedro J. J. Alvarez
Philip B. Bedient
Daniel Cohan
Reginald DesRoches
Leonardo A. Dueñas-Osorio
Menachem Elimelech
Qilin Li
Satish Nagarajaiah
Jamie Ellen Padgett
Pol D. Spanos
Mason B. Tomson

Associate Professors

Shihong Lin
Lauren Stadler

Assistant Professors

James Doss-Gollin
Bezawit Getachew
Kai Gong
Avantika Gori
Larissa Novelino

Xinwu Qian
Sang-ri Yi

Professors Emeriti

Ahmad J. Durrani
Ronald P. Nordgren

Assistant Teaching Professors

Kalil Erazo
Jorge Loyo

Professors in the Practice of Civil Engineering

Joseph Cibor
Edmund P. Segner III
Carol Haddock

Professor in the Practice of Environmental Law

James B. Blackburn

Lecturers

Philip C. deBlanc
Charles Irvine
Nestor Rubiano-Benavides

Joint Appointments

Sylvia Dee
Michael S. Wong
Noemi Vergopolan

For Rice University degree-granting programs:
To view the list of official course offerings, please see Rice's Course Catalog (https://courses.rice.edu/admweb/!SWKSCAT.cat?p_action=cata).
To view the most recent semester's course schedule, please see Rice's Course Schedule (https://courses.rice.edu/admweb/!SWKSCAT.cat).

Civil and Environmental Engineering (CEVE)

CEVE 100 - AP/OTH CREDIT IN ENVIRONMENTAL SCIENCE
Short Title: AP/OTH CREDIT ENVIRON SCIENCE
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Transfer
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Description: This course provides credit for students who have successfully completed approved examinations, such as Advanced Placement exams. This credit counts toward the total credit hours required for graduation.

CEVE 101 - FUNDAMENTALS OF CIVIL AND ENVIRONMENTAL ENGINEERING
Short Title: FUNDAMENTAL OF CIVIL & ENVIR
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hour: 1
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Description: Civil and Environmental Engineers (CEVEs) engage in the planning, design, construction, operation, and analysis of infrastructure systems that form the backbone of cities and societies. CEVEs work at the dynamic interface of the built environment, data systems, and natural environment on topics like smart cities and resilient infrastructure, sustainable energy and buildings, disaster resilience, automated transportation systems, climate change, and water management. In this course, students will explore how data science, environmental science, structural design, and systems thinking can be integrated to promote sustainability, resilience, and equity. Through a mix of technical lectures, topical seminars on applications and ideas of interest, and team-based projects, students will develop an understanding of the broad field of civil and environmental engineering and its applications.

CEVE 202 - INTRODUCTION TO SUSTAINABLE ENGINEERING
Short Title: INTRO SUSTAINABLE ENGINEERING
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Distribution Group: Distribution Group III
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Description: This course is an exploration of the fundamental role of engineering in the transition to a sustainable society and how different civil & environmental engineering subdisciplines are incorporating sustainability into their practice. The course introduces a systems-thinking framework through case studies that address engineering challenges through a sustainability lens, incorporating their context and critically evaluating the potential social and environmental impacts of proposed solutions.

CEVE 208 - WHAT THINGS ARE MADE OF: THE MATERIALS BEHIND MODERN LIFE
Short Title: MATERIALS BEHIND MODERN LIFE
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Distribution Group: Distribution Group III
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Description: This course introduces students to the materials that underpin modern life and how those materials are obtained, processed, and transformed into everyday products and systems. Rather than focusing on how technologies operate, the course examines where key materials come from, how they are extracted, separated, refined, and manufactured, and how these processes shape resource use and environmental impacts. Using examples drawn from the material foundations of daily life—including food, shelter, mobility, and energy—the course traces how raw materials become the products and systems that support modern living. Designed as a distribution course for first- and second-year undergraduates, the class assumes no prior engineering background and emphasizes conceptual understanding of material supply chains, industrial processing, and their environmental implications.

CEVE 210 - WILD TOPICS IN CHEMISTRY AND NANOTECHNOLOGY
Short Title: WILD TOPICS CHEM AND NANOTECH
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hour: 1
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Description: A variety of topics related to chemistry and nanotechnology will be discussed. Some topics are classical while others are current. Topics may include nanocars, molecular electronics, how to form a start-up company. Grades will be based upon attendance and quizzes. Cross-list: CHEM 210, MSNE 210. Repeatable for Credit.

CEVE 211 - ENGINEERING MECHANICS
Short Title: ENGINEERING MECHANICS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Prerequisite(s): (PHYS 101 or PHYS 111 or PHYS 125 or PHYS 141) and (MATH 101 or MATH 105) and (MATH 102 or MATH 106)
Description: The study equilibrium of static systems, the dynamics of a particle and particle systems, and rigid-body dynamics. Cross-list: MECH 211.

CEVE 238 - SPECIAL TOPICS
Short Title: SPECIAL TOPICS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Independent Study, Internship/Practicum, Laboratory, Lecture, Seminar, Lecture/Laboratory
Credit Hours: 1-4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Lower-Level
Description: Topics and credit hours vary each semester. Contact department for current semester's topic(s). Repeatable for Credit.

CEVE 301 - ENGINEERING ECONOMICS AND PROJECT MANAGEMENT
Short Title: ENG ECONOMICS & PROJECT MGMT
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CEVE 101
Description: Life cycle economics analysis to project development, project economic analysis, contracting, network scheduling, risk management, organizational structures and cases. Graduate/Undergraduate Equivalency: CEVE 505. Mutually Exclusive: Cannot register for CEVE 301 if student has credit for CEVE 201/CEVE 505/ENGI 505.

CEVE 302 - SUSTAINABLE DESIGN
Short Title: SUSTAINABLE DESIGN
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Distribution Group: Distribution Group III
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: The objective of this course is to develop skills in formulating and solving problems of societal development and advancement in light of increasing material, energy and water demands and decreasing resource availability. Sustainable design requires balancing economic, ecological/environmental and social issues to create physical as well as social structures that will work for current and future generations. In addition to learning to apply sustainable design principles to individual engineering and developing projects, students will be challenged to understand the application of sustainable design thinking a the municipal and corporate level. Cross-list: ENGI 302. Graduate/Undergraduate Equivalency: CEVE 502. Mutually Exclusive: Cannot register for CEVE 302 if student has credit for CEVE 502.

CEVE 307 - ENERGY AND THE ENVIRONMENT
Short Title: ENERGY AND THE ENVIRONMENT
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course explores the physical principles of energy use and its impacts on Earth's environment and climate. Topics will include energy mechanics, climate change, and the environmental impacts and future prospects of various fossil fuel and alternative energy sources. Cross-list: EEPS 307, ENST 307. Graduate/Undergraduate Equivalency: CEVE 507. Mutually Exclusive: Cannot register for CEVE 307 if student has credit for CEVE 507.

CEVE 308 - INTRODUCTION TO AIR POLLUTION CONTROL
Short Title: INTRO TO AIR POLLUTION CONTROL
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): (CHEM 112 or CHEM 122 or CHEM 152) and (MATH 101 or MATH 105) and (MATH 102 or MATH 106) and (PHYS 101 or PHYS 111 or PHYS 125 or PHYS 141)
Description: This course will discuss the history of air pollution and its effects as motivation for control of anthropogenic emissions to the atmosphere. Topics will include air pollution control strategies and regulations, predictive pollution concentration models, general ideas to reduce air pollution, and specific technologies to limit emissions of criteria pollutants and their precursors. Graduate/Undergraduate Equivalency: CEVE 508. Mutually Exclusive: Cannot register for CEVE 308 if student has credit for CEVE 508.

CEVE 310 - PRINCIPLES OF ENVIRONMENTAL ENGINEERING
Short Title: PRINCIPLES OF ENVI ENGINEERING
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course covers principles of water quality engineering, air pollution control and solid and hazardous waste management. Elements of risk assessment, global atmospheric change, and pollution prevention are also addressed to contribute to adequate-level competency in Environmental Engineering. Graduate students will write a term paper and prepare a lecture. Graduate/Undergraduate Equivalency: CEVE 510. Mutually Exclusive: Cannot register for CEVE 310 if student has credit for CEVE 510.

CEVE 311 - MECHANICS OF SOLIDS AND STRUCTURES
Short Title: MECHANICS OF SOLIDS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to students with a major in Bioengineering, Civil & Environmental Engineer, Civil Engineering or Mechanical Engineering. Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CEVE 211 or MECH 211
Description: Analysis of stress and the deformation of solids with applications to beams, circular shafts, and columns. Required for following undergraduate majors: civil and environmental engineering. Cross-list: MECH 311.

CEVE 312 - STRENGTH OF MATERIALS LAB
Short Title: STRENGTH OF MATERIALS LAB
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hour: 1
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CEVE 311 (may be taken concurrently) or MECH 311 (may be taken concurrently)
Description: Instruction in standard tension, compression, and torsion tests of ferrous and nonferrous metals. Includes experimental techniques and the behavior of structural elements. Prerequisites may be taken concurrently.

CEVE 313 - UNCERTAINTY AND RISK IN URBAN INFRASTRUCTURES
Short Title: RISK-BASED DEC UNDER UNCERT
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Distribution Group: Distribution Group III
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): STAT 312 or STAT 310 or STAT 315 or DSCI 301 or ECON 307 or ECON 382 or STAT 331 or ELEC 331
Description: This course explores methods for practical risk-based decision support, particularly for infrastructure systems. Uncertainty quantification (UQ) to external events including natural hazards is at the core of risk-informed design, operation, and mitigation actions. UQ also guides engineering practice and enables code developments. The course emphasizes decision theory, Bayesian approaches, risk analysis tools, and infrastructure safety. Cross-list: STAT 313. Repeatable for Credit.

CEVE 314 - SUSTAINABLE WATER PURIFICATION FOR THE DEVELOPING WORLD
Short Title: SUST WTR PURIF FOR DEV WORLD
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment limited to students with a class of Senior. Enrollment is limited to students with a major in E, E, Civil & Environmental Engineer, Civil Engineering or Environmental Engineering. Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course is an overview of sustainable strategies for safe water supply in off-the-grid, low-income regions. Topics covered include water quality and treatment, sustainability and WASH (water, sanitation and hygiene). A major element of the course is a project to solve a water-related issue in a real-world context. Cross-list: BIOE 365, GLHT 314. Repeatable for Credit.

CEVE 315 - URBAN WATER SYSTEMS: SOURCES, TREATMENT, DISTRIBUTION, RESOURCE RECOVERY AND REUSE
Short Title: URBAN WATER SYSTEMS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course will introduce urban water systems, including water sources, treatment processes, distribution and collection systems, and resource recovery and reuse. Student will learn the principles of physical, chemical, and biological processes, operations and reactor configurations commonly used for water quality control. In addition, students will learn analysis and design of specific water treatment and resource recovery processes and operations. Recommended Prerequisite(s): Recommend completion of CHEM 121, CHEM 122, MATH 211, and MATH 212.

CEVE 316 - URBAN WATER SYSTEMS LAB: WATER QUALITY PARAMETERS AND TREATMENT TECHNIQUES
Short Title: URBAN WATER SYSTEMS LAB
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hour: 1
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Corequisite: CEVE 315
Description: This course will introduce measurement of physicochemical water quality parameters. The principles behind the measurements and the significance of measured values will be covered . Selected conventional and advanced water treatment techniques will be introduced with emphasis on experimental design, group problem solving, and report writing.

CEVE 320 - ETHICS AND ENGINEERING LEADERSHIP
Short Title: ETHICS & ENGINRNG LEADERSHIP
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to students with a major in Civil & Environmental Engineer, Civil Engineering or Environment Analysis&Decisions. Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CEVE 101
Description: Seminar introduces students to a framework for discussing and making ethical engineering and professional decisions. Using case studies and exercises, students will look at their own profession and its Engineering Code of Ethics as well as at the issues and risks they may face as managers and executives. Cross-list: ENGI 320. Graduate/Undergraduate Equivalency: CEVE 529. Mutually Exclusive: Cannot register for CEVE 320 if student has credit for CEVE 529.

CEVE 323 - APPLIED SUSTAINABLE PLANNING AND DESIGN
Short Title: APPL. SUST. PLANNNG & DESIGN
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CEVE 302 or CEVE 502
Description: This course applies principles learned in CEVE 302/502 to real-world sustainability projects. Three to four case studies will comprise the class. These case studies will involve development of design solutions for (1) carbon neutral design, (2) ecosystem services transactions, (3) sustainable industrial applications and/or (4) air pollution and environmental justice. Graduate/Undergraduate Equivalency: CEVE 523. Mutually Exclusive: Cannot register for CEVE 323 if student has credit for CEVE 523.

CEVE 325 - STRUCTURAL ANALYSIS AND MODELING
Short Title: STRUCTURAL ANALYSIS & MODELING
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CEVE 311 or MECH 311
Description: This course provides students with a fundamental understanding of structural analysis and behavior with application to determinate and indeterminate structures. Classical methods of analysis along with an introduction to structural modeling will be examined. Mutually Exclusive: Cannot register for CEVE 325 if student has credit for CEVE 304.

CEVE 347 - WATER-ENERGY NEXUS
Short Title: WATER-ENERGY NEXUS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CEVE 310
Description: Water and energy are inextricably linked. This course examines their complex relationship, exploring the energy intensity of water management and the water footprint of energy production. Using principles of thermodynamics, mass transfer, electrochemistry, and process modeling, we will analyze case studies, including energy consumption in desalination and brine management, the potential of water electrolysis for hydrogen production, and the role of lithium extraction from brines in a circular economy. The course emphasizes technological advancements and integrated approaches for a secure water and energy future. Graduate/Undergraduate Equivalency: CEVE 547. Mutually Exclusive: Cannot register for CEVE 347 if student has credit for CEVE 547.

CEVE 348 - MACHINE LEARNING FOR CIVIL AND ENVIRONMENTAL ENGINEERS
Short Title: MACHINE LEARNING FOR CEVE
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CMOR 220 and (STAT 310 or ECON 307)
Description: Machine learning (ML) technologies are transforming science and engineering. This course is intended to provide CEE students with their first exposure to scientific programming and ML. In the class, students will learn different statistical and machine learning methods and practice implementing them using Python and real-world datasets. The examples are drawn from data and applications within civil and environmental engineering, including structural, transportation, hydrology, smart materials, air and water quality, among others. The methods cover introductory supervised and unsupervised learning methods. This class will provide students with a solid foundation in data analytics and insights into how ML is driving change across the CEE landscape.

CEVE 363 - APPLIED FLUID MECHANICS
Short Title: APPLIED FLUID MECHANICS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CEVE 211 and MATH 212 and (PHYS 101 or PHYS 111 or PHYS 125 or PHYS 141)
Description: Study of fluid properties, fluid statics, and incompressible fluid steady flow. Includes energy and momentum equations with many applications, similitude and dimensional analysis, and viscous fluid flow in pipe networks. Required for B.S.C.E.

CEVE 400 - ADVANCED MECHANICS OF MATERIALS
Short Title: ADV MECHANICS OF MATERIALS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): (MECH 202 or CEVE 211) and (MECH 311 or MECH 315 or CEVE 311)
Description: Advanced topics in materials mechanics, including elasticity, plasticity, and brittle and ductile fracture mechanics. A major focus of this course is to approach these advanced mechanics topics from a material perspective. Cross-list: MECH 400. Graduate/Undergraduate Equivalency: CEVE 500. Mutually Exclusive: Cannot register for CEVE 400 if student has credit for CEVE 500.

CEVE 401 - CHEMISTRY FOR ENVIRONMENTAL ENGINEERING AND SCIENCE
Short Title: ENVIRONMENTAL CHEMISTRY
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Topics include: introductory concepts of general chemistry; applied physical chemistry; and organic and biochemical concepts as used in the profession. Graduate/Undergraduate Equivalency: CEVE 501. Mutually Exclusive: Cannot register for CEVE 401 if student has credit for CEVE 501.

CEVE 404 - ATMOSPHERIC PARTICULATE MATTER
Short Title: ATMOSPHERIC PARTICULATE MATTER
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): (CHEM 112 or CHEM 122 or CHEM 152) and (MATH 101 or MATH 105) and (MATH 102 or MATH 106) and (PHYS 101 or PHYS 111 or PHYS 125 or PHYS 141)
Description: Description and examination of the processes determining the chemical and physical characteristics of atmospheric aerosol particles. Important focal points include aerosol measurements and control techniques and aerosol climate effects. Most attention will be paid to processes active in the troposphere, but important differences between the troposphere and stratosphere are addressed. Graduate/Undergraduate Equivalency: CEVE 504. Mutually Exclusive: Cannot register for CEVE 404 if student has credit for CEVE 504.

CEVE 406 - INTRODUCTION TO ENVIRONMENTAL LAW
Short Title: INTRO TO ENVIRONMENTAL LAW
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Introduction to Environmental Law is intended to introduce the student to the methods used by the United States and the international community to regulate and/or allocate air, water and land resources. A key focus of this course will be the emerging area of the law of sustainable development, including the implementation of full price costing, life cycle analysis, carbon cycle analysis, allocation of assimilative capacity and other similar issues. Cross-list: ENST 406. Graduate/Undergraduate Equivalency: CEVE 506.

CEVE 411 - ATMOSPHERIC CHEMISTRY AND CLIMATE
Short Title: ATMOSPHERIC CHEM & CLIMATE
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): (CHEM 111 or CHEM 121) and (CHEM 112 or CHEM 122) and (MATH 101 or MATH 105) and (MATH 102 or MATH 106) and (PHYS 101 or PHYS 111 or PHYS 125 or PHYS 141)
Description: Study of the chemical and physical processes that govern the formation, transformation, and transport of gases and particles in the atmosphere. Overview of urban and regional air pollution, including tropospheric ozone formation and particulate matter; stratospheric chemistry; and global climate change. Graduate/Undergraduate Equivalency: CEVE 511. Mutually Exclusive: Cannot register for CEVE 411 if student has credit for CEVE 511.

CEVE 412 - HYDROLOGY AND WATER RESOURCES ENGINEERING
Short Title: HYDROLOGY & WATER RESOURCE ENG
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: The purpose of this course is to introduce the student to the fundamentals of the hydrologic cycle, surface water, open channel flow concepts, and water resources. The course will introduce concepts related to the hydrologic cycle in urban and natural watersheds, rainfall runoff and hydrograph response, overland and channel flood routing, open channel flow, and the basics of floodplain. At the end of the semester, we will also cover the current state of flood policy, flood disasters, and discuss innovative strategies for tackling flood-related issues and adapting to changes in flood risk over time. There will be significant emphasis on applying and solving the governing equations, calculations and models to analyze water balance, and hydrologic and hydraulic response to severe rainfall events. Student participation and a completion of a HEC-HMS modeling exercise will be expected. Case studies will be presented and discussed near end of the class. Graduate/Undergraduate Equivalency: CEVE 509. Mutually Exclusive: Cannot register for CEVE 412 if student has credit for CEVE 509.

CEVE 414 - COASTAL HAZARDS IN A CHANGING CLIMATE
Short Title: COAST HAZARDS IN CHANG CLIMAT
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CEVE 363
Description: Coastal communities across the globe are routinely threatened by extreme winds, storm surge, and intense precipitation from landfalling storm systems, which cause loss of life and billions in economic damages each year. Climate change is projected to exacerbate coastal hazards due to increasing sea-levels and more intense storms. For risk assessment, mitigation, and long-term adaptation, it is crucial to understand the climatology and physical mechanisms of coastal hazards, as well as their links to climate change. This course will cover 1) the climatology of tropical and extra-tropical cyclones, 2) physical principles governing tropical cyclone wind, rainfall, and storm surge, 3) numerical prediction of coastal flooding, and 4) theoretical relationships between coastal hazards and climate change. The class assignments will consist of bi-weekly homework, two in-class exams, and a final project. Students are encouraged to work collaboratively on homework, and active class participation is required. The assignments will give students the opportunity to work with a variety of hydrometeorological datasets (i.e. tidal gauges, global reanalyses, satellite imagery, etc.), and use programming for hazard prediction. Graduate/Undergraduate Equivalency: CEVE 514. Mutually Exclusive: Cannot register for CEVE 414 if student has credit for CEVE 514.

CEVE 415 - URBAN INFRASTRUCTURE, ENVIRONMENT AND SUSTAINABILITY
Short Title: URBAN INFRA, ENVIRO & SUSTAIN
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course is an introduction to sustainable development and sustainable design. Sustainable development is one of the most interesting and challenging issues facing the world today. Sustainability is about living within the limits of natural and human systems as well as working to ensure that future generations have the ability to meet their needs even as we ensure that current generations can meet theirs. Sustainability is about social issues as well as environmental and economic ones. Sustainability either is or will become an issue of primary concern to virtually every country, state, city, corporation and institution in the world over the next decade or two. Upon completion of this course, you will be able to enter into the dialogue about sustainable human systems. Instructor Permission Required.

CEVE 416 - FUNDAMENTALS OF GROUNDWATER FLOW
Short Title: FUND. GROUNDWATER FLOW
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: The course will cover the fundamental principles of groundwater flow, including moisture flow in the unsaturated zone; aquifer testing and interpretation of field data; sustainable production of groundwater for public water supplies; models of groundwater flow in the saturated and unsaturated zones; groundwater policy – use and landowner rights; the future of groundwater management. Graduate/Undergraduate Equivalency: CEVE 516. Mutually Exclusive: Cannot register for CEVE 416 if student has credit for CEVE 516.

CEVE 417 - FINITE ELEMENT ANALYSIS
Short Title: FINITE ELEMENT ANALYSIS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): (MATH 212 or MATH 222) and (CAAM 210 or CAAM 211 or CMOR 220)
Description: An introduction to finite element analysis by Galerkin's method and the method of least squares as applied to both ordinary and partial differential equations common in engineering applications. Element interpolations, numerical integration, computational considerations for efficient solution and post-processing methods. Application of the commercial codes to ANSYS and Cosmosworks. Cross-list: MECH 417. Graduate/Undergraduate Equivalency: CEVE 517. Mutually Exclusive: Cannot register for CEVE 417 if student has credit for CEVE 517.

CEVE 418 - ENVIRONMENTAL HYDROGEOLOGY
Short Title: ENVIRONMENTAL HYDROGEOLOGY
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CEVE 363
Description: Darcy's law, 1-D and 2-D steady-state groundwater flow, transient groundwater flow, aquifer testing, movement of chemicals in the subsurface, modeling groundwater flow and contaminant transport, current issues in hydrogeology including salt water intrusion, subsidence, and emerging environmental contaminants. Includes a final project using groundwater flow and contaminant transport models MODFLOW and MT3D. Graduate/Undergraduate Equivalency: CEVE 518. Mutually Exclusive: Cannot register for CEVE 418 if student has credit for CEVE 518.

CEVE 420 - ENVIRONMENTAL REMEDIATION RESTORATION
Short Title: ENVI REMEDIATION RESTORATION
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Remediation principles and application of full-scale remediation technologies for restoration of contaminated soil, groundwater, and surface water. Topics include mass balances and distribution of chemicals in environmental media; development of remediation goals through risk assessment; treatment technology selection criteria and costs; groundwater, soil, and surface water restoration technologies; and regulatory considerations. Graduate/Undergraduate Equivalency: CEVE 520. Mutually Exclusive: Cannot register for CEVE 420 if student has credit for CEVE 520.

CEVE 421 - CLIMATE RISK MANAGEMENT
Short Title: CLIMATE RISK MANAGEMENT
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Climate variability and change pose threats to lives and livelihoods. These climate risks can be managed through the design and operation of infrastructure systems, as well as through disaster response and recovery. Decisions about how to develop and choose risk management strategies are often based on pure vibes, but occasionally rigorous quantitative analyses that make use of scientific information can inform them (we will focus on these cases). These analyses involve integrating knowledge from multiple disciplines to balance competing goals (objectives) under uncertainty. In this course, you will learn a structured bottom-up decision analytic framework for quantitative climate risk analysis. This involves (i) defining a system of interest and what constitutes desirable outcomes; (ii) understanding and modeling the specific pathways through which climate variability and change can create risk to this system; (iii) identifying possible levers for risk management; (iv) quantifying the performance of proposed decisions under climate and other interacting factors; and (v) generating possible alternatives. You will be assigned readings for every class that cover relevant methods or applications, and will work collaboratively to implement key concepts through programming problem sets. Active class participation is required. Methods covered include scenario analysis, exploratory modeling, cost-benefit analysis, single- and multi-objective policy search, stochastic control, deep uncertainty, robust decision making, and equitable decision making. Graduate/Undergraduate Equivalency: CEVE 521. Recommended Prerequisite(s): An introductory course in probability and statistics Mutually Exclusive: Cannot register for CEVE 421 if student has credit for CEVE 521.

CEVE 424 - TIME-DEPENDENT SYSTEM RELIABILITY METHODS AND APPLICATIONS
Short Title: SYSTEM RELIABILITY METHODS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Students will learn computational simulation and theoretical techniques for the reliability assessment of engineered systems as a function of their component failure probabilities. We will explore time-dependent and algorithmic system reliability, and will use modern structural infrastructure systems as case studies, including power systems, wind turbines, bridges, and buildings. Graduate/Undergraduate Equivalency: CEVE 524. Mutually Exclusive: Cannot register for CEVE 424 if student has credit for CEVE 524.

CEVE 425 - SUSTAINABLE INFRASTRUCTURE MATERIALS
Short Title: SUSTAIN INFRASTRUCT MATER
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CEVE 312
Description: This course delves into the structure and properties of various infrastructure materials, encompassing cement, concrete, steel, glass, timber, and asphalt. Building upon the foundational knowledge of materials currently used in the industry, we will also cover sustainable alternatives and strategies aimed at enhancing the sustainability, performance, and durability of these infrastructure materials. The course will also introduce recent advancements in concrete technologies, such as 3D printing, AI-driven modeling, and smart concrete. Graduate/Undergraduate Equivalency: CEVE 525. Mutually Exclusive: Cannot register for CEVE 425 if student has credit for CEVE 525.

CEVE 426 - SMART MATERIALS FOR THE ENVIRONMENT
Short Title: SMART MATERIALS FOR THE ENVI
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: The purpose of this course is to introduce students to the concept of smart materials and their application to address challenges in environmental engineering. The course will cover three broad categories of smart materials, namely self-healing materials, stimuli-responsive materials, and materials with molecular-recognition capabilities. The use of these materials for structural, sensing, water treatment, and energy applications will be highlighted. The course will emphasize the underlying chemical and thermodynamic principles driving the behavior and responses of smart materials. Graduate/Undergraduate Equivalency: CEVE 526.

CEVE 427 - PHYSICS GUIDED MACHINE LEARNING & DATA DRIVEN MODELING FEM
Short Title: PHY GUIDED ML-DATA DRIVEN FEM
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CEVE 311 or MECH 311 or MECH 315
Description: Introduction to physics guided machine learning and data driven modeling from a rigorous finite element analysis and system dynamics (& optimization) perspective. Programming needed will be introduced in the course. The course involves series of assignments involving programming. Project work will be assigned at the end of the semester in lieu of the final exam. Cannot be taken concurrently with CEVE/MECH 527. Prerequisites CEVE/MECH 311. Cross-list: MECH 427. Mutually Exclusive: Cannot register for CEVE 427 if student has credit for CEVE 527.
Course URL: Satishnagarajaiah.rice.edu (http://Satishnagarajaiah.rice.edu)

CEVE 431 - DESIGN AND BEHAVIOR OF CONCRETE BUILDINGS AND BUILDING ELEMENTS
Short Title: REINFORCED CONCRETE BUILDINGS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CEVE 311
Corequisite: CEVE 432
Description: Design of reinforced concrete buildings including concepts and code practices routinely used in professional structural engineering design for concrete members and structural systems. Behavior of building members as related to design will be discussed as well. Graduate/Undergraduate Equivalency: CEVE 531. Mutually Exclusive: Cannot register for CEVE 431 if student has credit for CEVE 407/CEVE 408/CEVE 530/CEVE 531.

CEVE 432 - CONCRETE AND STEEL STRUCTURES LABORATORY
Short Title: CONCRETE & STEEL LABORATORY
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hour: 1
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Corequisite: CEVE 431
Description: Instruction in testing and data analysis, design of concrete mix, casting concrete cylinders and reinforced concrete beams, fabrication of steel frame, testing of concrete beams and steel frame. Mutually Exclusive: Cannot register for CEVE 432 if student has credit for CEVE 407/CEVE 408.

CEVE 434 - FATE AND TRANSPORT OF CONTAMINANTS IN THE ENVIRONMENT
Short Title: FATE/TRANSPORT OF CONTAMINANTS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Physical and chemical principles governing the fate and transport of contaminants in the aqueous environment, and the applications of such principles in environmental engineering. Emphasis is put on mass transport and transportation processes in natural and engineering systems. Previous course work in fluid mechanics and calculus through differential equations is strongly suggested. Graduate/Undergraduate Equivalency: CEVE 534. Mutually Exclusive: Cannot register for CEVE 434 if student has credit for CEVE 534.

CEVE 437 - DESIGN OF PRESTRESSED CONCRETE STRUCTURES
Short Title: PRESTRESSED CONCRETE
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CEVE 431
Description: Fundamental principles for the design of prestressed concrete structures. Prestressing losses and anchorage. Analysis and design of prestressed members and systems subjected to axial, shear, torsion, and bending loading. Deflection computation and control. Use of design codes and standards in prestressed concrete design. Graduate/Undergraduate Equivalency: CEVE 537. Mutually Exclusive: Cannot register for CEVE 437 if student has credit for CEVE 537.

CEVE 439 - ADVANCED STRUCTURAL ANALYSIS
Short Title: ADVANCED STRUCTURAL ANALYSIS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): (CEVE 311 or MECH 311) and CEVE 325
Description: This advanced structural analysis course builds on fundamentals to expand students' understanding and methods to analyze the behavior of indeterminate structures, emphasizing 2D and 3D framed structures. Students will familiarize themselves with the Matrix Flexibility and Matrix Stiffness Methods, learn to program the Direct Stiffness Method and acquire the skills to model framed structures using commercial software. A brief overview of nonlinear analysis will conclude the course. Graduate/Undergraduate Equivalency: CEVE 539. Mutually Exclusive: Cannot register for CEVE 439 if student has credit for CEVE 539.

CEVE 441 - DESIGN AND BEHAVIOR OF STRUCTURAL STEEL BUILDINGS AND BUILDING ELEMENTS
Short Title: STRUCTURAL STEEL BUILDINGS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CEVE 311
Description: Design of structural steel buildings including concepts and material routinely used in professional structural engineering design practice for steel members, connections and assemblies. Behavior of building members as related to design will be discussed as well. Graduate/Undergraduate Equivalency: CEVE 541. Recommended Prerequisite(s): CEVE 304 or CEVE 325 Mutually Exclusive: Cannot register for CEVE 441 if student has credit for CEVE 541.

CEVE 444 - ENVIRONMENTAL MICROBIOLOGY AND MICROBIAL ECOLOGY
Short Title: ENVIRON MICROBIOL & ECOLOGY
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Fundamentals of microbiology and the ecology of microbes, highlighting their interactions with each other and the environment, and integration of these principles in the context of important natural and engineered environmental systems. Graduate/Undergraduate Equivalency: CEVE 544. Mutually Exclusive: Cannot register for CEVE 444 if student has credit for CEVE 544.

CEVE 445 - ORIGAMI ENGINEERING
Short Title: ORIGAMI ENG
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CEVE 311 or MECH 311
Description: This course introduces the key concepts of origami engineering, covering the science, art, and skills required to design and manufacture origami-inspired systems. Students will explore the properties of origami patterns and learn the principles for designing them. The course integrates fundamentals of solid mechanics with folding and geometry to examine structural and material phenomena, including single-degree of freedom kinematics, bi- and multistability, anisotropy, and auxeticity. The course features a hands-on component that allows students to engage directly in the prototyping of origami structures, making use of the facilities and resources available at the Oshman Engineering Design Kitchen (OEDK). Graduate/Undergraduate Equivalency: CEVE 545. Mutually Exclusive: Cannot register for CEVE 445 if student has credit for CEVE 545.

CEVE 452 - URBAN TRANSPORTATION SYSTEMS
Short Title: URBAN TRANSPORTATION SYSTEMS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Distribution Group: Distribution Group III
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Survey of operation characteristics of transport modes the elements of transportation planning, and the design of stationary elements.

CEVE 454 - COMPUTATIONAL FLUID MECHANICS
Short Title: COMPUTATIONAL FLUID MECHANICS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): MECH 371 (may be taken concurrently) or MECH 444 (may be taken concurrently) or CEVE 363 (may be taken concurrently) or CHBE 401 (may be taken concurrently) or BIOE 420 (may be taken concurrently) or CHBE 420 (may be taken concurrently)
Description: Fundamental concepts of finite element methods in fluid mechanics, including spatial discretization and numerical integration in multidimensions, time-integration, and solution of nonlinear ordinary differential equation systems. Advanced numerical stabilization techniques designed for fluid mechanics problems. Strategies for solution of complex, real-world problems. Topics in large-scale computing, parallel processing, and visualization. Prerequisites may be taken concurrently. Cross-list: BIOE 454, MECH 454. Graduate/Undergraduate Equivalency: CEVE 554. Mutually Exclusive: Cannot register for CEVE 454 if student has credit for CEVE 545/CEVE 554.

CEVE 455 - NUMERICAL METHODS FOR PARTIAL DIFFERENTIAL EQUATIONS
Short Title: NUMERICAL METHODS FOR PDES
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course covers various numerical methods for solving partial differential equations: aspects of finite difference methods, finite element methods, finite volume methods, mixed methods, discontinuous Galerkin methods, and meshless methods. Both theoretical convergence and practical implementation of the methods are studied for elliptic and parabolic problems. Cross-list: CMOR 423. Graduate/Undergraduate Equivalency: CEVE 555. Recommended Prerequisite(s): CAAM 336 or CMOR 304 Mutually Exclusive: Cannot register for CEVE 455 if student has credit for CEVE 555.

CEVE 456 - UNCERTAINTY QUANTIFICATION
Short Title: UNCERTAINTY QUANTIFICATION
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): STAT 312 or STAT 310 or ECON 307 or STAT 315
Description: This course introduces a series of computational methods in Uncertainty Quantification (UQ), a field of growing importance across various engineering domains and beyond. Focusing on mathematical theories and numerical methods, the course will cover global sensitivity analysis, multi-fidelity Monte Carlo, and probabilistic machine learning ("surrogate") models, such as Gaussian process and polynomial chaos expansion, with advanced topics of active learning and dimensionality reduction techniques. Graduate/Undergraduate Equivalency: CEVE 556. Mutually Exclusive: Cannot register for CEVE 456 if student has credit for CEVE 556.

CEVE 457 - TRANSPORTATION SYSTEMS MODELING AND DECISION-MAKING
Short Title: TRANS SYS MODELING
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CMOR 220 or MATH 211
Description: This course aims to provide a rigorous introduction to mathematical modeling of transportation systems that enables optimal decision-making, from the network routing and traffic equilibrium aspects. Graduate/Undergraduate Equivalency: CEVE 557. Mutually Exclusive: Cannot register for CEVE 457 if student has credit for CEVE 557.

CEVE 460 - BRIDGE ENGINEERING AND EXTREME EVENTS
Short Title: BRIDGE ENG. & EXTREME EVENTS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): (CEVE 311 or MECH 311) and (CEVE 304 or CEVE 325) and CEVE 431 (may be taken concurrently)
Description: This course integrates information from various engineering and scientific disciplines to provide a rational basis for bridge design under regular and extreme loading. It provides an introduction to bridge engineering, including bridge systems, construction material, loading, and reliability-based design. Design, analysis, and retrofit for seismic and coastal threats will be introduced. Graduate/Undergraduate Equivalency: CEVE 560. Mutually Exclusive: Cannot register for CEVE 460 if student has credit for CEVE 560.

CEVE 471 - PRINCIPLES OF SOIL MECHANICS AND FOUNDATION ENGINEERING
Short Title: SOIL MECHANICS AND FOUNDATIONS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Introduction to fundamentals of soil mechanics will include phase relationships, grain size, plasticity, soil classification, and clay mineralogy. The effect of water in soils, including capillarity, shrinkage and swelling, permeability, seepage and effective stress will be discussed. Consolidation, settlement, compressibility, failure theory, and the strength of sands and clays will be investigated. Design considerations will be discussed. Introduction to fundamentals of foundation engineering will include subsurface exploration methods and lateral earth pressures. The design of shallow and deep foundations, including pile installation and geophysical and geotechnical site investigation will be presented. CEVE 471, the undergrad version, includes a lab. Graduate/Undergraduate Equivalency: CEVE 571. Mutually Exclusive: Cannot register for CEVE 471 if student has credit for CEVE 470/CEVE 570/CEVE 571.

CEVE 472 - SOIL MECHANICS LABORATORY WITH INDIVIDUAL PARTICIPATION
Short Title: SOIL MECHANICS LABORATORY
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hour: 1
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Determine the water content, liquid limit, plastic limit, grain size from sieve and hydrometer analyses, falling head permeability, specific gravity, and the shear strength of clays from pocket penetrometer, Torvane, miniature vane, unconsolidated undrained triaxial compression and direct shear tests. Study the consolidation of clays and the compaction of clays and sands.

CEVE 476 - STRUCTURAL DYNAMIC SYSTEMS
Short Title: STRUCTURAL DYNAMIC SYSTEMS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CEVE 311 or MECH 311 or MECH 315
Description: Introduction to structural dynamic systems. Linear SDOF and MDOF discrete systems, undamped and damped systems, free and forced vibration, dynamic response to periodic and arbitrary excitations, numerical evaluation of dynamic response, response spectrum and modal analysis. Additional topics for graduate version 576: Linear systems theory, transform methods, state space methods, feedback control, observers and identification. Applications using MATLAB. Demonstrations and laboratory examples. Students will be required to do more advanced assignments and a project. Graduate/Undergraduate Equivalency: CEVE 576. Mutually Exclusive: Cannot register for CEVE 476 if student has credit for CEVE 576.

CEVE 477 - SPECIAL TOPICS
Short Title: SPECIAL TOPICS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Laboratory, Lecture, Internship/Practicum, Seminar, Lecture/Laboratory
Credit Hours: 1-4
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Topics and credit hours vary each semester. Contact department for current semester's topic(s). Repeatable for Credit.

CEVE 481 - INTRODUCTION TO SENIOR DESIGN
Short Title: INTRODUCTION TO SENIOR DESIGN
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hour: 1
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Semester. Lectures will focus on various engineering design topics and CAD training. Potential design projects will be introduced and students will form interdisciplinary design teams. Design teams will present before jury to win their design projects.

CEVE 482 - SENIOR DESIGN
Short Title: SENIOR DESIGN
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CEVE 481
Description: The senior (capstone) design course in the Spring Semester will provide senior engineering students with a complete design experience including fundamental engineering design issues in the major areas of the curriculum, small team experiences, project proposals, progress reports and presentations, engineering design analyses and software, design report writing, and a final presentation to the CEE faculty and an external jury of professional engineers. An established local firm will assist in teaching practical design methods and consultation with other faculty is required as part of the overall experience.

CEVE 484 - ENVIRONMENTAL RISK ASSESSMENT & HUMAN HEALTH
Short Title: ENVIRON RISK ASSESS&HUMAN HLTH
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): STAT 180 or STAT 280 or STAT 305
Description: Learn and apply quantitative risk assessment methodology to estimate human health risk from environmental exposure to contamination in air, soil and water. Students will conduct a series of team projects focused on toxicology, risk based screening levels, exposure concentration estimation and risk characterization. Cross-list: STAT 484. Graduate/Undergraduate Equivalency: CEVE 684. Mutually Exclusive: Cannot register for CEVE 484 if student has credit for CEVE 684.

CEVE 492 - MODELING AND ANALYSIS OF NETWORKED SYSTEMS
Short Title: MODELING & ANALYSIS OF NET SYS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: This course introduces methods for modeling, characterizing and predicting the behavior of complex infrastructure and technological systems. The discussed analysis methods rely on network science optimization, and computational complexity principles so as to unravel the emergent features of structural and infrastructure systems. Topological properties, ranking tools, dynamic processes, and percolation-based resilience are studied from analytical, algorithmic, and numerical simulation perspectives. The course also explores interdependencies and mitigation actions for spatially and temporally evolving systems. The graduate level course includes advanced exercises in homework and exams, as well as a research-oriented final project. Graduate/Undergraduate Equivalency: CEVE 592. Mutually Exclusive: Cannot register for CEVE 492 if student has credit for CEVE 592. Repeatable for Credit.

CEVE 496 - SYSTEM IDENTIFICATION OF DYNAMIC SYSTEMS WITH MACHINE LEARNING
Short Title: SYSTEM I.D. & MACHINE LEARNING
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Prerequisite(s): CEVE 311 or MECH 311 or MECH 315
Description: Introduction to modeling and system identification of dynamic systems with machine learning. Students in CEVE 596/MECH 566 will be required to do more advanced assignments and a project. Cross-list: MECH 466. Graduate/Undergraduate Equivalency: CEVE 596. Mutually Exclusive: Cannot register for CEVE 496 if student has credit for CEVE 596.

CEVE 499 - SPECIAL PROBLEMS
Short Title: SPECIAL TOPICS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Research
Credit Hours: 1-12
Restrictions: Enrollment is limited to Undergraduate, Undergraduate Professional or Visiting Undergraduate level students.
Course Level: Undergraduate Upper-Level
Description: Independent research and investigation, including a course toward directed research and/or a research project. Study of selected topics including individual investigations special lectures, and seminars. Student works independently with only minimal faculty direction. Offered upon mutual agreement of faculty and student. May earn varying amount of credit hours depending on the amount of time devoted and the amount of academic work associated with the course. Repeatable for Credit.

CEVE 500 - ADVANCED MECHANICS OF MATERIALS
Short Title: ADV MECHANICS OF MATERIALS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): (MECH 211 or CEVE 211) and (MECH 311 or CEVE 311)
Description: Advanced topics in solid mechanics and strength of materials including energy methods, principle of virtual work, conservation laws, constitutive modeling, aspects of elasticity theory, stability and fracture mechanics with application to the analysis and design of reliable structures. Cross-list: MECH 500. Graduate/Undergraduate Equivalency: CEVE 400. Mutually Exclusive: Cannot register for CEVE 500 if student has credit for CEVE 400.

CEVE 501 - CHEMISTRY FOR ENVIRONMENTAL ENGINEERING AND SCIENCE
Short Title: ENVIRONMENTAL CHEMISTRY
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Topics include: introductory concepts of general chemistry; applied physical chemistry; and organic and biochemical concepts as used in the profession. Graduate students are required to write and present an advanced paper. Graduate/Undergraduate Equivalency: CEVE 401. Mutually Exclusive: Cannot register for CEVE 501 if student has credit for CEVE 401.

CEVE 502 - SUSTAINABLE DESIGN
Short Title: SUSTAINABLE DESIGN
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: The objective of this course is to develop skills in formulating and solving problems of societal development and advancement in light of increasing material, energy and water demands and decreasing resource availability. Sustainable design requires balancing economic, ecological/environmental and social issues to create physical as well as social structures that will work for current and future generations. In addition to learning to apply sustainable design principles to individual engineering and developing projects, students will be challenged to understand the application of sustainable design thinking a the municipal and corporate level. Graduate students will be required to undertake additional assignments relative to sustainable design. Graduate/Undergraduate Equivalency: CEVE 302. Mutually Exclusive: Cannot register for CEVE 502 if student has credit for CEVE 302.

CEVE 503 - NONLINEAR FINITE ELEMENT ANALYSIS
Short Title: NONLINEAR FEM
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Formulation and solution of nonlinear initial/boundary value problems using the finite element method. Variational principles for nonlinear problems, finite element discretization, and equation-solving strategies for discrete nonlinear equation systems. Applications include: materially nonlinear systems, geometrically nonlinear systems, transient nonlinear problems, and treatment of non smooth constraints in a nonlinear framework. Cross-list: MECH 520.

CEVE 504 - ATOMSPHERIC PARTICULATE MATTER
Short Title: ATMOSPHERIC PARTICULATE MATTER
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): (CHEM 112 or CHEM 122 or CHEM 152) and (MATH 101 or MATH 105) and (MATH 102 or MATH 106) and (PHYS 101 or PHYS 111 or PHYS 125 or PHYS 141)
Description: Description and examination of the processes determining the chemical and physical characteristics of atmospheric aerosol particles. Important focal points include aerosol measurements and control techniques and aerosol climate effects. Most attention will be paid to processes active in the troposphere, but important differences between the troposphere and stratosphere are addressed. Extra work required for graduate students. Graduate/Undergraduate Equivalency: CEVE 404. Mutually Exclusive: Cannot register for CEVE 504 if student has credit for CEVE 404.

CEVE 505 - ENGINEERING ECONOMICS AND PROJECT MANAGEMENT
Short Title: ENG ECONOMICS & PROJECT MGMT
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to students with a major in Environment Analysis&Decisions. Enrollment is limited to Graduate level students. Enrollment limited to students in a Doctor of Philosophy degree.
Course Level: Graduate
Description: Life cycle economics analysis to project development, project economic analysis, contracting, network scheduling, risk management, organizational structures and cases. 505 requires an additional paper. Cross-list: ENGI 505. Graduate/Undergraduate Equivalency: CEVE 301. Mutually Exclusive: Cannot register for CEVE 505 if student has credit for CEVE 301/CEVE 479.

CEVE 506 - INTRODUCTION TO ENVIRONMENTAL LAW
Short Title: INTRO TO ENVIRONMENTAL LAW
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Introduction to Environmental Law is intended to introduce the student to the methods used by the United States and the international community to regulate and/or allocate air, water and land resources. A key focus of this course will be the emerging area of the law of sustainable development, including the implementation of full price costing, life cycle analysis, carbon cycle analysis, allocation of assimilative capacity and other similar issues. Graduate students will be required to undertake additional assignments Graduate/Undergraduate Equivalency: CEVE 406.

CEVE 507 - ENERGY AND THE ENVIRONMENT
Short Title: ENERGY AND THE ENVIRONMENT
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course explores the physical principles of energy use and its impacts on Earth's environment and climate. Topics will include energy mechanics, climate change, and the environmental impacts and future prospects of various fossil fuel and alternative energy sources. Additional problems will be assigned to Graduate students. Graduate/Undergraduate Equivalency: CEVE 307. Mutually Exclusive: Cannot register for CEVE 507 if student has credit for CEVE 307.

CEVE 508 - INTRODUCTION TO AIR POLLUTION CONTROL
Short Title: INTRO TO AIR POLLUTION CONTROL
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): (MATH 101 or MATH 105) and (MATH 102 or MATH 106)
Description: This course will discuss the history of air pollution and its effects as motivation for control of anthropogenic emissions to the atmosphere. Topics will include air pollution control strategies and regulations, predictive pollution concentration models, general ideas to reduce air pollution, and specific technologies to limit emissions of criteria pollutants and their precursors. Additional paper is required for graduate students. Graduate/Undergraduate Equivalency: CEVE 308. Mutually Exclusive: Cannot register for CEVE 508 if student has credit for CEVE 308.

CEVE 509 - HYDROLOGY AND WATER RESOURCES ENGINEERING
Short Title: HYDROLOGY & WATER RESOURCE ENG
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Fundamentals of the hydrologic cycle, meteorology, rainfall-runoff, flood routing, urban system design, and open channel flow are covered. Topics in ground water flow and well mechanics are also included. Applications include computational hydrology, floodplain analysis, watershed behavior, and low impact development. Group presentations are required. The graduate level course includes an extra paper. Graduate/Undergraduate Equivalency: CEVE 412. Mutually Exclusive: Cannot register for CEVE 509 if student has credit for CEVE 412.

CEVE 510 - PRINCIPLES OF ENVIRONMENTAL ENGINEERING
Short Title: PRINCIPLES OF ENVI ENGINEERING
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course covers principles of water quality engineering, air pollution control and solid and hazardous waste management. Elements of risk assessment, global atmospheric change, and pollution prevention are also addressed to contribute to adequate-level competency in Environmental Engineering. Graduate students will write a term paper and prepare a lecture. Graduate/Undergraduate Equivalency: CEVE 310. Mutually Exclusive: Cannot register for CEVE 510 if student has credit for CEVE 310.

CEVE 511 - ATMOSPHERIC CHEMISTRY AND CLIMATE
Short Title: ATMOSPHERIC CHEM & CLIMATE
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): (CHEM 111 or CHEM 121) and (CHEM 112 or CHEM 122) and (MATH 101 or MATH 105) and (MATH 102 or MATH 106) and (PHYS 101 or PHYS 111 or PHYS 125 or PHYS 141)
Description: Study of the chemical and physical processes that govern the formation, transformation, and transport of gases and particles in the atmosphere. Overview of urban and regional air pollution, including tropospheric ozone formation and particulate matter; stratospheric chemistry; and global climate change. Extra work required for graduate students. Graduate/Undergraduate Equivalency: CEVE 411. Mutually Exclusive: Cannot register for CEVE 511 if student has credit for CEVE 411.

CEVE 514 - COASTAL HAZARDS IN A CHANGING CLIMATE
Short Title: COAST HAZARD IN CHANG CLIMAT
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Coastal communities across the globe are routinely threatened by extreme winds, storm surge, and intense precipitation from landfalling storm systems, which cause loss of life and billions in economic damages each year. Climate change is projected to exacerbate coastal hazards due to increasing sea-levels and more intense storms. For risk assessment, mitigation, and long-term adaptation, it is crucial to understand the climatology and physical mechanisms of coastal hazards, as well as their links to climate change. This course will cover 1) the climatology of tropical and extra-tropical cyclones, 2) physical principles governing tropical cyclone wind, rainfall, and storm surge, 3) numerical prediction of coastal flooding, and 4) theoretical relationships between coastal hazards and climate change. The class assignments will consist of bi-weekly homework, two in-class exams, and a final project. Students are encouraged to work collaboratively on homework, and active class participation is required. The assignments will give students the opportunity to work with a variety of hydrometeorological datasets (i.e. tidal gauges, global reanalyses, satellite imagery, etc.), and use programming for hazard prediction. Graduate/Undergraduate Equivalency: CEVE 414. Recommended Prerequisite(s): Students should have previously taken classes in ODEs/PDEs, Fluids, and programming (in any language). Mutually Exclusive: Cannot register for CEVE 514 if student has credit for CEVE 414.

CEVE 516 - FUNDAMENTALS OF GROUNDWATER FLOW
Short Title: FUND. GROUNDWATER FLOW
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: The course will cover the fundamental principles of groundwater flow, including moisture flow in the unsaturated zone; aquifer testing and interpretation of field data; sustainable production of groundwater for public water supplies; models of groundwater flow in the saturated and unsaturated zones; groundwater policy – use and landowner rights; the future of groundwater management. Graduate/Undergraduate Equivalency: CEVE 416. Mutually Exclusive: Cannot register for CEVE 516 if student has credit for CEVE 416.

CEVE 517 - FINITE ELEMENT ANALYSIS
Short Title: FINITE ELEMENTS ANALYSIS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): (MATH 212 or MATH 222) and (CAAM 210 or CAAM 211 or CMOR 220)
Description: An introduction to Galerkin's method and the method of least squares applied to partial differential equations. Computational considerations for efficient interpolation, numerical integration, solution and post-processing methods. Error estimation and adaptive finite element analysis. Requires the use of solid works for a student project and a supporting literature survey. Cross-list: MECH 517. Graduate/Undergraduate Equivalency: CEVE 417. Mutually Exclusive: Cannot register for CEVE 517 if student has credit for CEVE 417.

CEVE 518 - ENVIRONMENTAL HYDROGEOLOGY
Short Title: ENVIRONMENTAL HYDROGEOLOGY
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Darcy's law, 1-D and 2-D steady-state groundwater flow, transient groundwater flow, aquifer testing, movement of chemicals in the subsurface, modeling groundwater flow and contaminant transport, current issues in hydrogeology including salt water intrusion, subsidence, and emerging environmental contaminants. Includes a final project using groundwater flow and contaminant transport models MODFLOW and MT3D. Graduate/Undergraduate Equivalency: CEVE 418. Mutually Exclusive: Cannot register for CEVE 518 if student has credit for CEVE 418.

CEVE 519 - ELASTICITY, PLASTICITY AND DAMAGE MECHANICS
Short Title: ELASTICITY/PLASTICITY/DAMAGE
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: An overview of phenomena that determine the response of solids to deformation and loading: elasticity, plasticity, damage mechanics and cracking. Review of continuum mechanics with emphasis on the physical mechanisms of deformation and fracture. Classification of the behavior of solids. Modeling of different types of material behavior. The physics underlying the phenomena and methods for the numerical analysis of the resulting equations are discussed. Cross-list: MECH 519.

CEVE 520 - ENVIRONMENTAL REMEDIATION RESTORATION
Short Title: ENVI REMEDIATION RESTORATION
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Remediation principles and application of full-scale remediation technologies for restoration of contaminated soil, groundwater, and surface water. Topics include mass balances and distribution of chemicals in environmental media; development of remediation goals through risk assessment; treatment technology selection criteria and costs; groundwater, soil, and surface water restoration technologies; and regulatory considerations. Graduate students receive additional, more challenging assignments. Graduate/Undergraduate Equivalency: CEVE 420. Mutually Exclusive: Cannot register for CEVE 520 if student has credit for CEVE 420.

CEVE 521 - CLIMATE RISK MANAGEMENT
Short Title: CLIMATE RISK MANAGEMENT
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Climate variability and change pose threats to lives and livelihoods. These climate risks can be managed through the design and operation of infrastructure systems, as well as through disaster response and recovery. Decisions about how to develop and choose risk management strategies are often based on pure vibes, but occasionally rigorous quantitative analyses that make use of scientific information can inform them (we will focus on these cases). These analyses involve integrating knowledge from multiple disciplines to balance competing goals (objectives) under uncertainty. In this course, you will learn a structured "bottom-up" decision analytic framework for quantitative climate risk analysis. This involves (i) defining a system of interest and what constitutes desirable outcomes; (ii) understanding and modeling the specific pathways through which climate variability and change can create risk to this system; (iii) identifying possible "levers" for risk management; (iv) quantifying the performance of proposed decisions under climate and other interacting factors; and (v) generating possible alternatives. You will be assigned readings for every class that cover relevant methods or applications, and will work collaboratively to implement key concepts through programming problem sets. Active class participation is required. Methods covered include scenario analysis, exploratory modeling, cost-benefit analysis, single- and multi-objective policy search, stochastic control, deep uncertainty, robust decision making, and equitable decision making. Graduate/Undergraduate Equivalency: CEVE 421. Recommended Prerequisite(s): An introductory course in probability and statistics Mutually Exclusive: Cannot register for CEVE 521 if student has credit for CEVE 421.

CEVE 523 - APPLIED SUSTAINABLE PLANNING AND DESIGN
Short Title: APPL. SUST. PLANNNG & DESIGN
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): CEVE 302 or CEVE 502
Description: This course applies principles learned in CEVE 302/502 to real-world sustainability projects. Three to four case studies will comprise the class. These case studies will involve development of design solutions for (1) carbon neutral design, (2) ecosystem services transactions, (3) sustainable industrial applications and/or (4) air pollution and environmental justice. Graduate/Undergraduate Equivalency: CEVE 323. Mutually Exclusive: Cannot register for CEVE 523 if student has credit for CEVE 323.

CEVE 524 - TIME-DEPENDENT SYSTEM RELIABILITY METHODS AND APPLICATIONS
Short Title: SYSTEM RELIABILITY METHODS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Students will learn computational simulation and theoretical techniques for the reliability assessment of engineered systems as a function of their component failure probabilities. We will explore time-dependent and algorithmic system reliability, and will use modern structural infrastructure systems as case studies, including power systems, wind turbines, bridges, and buildings. Extra provisions for graduate students in assignments, exams, and projects. Graduate/Undergraduate Equivalency: CEVE 424. Mutually Exclusive: Cannot register for CEVE 524 if student has credit for CEVE 424.

CEVE 525 - SUSTAINABLE INFRASTRUCTURE MATERIALS
Short Title: SUSTAIN INFRASTRUCT MATER
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course delves into the structure and properties of various infrastructure materials, encompassing cement, concrete, steel, glass, timber, and asphalt. Building upon the foundational knowledge of materials currently used in the industry, we will also cover sustainable alternatives and strategies aimed at enhancing the sustainability, performance, and durability of these infrastructure materials. The course will also introduce recent advancements in concrete technologies, such as 3D printing, AI-driven modeling, and smart concrete. Graduate/Undergraduate Equivalency: CEVE 425. Mutually Exclusive: Cannot register for CEVE 525 if student has credit for CEVE 425.

CEVE 526 - SMART MATERIALS FOR THE ENVIRONMENT
Short Title: SMART MATERIALS FOR THE ENVI
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: The purpose of this course is to introduce students to the concept of smart materials and their application to address challenges in environmental engineering. The course will cover three broad categories of smart materials, namely self-healing materials, stimuli-responsive materials, and materials with molecular-recognition capabilities. The use of these materials for structural, sensing, water treatment, and energy applications will be highlighted. The course will emphasize the underlying chemical and thermodynamic principles driving the behavior and responses of smart materials. Graduate/Undergraduate Equivalency: CEVE 426.

CEVE 527 - PHYSICS GUIDED MACHINE LEARNING & DATA DRIVEN MODELING FEM
Short Title: PHY GUIDED ML- DATA DRIVEN FEM
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): CEVE 311 or MECH 311 or MECH 315
Description: Introduction to physics guided machine learning and data driven modeling from a rigorous finite element analysis and system dynamics (& optimization) perspective. Programming needed will be introduced in the course. The course involves series of assignments involving programming. Project work will be assigned at the end of the semester in lieu of the final exam. Students in CEVE 527 (GR version) will be required to do more advanced assignments and a project. Prerequisites CEVE/MECH 311. Cross-list: MECH 527. Mutually Exclusive: Cannot register for CEVE 527 if student has credit for CEVE 427.
Course URL: Satishnagarajaiah.rice.edu (http://Satishnagarajaiah.rice.edu)

CEVE 529 - ETHICS AND ENGINEERING LEADERSHIP
Short Title: ETHICS & ENGINRNG LEADERSHIP
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to students with a major in Civil & Environmental Engineer, Civil Engineering or Environmental Analysis. Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Seminar introduces students to a framework for discussing and making ethical engineering and professional decisions. Using case studies and exercises, students will look at their own profession and its Engineering Code of Ethics as well as at the issues and risks they may face as managers and executives. Graduate students will do an extra paper. Instructor Permission Required. Cross-list: ENGI 529. Graduate/Undergraduate Equivalency: CEVE 320. Mutually Exclusive: Cannot register for CEVE 529 if student has credit for CEVE 320.

CEVE 531 - DESIGN AND BEHAVIOR OF CONCRETE BUILDINGS AND BUILDING ELEMENTS
Short Title: REINFORCED CONCRETE BUILDINGS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Design of reinforced concrete buildings including concepts and code practices routinely used in professional structural engineering design for concrete members and structural systems. Behavior of building members as related to design will be discussed as well. Graduate/Undergraduate Equivalency: CEVE 431. Recommended Prerequisite(s): CEVE 311. Mutually Exclusive: Cannot register for CEVE 531 if student has credit for CEVE 407/CEVE 431/CEVE 530.

CEVE 533 - NANOSCIENCE AND NANOTECHNOLOGY
Short Title: NANOSCIENCE & NANOTECHNOLOGY
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Enrollment is open to all students. Undergraduate enrollment requires instructor permission via special registration form. An introduction to the basic principles of nanoscience and nanotechnology. Size dependent physical properties of nanoscopic solids will be described using solid state physics and molecular orbital theory as a foundation. Wet chemical techniques that produce nanoscale materials (e.g. carbon nanotubes, semiconductor and metallic nanocrystals, dendrimers...) will be introduced in the second half of the semester. Expected to be taught Spring 2019. Cross-list: CHEM 533, MSNE 534.

CEVE 534 - FATE AND TRANSPORT OF CONTAMINANTS IN THE ENVIRONMENT
Short Title: FATE/TRANSPORT OF CONTAMINANTS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Physical and chemical principles governing the fate and transport of contaminants in the aqueous environment, and the applications of such principles in environmental engineering. Emphasis is put on mass transport and transportation processes in natural and engineering systems. Previous course work in fluid mechanics and calculus through differential equations is strongly suggested. Extra work required, for Graduate Students. Graduate/Undergraduate Equivalency: CEVE 434. Mutually Exclusive: Cannot register for CEVE 534 if student has credit for CEVE 434. Repeatable for Credit.

CEVE 535 - PHYSICAL CHEMICAL PROCESSES FOR WATER QUALITY CONTROL
Short Title: PHYS CHEM PROC WATER QUAL CTRL
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Principles, modeling and design aspects of physical chemical treatment processes in drinking water, wastewater and groundwater remediation applications. Modern treatment technologies such as membrane separation, advanced oxidation, and photocatalysis will be covered.

CEVE 536 - ENVIRONMENTAL BIOTECHNOLOGY AND BIOREMEDIATION
Short Title: ENVIRONMENTAL BIOTECHNOLOGY
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Theory and application of biochemical processes in environmental engineering.

CEVE 537 - DESIGN OF PRESTRESSED CONCRETE STRUCTURES
Short Title: PRESTRESSED CONCRETE
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Fundamental principles for the design of prestressed concrete structures. Prestressing losses and anchorage. Analysis and design of prestressed members and systems subjected to axial, shear, torsion, and bending loading. Deflection computation and control. Use of design codes and standards in prestressed concrete design. Graduate/Undergraduate Equivalency: CEVE 437. Mutually Exclusive: Cannot register for CEVE 537 if student has credit for CEVE 437.

CEVE 538 - COMPUATIONAL NANOSCIENCE FOR GREEN INFRASTRUCTURE
Short Title: COMPUTATIONAL NANOSCIENCE
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Computational methods such as first principles, kinetic Monte Carlo (KMC), classical MC (in Canonical, Grand Canonical, and isobaric-isothermal ensembles), and classic MD in predicting materials formation and properties. Case studies include cementitious materials, metals, and thermoelectric materials. Other case studies are possible depending on the student's background and instructor's approval. Cross-list: MSNE 538.

CEVE 539 - ADVANCED STRUCTURAL ANALYSIS
Short Title: ADVANCED STRUCTURAL ANALYSIS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This advanced structural analysis course builds on fundamentals to expand students' understanding and methods to analyze the behavior of indeterminate structures, emphasizing 2D and 3D framed structures. Students will familiarize themselves with the Matrix Flexibility and Matrix Stiffness Methods, learn to program the Direct Stiffness Method and acquire the skills to model framed structures using commercial software. A brief overview of nonlinear analysis will conclude the course. Graduate/Undergraduate Equivalency: CEVE 439. Mutually Exclusive: Cannot register for CEVE 539 if student has credit for CEVE 439.

CEVE 541 - DESIGN AND BEHAVIOR OF STRUCTURAL STEEL BUILDINGS AND BUILDING ELEMENTS
Short Title: STRUCTURAL STEEL BUILDINGS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Design of structural steel buildings including concepts and material routinely used in professional structural engineering design practice for steel members, connections and assemblies. Behavior of building members as related to design will be discussed as well. Graduate students registered to CEVE 541 will explore advanced topics in structural steel building behavior and design. Graduate/Undergraduate Equivalency: CEVE 441. Mutually Exclusive: Cannot register for CEVE 541 if student has credit for CEVE 441.

CEVE 543 - STATISTICAL-PHYSICAL METHODS FOR HYDROCLIMATE EXTREMES AND CATASTROPHES
Short Title: STATPHYS HYDROCLIMATE EXTREMES
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course explores the integration of physics-based and statistical (and machine learning) methods used to assess and model hydroclimate extremes and catastrophes, such as floods, droughts, and extreme rainfall. A central theme is quantifying uncertainty in extreme event probabilities, given the challenges posed by sparse observations and model biases. Through hands-on programming assignments, students will gain experience applying these methods to real-world problems. Topics include extreme value theory, optimal sampling, synthetic weather generation, downscaling and bias correction, surrogate models, and data assimilation. Recommended Prerequisite(s): A background in Bayesian statistics (e.g., 525) and/or machine learning (e.g., ELEC 478/578) is strongly recommended, along with familiarity with programming (e.g., Python, Julia, or R).

CEVE 544 - ENVIRONMENTAL MICROBIOLOGY AND MICROBIAL ECOLOGY
Short Title: ENVIRON MICROBIOL & ECOLOGY
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Fundamentals of microbiology and the ecology of microbes, highlighting their interactions with each other and the environment, and integration of these principles in the context of important natural and engineered environmental systems. Graduate/Undergraduate Equivalency: CEVE 444. Mutually Exclusive: Cannot register for CEVE 544 if student has credit for CEVE 444.

CEVE 545 - ORIGAMI ENGINEERING
Short Title: ORIGAMI ENG
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course introduces the key concepts of origami engineering, covering the science, art, and skills required to design and manufacture origami-inspired systems. Students will explore the properties of origami patterns and learn the principles for designing them. The course integrates fundamentals of solid mechanics with folding and geometry to examine structural and material phenomena, including single-degree of freedom kinematics, bi- and multistability, anisotropy, and auxeticity. The course features a hands-on component that allows students to engage directly in the prototyping of origami structures, making use of the facilities and resources available at the Oshman Engineering Design Kitchen (OEDK). Graduate/Undergraduate Equivalency: CEVE 445. Mutually Exclusive: Cannot register for CEVE 545 if student has credit for CEVE 445/CEVE 454.

CEVE 547 - WATER-ENERGY NEXUS
Short Title: WATER-ENERGY NEXUS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Water and energy are inextricably linked. This course examines their complex relationship, exploring the energy intensity of water management and the water footprint of energy production. Using principles of thermodynamics, mass transfer, electrochemistry, and process modeling, we will analyze case studies, including energy consumption in desalination and brine management, the potential of water electrolysis for hydrogen production, and the role of lithium extraction from brines in a circular economy. The course emphasizes technological advancements and integrated approaches for a secure water and energy future. Graduate/Undergraduate Equivalency: CEVE 347. Mutually Exclusive: Cannot register for CEVE 547 if student has credit for CEVE 347.

CEVE 550 - ENVIRONMENTAL ORGANIC CHEMISTRY
Short Title: ENVIRONMENTAL ORGANIC CHEM
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: A course covering parameter estimation methods, thermodynamics, and kinetic needed to predict the fate, transports, and reactivity of organic compounds in air, water, and soils. Topics: volatization, solubility, sorption, partitioning, diffusion, aquatic reactivity, photochemistry, and transport modeling.

CEVE 554 - COMPUTATIONAL FLUID MECHANICS
Short Title: COMPUTATIONAL FLUID MECHANICS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): MECH 371 (may be taken concurrently) or MECH 444 (may be taken concurrently) or CEVE 363 (may be taken concurrently) or CHBE 401 (may be taken concurrently) or BIOE 420 (may be taken concurrently) or CHBE 420 (may be taken concurrently)
Description: Fundamental concepts of finite element methods in fluid mechanics, including spatial discretization and numerical integration in multidimensions, time-integration, and solution of nonlinear ordinary differential equation systems. Advanced numerical stabilization techniques designed for fluid mechanics problems. Strategies for solution of complex, real-world problems. Topics in large-scale computing, parallel processing, and visualization. Prerequisites may be taken concurrently. Additional work required. Cross-list: BIOE 554, MECH 554. Graduate/Undergraduate Equivalency: CEVE 454. Mutually Exclusive: Cannot register for CEVE 554 if student has credit for CEVE 454.

CEVE 555 - NUMERICAL METHODS FOR PARTIAL DIFFERENTIAL EQUATIONS
Short Title: NUMERICAL METHODS FOR PDES
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course covers various numerical methods for solving partial differential equations: aspects of finite difference methods, finite element methods, finite volume methods, mixed methods, discontinuous Galerkin methods, and meshless methods. Both theoretical convergence and practical implementation of the methods are studied for elliptic and parabolic problems. May receive credit for only one of the following courses: CAAM 452/CEVE 455/CAAM 536/ CEVE 555. Cross-list: CMOR 523. Graduate/Undergraduate Equivalency: CEVE 455. Recommended Prerequisite(s): CAAM 336 or CMOR 304 Mutually Exclusive: Cannot register for CEVE 555 if student has credit for CEVE 455.

CEVE 556 - UNCERTAINTY QUANTIFICATION
Short Title: UNCERTAINTY QUANTIFICATION
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course introduces a series of computational methods in Uncertainty Quantification (UQ), a field of growing importance across various engineering domains and beyond. Focusing on mathematical theories and numerical methods, the course will cover global sensitivity analysis, multi-fidelity Monte Carlo, and probabilistic machine learning ("surrogate") models, such as Gaussian process and polynomial chaos expansion, with advanced topics of active learning and dimensionality reduction techniques. Graduate/Undergraduate Equivalency: CEVE 456. Mutually Exclusive: Cannot register for CEVE 556 if student has credit for CEVE 456.

CEVE 557 - TRANSPORTATION SYSTEMS MODELING AND DECISION-MAKING
Short Title: TRANS SYS MODELING
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course aims to provide a rigorous introduction to mathematical modeling of transportation systems that enables optimal decision-making, from the network routing and traffic equilibrium aspects. Graduate/Undergraduate Equivalency: CEVE 457. Mutually Exclusive: Cannot register for CEVE 557 if student has credit for CEVE 457.

CEVE 560 - BRIDGE ENGINEERING AND EXTREME EVENTS
Short Title: BRIDGE ENG. & EXTREME EVENTS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course integrates information from various engineering and scientific disciplines to provide a rational basis for bridge design under regular and extreme loading. It provides an introduction to bridge engineering, including bridge systems, construction material, loading, and reliability-based design. Design, analysis, and retrofit for seismic and coastal threats will be introduced. Graduate/Undergraduate Equivalency: CEVE 460. Recommended Prerequisite(s): CEVE 304 and CEVE 311. Mutually Exclusive: Cannot register for CEVE 560 if student has credit for CEVE 460.

CEVE 562 - INFRASTRUCTURE RESILIENCE TO MULTIPLE HAZARDS
Short Title: INFRASTRUCTURE RESILIENCE
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course will present concepts of resilience assessment and engineering in the context of civil structures and infrastructure systems, while acknowledging their role in supporting broader community resilience goals. We will explore the theoretical constructs, frameworks and formulations for evaluating resilience in the face of multiple hazards. Along the way, we review the key ingredients of such an evaluation ranging from hazard modeling and exposure to structural fragility and infrastructure performance assessment to restoration and recovery modeling. Topics will introduce students to relevant and timely resources such as open source modeling environments and cyberinfrastructure to support resilience quantification, while leveraging case studies and projects to provide realistic context. Course content will be delivered via formal lectures, readings and discussion sessions, invited speakers, and working sessions.

CEVE 564 - MEMBRANE SCIENCE AND TECHNOLOGY
Short Title: MEMBRANE SCIENCE & TECHNOLOGY
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course provides an in-depth study of membrane science and technology, covering principles, transport theories, materials, and applications of membrane-based separation processes. Topics include major classes of membrane technologies, solvent and solute transport mechanisms, and applications in chemical separations, water treatment, desalination, and energy systems. Students will also explore recent advances and emerging directions in membrane research.

CEVE 565 - NANOTECHNOLOGY ENVIRONMENTAL ENGINEERING FOR TEACHERS (NEET)
Short Title: NANOENVIRONMENTL ENGR-TEACHERS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: The Nano-Environmental Engineering for Teachers (NEET) course is designed to serve AP environmental science teachers. The purpose of the program is to increase the current knowledge of educators to empower them in implementing rigorous project-based engineering activities on the topic of water sustainability. Instructor Permission Required.

CEVE 571 - PRINCIPLES OF SOIL MECHANICS AND FOUNDATION ENGINEERING
Short Title: SOIL MECHANICS AND FOUNDATIONS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Introduction to fundamentals of soil mechanics will include phase relationships, grain size, plasticity, soil classification, and clay mineralogy. The effect of water in soils, including capillarity, shrinkage and swelling, permeability, seepage and effective stress will be discussed. Consolidation, settlement, compressibility, failure theory, and the strength of sands and clays will be investigated. Design considerations will be discussed. Introduction to fundamentals of foundation engineering will include subsurface exploration methods and lateral earth pressures. The design of shallow and deep foundations, including pile installation and geophysical and geotechnical site investigation will be presented. CEVE 471, the undergrad version, includes a lab. Students in CEVE 571 (GR version—does not include a laboratory) will be required to do more advanced assignments and a project. Graduate/Undergraduate Equivalency: CEVE 471. Mutually Exclusive: Cannot register for CEVE 571 if student has credit for CEVE 470/CEVE 471/CEVE 570.

CEVE 576 - STRUCTURAL DYNAMIC SYSTEMS
Short Title: STRUCTURAL DYNAMIC SYSTEMS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Introduction to structural dynamic systems. Linear SDOF and MDOF discrete systems, undamped and damped systems, free and forced vibration, dynamic response to periodic and arbitrary excitations, numerical evaluation of dynamic response, response spectrum and modal analysis. Additional topics for graduate version 576: Linear systems theory, transform methods, state space methods, feedback control, observers and identification. Applications using MATLAB. Demonstrations and laboratory examples. Students will be required to do more advanced assignments and a project. Cross-list: MECH 576. Graduate/Undergraduate Equivalency: CEVE 476. Mutually Exclusive: Cannot register for CEVE 576 if student has credit for CEVE 476.

CEVE 578 - EARTHQUAKE ENGINEERING
Short Title: EARTHQUAKE ENGINEERING
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Characteristics of ground motion, analysis methods for linear and nonlinear base excited structures, and principles of seismic design including case studies and performance based engineering concepts. Probabilistic methods in earthquake engineering including seismic hazard analysis, fragility modeling, and risk assessment and mitigation. Recommended Prerequisite(s): CEVE 576 or equivalent course in Structural Dynamics.

CEVE 590 - MCEE SPECIAL STUDY
Short Title: MCEE SPECIAL STUDY
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Research
Credit Hours: 2-3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Professional master Project course involves the following (1) a project of practical relevance to the practice of Civil and Environmental Engineering, and (2) detailed project report. Students need to work with a faculty advisor. Instructor Permission Required. Repeatable for Credit.

CEVE 592 - MODELING AND ANALYSIS OF NETWORKED SYSTEMS
Short Title: MODELING & ANALYSIS OF NET SYS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This course introduces methods for modeling, characterizing and predicting the behavior of complex infrastructure and technological systems. The discussed analysis methods rely on network science optimization, and computational complexity principles so as to unravel the emergent features of structural and infrastructure systems. Topological properties, ranking tools, dynamic processes, and percolation-based resilience are studied from analytical, algorithmic, and numerical simulation perspectives. The course also explores interdependencies and mitigation actions for spatially and temporally evolving systems. The graduate level course includes advanced exercises in homework and exams, as well as a research-oriented final project. Graduate/Undergraduate Equivalency: CEVE 492. Mutually Exclusive: Cannot register for CEVE 592 if student has credit for CEVE 492. Repeatable for Credit.

CEVE 596 - SYSTEM IDENTIFICATION OF DYNAMIC SYSTEMS WITH MACHINE LEARNING
Short Title: SYSTEM I.D. & MACHINE LEARNING
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): CEVE 311 or MECH 311 or MECH 315
Description: Introduction to modeling and system identification of dynamic systems with machine learning. Students in CEVE 596/ MECH 566 will be required to do more advanced assignments and a project. Cross-list: MECH 566. Graduate/Undergraduate Equivalency: CEVE 496. Mutually Exclusive: Cannot register for CEVE 596 if student has credit for CEVE 496.

CEVE 599 - SPECIAL TOPICS
Short Title: SPECIAL TOPICS
Department: Civil & Environmental Engr
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Independent Study
Credit Hours: 1-3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Independent research and investigation, including a course toward directed research and/or a research project. Study of selected topics including individual investigations special lectures, and seminars. Student works independently with only minimal faculty direction. Offered upon mutual agreement of faculty and student. May earn varying amount of credit hours depending on the amount of time devoted and the amount of academic work associated with the course. Repeatable for Credit.

CEVE 601 - SEMINAR
Short Title: SEMINAR
Department: Civil & Environmental Engr
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hour: 1
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Continuing seminar on Civil and Environmental research. Repeatable for Credit.

CEVE 602 - SEMINAR
Short Title: SEMINAR
Department: Civil & Environmental Engr
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hour: 1
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Continuing seminar on Civil and Environmental research. Repeatable for Credit.

CEVE 603 - NANOTECHNOLOGY-ENABLED WATER TREATMENT (NEWT) CORE CONCEPTS SEMINAR
Short Title: NEWT CORE COURSE
Department: Civil & Environmental Engr
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hour: 1
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: This seminar will introduce NEWT graduate students to the basic scientific concepts behind NEWT research. It is also intended to develop a common language for NEWT students in different research areas, and to contribute to the development of a center culture. Instructor Permission Required. Repeatable for Credit.

CEVE 635 - ADVANCED TOPICS: WATER CHEMISTRY
Short Title: ADV TOPICS: WATER CHEMISTRY
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 1-12
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Formal lecture and assigned reading in topics such as redox kinetics and thermodynamics, absorption and desorption, and the associated mathematics. An advanced topics course. Repeatable for Credit.

CEVE 636 - ADVANCED TOPICS IN BIOREMEDIATION
Short Title: ADV TOPICS IN BIOREMEDIATION
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Basic principles of Microbial Physiology, Metabolism, Stoichiometry, Thermodynamics and Kinetics applied to the selection, design and performance evaluation of engineered and intrinsic bioremediation systems. Repeatable for Credit.

CEVE 640 - ADVANCED TOPICS IN ENVIRONMENTAL ENGINEERING SCIENCES
Short Title: ADV TOPICS/ENVIRONMENTAL ENG
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 1-12
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Special topics in Graduate Study.

CEVE 641 - ADVANCED TOPICS IN ENVIRONMENTAL ENGINEERING
Short Title: ADV TOPICS/ENVIRONMENTAL ENG
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Seminar
Credit Hours: 1-12
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Advanced topics in Graduate Study.

CEVE 651 - M.S. RESEARCH AND THESIS
Short Title: M.S. RESEARCH AND THESIS
Department: Civil & Environmental Engr
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Research
Credit Hours: 1-15
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Repeatable for Credit.

CEVE 652 - M.S. RESEARCH AND THESIS
Short Title: M.S. RESEARCH AND THESIS
Department: Civil & Environmental Engr
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Research
Credit Hours: 1-15
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Repeatable for Credit.

CEVE 654 - ADVANCED COMPUTATIONAL MECHANICS
Short Title: ADV COMPUTATIONAL MECHANICS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): CEVE 554 or BIOE 554 or MECH 554 or BIOE 454 or CEVE 454 or MECH 454
Description: Advanced topics in computational mechanics with emphasis on finite element methods and fluid mechanics. Stabilized formulations. Fluid-particle and fluid-structure interactions and free-surface and two-fluid flows. Interface tracking and interface-capturing techniques, space-time formulations, and mesh update methods. Enhanced discretization and solution techniques. Iterative solution methods, matrix-free computations, and advanced preconditioning techniques. Cross-list: BIOE 654, MECH 654.

CEVE 677 - SPECIAL TOPICS
Short Title: SPECIAL TOPICS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Internship/Practicum, Laboratory, Lecture, Lecture/Laboratory, Seminar, Independent Study
Credit Hours: 1-4
Restrictions: Enrollment is limited to Graduate or Visiting Graduate level students.
Course Level: Graduate
Description: Topics and credit hours vary each semester. Contact department for current semester's topic(s). Repeatable for Credit.

CEVE 678 - APPLIED STOCHASTIC MECHANICS
Short Title: APPLIED STOCHASTIC MECHANICS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Nonlinear random vibrations, Statistical Linearization, ARMA filters modeling, Monte Carlo Simulation, Wiener-Volterra series, time-variant structural reliability, and Stochastic Finite Elements are presented from a perspective of usefulness to aerospace, civil, marine, and mechanical applications. Cross-list: MECH 678.

CEVE 679 - APPLIED MONTE CARLO ANALYSIS
Short Title: APPLIED MONTE CARLO ANALYSIS
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Probability density and power spectrum based simulation concepts and procedures are discussed. Scalar and vectorial simulation are addressed. Spectral decomposition and digital filter algorithms are presented. Applications from aerospace, earthquake, marine, and wind engineering, and from other applied science disciplines are included. Cross-list: MECH 679.

CEVE 684 - ENVIRONMENTAL RISK ASSESSMENT & HUMAN HEALTH
Short Title: ENVIRON RISK ASSESS&HUMAN HLTH
Department: Civil & Environmental Engr
Grade Mode: Standard Letter
Course Type: Lecture/Laboratory
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Prerequisite(s): STAT 180 or STAT 280 or STAT 305
Description: Learn and apply quantitative risk assessment methodology to estimate human health risk from environmental exposure to contamination in air, soil and water. Students will conduct a series of team projects focused on toxicology, risk based screening levels, exposure concentration estimation and risk characterization. Cross-list: STAT 684. Graduate/Undergraduate Equivalency: CEVE 484. Mutually Exclusive: Cannot register for CEVE 684 if student has credit for CEVE 484.

CEVE 736 - ADVANCED RESEARCH TOPICS: ENVIRONMENTAL BIOTECHNOLOGY AND NANOTECHNOLOGY
Short Title: ADV TOPICS:ENVIR BIOTECH & NAN
Department: Civil & Environmental Engr
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Seminar
Credit Hours: 3
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Research oriented presentations and discussions of landmark papers and experimental methods for doctoral students in the Alvarez research group. Repeatable for Credit.

CEVE 800 - PH.D. RESEARCH AND THESIS
Short Title: PH.D. RESEARCH AND THESIS
Department: Civil & Environmental Engr
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Research
Credit Hours: 1-15
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Repeatable for Credit.

CEVE 801 - PH.D. RESEARCH AND THESIS
Short Title: PHD RESEARCH AND THESIS
Department: Civil & Environmental Engr
Grade Mode: Satisfactory/Unsatisfactory
Course Type: Research
Credit Hours: 1-15
Restrictions: Enrollment is limited to Graduate level students.
Course Level: Graduate
Description: Repeatable for Credit.

Description and Code Legend

***Note**: Internally, the university uses the following descriptions, codes, and abbreviations for this academic program. The following is a quick reference:*

Course Catalog/Schedule

- Course offerings/subject code: CEVE

Home School Description and Code

- Engineering and Computing: EN

Home Department (or Program) Descriptions and Codes

- Civil and Environmental Engineering (BA, BSCE, BSEnVE, MCEE, MS, and PhD degrees): CEEG
- Energy and Water Sustainability (EWSU minor): EWSU

Undergraduate Degree Descriptions and Codes

- Bachelor of Arts degree: BA
- Bachelor of Science in Civil Engineering degree: BSCE
- Bachelor of Science in Environmental Engineering degree: BSEnvE

Undergraduate Major Descriptions and Codes

- Major in Civil Engineering (BSCE degree): CIVI
- Major in Civil and Environmental Engineering (BA degree): CEEG
- Major in Environmental Engineering (BSEnvE degree): ENVI

Undergraduate Major Concentration Descriptions and Codes

- Major Concentration in Civil Engineering (BA degree): CIEG
- Major Concentration in Environmental Engineering (BA degree): ENEG

Undergraduate Major Areas of Specialization Descriptions and Attribute Codes*

- Area of Specialization in Area I - Environmental Engineering (BSCE degree): CEEN
- Area of Specialization in Area II - Hydrology and Water Resources (BSCE degree): CEHW
- Area of Specialization in Area III - Structural Engineering and Mechanics (BSCE degree): CESM
- Area of Specialization in Area IV - Urban Infrastructure, Reliability, and Management (BSCE degree): CEUR
- Area of Specialization in Area I - Sustainable Water (BSEnvE degree): EESW
- Area of Specialization in Area II - Air, Climate, and Energy (BSEnvE degree): EEAC
- Area of Specialization in Area III - Resilient Infrastructure, Disasters, and Risk (BSEnvE degree): EERD
- Area of Specialization in Area IV - Environmental Management (BSEnvE degree): EEEM

Please Note: *Areas of Specialization are department/program-specific and are not formally recognized academic credentials. Unlike Major Concentrations, Areas of Specialization do not appear on the student's official academic transcript, etc. Students may informally choose to follow more than one Area of Specialization (or pre-specified collections of elective courses), however, when declaring their major they should identify and declare one Area of Specialization with the Office of the Registrar.*

Undergraduate Degree Program Option Descriptions and Codes*

- Degree Program Option (BA degree): BA-ENGI
- Degree Program Option (BSCE degree): BSCE-ENGI
- Degree Program Option (BSEnvE degree): BSENVE-ENGI

Undergraduate Minor Description and Code

- Minor in Energy and Water Sustainability: EWSU

Graduate Degree Descriptions and Codes

- Master of Civil and Environmental Engineering degree: MCEE
- Master of Science degree: MS
- Doctor of Philosophy degree: PhD

Graduate Degree Program Description and Code

- Degree Program in Civil and Environmental Engineering (MCEE, MS, and PhD degrees): CEEG

Graduate Degree Program Option Description and Code*

- Degree Program Option - Thesis (MS degree): MS-THESIS

CIP Code and Description [1]

- **CEEG** Major/Program: CIP Code/Title: *14.0801 - Civil Engineering, General*
- **CIVI** Major/Program: CIP Code/Title: *14.0801 - Civil Engineering, General*
- **ENVI** Major/Program: CIP Code/Title: *14.1401 - Environmental/ Environmental Health Engineering*
- **CIEG** Major Concentration: CIP Code/Title: *14.0801- Civil Engineering, General*
- **ENEG** Major Concentration: CIP Code/Title: *14.1401 - Environmental/ Environmental Health Engineering*
- **EWSU** Minor: CIP Code/Title: *30.3301 - Sustainability Studies*

* *Systems Use Only: this information is used solely by internal offices at Rice University (such as OTR, GPS, etc.) and primarily within student information systems and support.*

1 Classification of Instructional Programs (CIP) 2020 Codes and Descriptions from the National Center for Education Statistics: https://nces.ed.gov/ipeds/cipcode/.