Graduate studies in civil engineering are offered through the Department of Civil, Environmental and Architectural Engineering (http://www.colorado.edu/ceae). Fields emphasized in civil engineering include geotechnical engineering and geomechanics, structural mechanics and engineering, construction management and engineering, environmental and geoenvironmental engineering, hydrology, environmental fluid mechanics, civil engineering systems, and engineering science.

The Graduate Record Examination (GRE), consisting of the aptitude tests and advanced test in engineering, is used to evaluate Master of Science and Doctor of Philosophy candidates. Candidates who submit GRE scores may be more likely to be considered for financial assistance. Course code for this program is CVEN.

Research Interests and Facilities

The department has a wide variety of research facilities, including a 15g-ton centrifuge for geotechnical and structural model studies and a large 440g-ton geotechnical centrifuge for use in model testing. Also available is an instructional computing facility, the Bechtel Laboratory and the M.Y. Leung Computational Laboratory for Soils and Structures, both equipped with Windows and Linux high-performance workstations. In addition, extensive structural engineering, engineering mechanics and geotechnical capabilities exist such as a one-million-pound universal testing machine and several cubical cells for multiaxial testing of materials. A 40 ft. by 80 ft. structural strong floor with associated equipment permits the testing of a wide variety of structural configurations under controlled, both static and dynamic, loading. The hydraulics and water resources research laboratories include excellent facilities in water quality and environmental engineering. A unique workstation laboratory for advanced decision support systems is available. Programs in construction management and building energy are well supported. The 3600 sq. ft. mechanical and energy laboratory is capable of testing full-scale, commercial building systems and their controls using a one-of-a-kind data acquisition and experimental control system. The laboratory has been recently redesigned and renovated for maximum flexibility to encourage a wide variety of research and testing procedures.

The Environmental Engineering program maintains approximately 12,000 sq. ft. of laboratories in the areas of process research, environmental microbiology, environmental chemistry, water quality, air quality, molecular biology, toxicology, and field ecology. The Environmental Sustainability cluster and the Center for Environmental Mass Spectrometry offer formal collaborations between the CU Boulder Environmental Engineering Group, the Mechanical Engineering air research group, the US Geological Survey, and industry partners, providing state-of-the-art facilities for research and teaching.

The Center for Advanced Decision Support for Water and Environmental Systems (CADSWES) is an interdisciplinary center of excellence, housed within the Department of Civil, Environmental and Architectural Engineering. CADSWES focuses on applying advanced computing techniques to provide decision makers with decision support systems (DSSs) to help them more effectively manage water and environmental systems. Current research covers such topics as water and wastewater treatment, surface and subsurface contaminant transport, decision support systems, hydraulic research, land treatment, rapid infiltration and activated sludge processes. Cost prediction in construction, construction management, energy conservation in buildings, solar applications, and lighting systems are included. Advances in soil mechanics, rock mechanics, soil dynamics and geotechnical earthquake engineering, foundation engineering, computational geomechanics, centrifugal modeling, geosynthetics and glacier flows have been produced. Research in structures includes stability, damage and fracture, material microstructures, durability, finite element modeling, reinforced concrete, earthquake responses, reinforced masonry structures, prestressed concrete and dynamic control.

Master's Degrees

- Civil Engineering - Master of Science (MS) (catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/civil-engineering/civil-engineering-master-science-ms)
- Civil Engineering - Professional Master of Science (MSCVE) (catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/civil-engineering/civil-engineering-professional-master-science-mscve)

Doctoral Degree

- Civil Engineering - Doctor of Philosophy (PhD) (catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/civil-engineering/civil-engineering-doctor-philosophy-phd)

Certificate

- Engineering for Developing Communities - Graduate Certificate (catalog.colorado.edu/graduate/colleges-schools/engineering-applied-science/programs-study/civil-engineering/engineering-developing-communities-graduate-certificate)

Faculty

While many faculty teach both undergraduate and graduate students, some instruct students at the undergraduate level only. For more information, contact the faculty member's home department.

Amadei, Bernard (https://experts.colorado.edu/display/fisid_105978) 
Professor; PhD, University of California-Berkeley

Amy, Gary L. 
Professor Emeritus

Balaji, Rajagopalan (https://experts.colorado.edu/display/fisid_118480) 
Professor; PhD, Utah State University

Ball, L. Duane 
Professor Emeritus

Beamer, Charles Walter (https://experts.colorado.edu/display/fisid_151044) 
Instructor; PhD, University of Colorado Boulder

Bielefeldt, Angela R (https://experts.colorado.edu/display/fisid_110322) 
Professor, Associate Professor, Lecturer; PhD, University of Washington

Brandemuehl, Michael J. 
Professor Emeritus

Chinowsky, Paul (https://experts.colorado.edu/display/fisid_125496) 
Professor; PhD, Stanford University
Silverstein, Joann (https://experts.colorado.edu/display/fisid_101482)
Professor; PhD, University of California-Davis

Song, Jeong-Hoon (https://experts.colorado.edu/display/fisid_154468)
Assistant Professor; PhD, Northwestern University

Srubar III, Wilfred V. (https://experts.colorado.edu/display/fisid_153058)
Assistant Professor; PhD, Stanford University

Strzepek, Kenneth M.
Professor Emeritus

Sture, Stein (https://experts.colorado.edu/display/fisid_104029)
Professor; PhD, University of Colorado Boulder

Summers, Luis L.
Professor Emeritus

Summers, R Scott (https://experts.colorado.edu/display/fisid_113151)
Professor; PhD, Stanford University

Tulin, Leonard G.
Professor Emeritus

Vasconez, Sandra L. (https://experts.colorado.edu/display/fisid_144198)
Senior Instructor; MA, University of Denver

Weers, Walter A.
Professor Emeritus

William, Kaspar J.
Professor Emeritus

Xi, Yunping (https://experts.colorado.edu/display/fisid_110518)
Professor; PhD, Northwestern University

Zhai, Zhiqiang (https://experts.colorado.edu/display/fisid_130604)
Professor, Associate Professor; PhD, Massachusetts Institute of Technology

Znidarcic, Dobroslav (https://experts.colorado.edu/display/fisid_104109)
Professor; PhD, University of Colorado Boulder

Courses

**CVEN 5111 (3) Structural Dynamics**
Focusses on the response of single- and multi-degree of freedom structures subjected to harmonic, impulsive and arbitrary loads (including earthquake base excitation). Sources and modeling of damping will be discussed. Analytical and numerical solutions will be considered for both linear and nonlinear structural systems. Elastic and inelastic response spectra will be discussed.

**Requisites:** Restricted to graduate students only.

**Additional Information:** Departmental Category: Mechanics

**CVEN 5131 (3) Continuum Mechanics and Elasticity**
Provides foundation for advanced study of structural, mechanical and geo-material behavior and continuum theories in mechanics. Topics: Cartesian tensors, formulation of continuum mechanics for small and large deformation, constitutive laws for elastic solids, energy principles, methods of potentials, formulations and solutions of 2D and 3D elastostatic and elastodynamic problems, analytical and numerical formulations.

**Recommended:** Prerequisite CVEN 4161.

**Additional Information:** Departmental Category: Mechanics

**CVEN 5147 (3) Civil Engineering Systems**
Theory and application of the principles of engineering economics and classical and metaheuristic optimization techniques for evaluating problems in civil and environmental engineering.

**Equivalent - Duplicate Degree Credit Not Granted:** CVEN 4147

**Requisites:** Restricted to graduate students only.

**Additional Information:** Departmental Category: Miscellaneous

**CVEN 5161 (3) Advanced Mechanics of Materials I**
Covers advanced topics in the mechanics of solids. Some topics such as asymmetric bending of beams, torsion of non-circular cross-sections, are extensions of topics seen in CVEN 3161. Others like 3-D stress and strain analysis, failure theories and stability of columns and frames are new. Includes selected laboratory experiments.

**Equivalent - Duplicate Degree Credit Not Granted:** CVEN 4161

**Requisites:** Restricted to graduate students only.

**Additional Information:** Departmental Category: Mechanics

**CVEN 5206 (3) Design Development**
Provides an overview of the development process and proforma, investigates the interrelationship between design decisions and building costs, and evaluates the impact of each major building system on the development budget and schedule. Provides a simulated development experience where students respond to a Request for Proposal, including proformas, design, estimates and outline specifications. Department consent required. Taught intermittently.

**Additional Information:** Departmental Category: Construction

**CVEN 5226 (3) Construction Safety**
Comprehensively studies construction safety in the construction industry. Focuses on advanced safety management issues such as accident causation theory, economic modeling, safety risk quantification and analysis, design for safety, predictive analytics and learning. Skills developed in this course will prepare graduate students to be effective quality and safety managers or researchers.

**Additional Information:** Departmental Category: Construction

**CVEN 5246 (3) Legal Aspects of Construction**
Applies law in engineering practice; contracts, construction contract documents, construction specification writing, agency, partnership, and property; types of construction contracts; and legal responsibilities and ethical requirements of the professional engineer. Taught intermittently.

**Recommended:** graduate standing or department consent required.

**Additional Information:** Departmental Category: Construction

**CVEN 5276 (3) Engineering Risk and Decision Analysis**
Acquaints students with the fundamental principles and techniques of risk and decision analysis. Oriented toward project-level decisions in which risk or uncertainty plays a central role. Introduces students to Monte Carlo analyses, and various types of multicriteria decision analyses. Culminates in a larger term project.

**Recommended:** Prerequisite CVEN 3227 and graduate standing or instructor consent required.

**Additional Information:** Departmental Category: Construction

**CVEN 5286 (3) Design Construction Operations**
Considers effective/efficient design of construction operations. Front end planning; construction labor relations; productivity management. Emphasizes construction productivity improvement by group field studies and discrete event simulation modeling. How overtime, changes, weather, and staffing levels influence productivity. Industrial engineering techniques are applied to the construction environment to improve the use of equipment, human, and material resources.

**Recommended:** graduate standing or department consent required.

**Additional Information:** Departmental Category: Construction
CVEN 5313 (3) Environmental Fluid Mechanics
Analysis of viscous incompressible flows, with first-principle solutions for environmental fluid flows in oceans, rivers, lakes and the atmosphere. Topics include the Navier-Stokes equations, kinematics, vorticity dynamics, geophysical fluid dynamics, and density stratification.
**Requisites:** Restricted to graduate students only.
**Recommended:** Prerequisites APPM 2350 and APPM 2360 and CVEN 3313.
**Additional Information:** Departmental Category: Fluid Mechanics and Water Resources

CVEN 5323 (3) Applied Stream Ecology
Emphasizes the integration of hydrologic, chemical, and biological processes in controlling river, stream, and reservoir ecosystems at several spatial scales. Students apply ecosystem concepts to current environmental and water quality problems and learn field methods in field trips and a team project.
**Requisites:** Restricted to graduate students only.
**Additional Information:** Departmental Category: Environmental

CVEN 5333 (3) Physical Hydrology
Introduces hydrology as a quantitative science describing the occurrence, distribution and movement of water at and near the surface of the earth. Develops a quantitative understanding of atmospheric water, infiltration, evapotranspiration and surface runoff. Studies global climatology and large scale climate drivers of regional hydrology at interannual time scales. Solves engineering problems related to water resources.
**Requisites:** Restricted to graduate students only.
**Recommended:** Prerequisite CVEN 4333.
**Additional Information:** Departmental Category: Fluid Mechanics and Water Resources

CVEN 5343 (3) Transport and Dispersion in Surface Water
Studies transport and dispersion of introduced contaminants in turbulent surface water flows. Emphasizes developing a physical understanding of fluid processes responsible for turbulent dispersion. Includes analytical development, numerical modeling, and experimental approaches to the problem.
**Additional Information:** Departmental Category: Fluid Mechanics and Water Resources

CVEN 5346 (3) Managing Construction and Engineering Projects and Organizations
Explores organizational and managerial issues and concerns facing executives in engineering and construction organizations. Through readings, case studies, simulation exercises, and projects, students are introduced to and apply concepts of strategy, core competencies, vision, innovation, team dynamics, interpersonal influence, organizational design issues, and global projects to engineering and construction organizations.
**Additional Information:** Departmental Category: Construction

CVEN 5353 (3) Groundwater Hydrology
Studies the occurrence, movement, extraction for use, and quantity and quality aspects of groundwater. Introduces and uses basic concepts to solve engineering and geohydrologic problems.
**Requisites:** Restricted to graduate students only.
**Recommended:** Prerequisites CVEN 3313 or AREN 2120 or CHEN 3200 or GEEN 3853 or MCEN 3021 and APPM 2360.
**Additional Information:** Departmental Category: Fluid Mechanics and Water Resources

CVEN 5363 (3) Modeling of Hydrologic Systems
Introduces students to modeling techniques. Focus areas include physical hydrology and hydrometeorology; measurement and inference; climate change impacts; role of scale in hydrology; uncertainty analysis; and a case study project. Projects will examine hydrologic impacts of various drivers such as climate warming or land cover change, utilizing an assessment of historic conditions to better understand and model future disturbance scenarios.
**Additional Information:** Departmental Category: Fluid Mechanics and Water Resources

CVEN 5373 (3) Water Law, Policy, and Institutions
Discusses contemporary issues in water management based on legal doctrine. Identifies legal issues in water resources problems and discusses in close relationship with technical, economic, and political considerations.
**Requisites:** Restricted to students with 87-180 credits (Seniors) or graduate students only.
**Additional Information:** Departmental Category: Fluid Mechanics and Water Resources

CVEN 5383 (3) Applied Groundwater Modeling
Studies analytical and numerical methods for solving problems of groundwater flow and chemical transport. Emphasizes fundamental modeling techniques and the relationship between the physical system and the model results. Applies models and modeling techniques to solve problems in ground water hydrology using contemporary software.
**Equivalent - Duplicate Degree Credit Not Granted:** CVEN 4383
**Recommended:** Prerequisites APPM 2360 and CVEN 4353 or CVEN 5353.
**Additional Information:** Departmental Category: Fluid Mechanics and Water Resources

CVEN 5393 (3) Water Resources System and Management
Introduces water resources planning and management as an integrated systems problem that satisfies multiple competing objectives under constraints and uncertainty. Includes problem formulation and solution using decision support systems, optimization with and without uncertainty, stochastic simulation, and multiobjective optimization. Introduces water resources economics and planning under uncertainties such as climate change and increasing urbanization.
**Requisites:** Restricted to students with 87-180 credits (Seniors) or graduate students only.
**Additional Information:** Departmental Category: Fluid Mechanics and Water Resources

CVEN 5404 (3) Water Chemistry
Introduces chemical fundamentals governing the chemistry of natural and treated waters. Topics include thermodynamics and kinetics of acid and base reactions, carbonate chemistry, air-water exchange, precipitation, dissolution, complexation, oxidation-reduction, and sorption.
**Requisites:** Restricted to concurrent BS/MS (C-CVEN or C-EVENCVEN) or graduate students only.
**Additional Information:** Departmental Category: Environmental
CVEN 5414 (3) Water Chemistry Laboratory
Uses experimental and analytical laboratory techniques to develop a better understanding of the concepts of aquatic chemistry and to investigate water chemistry in treated and natural water systems. Techniques include titration, spectrophotometry, gas chromatography, other advanced instrumentation, sampling, portable analyses, and basic statistics and experimental design. Course focuses on water chemistry of Boulder Creek and other local waters.

**Requisites:** Requires prerequisite course of CVEN 5404 or GEOL 5280 (minimum grade C). Requires corequisite course of CVEN 5424.

**Additional Information:** Departmental Category: Environmental

CVEN 5423 (3) Water Resources Engineering Design
Studies principles and techniques of water resources engineering design. Introduces environmental modeling under uncertainty, stormwater design, precipitation estimation and flow routing. Surveys hydropower, reservoir management and water resources economics.

**Equivalent - Duplicate Degree Credit Not Granted:** CVEN 4323

**Additional Information:** Departmental Category: Fluid Mechanics and Water Resources

CVEN 5424 (3) Environmental Organic Chemistry
Examines the fundamental physical and chemical processes that impact the fate and transport of organic contaminants in natural and engineered systems. Emphasizes both equilibrium and kinetic aspects, including solubility, vapor pressure, air-water exchange, sorption, abiotic redox reactions, and photo degradation.

**Additional Information:** Departmental Category: Environmental

CVEN 5434 (3) Environmental Engineering Design
Team-based design of facilities or processes for water or wastewater or solid waste treatment or remediation under multiple real-world constraints. Department consent required.

**Recommended:** Prerequisite CVEN 5524 or CVEN 5534 or CVEN 5474.

**Additional Information:** Departmental Category: Environmental

CVEN 5444 (3) Municipal Des Proj

**Additional Information:** Departmental Category: Environmental

CVEN 5454 (3) Statistical Methods for Natural and Engineered Systems
Applies traditional and modern probability and statistical methods to environmental, hydrological, climatological and engineering data analysis. Topics include: basic probability, data visualization, fitting univariate and multivariate distributions, Monte Carlo simulations, extreme value distributions, confidence intervals and hypothesis testing, nonparametric density estimators, linear regression, and Bayesian analysis. The data analysis tool, R, is used throughout the course.

**Additional Information:** Departmental Category: Environmental

CVEN 5464 (3) Environmental Engineering Processes
Develops and utilizes analytic solutions for environmental process models that can be used in a) reactor design for processes used in the treatment of water, wastewater and hazardous waste and b) process analysis of natural systems, such as streams and groundwater flow. Models facilitate the tracking of contaminants in engineered and natural systems.

**Equivalent - Duplicate Degree Credit Not Granted:** CVEN 4464 and EVEN 4464

**Requisites:** Restricted to graduate students only.

**Additional Information:** Departmental Category: Environmental

CVEN 5474 (3) Hazardous and Industrial Waste Management
Evaluates processes used for treatment of wastes requiring special handling and disposal: toxic organic chemicals, heavy metals, acidic, caustic and radioactive waste material. Discusses techniques for destruction, immobilization and resource recovery and assessment of environmental impact of treatment process end products.

**Equivalent - Duplicate Degree Credit Not Granted:** CVEN 4474

**Requisites:** Restricted to graduate students only.

**Additional Information:** Departmental Category: Environmental

CVEN 5484 (3) Applied Microbiology and Toxicology
Surveys microbiology topics germane to modern civil and environmental engineering. Provides fundamentals needed to understand microbial processes and ecology in engineered and natural systems and reviews applications emphasizing the interface between molecular biology and classical civil engineering.

**Equivalent - Duplicate Degree Credit Not Granted:** CVEN 4484 and EVEN 4484

**Additional Information:** Departmental Category: Environmental

CVEN 5494 (3) Surface Water Quality Modeling
Examines the relationships among air, water, and land pollution, water quality, and beneficial uses. Using models, develops the ability to quantify and predict the impacts of pollutants in the aquatic environment, and to develop approaches to minimize unfavorable water quality conditions. Department consent required.

**Additional Information:** Departmental Category: Environmental

CVEN 5511 (3) Introduction to Finite Element Analysis
Covers systematic formulation of finite element approximation and isoparametric interpolation (weighted residual and energy methods, triangular and quadrilateral elements). Includes computation applications to the solution of one- and two-dimensional stress-deformation problems and steady and transient heat conduction.

**Equivalent - Duplicate Degree Credit Not Granted:** CVEN 4511

**Requisites:** Restricted to graduate students only.

**Additional Information:** Departmental Category: Mechanics

CVEN 5514 (3) Bioremediation
Advanced study on biological processes used to treat toxic organic and inorganic compounds contained in contaminated water, air, and soil; design and evaluation of in situ toxic compound biotransformation; fundamentals of phytoremediation; critical reviews of current literature on bioremediation.

**Recommended:** Prerequisite CVEN 4484 or CVEN 5424 or CVEN 5484.

**Additional Information:** Departmental Category: Environmental

CVEN 5524 (3) Drinking Water Treatment
Provides advanced study on theory-of-treatment processes, including design and operation of municipal water supplies.

**Recommended:** Prerequisite CVEN 4464 or CVEN 5464 or graduate standing or instructor consent required.

**Additional Information:** Departmental Category: Environmental

CVEN 5525 (3) Matrix Structural Analysis

**Equivalent - Duplicate Degree Credit Not Granted:** CVEN 4525

**Requisites:** Restricted to graduate students only.

**Additional Information:** Departmental Category: Structures
CVEN 5534 (3) Wastewater Treatment
Covers the processes used to treat municipal wastewater, focusing on biological processes. Includes: design of aerobic, anoxic, anaerobic and suspended growth technologies to remove and transform pollutants; design and assessment of treatment approaches that recover energy, nutrients and water from wastewater; application of fundamental concepts of aquatic chemistry, environmental microbiology and computational models.
**Requisites:** Restricted to graduate students only.
**Recommended:** Prerequisites CVEN 5404 and CVEN 5484 and CVEN 5464.
**Additional Information:** Departmental Category: Environmental

CVEN 5537 (3) Numerical Methods in Civil Engineering
Introduces the use of numerical methods in the solution of civil engineering problems, emphasizing obtaining solutions with high-speed electronic computers. Applies methods to all types of civil engineering problems.
**Equivalent - Duplicate Degree Credit Not Granted:** CVEN 4537
**Requisites:** Restricted to graduate students only.
**Additional Information:** Departmental Category: Miscellaneous

CVEN 5544 (3) Solid Waste Management and Resource Recovery
Covers the scope of the nonhazardous solid waste problem and regulations that drive its management; discussions of nonengineering factors that impact waste management and recycling; design of incinerators, composting facilities, and landfills used to treat and dispose of solid waste.
**Recommended:** Prerequisite CVEN 3414.
**Additional Information:** Departmental Category: Environmental

CVEN 5554 (3) Fundamentals of Air Quality Management
Introduces engineering methods for the study of air quality. Topics include: indoor air quality, greenhouse gases, dispersion modeling, source apportionment modeling, chemistry of combustion, pollution sources and controls, human exposure to air pollutants. A focus on Engineering for Developing Communities runs throughout. Required for CVEN environmental engineering graduate students.
**Equivalent - Duplicate Degree Credit Not Granted:** CVEN 4554
**Additional Information:** Departmental Category: Environmental

CVEN 5564 (3) Water Profession: Leadership & Communication
Develops and improves the skills and tools needed for graduate students and young professionals. Focusing on highly effective leaders; leadership with impact; effective communication tools; and communicating with teams, city councils, governing boards, and the public.
**Requisites:** Restricted to graduate students only.
**Grading Basis:** Letter Grade
**Additional Information:** Departmental Category: Environmental

CVEN 5565 (3) Life-Cycle Engineering of Civil Infrastructure Systems
Philosophical and analytical issues for lifetime design and operation of civil systems. Optimization tradeoffs of construction, management, and sustainability. Utility of operation and service, including present-value economic analysis. Decision-making alternatives of safety and performance, including hazards consideration. Undergraduates may enroll with the permission of the instructor.
**Recommended:** Prerequisite CVEN 3227 or equivalent.
**Additional Information:** Departmental Category: Structures

CVEN 5574 (3) Water Utility Management: Current Issues and Future Challenges
Develops the skills and tools for graduate students and young professionals to work in the water profession. Focuses on management, leadership, communication and utility financial in the new water profession era. Undergraduate seniors may contact instructor for permission to enroll.
**Requisites:** Restricted to graduate students only.
**Additional Information:** Departmental Category: Environmental

CVEN 5575 (3) Advanced Topics in Steel Design
Covers steel structure design and analysis. Includes plate girders, moment connections for beams, design of multistory frames, and other topics determined by class interest. Undergraduate may enroll with permission of the instructor.
**Requisites:** Restricted to graduate students only.
**Recommended:** Prerequisite CVEN 4545.
**Additional Information:** Departmental Category: Structures

CVEN 5584 (3) Water Profession: Financial and Management
Develops the skills and tools for graduate students and young professionals to work in the water profession. Focuses on financing water services, capital planning, rates, management planning, staffing and organization and critical thinking. Undergraduates may request instructor permission to enroll.
**Requisites:** Restricted to graduate students only.
**Recommended:** Prerequisite CVEN 4555.
**Additional Information:** Departmental Category: Environmental

CVEN 5585 (3) Advanced Topics in Reinforced Concrete Design
Covers design and analysis topics for prestressed concrete and reinforced concrete structures. Includes review of the current ACI design code, slabs, prestressed concrete, seismic design, folded plates and shells, finite element analysis, and other topics determined by class interest. Undergraduates may enroll with the permission of the instructor.
**Requisites:** Restricted to graduate students only.
**Recommended:** Prerequisite CVEN 4555.
**Additional Information:** Departmental Category: Structures

CVEN 5594 (3) Water Reuse and Reclamation
Explores development of a safe, reliable and acceptable program for reusing impaired waters. As fresh water becomes scarcer around the world, communities are looking for security through development of new water resources. Reuse of impaired water is one solution to the growing water crisis. Focus is on advanced treatment technologies with emphasis on public perception, economics and regulations.
**Equivalent - Duplicate Degree Credit Not Granted:** CVEN 4594
**Requisites:** Restricted to graduate students only.
**Recommended:** Prerequisites CVEN 3141 and CVEN 3424.
**Additional Information:** Departmental Category: Environmental

CVEN 5604 (3) UV Processes in Environmental and Engineered Systems
Provides a fundamental basis for design of UV processes in water and wastewater treatment. Includes principles of photochemistry and photobiology. Applications to disinfection of water and degradation of chemical compounds in the environment. Design of UV disinfection systems and reactors and advanced oxidation processes. Environmental UV-based decay of pollutants.
**Requisites:** Restricted to graduate students only.
**Recommended:** Prerequisites CVEN 3414 and CVEN 3424.
**Additional Information:** Departmental Category: Environmental
CVEN 5614 (3) Bioenergy & Bioresource Recovery
Introduces fundamental theories and applied technologies used in production and conversion of renewable biomass including waste materials into bioenergy and other value-added products. Conducts quantitative evaluations on conversion processes such as renewable biogas production, electricity generation, liquid fuels, metal and nutrients recovery and organic chemical production.
Requisites: Restricted to graduate students only.
Recommended: Prerequisite CVEN 4484.
Grading Basis: Letter Grade
Additional Information: Departmental Category: Environmental

CVEN 5628 (3) Seepage and Slopes
Covers fundamental principles of seepage in soils under both saturated and unsaturated conditions and limit equilibrium solution to slope stability problems. The seepage effects on slope stability are analyzed in detail and both conventional slope stability method and the finite element technique are applied to solving the engineering problems.
Recommended: Prerequisites CVEN 3708 and CVEN 3718.
Additional Information: Departmental Category: Geotechnical

CVEN 5678 (3) Soil Improvement and Reinforcement
Provides students with principles and working knowledge of design and construction procedures in soil stabilization, retaining structures, geosynthetics, and soil reinforcement.
Recommended: Prerequisite CVEN 3718.
Additional Information: Departmental Category: Geotechnical

CVEN 5688 (3) Environmental Geotechnics
Provides an understanding of the use of geotechnical concepts in the analysis and design of environmental systems. Focus is placed on the evaluation of waste containment facilities. Including relevant saturated, unsaturated, and multiphase flow mechanisms in cover and liner systems. Includes stability analyses for landfills and geosynthetic interface shear strength. Covers relevant aspects of mining geotechnics and remediation technologies of contaminated sites.
Additional Information: Departmental Category: Geotechnical

CVEN 5708 (3) Soil Mechanics
Offers an advanced course in soil mechanics. Coverage includes basic principles of continuum mechanics; elasticity, viscoelasticity, and plasticity theories applied to soils; effective stress principle; consolidation; shear strength; critical state concepts; and constitutive, numerical, and centrifuge modeling.
Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Geotechnical

CVEN 5718 (3) Mechanics and Dynamics of Glaciers
Develops a quantitative physical basis for understanding the functions of snow, ice and glaciers in the environment, with emphasis on developing an understanding of continuum mechanics and thermodynamics and their application to Earth systems.
Equivalent - Duplicate Degree Credit Not Granted: CVEN 4718
Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Geotechnical

CVEN 5728 (3) Foundation Engineering
Focuses on geotechnical design of shallow and deep foundations, including spread footings, mats, driven piles and drilled piers. Coverage includes bearing capacity, settlement, group effects and lateral load capacity of the various foundation types. Additional topics include subsurface exploration, construction of deep foundations and analysis of pile behavior using wave equation and dynamic monitoring methods.
Equivalent - Duplicate Degree Credit Not Granted: CVEN 4728
Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Geotechnical

CVEN 5738 (3) Design of Earth Structures
Studies applications of limiting equilibrium and plasticity analysis methods to stability problems in geotechnical engineering, such as slopes, lateral earth pressures on retaining structures, and bearing capacities of foundations. Also includes elastic and consolidation analysis of deformations in soil structures.
Requisites: Requires a prerequisite course of CVEN 5708 (minimum grade C).
Additional Information: Departmental Category: Geotechnical

CVEN 5748 (3) Design of Earth Structures
Covers theory, design, and construction of earth embankments and waste facilities, including isolation systems. Uses published data, field exploration, and laboratory tests on soils and rock in investigating foundations and construction materials. Involves principles of compaction and settlement, permeability analysis, landslide recognition and control, use of composite clay, and liner systems.
Requisites: Requires a prerequisite course of CVEN 5708 (minimum grade C).
Additional Information: Departmental Category: Geotechnical

CVEN 5758 (3) Flow Processes in Soils
Examines fundamental principles of flow through porous media and related engineering problems. Topics include the saturated seepage theory and flow nets; the unsaturated flow theory; suction-saturation and saturation-hydraulic conductivity relationships; nonlinear finite strain consolidation and desiccation theory; laboratory and field testing methods for determining material characteristics; and numerical models for flow-related engineering problems.
Recommended: Prerequisite CVEN 3718.
Additional Information: Departmental Category: Geotechnical

CVEN 5768 (3) Introduction to Rock Mechanics
Nature of rocks and rock masses; engineering properties rock and rock mass; rock mass classifications; planes of weakness; application of rock mechanics to design of rock slopes, underground excavations, and foundations.
Recommended: Prerequisites CVEN 3708 and CVEN 3718.
Additional Information: Departmental Category: Geotechnical

CVEN 5788 (3) Computational Modeling in Geotechnical Engineering
Introduces computational modeling for geotechnical engineering applications such as the Discrete Element Method (DEM) for granular materials, nonlinear Finite Element Analysis (FEA) of seepage, coupled soil elastoplastic consolidation, elastoplasticity models for soil and rock, and advanced computational methods for failure in soil and rock. Uses DEM, FEA, and other software programs for analysis. Recommended Prereq: CVEN 5708
Additional Information: Departmental Category: Geotechnical
CVEN 5798 (3) Dynamics of Soils and Foundations
Covers fundamental characterization of soils, foundations and structures under general dynamic and earthquake loads. Principles of vibrations and wave propagation for 1D, 2D, 3D. In-situ and laboratory determination of dynamic soil properties; methods for site response analysis, foundation vibrations, dynamic soil-structure interaction and liquefaction problems.

Recommended: Prerequisite CVEN 3718.
Additional Information: Departmental Category: Geotechnical

CVEN 5818 (3) Geotechnical Earthquake Engineering
Familiarizes students with the fundamentals of engineering seismology, soil and structural dynamics, and the modern practice of geotechnical earthquake engineering. Focuses on describing earthquake hazards and methods for seismic analysis and design.

Requisites: Restricted to graduate students only.
Recommended: Prerequisite CVEN 5798.
Additional Information: Departmental Category: Geotechnical

CVEN 5822 (3) Geographical Information Systems for Civil and Environmental Systems
Theory and use of geographical information systems in civil engineering, environmental studies, natural resources and other related disciplines. Topics include spatial data models, data capture, global positioning system, database linkage, use in design, analysis and implementation. Laboratory work includes applications of Arc-View and Arc-GIS software.

Additional Information: Departmental Category: Surveying and Transportation

CVEN 5830 (3) Special Topics for Seniors/Grads
Department consent required.

Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.

Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Building Systems

CVEN 5831 (3) Special Topics
Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.

Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Mechanics

CVEN 5833 (1-3) Special Topics
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.

Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Fluid Mechanics and Water Resources

CVEN 5834 (1-3) Special Topics
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.

Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Environmental

CVEN 5835 (1-3) Special Topics for Seniors/Grads
Supervised study of special topics of interest to students under instructor guidance. Department consent required.

Repeatable: Repeatable for up to 15.00 total credit hours. Allows multiple enrollment in term.

Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Structures

CVEN 5836 (1-3) Special Topics for Seniors/Grads
Supervised study of special topics of interest to students under instructor guidance. Department consent required.

Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.

Requisites: Restricted to graduate students only.
Additional Information: Departmental Category: Construction

CVEN 5837 (3) Special Topics for Seniors/Grads
Supervised study of special topics of interest to students under instructor guidance. Department consent required.

Repeatable: Repeatable for up to 12.00 total credit hours. Allows multiple enrollment in term.

Additional Information: Departmental Category: Miscellaneous

CVEN 5838 (1-3) Special Topics
Repeatable: Repeatable for up to 12.00 total credit hours. Allows multiple enrollment in term.

Additional Information: Departmental Category: Geotechnical

CVEN 5849 (1-6) Independent Study
Available only through approval of graduate advisor. Subject arranged to fit needs of student.

Repeatable: Repeatable for up to 6.00 total credit hours. Allows multiple enrollment in term.

Additional Information: Departmental Category: Special Topics

CVEN 5919 (3) Sustainable Community Development 1
Focuses on the fundamental tools necessary to address sustainable community development projects in low-income communities (LICs). Topics include: human development, sustainable development, and presentation of an integrative and participatory framework for development projects in LICs. The framework consists of a combination of development and engineering project management tools. Framework is illustrated through case studies and student-driven team projects.

Requisites: Restricted to students with sub-plan of Engineering Developing Communities (EDC).

Additional Information: Departmental Category: Special Topics

CVEN 5929 (3) Sustainable Community Development 2
Covers the principles, practices and strategies of appropriate technology as part of an integrated and systems approach to community-based development. Course content areas include technical issues in development, environmental health and communicable disease, appropriate and sustainable technologies with hands-on workshops, and global cooperation in development.

Requisites: Requires prerequisite course of CVEN 5919 (minimum grade C). Restricted to students with EDC Sub-Plan.

Additional Information: Departmental Category: Special Topics

CVEN 5939 (3) Sustainable Community Development Field Practicum
Provides a supervised in-field practicum experience in which the student applies theories and concepts learned in CVEN 5919 and CVEN 5929.

Requisites: Requires prerequisites courses of CVEN 5919 and CVEN 5929 (all minimum grade C). Restricted to students with sub-plan of Engineering Developing Communities (EDC).

Additional Information: Departmental Category: Miscellaneous
CVEN 5969 (1-3) Water, Sanitation, and Hygiene
Studies the fundamentals behind effective hygiene and remediation processes and engineering solutions developed/designated for specific international problems. Approaches to hygiene, clean water and sanitation in lesser industrialized countries often demand alternative solutions to those developed for industrialized societies. Explores issues and solutions developed to tackle these problems.
**Repeatability:** Repeatably for up to 3.00 total credit hours.
**Requisites:** Restricted to graduate students only.
**Recommended:** Prerequisites CVEN 3424 and CVEN 3414.
**Additional Information:** Departmental Category: Environmental

CVEN 6161 (3) Advanced Mechanics of Materials 2
Fundamentals of continuum mechanics, finite deformations, Lagrangian finite strains, Cauchy and Piola Kirchoff stress tensors, plasticity and thermo-elasticity, elements of damage mechanics, elements of fracture mechanics, rheological and visoelastic theories, and modern experimental techniques.
**Recommended:** Prerequisite CVEN 5161.
**Additional Information:** Departmental Category: Mechanics

CVEN 6333 (3) Introduction to Multi-Scale Variability and Scaling in Hydrology
Provides a foundational understanding of channel networks, runoff, precipitation, and evapotranspiration at multiple spatial scales of drainage basins using modern analytical concepts for understanding non-linear phenomena, e.g., fractals, multifractals, statistical scaling, criticality, and renormalization.
**Requisites:** Requires a prerequisite course of CVEN 5333 (minimum grade C-).
**Additional Information:** Departmental Category: Fluid Mechanics and Water Resources

CVEN 6338 (3) Flow and Transport through Porous Media
Studies basic physics of flow and transport of water, air, and other fluid mixtures through a porous medium. Course topics are relevant to applications in contaminant hydrology, contaminant transport in aquifers, hazardous waste management, geohydrology, soil physics, and geoenvironmental engineering.
**Additional Information:** Departmental Category: Fluid Mechanics and Water Resources

CVEN 6339 (1) Hydrologic Sciences and Water Resources Engineering Seminar
Provides a broad introduction to a variety of research topics from hydrologic sciences and water resources engineering. Offered as a one-hour weekly seminar by the departmental water faculty, graduate students, and external speakers.
**Requisites:** Restricted to graduate student Civil (CVEN) Engineering students only.
**Additional Information:** Departmental Category: Fluid Mechanics and Water Resources

CVEN 6414 (3) Aquatic Surfaces and Particles
Examines the role of surfaces and particles in the fate and transport of contaminants in the aquatic environment. Emphasizes modeling of absorption, dissolution, precipitation, surface-catalyzed reactions, and coagulation and filtration kinetics.
**Requisites:** Requires prerequisite course of CVEN 5404 or GEOL 5280 (minimum grade C-).
**Additional Information:** Departmental Category: Environmental

CVEN 6511 (3) Nonlinear Finite Element Analysis of Solids and Porous Media
Covers constitutive modeling, multiphase mechanics, and finite element implementation of constitutive models and coupled solid-fluid mechanical governing equations for inelastic porous media at small strain. Considers transient and steady state conditions. Analyzes structural, geotechnical, geological, mechanical, biomechanical, and other related modern engineering problems. Uses general purpose finite element software program for implementation and analysis.
**Additional Information:** Departmental Category: Mechanics

CVEN 6525 (3) Nonlinear Analysis of Framed Structures
Explores theoretical underpinnings of nonlinear static and dynamic analysis of framed structures, along with exposure to the corresponding programming techniques in Matlab. Topics covered are: flexibility and fiber based beam-column element formulation; structural, section and fiber plasticity; geometric and material nonlinearities; nonlinear pushover and transient analysis of framed structures.
**Requisites:** Requires prerequisite course of CVEN 5525 (minimum grade of C-). Restricted to graduate students only.
**Additional Information:** Departmental Category: Structures

CVEN 6595 (3) Earthquake Engineering
Analyzes and designs structures for earthquake load covering: properties of earthquake ground motions, motion prediction equations, seismic hazard analysis, response spectra, response of linear and nonlinear structures, construction of design spectra, seismic design methods, and building code requirements.
**Requisites:** Requires prerequisite course of CVEN 5111 (minimum grade of C-). Restricted to graduate students only.
**Additional Information:** Departmental Category: Structures

CVEN 6830 (3) Special Topics
Repeatable: Repeatable for up to 6.00 total credit hours.
**Additional Information:** Departmental Category: Structures

CVEN 6831 (3) Special Topics
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.
**Requisites:** Restricted to graduate students only.
**Additional Information:** Departmental Category: Mechanics

CVEN 6833 (1-3) Special Topics
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.
**Requisites:** Restricted to graduate students only.
**Additional Information:** Departmental Category: Fluid Mechanics and Water Resources

CVEN 6834 (1-3) Special Topics
Repeatable: Repeatable for up to 9.00 total credit hours. Allows multiple enrollment in term.
**Additional Information:** Departmental Category: Environmental

CVEN 6835 (3) Special Topics
Repeatable: Repeatable for up to 6.00 total credit hours.
**Additional Information:** Departmental Category: Structures

CVEN 6836 (3) Special Topics
Repeatable: Repeatable for up to 6.00 total credit hours.
**Additional Information:** Departmental Category: Construction

CVEN 6837 (3) Sp Tpcs Comp Graphics
Repeatable: Repeatable for up to 6.00 total credit hours.
**Additional Information:** Departmental Category: Miscellaneous
CVEN 6838 (3) Special Topics
Repeatable: Repeatable for up to 6.00 total credit hours.
Additional Information: Departmental Category: Geotechnical

CVEN 6839 (1-3) Special Topics
Repeatable: Repeatable for up to 6.00 total credit hours.
Additional Information: Departmental Category: Special Topics

CVEN 6943 (1) Master’s Degree Candidacy
Grading Basis: Pass/Fail
Additional Information: Departmental Category: Fluid Mechanics and Water Resources

CVEN 6944 (1) Master’s Degree Candidacy
Grading Basis: Pass/Fail
Additional Information: Departmental Category: Environmental

CVEN 6945 (1) Master’s Degree Candidacy
Grading Basis: Pass/Fail
Additional Information: Departmental Category: Structures

CVEN 6946 (1) Master’s Degree Candidacy
Grading Basis: Pass/Fail
Additional Information: Departmental Category: Construction

CVEN 6947 (1) Master’s Degree Candidacy
Grading Basis: Pass/Fail
Additional Information: Departmental Category: Miscellaneous

CVEN 6948 (1) Master’s Degree Candidacy
Grading Basis: Pass/Fail
Additional Information: Departmental Category: Geotechnical

CVEN 6949 (1) Master’s Degree Candidacy
Grading Basis: Pass/Fail
Additional Information: Departmental Category: Special Topics

CVEN 6951 (1-4) Master’s Thesis
Additional Information: Departmental Category: Mechanics

CVEN 6952 (1-4) Master’s Thesis
Additional Information: Departmental Category: Surveying and Transportation

CVEN 6953 (1-6) Master’s Thesis
Additional Information: Departmental Category: Fluid Mechanics and Water Resources

CVEN 6954 (1-6) Master’s Thesis
Additional Information: Departmental Category: Environmental

CVEN 6955 (1-6) Master’s Thesis
Additional Information: Departmental Category: Structures

CVEN 6956 (1-6) Master’s Thesis
Additional Information: Departmental Category: Construction

CVEN 6957 (1-4) Master’s Thesis
Additional Information: Departmental Category: Miscellaneous

CVEN 6958 (1-6) Master’s Thesis
Additional Information: Departmental Category: Geotechnical

CVEN 6959 (1-4) Master’s Thesis
Additional Information: Departmental Category: Special Topics

CVEN 6961 (1-3) Master’s Report
Repeatable: Repeatable for up to 6.00 total credit hours.
Additional Information: Departmental Category: Mechanics

CVEN 6962 (1-3) Master’s Report
Repeatable: Repeatable for up to 6.00 total credit hours.
Additional Information: Departmental Category: Surveying and Transportation

CVEN 6963 (1-3) Master’s Report
Repeatable: Repeatable for up to 6.00 total credit hours.
Additional Information: Departmental Category: Fluid Mechanics and Water Resources

CVEN 6964 (1-3) Master’s Report
Repeatable: Repeatable for up to 6.00 total credit hours.
Additional Information: Departmental Category: Environmental

CVEN 6965 (1-3) Master’s Report
Repeatable: Repeatable for up to 6.00 total credit hours.
Additional Information: Departmental Category: Structures

CVEN 6966 (1-3) Master’s Report
Repeatable: Repeatable for up to 6.00 total credit hours.
Additional Information: Departmental Category: Construction

CVEN 6967 (1-3) Master’s Report
Repeatable: Repeatable for up to 6.00 total credit hours.
Additional Information: Departmental Category: Miscellaneous

CVEN 6968 (1-3) Master’s Report
Repeatable: Repeatable for up to 6.00 total credit hours.
Additional Information: Departmental Category: Geotechnical

CVEN 6969 (1-3) Master’s Report
Repeatable: Repeatable for up to 6.00 total credit hours.
Additional Information: Departmental Category: Special Topics

CVEN 7111 (3) Advanced Structural Dynamics
Includes general vibrations of civil engineering structures and their response to various types of time-dependent loads.
Requisites: Requires prerequisite course of CVEN 5111 (minimum grade C-).
Additional Information: Departmental Category: Mechanics

CVEN 7141 (3) Plates and Shells
Teaches mathematical theories of plate and shell structures and their applications. Involves numerical finite element solutions of plates and shells of various shapes under static and dynamic loadings.
Requisites: Requires prerequisite courses of CVEN 5131 or CVEN 5161 (minimum grade C-).
Additional Information: Departmental Category: Mechanics

CVEN 7161 (3) Fracture Mechanics
Includes three parts: 1) fundamentals through rigorous mathematical formulations of linear/nonlinear elastic fracture mechanics, 2) materials’ theoretical strength, including metals, granular materials, polymers and steel, 3) numerical (finite element) methods in fracture mechanics. Heavy emphasis on project and independent work.
Additional Information: Departmental Category: Mechanics
CVEN 7511 (3) Computational Finite Inelasticity and Multiphase Mechanics
Recommended: Prerequisites CVEN 5131 and CVEN 5511 and CVEN 6511.
Additional Information: Departmental Category: Mechanics

CVEN 7718 (3) Engineering Properties of Soils
Emphasizes engineering aspects of soil mechanics. Implications of soil strength, volume change, consolidation behavior in engineering problems such as slope stability, deformation of retaining walls, surface subsidence due to tunneling. Time effects in soil/long-term bearing capacity of piles. Laboratory determination of constitutive parameters of soils. Field tests/their correlations with soil properties. Case studies using finite element software.
Requisites: Requires prerequisite course of CVEN 5708 (minimum grade of C-).
Additional Information: Departmental Category: Geotechnical

CVEN 7788 (3) Soil Behavior
Topics include soil mineralogy, formation of soils through sedimentary processes and weathering, determination of soil composition, soil water, colloidal phenomena in soils, fabric property relationships, analysis of mechanical behavior including compressibility, strength and deformation, and conduction phenomena in terms of physicochemical principles. Involves applications for stabilization and improvement of soils, and disposal of waste materials.
Recommended: Prerequisite CVEN 3718.
Additional Information: Departmental Category: Geotechnical

CVEN 7831 (1-3) Sp Tpc-Constitutive Mech
Repeatable: Repeatable for up to 10.00 total credit hours. Allows multiple enrollment in term.
Additional Information: Departmental Category: Mechanics

CVEN 7838 (3) Special Topics
Additional Information: Departmental Category: Geotechnical

CVEN 7849 (1-3) Independent Study
Repeatable: Repeatable for up to 6.00 total credit hours.
Additional Information: Departmental Category: Special Topics

CVEN 8991 (1-10) Doctor's Thesis
Additional Information: Departmental Category: Special Topics

CVEN 8992 (1-10) Doctor's Thesis
Additional Information: Departmental Category: Surveying and Transportation

CVEN 8993 (1-10) Doctor's Thesis
Additional Information: Departmental Category: Fluid Mechanics and Water Resources

CVEN 8994 (1-10) Doctor's Thesis
Additional Information: Departmental Category: Environmental

CVEN 8995 (1-10) Doctor's Thesis
Additional Information: Departmental Category: Structures

CVEN 8996 (1-10) Doctor's Thesis
Additional Information: Departmental Category: Construction