

CIVIL AND ENVIRONMENTAL ENGINEERING

Contact Information

Civil and Environmental Engineering

<https://cee.rice.edu/>

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Civil and Environmental Engineering (CEE) is a broad and diverse field of study that offers students an education with several degree options. 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 or the Bachelor of Arts (BA) degree. The more scientific BSCE includes 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.

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-environmental-engineering-bsce/>)

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

Doctoral Programs

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

Chair

Jamie Ellen Padgett

Professors

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

Associate Professor

Daniel Cohan

Assistant Professors

James Doss-Gollin
 Bezawit Getachew
 Kai Gong
 Larissa Novelino
 Lauren Stadler

Professors Emeriti

Ahmad J. Durrani
Ronald P. Nordgren
Anestis S. Veletsos
Calvin H. Ward

Assistant Teaching Professor

Kalil Erazo Cruz

Professor in the Practice of Civil Engineering

Edmund P. Segner III

Professor in the Practice of Environmental Law

James B. Blackburn

Lecturers

Mandi Chapa
Philip C. deBlanc
Nestor Rubiano-Benavides
Christof Spieler
Bob Stevens

Joint Appointments

Sylvia Dee
Michael S. Wong

Adjunct Professors

Jean-Yves Bottero
Samuel Brody
Marcio Busi Da Silva
Wei Chen
Joseph Cibor
Nick Fang
Robert J. Griffin
Jorge Loyo
Charles J. Newell
Javier Rojo
Jerome Rose
Baxter Vieux
Zongming Xiu
Yetkin Yildirim

For Rice University degree-granting programs:

To view the list of official course offerings, please see [Rice's Course Catalog \(https://courses.rice.edu/admweb!/SWKSCAT.cat?p_action=cata\)](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 \(https://courses.rice.edu/admweb!/SWKSCAT.cat\)](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 Hours: 2

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 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:** Internship/Practicum, Laboratory, Lecture, Seminar, Independent Study**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 at 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 and mechanical 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 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 322 - ENGINEERING ECONOMICS****Short Title:** ENGINEERING ECONOMICS**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 the evaluation of alternative investment opportunities with emphasis on engineering projects and capital infrastructure. Time value of money concepts are developed in the context of detailed project evaluation and presentations. In addition, concepts and applications of risk analysis and investment under uncertainty are introduced. Requires oral and written presentations by students. Cross-list: ENGI 303. Graduate/Undergraduate Equivalency: CEVE 528. Mutually Exclusive: Cannot register for CEVE 322 if student has credit for RCEL 505.**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 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):** 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 MECH 211 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 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 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 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**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. Recommended Prerequisite(s): CEVE 304 or CEVE 325 and CEVE 311 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 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 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 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 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

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 at 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 - 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 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 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.

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. PLANNING & 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 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 528 - ENGINEERING ECONOMICS**Short Title:** ENGINEERING ECONOMICS**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 the evaluation of alternative investment opportunities with emphasis on engineering projects and capital infrastructure. Time value of money concepts are developed in the context of detailed project evaluation and presentations. In addition, concepts and applications of risk analysis and investment under uncertainty are developed. Requires oral and written presentations by students. Grad students will have an additional case study to perform beyond CEVE 322 requirements. Cross-list: ENGI 528. Graduate/Undergraduate Equivalency: CEVE 322. Mutually Exclusive: Cannot register for CEVE 528 if student has credit for RCEL 505.

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 Environment Analysis&Decisions. 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 538 - COMPUTATIONAL 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 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 - DATA-DRIVEN MODELS FOR CLIMATE HAZARD**Short Title:** DATA-DRIVEN CLIMATE HAZARD**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 the use of tools from data science (statistics, machine learning, and programming) to model climate hazards such as floods and droughts. Through hands-on programming assignments based on state-of-the-art published research, students will learn to apply methods to real-world problems with a strong emphasis on probabilistic methods and uncertainty quantification. Examples of potential topics covered include nonparametric statistics, convolutional neural networks, Gaussian processes, wavelets and spectral analysis, extreme value distributions, hierarchical models, and graph neural networks. Recommended Prerequisite(s): Prior coursework in Bayesian statistics (e.g., STAT 425/525) and/or machine learning (e.g., ELEC 478/578) and some comfort writing code.

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 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: volatilization, 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 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 opensource 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 565 - NANOTECHNOLOGY ENVIRONMENTAL ENGINEERING FOR TEACHERS (NEET)**Short Title:** NANOENVIRONMENTAL 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

Department Description and Code

- Civil and Environmental Engineering: CEEG

Undergraduate Degree Descriptions and Codes

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

Undergraduate Major Descriptions and Codes

- Major in Civil Engineering (offered to students pursuing the BSCE degree): CIVI
- Major in Civil and Environmental Engineering (offered to students pursuing the BA degree): CEEG

Undergraduate Major Concentration Descriptions and Codes

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

Undergraduate Major Areas of Specialization Descriptions and Attribute Codes*

- Area of Specialization in Area I - Environmental Engineering (BSCE degree only): CEEN
- Area of Specialization in Area II - Hydrology and Water Resources (BSCE degree only): CEHW
- Area of Specialization in Area III - Structural Engineering and Mechanics (BSCE degree only): CESM
- Area of Specialization in Area IV - Urban Infrastructure, Reliability, and Management (BSCE degree only): CEUR

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 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 Descriptions and Codes

- Degree Program in Civil Engineering: CIVI
- Degree Program in Environmental Engineering: ENVI

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: 14.0802 - Geotechnical and Geoenvironmental Engineering
- ENEG Major Concentration: CIP Code/Title: 14.1401 - Environmental/Environmental Health Engineering
- EWSU Minor: CIP Code/Title: 40.0605 - Hydrology and Water Resources Science

* *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/>