# Civil and Environmental Engineering

## Degrees Offered

- Master of Science (Civil and Environmental Engineering)
- Doctor of Philosophy (Civil and Environmental Engineering)
- Master of Science (Environmental Engineering Science)
- Doctor of Philosophy (Environmental Engineering Science)

## Program Description

The Civil and Environmental Engineering Department offers two M.S. and Ph.D. graduate degrees - Civil & Environmental Engineering (CEE) and Environmental Engineering Science (EES). The Civil and Environmental Engineering (CEE) degree is designed for students who wish to earn a degree to continue the path towards professional engineering registration. Students entering this degree program should have a B.S. degree in engineering, or will generally need to take engineering prerequisite courses. Within the CEE degree, students complete specified requirements in one of three different emphasis areas: Environmental and Water Engineering, Geotechnical Engineering (GT), and Structural Engineering (SE).

The Environmental Engineering Science (EES) degree does not require engineering credentials and has a flexible curriculum that enables students with a baccalaureate degree in biology, chemistry, math, physics, geology, engineering, and other technical fields, to tailor a course-work program that best fits their career goals.

The specific requirements for the EES & CEE degrees, as well as for the four emphasis areas within the CEE degree, are described in detail under the Major tab.

The M.S. and Ph.D. degrees in Environmental Engineering Science (EES) has been admitted to the Western Regional Graduate Program (WRGP/WICHE), a recognition that designates this curriculum as unique within the Western United States. An important benefit of this designation is that students who are residents from Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming are given the tuition status of Colorado residents.

To achieve the Master of Science (M.S.) degree, students may elect the Non-Thesis option, based exclusively upon coursework and project activities, or the Thesis option, which requires coursework and rigorous research conducted under the guidance of a faculty advisor and M.S. thesis committee, that is described in a final written thesis that is defended in an oral presentation.

The Doctor of Philosophy (Ph.D.) degree requires students to complete a combination of coursework and original research, under the guidance of a faculty advisor and doctoral committee, that culminates in a significant scholarly contribution (e.g., in the form of published journal articles) to a specialized field in Civil and Environmental Engineering or Environmental Engineering Science. The written dissertation must be defended in an public oral presentation before the advisor and dissertation committee. The Ph.D. program may build upon one of the CEE or EES M.S. programs or a comparable M.S. program at another university. Full-time PhD enrollment is expected and leads to the greatest success, although part-time enrollment may be allowed under special circumstances.

## Faculty Expertise and General Emphasis Areas:

Civil and Environmental Engineering faculty have expertise in environmental science and engineering, geotechnical engineering, hydrology, water-resources engineering, structural engineering, and underground construction and tunneling. These areas also serve as topic areas for coursework and for M.S. thesis or PhD dissertation research, and are the basis for degree requirements.

**Environmental Engineering and Science:** Is the application of environmental processes in natural and engineered systems. CEE faculty have expertise in water resource engineering, biosystems engineering, environmental chemistry, environmental microbiology, microbial genomics, wastewater treatment, water treatment, bioremediation, mining treatment processes and systems, remediation processes, biogeochemical reactions in soils, geobiology, membrane processes, humanitarian engineering, social aspects of engineering, and energy recovery from fluids.

**Geotechnical Engineering:** Geotechnical Engineering is concerned with the engineering properties and behavior of natural and engineered geomaterials (soils and rocks), as well as the design and construction of foundations, earth dams and levees, retaining walls, embankments, underground structures and tunnels. Almost all constructed projects require input from geotechnical engineers as most structures are built on, in or of geomaterials. Additionally, mitigation of the impact of natural hazards such as earthquakes and landslides, sustainable use of energy and resources, and reduction of the environmental impacts of human activities require geotechnical engineers who have in-depth understanding of how geomaterials respond to loads, and environmental changes. Students who pursue this discipline complete the requirements of the Geotechnical Engineering emphasis area within the Civil & Environmental Engineering degree program.

**Structural Engineering:** Is a multidisciplinary subject spanning the disciplines of civil engineering, aerospace engineering, mechanical engineering, and marine engineering. In all these disciplines, structural engineers use engineered materials and conduct analyses using general principles of structural mechanics, to design structures for civil systems. Designed systems may include bridges, dams, buildings, tunnels, sustainable infrastructure, highways, biomechanical apparatus, sustainable civil engineering materials and numerous other structures and devices. Students who pursue this discipline complete the requirements of the Structural Engineering (SE) emphasis area within the Civil & Environmental Engineering Degree program.

**Hydrology and Water Resources Engineering:** Students interested in this area have two options. Students interested in natural-systems hydrology, ground-water resources, contaminant transport, and hydrochemical processes often choose to earn a degree in "Hydrology" in the interdisciplinary Hydrologic Science and Engineering (HSE) program (see HSE section of this graduate catalog). Students interested in engineered water systems or water-resources engineering, such as water infrastructure, water reclamation and reuse, ground-water remediation, contaminated water bodies, urban hydrology, water-resources management, and fluid mechanics typically choose the CEE degree - Environmental and Water Engineering Emphasis area. Students who are interested in the chemical, biological and fundamental water science that serves as the foundation for hydrology and water resources engineering may also elect the EES degree.
Underground Construction & Tunneling (UC&T): UC&T involves the planning, design, construction and rehabilitation of underground space (caverns, shafts, tunnels) in soil and rock. The main domains for UC&T include civil infrastructure, e.g., water and wastewater conveyance and storage, construction, transportation, and utilities, as well as underground facilities for civil, commercial and military use. UC&T is an interdisciplinary field involving civil, geological and mining engineering programs. Students interested in interdisciplinary studies including soil & rock mechanics, engineering geology and excavation methods can pursue the M.S. and/or Ph.D. in UC&T (see UC&T section of this graduate catalog, and the website uct.mines.edu). CEE students may also take elective courses and pursue research in UC&T yet emphasize geotechnical and/or structural engineering within the CEE graduate degrees.

Combined Degree Program Option

CSM undergraduate students have the opportunity to begin work on a M.S. degree in Civil & Environmental Engineering or Environmental Engineering Science while completing their Bachelor's degree. For more information please contact the CEE Office or visit cee.mines.edu

Program Requirements

General Degree Requirements for CEE and EES degrees:

M.S. Non-Thesis Option: 30 total credit hours, consisting of coursework (27 h) and either a three credit hour research based Independent Study (CEEN599) or a designated design course (3 h) and seminar.

M.S. Thesis Option: 30 total credit hours, consisting of coursework (24 h), seminar, and research (6 h). Students must also write and orally defend a research thesis.

Ph.D.: 72 total credit hours, consisting coursework (at least 24 h), seminar, and research (6 h). Students must also successfully complete written and oral qualifying examinations, prepare and present a dissertation proposal, and write and defend a doctoral dissertation. Ph.D. students are also expected to submit the dissertation work for publication in scholarly journals.

Prerequisites for CEE and EES degrees:

• Baccalaureate degree: required, preferably in a science or engineering discipline
• College calculus I & II: two semesters required
• College physics: one semester required, two semesters highly recommended
• College chemistry I & II: two semesters required
• College probability & statistics: one semester required
• All CEE degree emphasis areas require completion of the general science pre-requisites listed above, and also requires statics, dynamics, and differential equations. In addition, the CEE degree emphasis areas may require specific additional pre-requisites as listed below.

Required Curriculum for Environmental Engineering Science (EES) Degree:

The EES curriculum consists of common core and elective courses that may be focused toward specialized areas of emphasis. The common core includes:

• CEEN550 CEEN550: Principles of Environmental Chemistry
• CEEN592: Environmental Law or approved policy / law course
• CEEN580: Environmental Fate and Transport
• CEEN560 Molecular Microbial Ecology or CEEN562 Applied Geomicrobiology or CEEN566 Microbial Processes, Analysis and Modeling
• 3-credit Independent Study (CEEN599) or a 3 credit hour design course

Students earning an EES degree work with their academic advisor to establish plans of study that best fit their individual interests and goals. Each student will develop and submit a plan of study during the first semester of enrollment; this plan must be submitted with the admission to candidacy form. Electives may be chosen freely from courses offered at CSM and other local universities. Please visit the CEE website for a complete outline of curriculum requirements and options (www.cee.mines.edu).

Required Curriculum for Civil and Environmental Engineering (CEE) Degree:

The CEE curriculum contains emphasis areas: Environmental and Water Engineering, Geotechnical Engineering, and Structural Engineering. CEE students must complete the requirements for at least one emphasis area.

Core Courses: Each emphasis area has required core courses that apply to MS and PhD degrees. These core courses are listed below.

Electives: CEE degree emphasis areas require additional engineering-course electives: 12 credits for M.S. thesis option, 15 credits for M.S. non-thesis option and 18 credits for Ph.D. A variety of engineering courses may be taken for electives in the CEE emphasis areas, including additional CEEN courses, as well as courses from other departments on campus. The student’s advisor and committee must approve elective courses.

Non thesis students must take at least 21 elective credits within the CEEN prefix.

CEE Degree Emphasis Areas

GEOTECHNICAL ENGINEERING

Additional Prerequisites Courses: soil mechanics, structural theory/structural analysis

Geotechnical Core Courses: Students are required to successfully complete four courses (12 credit hours) from the following core course list plus CEEN590 Civil Engineering seminar.

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<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>CEEN510</td>
<td>ADVANCED SOIL MECHANICS</td>
<td>3.0</td>
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<td>3.0</td>
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<tr>
<td>CEEN523</td>
<td>UNDERGROUND CONSTRUCTION ENGINEERING IN SOFT GROUND (*)</td>
<td>4.0</td>
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* Design Course

ENVIRONMENTAL AND WATER ENGINEERING
### Civil and Environmental Engineering

#### Additional Prerequisites Courses: fluid mechanics.

Environmental & Water Engineering Core Courses: Students are required to successfully complete one course as specified in each of the following areas plus CEEN596 Environmental Seminar:

**Chemistry:** CEEN550 Principles of Env Chemistry  
**Physical Transport:** CEEN580 Env Pollution  
**Bio Processes:** CEEN560 Molecular Microbial Ecology or CEEN562 Geomicrobial Systems or CEEN566 Microbial Processes, Analysis and Modeling*  
**Systems Design:** CEEN570 Treatment of Waters & Waste * or CEEN471 Water & Wastewater Treatment Systems*

*Design Course

### STRUCTURAL ENGINEERING

#### Additional Prerequisites Courses: soil mechanics, structural theory / structural analysis.

Structural Engineering Core Courses: Three courses from the following, 9 credits total including at least 3 credits of design course, plus CEEN590 Civil Engineering seminar.

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<tr>
<td>CEEN531</td>
<td>STRUCTURAL DYNAMICS</td>
<td>3.0</td>
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<tr>
<td>CEEN540</td>
<td>ADVANCED DESIGN OF STEEL STRUCTURES (*)</td>
<td>3.0</td>
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<tr>
<td>CEEN541</td>
<td>DESIGN OF REINFORCED CONCRETE STRUCTURES II (*)</td>
<td>3.0</td>
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<tr>
<td>CEEN542</td>
<td>TIMBER AND MASONRY DESIGN (*)</td>
<td>3.0</td>
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<tr>
<td>CEEN543</td>
<td>CONCRETE BRIDGE DESIGN BASED ON THE AASHTO LRFD SPECIFICATIONS (*)</td>
<td>3.0</td>
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* Design Course

### Department Head

Terri Hogue

#### Professors

Tzahi Cath  
Linda Figueroa  
D.V. Griffiths  
Marte Gutierrez, James R. Paden Distinguished Chair  
Terri Hogue  
Tissa Illangasekare, AMAX Distinguished Chair  
Ning Lu  
John E. McCray  
Michael Mooney, Grewcock Distinguished Chair  
Kamini Singha  
John R. Spear  
Timothy Strathmann

#### Associate Professors

Christopher Higgins  
Panos Kiousis  
Junko Munakata Marr  
Jonathan O. Sharp

#### Assistant Professors

Christopher Bellona  
Reza Hedayat  
Shiling Pei  
Kathleen Smits

#### Teaching Professors

Joseph Crocker  
Kristoph Kinzli  
Susan Reynolds

#### Teaching Associate Professors

Andres Guerra  
Hongyan Liu  
Alexandra Wayllace

#### Teaching Assistant Professor

Jeffery Holley

#### Adjunct Faculty

Sidney Innerebner  
Paul B. Queneau  
Tanja Rauch  
Patrick Ryan

### Courses

**CEEN501. LIFE CYCLE ASSESSMENT. 3.0 Semester Hrs.**  
(II) Which is more sustainable: paper vs plastic, hybrid vs electric vehicles? LCA is a powerful tool used to answer these questions; LCA quantifies the environmental sustainability of a product or process. Students will learn to conduct an LCA during a semester-long project of their choosing. At the end of the course students should be able to sit for the ACLCA professional LCACP certification exam. 3 hours lecture; 3 semester hours.
CEEN505. NUMERICAL METHODS FOR ENGINEERS. 3.0 Semester Hrs.
Equivalent with EGGN560.
(S) Introduction to the use of numerical methods in the solution of commonly encountered problems of engineering analysis. Structural/solid analysis of elastic materials (linear simultaneous equations); vibrations (roots of nonlinear equations, initial value problems); natural frequency and beam buckling (eigenvalue problems); interpretation of experimental data (curve fitting and differentiation); summation of pressure distributions (integration); beam deflections (boundary value problems). Prerequisites: MATH225. 3 hours lecture; 3 semester hours.

CEEN506. FINITE ELEMENT METHODS FOR ENGINEERS. 3.0 Semester Hrs.
Equivalent with EGGN542.
(I) A course combining finite element theory with practical programming experience in which the multidisciplinary nature of the finite element method as a numerical technique for solving differential equations is emphasized. Topics covered include simple structural elements, beams on elastic foundations, solid elasticity, steady state analysis and transient analysis. Some of the applications will lie in the general area of geomechanics, reflecting the research interests of the instructor. Students get a copy of all the source code published in the course textbook. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN510. ADVANCED SOIL MECHANICS. 3.0 Semester Hrs.
Equivalent with EGGN548.
Advanced soil mechanics theories and concepts as applied to analysis and design in geotechnical engineering. Topics covered will include seepage, consolidation, shear strength, failure criteria and constitutive models for soil. The course will have an emphasis on numerical solution techniques to geotechnical problems by finite elements and finite differences. Prerequisites: A first course in soil mechanics. 3 Lecture Hours, 3 semester hours. Fall even years.

CEEN511. UNSATURATED SOIL MECHANICS. 3.0 Semester Hrs.
Equivalent with EGSSS33, EGGN533.
The focus of this course is on soil mechanics for unsaturated soils. It provides an introduction to thermodynamic potentials in partially saturated soils, chemical potentials of adsorbed water in partially saturated soils, phase properties and relations, stress state variables, measurements of soil water suction, unsaturated flow laws, measurement of unsaturated permeability, volume change theory, effective stress principle, and measurement of volume changes in partially saturated soils. The course is designed for seniors and graduate students in various branches of engineering and geology that are concerned with unsaturated soils? hydrologic and mechanics behavior. When this course is cross-listed and concurrent with CEEN511, students that enroll in CEEN512 will complete additional and/or more complex assignments. Prerequisites: CEEN312. 3 hours lecture; 3 semester hours. Spring even years.

CEEN512. SOIL BEHAVIOR. 3.0 Semester Hrs.
Equivalent with EGGN534.
(I) The focus of this course is on interrelationships among the composition, fabric, and geotechnical and hydrologic properties of soils that consist partly or wholly of clay. The course will be divided into two parts. The first part provides an introduction to the composition and fabric of natural soils, their surface and pore-fluid chemistry, and the physico-chemical factors that govern soil behavior. The second part examines what is known about how these fundamental characteristics and factors affect geotechnical properties, including the hydrologic properties that govern the conduction of pore fluid and pore fluid constituents, and the geomechanical properties that govern volume change, shear deformation, and shear strength. The course is designed for graduate students in various branches of engineering and geology that are concerned with the engineering and hydrologic behavior of earth systems, including geotechnical engineering, geological engineering, environmental engineering, mining engineering, and petroleum engineering. When this course is cross-listed and concurrent with CEEN411, students that enroll in CEEN512 will complete additional and/or more complex assignments. Prerequisites: CEEN361 Soil Mechanics. 3 hours lecture; 3 semester hours.

CEEN513. ADVANCED GEOMATERIAL MECHANICS. 4.0 Semester Hrs.
(I) This course deals with the classification and engineering behavior of soil and rock materials as well as materials used in underground construction such as structural steel, aggregates, cement, timber, concrete, shotcrete, accelerators and ground conditioning agents. This course presents an advanced treatment of soil and rock mechanics with focus on the following topics: Index and classification properties of soils, Physical properties and classification of intact rock and rock masses, Fluid flow in soils and rocks, Compressibility of soils and rocks, Failure theories and strength testing of soils and rocks, Shear strength of soils and rocks, Stresses and deformations around underground openings, Laboratory and field methods for evaluation of soil and rock properties, and Analytical and empirical approaches for the design and construction of structures in soil and rock materials. Prerequisites: Undergraduate degree in a pertinent discipline of engineering or equivalent and undergraduate level knowledge of material behavior. Co-requisites: GEGN561. 4 hours lecture; 4 semester hours.

CEEN514. SOIL DYNAMICS. 3.0 Semester Hrs.
Equivalent with EGGN531.
(II) Dynamic phenomena in geotechnical engineering, e.g., earthquakes, pile and foundation vibrations, traffic, construction vibrations; behavior of soils under dynamic loading, e.g., small, medium and large strain behavior, soil liquefaction; wave propagation through soil and rock; laboratory and field techniques to assess dynamic soil properties; analysis and design of shallow and deep foundations subjected to dynamic loading; analysis of construction vibrations. Prerequisites: CEEN312, MEGN315, CEEN415. 3 hours lecture; 3 semester hours.

CEEN515. HILLSLOPE HYDROLOGY AND STABILITY. 3.0 Semester Hrs.
Equivalent with EGGN536.
CEEN520. EARTH RETAINING STRUCTURES / SUPPORT OF EXCAVATIONS. 3.0 Semester Hrs.
(II) Analysis, design, construction and monitoring of earth retaining structures and support of excavations used for permanent and temporary support of transportation facilities, bridges, underground structures and tunnels, shafts, waterfront structures, earth slopes and embankments. Includes gravity, semi-gravity, cantilevered, anchored, geo-synthetic and ground improvement walls. Addresses fundamental geomechanics required for analysis and design, ASD (allowable stress design) and LRFD (load resistance factor design) design techniques, and construction techniques. Prerequisites: Undergraduate Introduction to Geotechnical Engineering course (i.e., similar to CEEN312). 3 hours lecture and discussion; 3 semester hours.

CEEN523. UNDERGROUND CONSTRUCTION ENGINEERING IN SOFT GROUND. 4.0 Semester Hrs.
(II) Design and construction of water, wastewater, transportation and utility tunnels, underground space and shafts/excavations in soft ground conditions (soil and weak rock). Addresses geotechnical site characterization, selection of design parameters, stability and deformation analysis of the ground and overlying structures, and construction methods. Includes design of temporary and permanent structural ground support according to ASD (allowable stress design) and LRFD (load resistance factor design) approaches, and design of ground improvement schemes and instrumentation/monitoring approaches to mitigate risk. This course requires post-graduate level knowledge of soil mechanics, fundamental understanding of engineering geology, and an undergraduate level knowledge of structural analysis and design. Prerequisites: CEEN513 and GEGN468. Co-requisites: GEGN562. 4 hours lecture; 4 semester hours.

CEEN530. ADVANCED STRUCTURAL ANALYSIS. 3.0 Semester Hrs.
Equivalent with EGGN541.

CEEN531. STRUCTURAL DYNAMICS. 3.0 Semester Hrs.
Equivalent with EGGN557.
An introduction to the dynamics and earthquake engineering of structures is provided. Subjects include the analysis of linear and nonlinear single-degree and multi-degree of freedom structural dynamics. The link between structural dynamics and code-based analysis and designs of structures under earthquake loads is presented. The focus applications of the course include single story and multi-story buildings, and other types of structures that under major earthquake may respond in the inelastic range. Prerequisites: CEEN314 Structural Theory. 3 semester hours.

CEEN533. MATRIX STRUCTURAL ANALYSIS. 3.0 Semester Hrs.
Equivalent with CEEN433.
(I) Focused study on computer oriented methods for solving determinate and indeterminate structures such as trusses and frames. Classical stiffness based analysis method will be introduced with hands-on practice to develop customized matrix analysis program using Matlab. Commercial structural analysis programs will also be introduced during the class and practiced through class projects. When this course is cross-listed and concurrent with CEEN433, students that enroll in CEEN533 will complete additional and/or more complex assignments. Prerequisites: CEEN314 Elementary Structural Theory. 3 lecture hours, 3 semester hours.

CEEN540. ADVANCED DESIGN OF STEEL STRUCTURES. 3.0 Semester Hrs.
Equivalent with EGGN549.
The course extends the coverage of steel design to include the topics: slender columns, beam-columns, frame behavior, bracing systems and connections, stability, moment resisting connections, composite design, bolted and welded connections under eccentric loads and tension, and semi-rigid connections. Prerequisite: CEEN443 or equivalent. 3 hours lecture; 3 semester hours. Spring even years.

CEEN541. DESIGN OF REINFORCED CONCRETE STRUCTURES II. 3.0 Semester Hrs.
Equivalent with EGGN556.
Advanced problems in the analysis and design of concrete structures, design of slender columns; biaxial bending; two-way slabs; strut and tie models; lateral and vertical load analysis of multistory buildings; introduction to design for seismic forces; use of structural computer programs. Prerequisite: CEEN445. 3 hour lectures, 3 semester hours. Delivered in the spring of even numbered years.

CEEN542. TIMBER AND MASONRY DESIGN. 3.0 Semester Hrs.
Equivalent with EGGN547.
The course develops the theory and design methods required for the use of timber and masonry as structural materials. The design of walls, beams, columns, beam-columns, shear walls, and structural systems are covered for each material. Gravity, wind, snow, and seismic loads are calculated and utilized for design. Connection design and advanced seismic analysis principles are introduced. Prerequisite: CEEN314 or equivalent. 3 hours lecture; 3 semester hours. Spring odd years.

CEEN543. CONCRETE BRIDGE DESIGN BASED ON THE AASHTO LRFD SPECIFICATIONS. 3.0 Semester Hrs.
Equivalent with EGGN558.
This course presents the fundamentals of concrete bridge analysis and design including conceptual design, superstructure analysis, AASHTO-LRFD bridge specifications, flat slab bridge design, and pre-stressed concrete bridge design. The course is presented through the complete design of the superstructure of an example bridges. At the conclusion of the course, students will be able to analyze and design simple, but complete concrete bridge superstructures. Prerequisites: CEEN445, Design of Reinforced Concrete Structure. 3 hours lecture; 3 semester hours.

CEEN544. STRUCTURAL PRESERVATION OF EXISTING AND HISTORIC BUILDINGS. 3.0 Semester Hrs.
(I, II) A broad discussion of historic structural systems in the United States, including stone and brick masonry, terra cotta, timber, cast and wrought iron, early steel, and early concrete. Combines research of historic manuals with contemporary analysis. Introduces nondestructive tests for historic structures. Enables prediction of deterioration mechanisms and structural deficiencies. Synthesizes structural retrofit solutions with preservation philosophy and current building codes. Emphasizes the engineer?'s role in stewardship of historic buildings. Prerequisites: CEEN443 and CEEN445. 3 hours lecture and discussion; 3 semester hours.

CEEN545. STEEL BRIDGE DESIGN. 3.0 Semester Hrs.
(I, II, S) Students are introduced to, and will develop an understanding of, the theory, analysis, and AASHTO code requirements for the design of steel bridge superstructures. The students will become familiar with bridge types, required loadings, composite action, plate girder design, and the Load and Resistance Factor Design method. The students will recognize the design requirements for a steel bridge superstructure and perform calculations for member loads and the loadings it transfers to the substructure. Prerequisites: CEEN443. 3 hours lecture; 3 semester hours.
CEEN46. STATISTICAL METHODS FOR RELIABILITY AND ENGINEERING DESIGN. 3.0 Semester Hrs. 
(I, II, S) The course will introduce methods and principles that help quantify the effects of uncertainty in the performance prediction of civil infrastructure systems. Students will learn to apply quantitative risk analysis and modeling approaches relevant to design problems in civil engineering. The course emphasizes that the systematic treatment of uncertainty and risk quantification are essential for adequate engineering planning, design, and operation of systems. The statistical approaches fundamental to engineering design and theory of reliability in structural and underground infrastructure design will be the focus of the course and examples. 3 hours lecture; 3 semester hours.

CEEN50. PRINCIPLES OF ENVIRONMENTAL CHEMISTRY. 3.0 Semester Hrs. 
Equivalent with ESGN500, This course provides an introduction to chemical equilibria in natural waters and engineered systems. Topics covered include chemical thermodynamics and kinetics, acid/base chemistry, open and closed carbonate systems, precipitation reactions, coordination chemistry, adsorption and redox reactions. Prerequisites: none. 3 hours lecture; 3 semester hours.

CEEN51. ENVIRONMENTAL ORGANIC CHEMISTRY. 3.0 Semester Hrs. 
Equivalent with ESGN555, A study of the chemical and physical interactions which determine the fate, transport and interactions of organic chemicals in aquatic systems, with emphasis on chemical transformations of anthropogenic organic contaminants. Prerequisites: A course in organic chemistry and CHGN503, Advanced Physical Chemistry or its equivalent. Offered in alternate years. 3 hours lecture; 3 semester hours.

CEEN52. CHEMISTRY OF THE SOIL / WATER INTERFACE. 3.0 Semester Hrs. 
Equivalent with ESGN525, The fate of many elements in the soil/water environment is regulated by sorption reactions. The content of this course focuses on the physical chemistry of reactions occurring at the soil-particle/water interface. The emphasis is on the use of surface complexation models to interpret solute sorption at the particle/water interface. Prerequisites: CEEN550. 3 hours lecture; 3 semester hours.

CEEN53. ENVIRONMENTAL RADIOCHEMISTRY. 3.0 Semester Hrs. 
Equivalent with ESGN510, This course covers the phenomena of radioactivity (e.g., modes of decay, methods of detection and biological effects) and the use of naturally occurring and artificial radionuclides as tracers for environmental processes. Discussions of tracer applications will range from oceanic trace element scavenging to contaminant transport through groundwater aquifers. Prerequisites: CEEN 550. 3 hours lecture; 3 semester hours.

CEEN55. LIMNOLOGY. 3.0 Semester Hrs. 
Equivalent with ESGN513, This course covers the natural chemistry, physics, and biology of lakes as well as some basic principles concerning contamination of such water bodies. Topics include heat budgets, water circulation and dispersal, sedimentation processes, organic compounds and their transformations, radionuclide limnochronology, redox reactions, metals and other major ions, the carbon dioxide system, oxygen, nutrients; planktonic, benthic and other communities, light in water and lake modeling. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN56. MINING AND THE ENVIRONMENT. 3.0 Semester Hrs. 
Equivalent with ESGN556, The course will cover many of the environmental problems and solutions associated with each aspect of mining and ore dressing processes. Mining is a complicated process that differs according to the type of mineral sought. The mining process can be divided into four categories: Site Development; Extraction; Processing; Site Closure. Procedures for hard rock metals mining; coal mining; underground and surface mining; and in situ mining will be covered in relation to environmental impacts. Beneficiation, or purification of metals will be discussed, with cyanide and gold topics emphasized. Site closure will be focused on; stabilization of slopes; process area cleanup; and protection of surface and ground water. After discussions of the mining and beneficiation processes themselves, we will look at conventional and innovative measures to mitigate or reduce environmental impact.

CEEN58. ENVIRONMENTAL STEWARDSHIP OF NUCLEAR RESOURCES. 3.0 Semester Hrs. 
Equivalent with ESGN511, The stewardship of nuclear resources spans the entire nuclear fuel cycle, which includes mining and milling through chemical processing on the front end of the materials life cycle. On the back end, stewardship continues from materials removal from the power plant during re-fueling or facility decommissioning, through storage, recycling and disposal, as well as the management of activated or contaminated materials generated during facility decommissioning. Each stage in the fuel cycle has a different risk of public exposure through different pathways and the presence of different isotopes. These risks are an integral part in considering the long-term efficacy of nuclear as an energy alternative. Furthermore, nuclear energy has long been vilified in public opinion forums via emotional responses. Stewardship extends beyond quantification of risks to the incorporation and communication of these risks and the associated facts regarding nuclear power to the public at large. Prerequisite: Graduate standing. 3 hours lecture; 3 semester hours.

CEEN59. MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT. 3.0 Semester Hrs. 
Equivalent with ESGN586, This course explores the diversity of microbe in a few of the countless environments of our planet. Topics include microbial ecology (from a molecular perspective), microbial metabolism, pathogens, extreme environments, engineered systems, oxidation / reduction of metals, bioremediation of both organisms and inorganics, microbial diversity, phylogenetics, analytical tools and bioinformatics. The course has an integrated laboratory component for applied molecular microbial ecology to learn microscopy, DNA extraction, PCR, gel electrophoresis, cloning, sequencing, data analysis and bioinformatic applications. Prerequisite: College Biology and/or CHGC562, CHGC563 or equivalent and enrollment in the ESE graduate program. 3 hours lecture, some field trips; 3 semester hours.
CEEN562. ENVIRONMENTAL GEOMICROBIOLOGY. 3.0 Semester Hrs.
Equivalent with BELS596, ESGN596.
This course explores the functional activities and biological significance of microorganisms in geological and engineered systems with a focus on implications to water resources. Topics include: microorganisms as geochemical agents of change, mechanisms and thermodynamics of microbial respiration, applications of analytical, material science and molecular biology tools to the field, and the impact of microbes on the fate and transport of problematic water pollutants. Emphasis will be placed on critical analysis and communication of peer-reviewed literature on these topics. 3 hours lecture and discussion; 3 semester hours.

CEEN564. ENVIRONMENTAL TOXICOLOGY. 3.0 Semester Hrs.
Equivalent with BELS545, ESGN545.
This course provides an introduction to general concepts of ecology, biochemistry, and toxicology. The introductory material will provide a foundation for understanding why, and to what extent, a variety of products and by-products of advanced industrialized societies are toxic. Classes of substances to be examined include metals, coal, petroleum products, organic compounds, pesticides, radioactive materials, and others. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN565. AQUATIC TOXICOLOGY. 3.0 Semester Hrs.
Equivalent with BELS544, ESGN544.
This course provides an introduction to assessment of the effects of toxic substances on aquatic organisms, communities, and ecosystems. Topics include general toxicological principles, water quality standards, sediment quality guidelines, quantitative structure-activity relationships, single species and community-level toxicity measures, regulatory issues, and career opportunities. The course includes hands-on experience with toxicity testing and subsequent data reduction. Prerequisite: none. 2.5 hours lecture; 1 hour laboratory; 3 semester hours.

CEEN566. MICROBIAL PROCESSES, ANALYSIS AND MODELING. 3.0 Semester Hrs.
Equivalent with BELS541, ESGN541.
Microorganisms facilitate the transformation of many organic and inorganic constituents. Tools for the quantitative analysis of microbial processes in natural and engineered systems will be presented. Stoichiometries, energetics, mass balances and kinetic descriptions of relevant microbial processes allow the development of models for specific microbial systems. Simple analytical models and complex models that require computational solutions will be presented. Systems analyzed include suspended growth and attached growth reactors for municipal and industrial wastewater treatment as well as in-stitu bioremediation and bioenergy systems. 3 hours lecture; 3 semester hours.

CEEN570. WATER AND WASTEWATER TREATMENT. 3.0 Semester Hrs.
Equivalent with ESGN504.
Unit operations and processes in environmental engineering are discussed in this course, including physical, chemical, and biological treatment processes for water and wastewater. Treatment objectives, process theory, and practice are considered in detail. Prerequisites: none. 3 hours lecture; 3 semester hours.

CEEN571. ADVANCED WATER TREATMENT ENGINEERING AND WATER REUSE. 3.0 Semester Hrs.
Equivalent with ESGN506.
This course presents issues relating to theory, design, and operation of advanced water and wastewater treatment unit processes and water reuse systems. Topics include granular activated carbon (GAC), advanced oxidation processes (O3/H2O2), UV disinfection, pressure-driven, current-driven, and osmotic-driven membranes (MF, UF, NF, RO, electrodialysis, and forward osmosis), and natural systems such as riverbank filtration (RBF) and soil-aquifer treatment (SAT). The course is augmented by CEEN571L offering hands-on experience using bench- and pilot-scale unit operations. Prerequisite: CEEN470 or CEEN471 or CEEN570 or CEEN572. 3 hours lecture; 3 semester hours.

CEEN571L. ADVANCED WATER TREATMENT ENGINEERING AND WATER REUSE - LABORATORY. 1.0 Semester Hr.
Equivalent with ESGN506L.
This course provides hands-on experience using bench- and pilotscale unit operations and computer exercises using state-of-the art software packages to design advanced water treatment unit processes. Topics include adsorption processes onto powdered and granular activated carbon, low-pressure membrane processes (microfiltration, ultrafiltration), and highpressure and current-driven membrane processes (nanofiltration, reverse osmosis, and electrodialysis). The course is a highly recommended component of CEEN571 and meets 5 - 6 times during the semester to support the work in CEEN571. Co- or Pre-requisite: CEEN571. 1 semester hour.

CEEN572. ENVIRONMENTAL ENGINEERING PILOT PLANT LABORATORY. 4.0 Semester Hrs.
Equivalent with ESGN530.
This course provides an introduction to bench and pilot-scale experimental methods used in environmental engineering. Unit operations associated with water and wastewater treatment for real-world treatment problems are emphasized, including multi-media filtration, oxidation processes, membrane treatment, and disinfection processes. Investigations typically include: process assessment, design and completion of bench- and pilot-scale experiments, establishment of analytical methods for process control, data assessment, upscaling and cost estimation, and project report writing. Projects are conducted both at CSM and at the City of Golden Water Treatment Pilot Plant Laboratory. Prerequisites: CEEN550 and CEEN570. 6 hours laboratory; 4 semester hours.

CEEN573. RECLAMATION OF DISTURBED LANDS. 3.0 Semester Hrs.
Equivalent with ESGN552.
Basic principles and practices in reclaiming disturbed lands are considered in this course, which includes an overview of present legal requirements for reclamation and basic elements of the reclamation planning process. Reclamation methods, including contouring, erosion control, soil preparation, plant establishment, seed mixtures, nursery stock, and wildlife habitat rehabilitation, will be examined. Practitioners in the field will discuss their experiences. Prerequisite: none. 3 hours lecture; 3 semester hours.
CEEN574. SOLID WASTE MINIMIZATION AND RECYCLING. 3.0 Semester Hrs.
Equivalent with ESGN562.
This course will examine, using case studies, ways in which industry applies engineering principles to minimize waste formation and to meet solid waste recycling challenges. Both proven and emerging solutions to solid waste environmental problems, especially those associated with metals, will be discussed. Prerequisite: CEEN550. 3 hours lecture; 3 semester hours.

CEEN575. HAZARDOUS WASTE SITE REMEDIATION. 3.0 Semester Hrs.
Equivalent with ESGN575.
This course covers remediation technologies for hazardous waste contaminated sites, including site characteristics and conceptual model development, remedial action screening processes, and technology principles and conceptual design. Institutional control, source isolation and containment, subsurface manipulation, and in situ and ex situ treatment processes will be covered, including unit operations, coupled processes, and complete systems. Case studies will be used and computerized tools for process selection and design will be employed. Prerequisite: CEEN550 and CEEN580. 3 hours lecture; 3 semester hours.

CEEN575L. HAZARDOUS WASTE SITE REMEDIATION: TREATABILITY TESTING. 1.0 Semester Hr.
 Equivalent with ESGN575L.
This laboratory module is designed to provide hands-on experience with treatability testing to aid selection and design of remediation technologies for a contaminated site. The course will be comprised of laboratory exercises in Coolbaugh Hall and possibly some field site work near CSM. Pre-requisite: CEEN575. 2 hours laboratory; 1 semester hour.

CEEN576. POLLUTION PREVENTION: FUNDAMENTALS AND PRACTICE. 3.0 Semester Hrs.
Equivalent with ESGN563.
The objective of this course is to introduce the principles of pollution prevention, environmentally benign products and processes, and manufacturing systems. The course provides a thorough foundation in pollution prevention concepts and methods. Engineers and scientists are given the tools to incorporate environmental consequences into decision-making. Sources of pollution and its consequences are detailed. Focus includes sources and minimization of industrial pollution; methodology for life-cycle assessments and developing successful pollution prevention plans; technological means for minimizing the use of water, energy, and reagents in manufacturing; and tools for achieving a sustainable society. Materials selection, process and product design, and packaging are also addressed. 3 hours lecture; 3 semester hours.

CEEN580. CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT. 3.0 Semester Hrs.
Equivalent with ESGN503.
This course describes the environmental behavior of inorganic and organic chemicals in multimedia environments, including water, air, sediment and biota. Sources and characteristics of contaminants in the environment are discussed as broad categories, with some specific examples from various industries. Attention is focused on the persistence, reactivity, and partitioning behavior of contaminants in environmental media. Both steady and unsteady state multimedia environmental models are developed and applied to contaminated sites. The principles of contaminant transport in surface water, groundwater, and air are also introduced. The course provides students with the conceptual basis and mathematical tools for predicting the behavior of contaminants in the environment. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN581. WATERSHED SYSTEMS MODELING. 3.0 Semester Hrs.
Equivalent with ESGN527.
Introduction to surface water modeling, including rainfall-runoff analysis, input data, uncertainty analysis, lumped and distributed modeling, parameter estimation and sensitivity analysis. Course is heavy on application of models across a range of diverse watersheds for streamflow and snowmelt predictions. In general, theoretical topics are covered in the first meeting each week, followed by hands-on application of concepts and models in the second meeting. Laptops and student Matlab licenses will be required for in-class activities. Prerequisite: none. 3 hours lecture per week; 3 semester hours.

CEEN582. MATHEMATICAL MODELING OF ENVIRONMENTAL SYSTEMS. 3.0 Semester Hrs.
Equivalent with ESGN528.
This is an advanced graduate-level course designed to provide students with hands-on experience in developing, implementing, testing, and using mathematical models of environmental systems. The course will examine why models are needed and how they are developed, tested, and used as decision-making or policy-making tools. Typical problems associated with environmental systems, such as spatial and temporal scale effects, dimensionality, variability, uncertainty, and data insufficiency, will be addressed. The development and application of mathematical models will be illustrated using a theme topic such as Global Climate Change, In Situ Bioremediation, or Hydrologic Systems Analysis. Prerequisites: CEEN580 and knowledge of basic statistics and computer programming. 3 hours lecture; 3 semester hours.

CEEN583. SURFACE WATER QUALITY MODELING. 3.0 Semester Hrs.
Equivalent with ESGN520.
This course will cover modeling of water flow and quality in rivers, lakes, and reservoirs. Topics will include introduction to common analytical and numerical methods used in modeling surface water flow, water quality, modeling of kinetics, discharge of waste water into surface systems, sedimentation, growth kinetics, dispersion, and biological changes in lakes and rivers. Prerequisites: CEEN480 or CEEN580 recommended. 3 hours lecture; 3 semester hours.

CEEN584. SUBSURFACE CONTAMINANT TRANSPORT. 3.0 Semester Hrs.
Equivalent with ESGN522.
This course will investigate physical, chemical, and biological processes governing the transport and fate of contaminants in the saturated and unsaturated zones of the subsurface. Basic concepts in fluid flow, groundwater hydraulics, and transport will be introduced and studied. The theory and development of models to describe these phenomena, based on analytical and simple numerical methods, will also be discussed. Applications will include prediction of extents of contaminant migration and assessment and design of remediation schemes. Prerequisites: CEEN580. 3 hours lecture; 3 semester hours.
CEEN589. WATER SUSTAINABILITY AND ENERGY PRODUCTION: CURRENT SCIENCE AND PRACTICE. 1.0 Semester Hr.
(I) This course is designed to provide students with valuable communication and professional skills while exploring in depth the topic of joint sustainability of water and unconventional petroleum energy production. A survey of current literature combined with key speakers will introduce the students to the field, while class sessions and practical exercises will help develop important communication, research, and interpersonal skills needed for future professionals. Course curriculum includes specific topics such as speaking/writing for a variety of audiences and critical thinking and analysis. This course is required for all ConocoPhillips - WE2ST Fellows, but is also open to any interested graduate students. 1 hour seminar; 1 semester hour.

CEEN590. CIVIL ENGINEERING SEMINAR. 1.0 Semester Hr.
(I) Introduction to contemporary and advanced methods used in engineering design. Includes, need and problem identification, methods to understand the customer, the market and the competition. Techniques to decompose design problems to identify functions, ideation methods to produce form from function. Design for X topics. Methods for prototyping, modeling, testing and evaluation of designs. Embedment and detailed design processes. Prerequisites: EGGN491 and EGGN492, equivalent senior design project experience or industrial design experience, graduate standing. 3 hours lecture; 3 semester hours. Taught on demand.

CEEN591. ENVIRONMENTAL PROJECT MANAGEMENT. 3.0 Semester Hrs.
Equivalent with ESGN571, This course investigates environmental project management and decision making from government, industry, and contractor perspectives. Emphasis is on (1) economics of project evaluation; (2) cost estimation methods; (3) project planning and performance monitoring; (4) and creation of project teams and organizational/communications structures. Extensive use of case studies. Prerequisite: none. 3 hours lecture; 3 semester hours.

CEEN592. ENVIRONMENTAL LAW. 3.0 Semester Hrs.
Equivalent with CEEN492, ESGN490, ESGN502, PEGN530, This is a comprehensive introduction to U.S. Environmental Law, Policy, and Practice, especially designed for the professional engineer, scientist, planner, manager, consultant, government regulator, and citizen. It will prepare the student to deal with the complex system of laws, regulations, court rulings, policies, and programs governing the environment in the USA. Course coverage includes how our legal system works, sources of environmental law, the major USEPA enforcement programs, state/local matching programs, the National Environmental Policy Act (NEPA), air and water pollution (CAA, CWA), EPA risk assessment training, toxic/hazardous substances laws (RCRA, CERCLA, EPCRA, TSCA, LUST, etc.), and a brief introduction to international environmental law. Prerequisites: none. 3 hours lecture; 3 semester hours.

CEEN593. ENVIRONMENTAL PERMITTING AND REGULATORY COMPLIANCE. 3.0 Semester Hrs.
Equivalent with ESGN593, The purpose of this course is to acquaint students with the permit writing process, developing information requirements for permit applications, working with ambiguous regulations, negotiating with permit writers, and dealing with public comment. In addition, students will develop an understanding of the process of developing an economic and legally defensible regulatory compliance program. Prerequisite: CEEN592. 3 hours lecture; 3 semester hours.

CEEN594. RISK ASSESSMENT. 3.0 Semester Hrs.
Equivalent with ESGN501, This course evaluates the basic principles, methods, uses, and limitations of risk assessment in public and private sector decision making. Emphasis is on how risk assessments are made and how they are used in policy formation, including discussion of how risk assessments can be objectively and effectively communicated to decision makers and the public. Prerequisite: CEEN592 and one semester of statistics. 3 hours lecture; 3 semester hours.

CEEN595. ANALYSIS OF ENVIRONMENTAL IMPACT. 3.0 Semester Hrs.
Equivalent with ESGN591, Techniques for assessing the impact of mining and other activities on various components of the ecosystem. Training in the procedures of preparing Environmental Impact Statements. Course will include a review of pertinent laws and acts (i.e. Endangered Species Act, Coordination Act, Clean Air Act, etc.) that deal with environmental impacts. Prerequisite: none. 3 hours lecture, some field trips; 3 semester hours.

CEEN596. ENVIRONMENTAL SCIENCE AND ENGINEERING SEMINAR. 0.0 Semester Hrs.
Equivalent with ESGN590, Research presentations covering current research in a variety of environmental topics.

CEEN598. SPECIAL TOPICS IN CIVIL AND ENVIRONMENTAL ENGINEERING. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CEEN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CEEN610. INTERNATIONAL ENVIRONMENTAL LAW. 3.0 Semester Hrs.
Equivalent with ESGN602, The course covers an introductory survey of International Environmental Law, including multi-nation treaties, regulations, policies, practices, and politics governing the global environment. It surveys the key issues of sustainable development, natural resources projects, transboundary pollution, international trade, hazardous waste, climate change, and protection of ecosystems, wildlife, and human life. New international laws are changing the rules for engineers, project managers, scientists, teachers, businesspersons, and others both in the US and abroad, and this course is especially designed to keep professionals fully, globally informed and add to their credentials for international work. Prerequisites: CEEN592. 3 hours lecture; 3 semester hours.
CEEN611. MULTIPHASE CONTAMINANT TRANSPORT. 3.0 Semester Hrs.
Equivalent with ESGN622.
Principles of multiphase and multicomponent flow and transport are applied to contaminant transport in the unsaturated and saturated zones. Focus is on immiscible phase, dissolved phase, and vapor phase transport of low solubility organic contaminants in soils and aquifer materials. Topics discussed include: capillarity, interphase mass transfer, modeling, and remediation technologies. Prerequisites: CEEN550 or equivalent, CEEN580 or CEEN584 or equivalent. 3 hours lecture; 3 semester hours.

CEEN698. SPECIAL TOPICS IN CIVIL AND ENVIRONMENTAL ENGINEERING. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CEEN699. ADVANCED INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CEEN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
Equivalent with EGGN707C, ESGN707.
(I, II, S) GRADUATE THESIS/DISSERTATION RESEARCH CREDIT Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.