CIVIL ENGINEERING (CE)

CE 08999 Research Experience for High School Students (0 Credit Hours)
Research will be conducted in Environmental Engineering with Professor Kyle Doudrick. No coursework is required

CE 10110 Planet Earth (3 Credit Hours)
An introduction to the Earth, its processes, composition, evolution, and structure. The course introduces the student to mineralogy, petrology, structural geology, oceanography, surficial processes, geophysics, environmental geology, and planetology. Lecture and laboratory meetings.
Corequisites: CE 11110
Satisfies the following University Core Requirements: WKST-Core Science & Technology

CE 10115 Build Break Perfect (3 Credit Hours)
Project based course that bridges the gap between theory and practice by exposing students to hands on experiences in civil and environmental engineering. Basic concepts in civil and environmental engineering and the interrelationships among engineering, science, mathematics, and society will be introduced through project based learning experiences that examine the engineering aspects of various systems.

CE 10300 Global Change, Water and Energy (3 Credit Hours)
This course examines the topic of global environmental change and the mechanisms by which global change occurs. Analysis will include the relationships between physical and ecological changes on Earth, and our current understanding of how climate evolves under natural and human influences. Topics covered include the global energy balance, structure and circulation of the atmosphere and oceans, climate variability, and implications of climate change for natural and human systems.

CE 10700 Sustainable Development in a Changing World (3 Credit Hours)
World population has doubled in the last 50 years, and sustainable development in the face of global change is the greatest challenge of our time. Through readings, lectures and class discussions by topic (water, energy, resources, waste, environment and related topics), this class provides an overview of the origin, scale and complexity of the challenge, and discusses how we can contribute, as engineers, scientists and professionals to help address it. We will learn the fundamental quantitative tools to measure and evaluate environmental and resources problems, which will be applied in class projects focusing on specific sustainability issues. The course will conclude by studying how environmental and resources policy decisions are made, and discuss the tradeoffs and ethical dilemmas involved.
Prerequisites: (PHYS 10310 (may be taken concurrently) or PHYS 10093 or PHYS 10111 or PHYS 11661 or PHYS 10411 or PHYS 20210) and (MATH 10550 or MATH 10091 or MATH 10350 or MATH 10850)

CE 11110 Planet Earth Laboratory (1 Credit Hour)
This is the laboratory portion of CE 10110.
Corequisites: CE 10110

CE 20110 Planet Earth (3 Credit Hours)
An introduction to the Earth, its processes, composition, evolution, and structure. The course introduces the student to mineralogy, petrology, structural geology, oceanography, surficial processes, geophysics, environmental geology, and planetology. Lecture and laboratory meetings.
Corequisites: CE 21110
Satisfies the following University Core Requirements: WKST-Core Science & Technology
Enrollment is limited to students with a major in Environmental Engineering or Environmental Earth Sciences.

CE 20111 Planet Earth (3 Credit Hours)
An introduction to the Earth, its processes, composition, evolution, and structure. The course introduces the student to mineralogy, petrology, structural geology, oceanography, surficial processes, geophysics, environmental geology, and planetology. Lecture and laboratory meetings. A 1-credit co-requisite lab is required except for CE majors
Satisfies the following University Core Requirements: WKST-Core Science & Technology

CE 20150 Statics (3 Credit Hours)
The Introduction to systems of forces and couples; vector mechanics. Equilibrium of rigid bodies. Internal forces and moments, trusses and beams, distributed loads and properties of areas. Friction and virtual work.
Prerequisites: (EG 10111 or EG 10112) and (MATH 10560 or MATH 10092) and (PHYS 10310 or PHYS 10093)

CE 20230 Engineering Programming (1 Credit Hour)
Introduction to programming for engineers. This course will cover the fundamentals of programming in C and MATLAB, including basic structures, algorithm development, and implementation and debugging of programs. Assignments will illustrate the advantages of each programming environment. An emphasis will be placed on team-based learning; some assignments will require students to work together to write community programs.
Enrollment is limited to students with a major in Civil Engineering, Environmental Geosciences, Environmental Engineering or Environmental Earth Sciences.

CE 20300 Global Change, Water and Energy (3 Credit Hours)
This course examines global environmental change within Earth systems and how these evolve under natural and human influence. Topics covered encompass atmosphere, oceans, water, land and ecosystems and how natural and human-induced processes are reshaping Earth's environments. Central to this discussion are water and air pollution, water management, freshwater availability and scarcity and impact of these issues on society. Sustainable energy is investigated and renewable energy sources that meet current needs and those of future generations are explored. This discussion includes energy production but also incorporates energy efficiency measures and responsible energy consumption. The course concludes with a discussion on the implications of climate change for Earth systems and human society.

CE 20305 Climate, Environment, & Society (3 Credit Hours)
This course will examine the scientific basis of climate change and its intersection with human society (including policy, economics, public health, energy, ecosystems, environmental engineering, and journalism). We will begin by developing a foundation in the physical science of Earth's climate, examining climate data and the record of climate variability through time, before considering ongoing and projected future climate change impacts (including water availability, weather patterns, agriculture). We will continue by assessing how humans shape the climate and how that climate in turn shapes society. Class session will be composed of lectures, short videos, TED-talk style presentations, in-class lab experiments, and data visualization exercises, and discussions. This multidisciplinary class will involve rigorous analytical reason and connection of methodologies and complex themes, but not necessarily mathematical problem sets.

CE 20310 General Meteorology (3 Credit Hours)
This course is a survey of the discipline of meteorology. It quantitatively and conceptually explores the relationships in the atmosphere that drive the weather around the globe. Topics will include: atmospheric composition, energy transfer, cloud formation and precipitation, atmospheric measurement, numerical weather prediction, and an introduction to forecasting.

CE 20320 Environmental Aquatic Chemistry (3 Credit Hours)
The fundamentals of water chemistry from both thermodynamic and kinetic standpoints. This course focuses primarily on natural water chemistry with an emphasis on the carbonate system. The course also includes introductions to metal and organic pollutants, as well as atmospheric chemistry as related to the water cycle.
Prerequisites: CHEM 10171 or CHEM 10097

CE 20520 Environmental Mineralogy (4 Credit Hours)
Explores the compositions and structures of rock forming minerals in the context of environmental systems. Case studies emphasize the role of mineralogy in the transport of heavy metals and radionuclides in the subsurface, geologic disposal of nuclear waste, and acid mine drainage. Various remediation strategies are examined and contrasted.
Prerequisites: (CE 10110 or CE 20110 or CE 20111 or SC 10100 or SC 20110)
Corequisites: CE 21520
Satisfies the following University Core Requirements: WKST-Core Science & Technology

CE 20600 Computational Visualization and BIM of Engineering Systems (2 Credit Hours)
This is an introductory course that focuses on integrating Computer-Aided-Design (CAD) techniques into the engineering workflow. We will be exploring a range of technologies used in civil engineering as well as other design disciplines. A substantial portion of the class will be dedicated to learning core concepts of technical drawing as used in different programs. At the end of this course, students will be proficient in CAD programs like AutoCAD, Civil 3D and Revit. We will also introduce the use of Revit in BIM (Building Information Modeling), and explore how these technologies are rapidly changing the whole construction industry.

CE 20700 Sustainable Development in a Changing World (3 Credit Hours)
World population has doubled in the last 50 years, and sustainable development in the face of global change is the greatest challenge of our time. Through readings, lectures and class discussions by topic (water, energy, resources, waste, environment and related topics), this class provides an overview of the origin, scale and complexity of the challenge, and discusses how we can contribute, as engineers, scientists and professionals to help address it. We will learn the fundamental quantitative tools to measure and evaluate environmental and resources problems, which will be applied in class projects focusing on specific sustainability issues. The course will conclude by studying how environmental and resources policy decisions are made, and discuss the tradeoffs and ethical dilemmas involved.
Prerequisites: (MATH 10550 or MATH 10091 or MATH 10350 or MATH 10850) and (PHYS 10310 or PHYS 10093 or PHYS 10111 or PHYS 11661 or PHYS 10411 or PHYS 20210)

CE 20900 Career Choices in Civil and Environmental Engineering (1 Credit Hour)
A seminar series featuring selected speakers who are employed in fields related to Civil and Environmental Engineering or are career development professionals. The presentations and open symposium format emphasizes career opportunities for Civil and Environmental Engineering graduates. Course assignments are focused on personal career development (resume, cover letter, interviewing, networking).

CE 21110 Planet Earth Laboratory (1 Credit Hour)
This is the laboratory portion of CE 20110.
Corequisites: CE 20110

CE 21520 Environmental Mineralogy Lab (0 Credit Hours)
Lab componet for CE 20520
Corequisites: CE 20520

CE 23600 Challenges and Innovations in Civil and Environmental Engineering (0.5 Credit Hours)
This course will focus on examining large scale civil and environmental engineering problems, the technological challenges encountered, and the resulting innovative solutions. The emphasis will be on the engineering systems and will include problems in structural, ocean, hydraulic, groundwater, soils and environmental engineering. Course format: 6-10 lectures per semester presented by senior project engineers, university faculty and researchers who are leaders in the field. Each lecture will be 75 minutes and consist of a 1 hour presentation with 15 minutes for discussion and questions. The lectures will be targeted to tie the problems discussed to concepts emphasized in the current curriculum.
Course offered: Each spring and fall semester
Course may be repeated.
Enrollment limited to students in the Cvl & Envmntl Engr & Earth Sci department.

CE 24150 Statics (3 Credit Hours)
The Introduction to systems of forces and couples; vector mechanics. Equilibrium of rigid bodies. Internal forces and moments, trusses and beams, distributed loads and properties of areas. Friction and virtual work.

CE 24300 Global Change, Water, & Energy (3 Credit Hours)
In this course we will study the main mechanisms governing climate change in the past, the present, and the future. The motivation is that recent trends of climate and other environmental changes, whether due to human activity or natural variability, have focused societal attention on their potential negative impacts on human and environmental health. An understanding of past climate variability and its underlying causes and mechanisms is the basis for separating natural and anthropogenic climate change and for making useful projections of future climate and assessing its impacts. To get to this understanding, the course takes a journey from deep time through to the present describing periods when the climate was strikingly different than it is today and revealing the mechanisms and feedbacks that govern the climate system. Students will travel to Iceland, where they will explore the glaciers, the volcanoes and the landscape in Southern Iceland, hike on an outlet glacier and experience first-hand the amazing interaction between ice and geothermal activity. They will experience the local culture and language, delve into the history of Iceland and investigate the links between changes in climate and in society in the past. Furthermore, they will learn how geothermal energy can be harnessed in a renewable way, and maybe take a relaxing swim in the outdoor thermal pools. CU GEOG 2167 description: This course focuses on the formation, production, transportation, utilization/consumption of fossil fuels (i.e., petroleum, natural gas, and coal) and alternative energy sources (i.e., solar, hydro, wind, nuclear and geothermal). It also provides students with up-to-date knowledge and techniques for understanding and assessing effects of both conventional and alternative energy sources on human health, climate change, and the contamination of soil, water, and atmosphere at various scales. This course is intended for students having limited background in science or mathematics.

CE 27600 Special Studies (0-8 Credit Hours)
Individual or small group study under the direction of a faculty member in an undergraduate subject not concurrently covered by any University course.

CE 28600 Undergraduate Research (1-3 Credit Hours)
A research project at the undergraduate level under the supervision of a faculty member.
Course may be repeated.

CE 30110 Differential Equations for Engineers (3 Credit Hours)
This course is an introduction to differential equations, focusing on analysis and techniques encountered in engineering. Topics include first and second order linear equations and systems of differential equations. Mathematical modeling of dynamical systems, such as structural vibrations, predator-prey models, and fluid dynamics, will be addressed.
Prerequisites: (MATH 20550 or MATH 10093) and MATH 20580 (may be taken concurrently)

CE 30125 Computational Methods (3 Credit Hours)
Fundamentals of numerical methods and development of programming techniques to solve problems in civil and environmental engineering. This course requires significant computer use via a scientific program language such as Matlab and/or FORTRAN. Standard topics in numerical linear algebra, interpolation, discrete differentiation, discrete integration, and approximate solutions to ordinary differential equations are treated in a context-based approach. Applications are drawn from hydrology, environmental modeling, geotechnical engineering, modeling of material behavior, and structural analysis. Fall.

CE 30150 Modeling and Dynamics of Building Systems (3 Credit Hours)
Course provides a primer on structural dynamics for single and multi-degree-of-freedom systems with application to building systems, as well as an introduction to modeling of building systems within commercial software packages.
Prerequisites: CE 30200 or CE 34200

CE 30160 Civil Engineering Materials (3 Credit Hours)
A study of mechanical properties of civil engineering materials and how they relate to the atomic, microscopic, and macroscopic structure. Weekly laboratories are used to study materials such as steel, concrete, wood, and bituminous materials. Spring
Corequisites: CE 31160
Satisfies the following University Core Requirements: WRIT - Writing Intensive

CE 30161 Civil Engineering Materials - Updated (3 Credit Hours)
A study of mechanical properties of civil engineering materials and how they relate to the atomic, microscopic, and macroscopic structure. Weekly laboratories are used to study materials such as steel, concrete, wood, and bituminous materials. Spring
Corequisites: CE 31160

CE 30200 Introduction to Structural Engineering (3 Credit Hours)
Introduction to structural engineering; analysis of statically determinate structures; deflection analysis; analysis of indeterminate structures using classical and matrix methods; introduction to analysis software, structural design concepts and codes and standards. Fall.
Prerequisites: AME 20241

CE 30210 Structural Analysis (3 Credit Hours)
The fundamentals of matrix methods of analysis. Application to trusses and rigid frames. Introduction to the use of commercial analysis software. Advanced topics of analysis: plastic analysis, introduction to structural dynamics. The first course in the structures track. Spring.
Prerequisites: CE 30200 or CE 34200

CE 30267 Structural Wood Design (1 Credit Hour)
This course provides a foundation of wood design concepts for the aspiring wood builders and designers of tomorrow. Through hands-on design tasks projects and lectures students will get an in-depth knowledge of the engineering capabilities of wood and wood products. Students will be able to describe and apply design techniques for individual wood components including beams, columns, and connections, using engineered wood composites and conventional lumber products. The course additionally develops technical competencies essential for practicing engineers when conceptualizing systems for real-world projects include detailing for constructability and robustness. Contemporary issues, case studies and modern tools of practice (codes, standards, and potentially commercial software) are integrated throughout the course. This course is worth one credit hour.

CE 30300 Introduction to Environmental Engineering (3 Credit Hours)
An introduction to the fundamental concepts and principles to qualitatively and quantitatively assess complex natural and engineering systems relevant to environmental engineering. This course serves to assist students to identify, evaluate and solve problems involved in the control of water, air, and land pollution and challenges for environmental sustainability. The course introduces how fundamental science and engineering methodology is applied to solve real world environmental problems. This is the first course in the environmental engineering track. Fall.
Enrollment is limited to students with a major in Civil Engineering or Environmental Geosciences.

CE 30320 Physical-Chemical Water Treatment Processes (3 Credit Hours)
An introduction to the physical and chemical processes used for drinking water treatment, including principles and design. We will also discuss basic water chemistry, water quality, water sources, environmental policy, and current issues in the industry.
Prerequisites: CE 30300

CE 30338 Design Tools for Environmental Engineers (1 Credit Hour)
Students will be introduced to several programs used in environmental design such as Biowin, CAD, and GIS.
Prerequisites: CE 40341 (may be taken concurrently)

CE 30339 Laboratory and Field Methods for Environmental Engineering (3 Credit Hours)
The objectives of this course are to learn principles and methods for designing, building and testing systems to sense and quantify environmental processes. Measurements in the environment focus on monitoring natural ecosystems, sustainable environmental infrastructure, atmospheres and water bodies. Design and fabrication of sensing systems for monitoring heat, mass, chemicals, energy, and biota will be considered. Measurements of velocity, temperature, transport and concentration levels will be covered. The concentrations of hazards in the air, water, land and urban environment will also be explored. Group research sessions and fieldwork are an integral part of the course. The course will involve the class in the planning and execution of studies to sense environmental systems: such as the South Bend/Lake Michigan waterways and other terrestrial/aquatic systems; Green Roofs, Combined Sewage Overflow (CSO); terrestrial hazards; urban air-quality, and field method design/development/execution.

CE 30455 Environmental Hydrology (3 Credit Hours)
An Introduction to the hydrologic cycle and review of the main processes. This includes precipitation, evaporation and transpiration, runoff, infiltration and a brief introduction to ground water. Some concepts and tools commonly used by water resources managers will also be discussed. Transport of pollutants will be introduced. Finally, biological elements of the water cycle will be introduced. Laboratory techniques complement lecture topics.

CE 30460 Fluid Mechanics (3 Credit Hours)
A basic course in Fluid Mechanics.
Prerequisites: MATH 20580 or MATH 10094

CE 30500 Geomorphology for Engineers and Scientists (3 Credit Hours)
This course introduces students to principles and processes of landform evolution with emphasis on global-scale Earth processes, volcanic & tectonic geomorphology, weathering processes & soils and mass movement. Processes and landform evolution in fluvial, desert, glacial, coastal and karst environments are investigated, and the effects on human structures and developments are explored. The course concludes with a discussion on the impact of climate change on Earth's surface features.

CE 30510 Geotechnical Engineering (3.5 Credit Hours)
The objective of this course is to introduce and familiarize the student with the fundamentals of soil mechanics, including behavior of soils in compression and shear, and the principles of geotechnical engineering through lectures and laboratory experiments. Spring.
Prerequisites: AME 20241 or CE 20150
Corequisites: CE 31510

CE 30530 Sedimentology and Stratigraphy (3 Credit Hours)
Physical, chemical and compositional properties of sediments are used to investigate formation, origin and occurrence of sedimentary rocks. Sedimentary environments from a physical, biological and tectonic perspective are explored. Stratigraphic relationships of layered rock successions are used to examine the distribution of strata in space and time. The course concludes with the application of sedimentologic, stratigraphic and tectonic principles to basin analysis in order to interpret the geologic history and evaluate the economic potential of sedimentary environments.

CE 30540 Petrology/Earth Materials (3 Credit Hours)
This course brings together the wide-ranging fundamentals students need to understand rocks and minerals, and will illustrate how they relate to the broader Earth, materials and environmental sciences. An introduction and overview of key and basic geological concepts will be provided. Key concepts in mineralogy, including optical microscopy and igneous and metamorphic petrology are covered; these include origin and identification of these rocks within a plate tectonics framework. Geochemistry and petrography are used to investigate mineral equilibria, magma generation and crystallization, pressure and temperatures of deformation, and the interior of the Earth. Emphasis will also be placed on minerals of economic importance and selected resources of Earth materials, in particular those of significant value for emerging and renewable energies.
Prerequisites: CE 20520

CE 30555 Living and Working on Our Moon: Science fiction or Science Fact? (3 Credit Hours)
Can humans live and work successfully on the Moon? This course will endeavor to address this question by informing the students of what we have learned about our nearest celestial neighbor during and since Apollo. This will include details about resources that could be used to build, maintain and grow any human field station that is set up, and would discuss the criteria for the location of such a station. The first series of classes will be the traditional lecture format to get the baseline data imparted to the students. The next segment of the course will be team discussions to address a series of questions where the class will divide into teams and work on a solution to a particular question as part of their homework. They will present their results in subsequent classes and will be graded on this. The final lecture will be a Capstone to tie together the results of the semesters work.

CE 30556 Sustainability and Resilience of Energy Systems and Supplies (3 Credit Hours)
Human living standards are directly correlated with energy availability and consumption. About 1 billion people in the world today have no access to electricity, at least another billion have unreliable electricity and often only enough to power a few light bulbs, and more than two billion people cook food over open fires. This technical-oriented but accessible-to-all course focuses on the history, evolution, and current deployment of energy systems worldwide. Emphases are on the utilization, limitations, and drawbacks of world energy supplies including fossil fuels, nuclear, and renewables relative to sustainability and resilience. Case studies will include the electrical grid failure in Puerto Rico during and after hurricane Maria, the nuclear plant accidents at Fukushima (Japan) and Chernobyl (Ukraine), conflicts related to energy, and the changing energy mix of the local country/city where the course is taught.

CE 30560 Dynamic Earth and Natural Disasters (3 Credit Hours)
This course focuses on Earth processes involved in the formation and reshaping of the land surface and the oceans and how these relate to major natural hazards such as earthquakes and volcanic eruptions. The plate tectonics framework of a dynamic Earth is central to the discussion as it relates to the occurrence of surface structures on a regional and global scale. Processes of rock deformation including faulting, fracturing and folding in the Earth's crust are discussed. Topics covered in this course encompass compressional settings such as the Cascades and Alaska, extensional settings including the Basin and Range Province, transform settings such as the San Andreas Fault and hotspots including Hawai'i, Iceland and Yellowstone.
Prerequisites: CE 20110 or SC 20110 or CE 20111 or CE 10110 or SC 10100

CE 30610 Fundamentals of Construction Management (3 Credit Hours)
An introduction to construction management, including fundamentals of safety, quality estimating, scheduling, subcontracting, and delivery methods. In this course, students will explore risk management, negotiations, and claims in the context of construction. The course's main objective is to provide students with a broad understanding of the skills required for a career in construction in the context of today's complex large scale projects.

CE 30720 Resiliency of Engineering Systems (3 Credit Hours)
This course will discuss fundamental concepts needed to understand and engineer for mitigation and resilience against multi-hazard vulnerability of critical infrastructure, environment, energy, communities, and other complex and inter-connected engineering systems. It will include significant components in decision-making and public policy.

CE 31160 Materials Laboratory (1 Credit Hour)
The concurrent laboratory portion of CE 30160. Spring.
Corequisites: CE 30161

CE 31300 CE 31300 - Introduction to Environmental Engineering Laboratory (1 Credit Hour)
The laboratory component of the Intro to Environmental Engineering course. Fall.

CE 31510 Geotechnical Engineering Lab (0 Credit Hours)
The current laboratory portion of CE 30510.
Corequisites: CE 30510
Course may be repeated.

CE 31540 Petrology/Earth Materials Lab (1 Credit Hour)
Lab component of CE 30540
Corequisites: CE 30540

CE 33100 Geographic Information Systems (3 Credit Hours)
This course is aimed to provide a basic understanding of how Geographic Information Systems (GIS) and satellite imagery can be used to visualize and analyze environmental data. Students will learn basic techniques for analyzing, manipulating and creating geospatial data in both pixel-based (satellite imagery and digital terrain models) and vector based (point, line and polygon representation of spatial data) formats. Students will also learn how acquire high resolution satellite imagery and other GIS data from online data servers.
Enrollment is limited to students with a major in Civil Engineering, Environmental Engineering or Environmental Earth Sciences.

CE 33400 Environmental Fluid Dynamics Seminar (1 Credit Hour)
This weekly seminar series for senior undergraduate students who are interested in pursuing a greater understanding of fluid mechanics with particular relevance to motions in the environment (atmosphere, oceans and solid earth). Many of the lectures will be dedicated for invited speakers from other institutions and the rest will be given by Notre Dame Speakers. These seminars are expected to expose students and faculty to a wide swath of research problems as well as to state-of-the-art analytical, numerical and experimental tools.
Course may be repeated.

CE 33600 Challenges and Innovations in Civil and Environmental Engineering (0.5 Credit Hours)
This course will focus on examining large scale civil and environmental engineering problems, the technological challenges encountered, and the resulting innovative solutions. The emphasis will be on the engineering systems and will include problems in structural, ocean, hydraulic, groundwater, soils and environmental engineering. Course format: 6-10 lectures per semester presented by senior project engineers, university faculty and researchers who are leaders in the field. Each lecture will be 75 minutes and consist of a 1 hour presentation with 15 minutes for discussion and questions. The lectures will be targeted to tie the problems discussed to concepts emphasized in the current curriculum.
Course offered: Each spring and fall semester
Course may be repeated.
Enrollment limited to students in the Cvl & Envmntl Engr & Earth Sci department.

CE 34111 Geology of Ireland (3 Credit Hours)
The proposed course will consist of classroom lectures by me and student presentations, with several field trips interspersed throughout the 6 week program to study natural geologic formations in person. Each student will conduct a small independent quantitative research project that relies on field observations and measurements during the field trips. In the beginning of the course, I will present 1 week of lectures on introductory geology and the geology of Ireland including plate tectonics, an introduction to minerals and rock types, quantitative structural geology, geochemistry, and how with all of this information, the geologic history of a rock and region can be deciphered. After the introductory lectures, the students will break into groups of 4-5 students, with each group focusing on one of the 5-6 geologic sites that will be visited. I will work with each group to help them develop topics and to insure accurate and complete coverage of the necessary geologic concepts. Each student within each group will focus on a different aspect of the geologic site, and the group as a whole will prepare a presentation for the class, using Web of Science and internet sources as references. Each student will be required to conduct a quantitative independent field research project that incorporates measurements made during the field trips, and which involves a chemical and/or a physical aspect of the rocks that we see, and each student will prepare a final research report on their results. Each project must include a rigorous quantitative aspect. For example, quantitative stress fields and regional stress dynamics can be calculated from measured rock folding and/or fossil deformation patterns; tectonic or glacial forces can be quantified from field measurements of regional fold and fault relationships or glaciation patterns; and global climate effects can be calculated from quantitative considerations of carbonate chemistry and limestone weathering extents measured in the field.
The students will present the results of their research projects both as individual research reports and in short class presentations at the end of the course.

CE 34125 Computational Methods (3 Credit Hours)
Most problems in Applied Mathematics are modelled using a set of equations that can be written down but cannot be solved analytically. In this module we examine numerical methods that can be used to solve such problems with a computer. Practical computer lab sessions will cover the implementation of these methods using mathematical software (Python). No previous knowledge of computing is assumed.

CE 34200 Introduction to Structural Engineering (3 Credit Hours)
This course focuses on the analysis of the response of a structure under given loading conditions, and upon completion, the student should be able to understand the principles of structural behaviour in withstanding external forces and environmental effects, and to determine internal forces, reactions and displacements of skeletal structural systems.

CE 34285 Introduction to Bridge Engineering (3 Credit Hours)
In this class we will study how bridges are built and why they don't fall. We will review their history, from the classical roman arch to modern cable-stayed bridges, and apply principles of mechanics to understand load paths and material strength. By the end of the class students will be able to identify the components of a bridge, differentiate bridge types and the span range for each type, track their historic evolution, list common problems encountered in bridges, recognize market sectors for professional development and opportunities offered by the bridge engineering industry.
Prerequisites: PHYS 10310

CE 34300 Introduction to Environmental Engineering (3 Credit Hours)
This module is designed primarily for engineering students intending to focus in the area of environmental engineering. The module lays a foundation for more intensive modules in later stages by introducing concepts about, among other things, environmental ethics, engineering calculations, and the fundamental biological, chemical and physical processes used in environmental engineering. Applications of these concepts to developing engineering solutions for several contemporary environmental problems are also examined. This module will cover the following topics: Sustainability, Units for Environmental Measurements, Physical, Chemical and Biological Principle, Engineering Approximations, Hydrology, Pollution Transport Processes, Solid Waste Management, Ethics, Environmental Laws and EU Regulation.

CE 34325 Water and Sanitation From the Roman Empire to Today (3 Credit Hours)
The Roman Empire's water system was one of the most extensive and sophisticated in the ancient world and played a critical role in the growth and expansion of the Roman Empire. Specific components included aqueducts, pipe networks, fountains, cisterns for water storage, and an extensive sewer system. In this class we will use the backdrop of the Roman urban water cycle to learn the basics of water sourcing, water quality, fluid flow, and water and wastewater treatment. By the end of this course, students will be able to explain the engineered urban water cycle; apply basic engineering principles for water and wastewater conveyance, storage, and treatment; and understand health impacts associated with drinking water and sanitation and the application of risk assessment for engineering decision-making related to drinking water and sanitation.
Prerequisites: MATH 10550 and CHEM 10171 and PHYS 10310

CE 34455 Environmental Hydrology (2.5-3 Credit Hours)
Hydrology is the term that broadly describes the study of water on, in and above the Earth's surface. This introductory course is designed to introduce the students to the theories and concepts underpinning the discipline and to allow them to learn how to measure, estimate and calculate river and groundwater flows in the field and in the lab. Learning Outcomes 1. Have an appreciation of the nature of the relationships that exist between water the land 2. Prepare and produce water balances at local and regional scales 3. Use the tools acquired in the class to break down complex water management issues into negotiable sub-units 4. Compare and differentiate between methods for measuring, estimating and calculating hydrological data sets 5. Assess past hydrological events and future (predicted) events and contextualise these in terms of the frequency with which they are likely to occur, and the risks associated with their occurence 6. Incorporate field data, published data and interpreted data to make reasonable inferences about water and the land 7. Frame research questions about water resource management and water resource allocation IR - Dublin, Ireland 1. Purpose of numerical modelling / specifying a modelling brief 2. Types of numerical model 3. Parameter estimation and optimisation 4. Model checking and validation 5. Model assessment and sensivity 6. Equifinality and its implications 7. Examples and applications of surface water models / rivers and lakes 8. Examples and applications of waste related models. 9. Wastewater Treatment Plant (WWTP) modelling using activated sludge models

CE 34460 Fluid Mechanics (3 Credit Hours)
This course consists of an introduction to the theory of fluid mechanics. Topics covered include: a review of vector calculus and differential operators, ideal fluids, Bernoulli's equation, irrotational flow, stream functions, potential theory, the Navier-Stokes equations, elementary viscous flow with examples, very viscous flows.

CE 34556 Sustainability and Resilience of Energy Systems and Supplies (3 Credit Hours)
Human living standards are directly correlated with energy availability and consumption. About 1 billion people in the world today have no access to electricity, at least another billion have unreliable electricity and often only enough to power a few light bulbs, and more than two billion people cook food over open fires. This technical-oriented but accessible-to-all course focuses on the history, evolution, and current deployment of energy systems worldwide. Emphases are on the utilization, limitations, and drawbacks of world energy supplies including fossil fuels, nuclear, and renewables relative to sustainability and resilience. Case studies will include the electrical grid failure in Puerto Rico during and after hurricane Maria, the nuclear plant accidents at Fukushima (Japan) and Chernobyl (Ukraine), conflicts related to energy, and the changing energy mix of the local country/city where the course is taught.

CE 34600 Special Studies (3 Credit Hours)
Environmental pollution is one the major problems that affects biodiversity, ecosystems, and human health worldwide by contaminating air, soil and water. This course will give you foundation knowledge of ecological principles which in turn will help you to ascertain how human activity may impact natural processes, often contributing to degradation of many natural ecosystems/climate change. Ecology is the study of the interactions of organisms - animals, plants, fungi, and bacteria - with each other and with their environment. And ecology matters on so many different levels. Ecology matters because of the impact humans are having on the natural world - directly, through fishing, harvesting, changing land use, urbanisation; and indirectly, most notably through the effects of climate change. Ecology matters because the natural world provides many benefits for people to live healthily on our planet. And ecology matters because, well, the natural world matters in itself. IR - Dublin, Ireland Effective climate action requires rapid reductions in emissions of CO2 across all sectors. However, reductions in gross emissions alone do not meet the EU 2030 climate action plan targets. Negative emissions technologies (NETs) are the sustained gross removals of CO2 from the atmosphere and subsequent secure, long-term storage of carbon in 'carbon sinks' A range of NETs measures are currently being explored across EU countries for integration in national inventory. Negative emissions technologies are either natural climate solutions or engineered solutions. This module will cover the carbon capture and storage potential of a range of measures such as afforestation, soil carbon sequestration, bioenergy with carbon capture and storage, direct air carbon capture and storage, and enhanced weathering. The suitability of NETs for deployment for Ireland will be reviewed.

CE 34720 Resiliency and Sustainability of Engineering Systems (3 Credit Hours)
This course will discuss fundamental concepts needed to understand and engineer for mitigation and resilience against multi-hazard vulnerability of critical infrastructure, environment, energy, communities, and other complex and inter-connected engineering systems. It will include significant components in decision-making and public policy.

CE 34999 Special Studies (3 Credit Hours)
The students will be presented with a case study dealing with surface water that is suspected of being polluted. They will be instructed in the composition of various environmental media, the nature of potential pollutants and guided through the selection of the media that need to be analysed to identify the contaminants, sampling locations and the appropriate chemical analyses to address the problem posed. They will then organise the collection of the relevant media (soil, water, etc.) and will be trained in their chemical analyses in the Environmental Chemistry Laboratory, School of Biology & Environmental Science. The results generated will be analysed with respect to available thresholds/ regulations for the various contaminants and students will write a report on the full investigation process.

CE 35506 Practicum in Field Environmental Geosciences: Galapagos Islands (2 Credit Hours)
The course will explore the complex interplay between geological and biological processes on the Galapagos islands, as well as the crucial role the islands played historically as Darwin developed his theory of evolution. The course will meet once each week for 1.5 hours with discussions of the geology, ecology, and evolutionary biology of the islands. There is an optional 8-day trip to the Galapagos Islands that complements the course, with a prior application and trip fees required. The field trip to the Galápagos is optional, it is not an alternate to class requirements, and it is not a means of earning extra credit in the course. Students who go on the trip will develop and conduct research projects while on the trip. Students who opt to take the course without going on the field trip will conduct research projects either using observations made by trip participants or using literature sources. All students will report results of the research during the second half of the semester course meetings.

CE 35610 Engineering for International Development I (1-3 Credit Hours)
Engineering for International Development I Engineering for International Development I partners students with community organizations to put their engineering skills into service, in this case Bridges2Prosperity, a nonprofit organization providing pedestrian bridges to communities worldwide who lack such basic infrastructure. Under the banner of the ND SEED (Notre Dame Students Empowering Engineering Development), up to a dozen students will be accepted each academic year for this course and will supervise all aspects of bridge design and construction, including fundraising and international study via site surveys over Fall Break and construction in May following the spring semester. To join this course in the fall of any academic year, students must apply and be accepted by ND SEED in the prior spring semester. Students are expected to participate in the course for a full academic year, through bridge construction in May. The project is also affiliated with the Center for Social Concerns International Summer Service Learning Program (ISSLP) and has additional curricular requirements through ISSLP. Course may be repeated.

CE 37600 Special Studies (1-8 Credit Hours)
Individual or small group study under the direction of a faculty member in an undergraduate subject not concurrently covered by any University course.

CE 40256 Coastal Engineering (3 Credit Hours)
This course teaches the fundamentals of coastal engineering for upper level undergraduate and beginning graduate students. A background in engineering or science is required, and fluid mechanics and calculus experience will be helpful in some parts. Course topics include: 1. Mechanics of waves, tides, and surge, 2. Short term and long term wave climatology and statistics, 3. Sediment transport and coastal morphology, 4. Types and design of coastal engineering structures, 5. Wave, surge, and tsunami loads on near-coast structures 6. Long term coastal outlooks 7. Other topics to fit into the available time. Although both geophysical and engineering topics will be discussed, the focus will be more on the engineering side of the system.

CE 40270 Reinforced Concrete Design (4 Credit Hours)
Mechanics and behavior of reinforced concrete members and structures. Design of reinforced concrete members and structures, including continuous beams, slabs, columns, and frames. Strength and serviceability considerations for design. Building codes and specifications for reinforced concrete design. Includes a semester-long project on the design of a five-story, five-bay reinforced concrete frame building. The second or third course in the structures track.
Prerequisites: CE 30200 or CE 34200

CE 40275 Prestressed Concrete Design (3 Credit Hours)
Mechanics of prestressed concrete structural members. Design of prestressed concrete structural members and simple systems. Strength and serviceability considerations.
Prerequisites: CE 40270
Course may be repeated.

CE 40280 Structural Steel Design (4 Credit Hours)
Design of structural steel members/systems using basic fundamentals of mechanics, principles of steel behavior at element and system level. Course integrates current codes/standards and commercial software into semester-long project, providing for direct application of concepts to the design of a mid-rise structural steel residential/commercial building. The second or third course in the structures track.
Prerequisites: CE 30160 and (CE 20150 or AME 20221) and AME 20241 and (CE 30200 or CE 34200)

CE 40285 Bridge Engineering (3 Credit Hours)
Overview of bridge engineering, focusing on behavior, analysis, and design. Course will highlight standard forms for highway and long-span bridges, including girder, truss, arch, suspension, and cable-stay bridges. Fundamental techniques for analysis and design will be emphasized (e.g. influence lines, graphic states) and current design code will be introduced.
Enrollment limited to students in the Cvl & Envmntl Engr & Earth Sci department.

CE 40300 Geochemistry (3 Credit Hours)
An introduction to the use of chemical thermodynamics and chemical kinetics in modeling geochemical processes. Special emphasis is placed on water-rock interactions of environmental interest.
Prerequisites: (CE 10110 or CE 20110 or CE 20111 or SC 10100 or SC 20110) and (CHEM 10122 or CHEM 10171 or CHEM 10097 or CHEM 10181)

CE 40323 Advanced Physical-Chemical Water Treatment Processes (3 Credit Hours)
This course explores the fundamental principles and design considerations of advanced water treatment technologies used in drinking water production and water reuse applications. Students will gain a comprehensive understanding of key treatment processes, including adsorption with activated carbon, membrane filtration (e.g., reverse osmosis), and advanced oxidation processes. Emphasis will be placed on the engineering aspects of these processes, their applications in real-world scenarios, and the challenges associated with implementation. By the end of the course, participants will be equipped with the knowledge to design and evaluate advanced treatment systems to meet stringent water quality standards.

CE 40330 Environmental Biotechnology (3 Credit Hours)
Environmental biotechnology is the application of biological processes to the solution of environmental problems. Applications include municipal and industrial wastewater treatment, drinking water treatment, remediation of soils and groundwaters, remediation of surface waters and sediments, and control of air contaminants.
Prerequisites: CE 40341

CE 40341 Biological Process Design (3 Credit Hours)
A study of the theory, design, and operation of facilities both for industrial and municipal treatment and disposal. Design of municipal wastewater treatment systems is emphasized. A significant project design component is included with a tutorial section. Fall.

CE 40350 Environmental Microbiology (3 Credit Hours)
Bacteria are everywhere. They survive in extreme environments that include the deepest ocean regions, hot springs (like Old Faithful), Antarctica, and Death Valley. These organisms span the gamut of utility as some bacteria are absolutely required to maintain our own health while other bacteria display pathogenicity where the smallest of doses can kill. Separate from these extremes, there are other bacteria being utilized everyday in various industries to generate chemicals, antibiotics, food products, and clean water. This course will address the fundamental processes used by all bacteria, the chemical reactions and molecular interactions mediated by bacteria to function and survive, and the diversity and specific characteristics of several specific bacterial genera and species.

CE 40355 Water, Disease, and Global Health (3 Credit Hours)
The main emphasis of the course will be to study the diseases important to both the developed and developing world. Basic principles of public health, epidemiology, infectious disease microbiology, immunology, and engineering application will be learned utilizing both local and global examples. Particular emphasis will be given to diseases transmitted by water. As a complement to environmental engineering design classes, this class will focus upon the disease agents removed in properly designed municipal water and waste systems.
Prerequisites: (CHEM 10122 or BIOS 10161)

CE 40358 Genomics and Bioinformatics in Environmental Microbiology (3 Credit Hours)
This course will cover emerging genomics and bioinformatics approaches in environmental microbiology. Topics covered will include microbial community characterization by 16S rRNA and shotgun metagenomic sequencing as well as pure-culture genomic methods such as transcriptomics and genome sequencing. The course will include lecture, literature review, and an in-depth project applying the covered methods.
Prerequisites: CE 40350

CE 40360 Geomicrobiology (3 Credit Hours)
This course explores current research involving the interaction between microbes and geologic systems, focusing on the ability of microbes to affect mass transport in fluid-rock systems. Readings concentrate on laboratory, field, and modeling studies of environmental and/or geologic interest.

CE 40381 Environmental Isotope Geochemistry (3 Credit Hours)
This course introduces students to principles of radiogenic and stable isotope geochemistry. Common radiogenic isotope methods are investigated including processes and equations of radioactive decay and the geochemical behavior of radiogenic isotopes in terrestrial systems. Isotope systematics of rocks, sediments, natural waters and the oceans and their significance as geologic and environmental tracers and as energy resources are explored. The course encompasses an investigation of the behavior of stable isotopes, their fractionation in terrestrial systems and stable isotope applications to environmental studies and renewable energy.
Prerequisites: (ENVG 20110 or SC 20110 or SC 10100 or CE 20110 or CE 20111) and (CE 20520 or ENVG 20200)

CE 40410 Advanced Fluid Dynamics (3 Credit Hours)
This course is designed to provide an in-depth understanding of fundamental principals and concepts of fluid mechanics for beginning graduate students and upper level undergraduate students. It will be a useful precursor to advance courses in turbulence, environmental fluid mechanics, stability theory, waves, oceanography and meteorology.
Prerequisites: CE 30460 or CE 34460

CE 40420 Air Quality and Reactive Transport (3 Credit Hours)
This course investigates air pollutants' fate from their emission sources, to their transport and chemical transformations in the atmosphere. The impacts of air pollutants on human health, air quality and climate are also discussed. Removal and control technologies to reduce air quality issues are examined.

CE 40450 Hydraulics (3 Credit Hours)
Theory, analysis and design of pipe flow, sewer flow, open channel flow, and reservoirs and pumping facilities for water distribution and wastewater collection. Student team design of water distribution and sewer collection systems is emphasized. Fall.
Prerequisites: AME 30031 or AME 30331 or AME 34331 or CE 34330 or CE 30460

CE 40460 Groundwater Hydrology (3 Credit Hours)
Lectures and laboratory cover the fundamentals of flow and transport in porous media. Methods of analysis for development of groundwater resources. Fall.

CE 40465 Mechanics of Environmental Motions (3 Credit Hours)
This course covers fluid dynamics framework of environmental fluid motions, in particular, the application of the equations of motion to predict them. A special emphasis will be made on the effects of earth's rotation and background density stratification, both of which give rise to intriguing natural phenomena. The modification of environmental motions by human influence will be described paying particular attention to engineering applications. Some necessary mathematical tools such as tensors will be covered to some extent.
Prerequisites: CE 30460 or CE 34460

CE 40610 Construction Management (3 Credit Hours)
An introduction to construction management, including fundamentals of safety, quality estimating, scheduling, subcontracting, and delivery methods. In this course, students will explore risk management, negotiations, and claims in the context of construction. The course's main objective is to provide students with a broad understanding of the skills required for a career in construction in the context of today's complex large scale projects.
Students cannot enroll who have a major in Civil Engineering or Environmental Engineering.

CE 40620 Transportation Engineering and Construction (3 Credit Hours)
The planning, design, operation, safety, and economics of transportation systems. Spring.
Prerequisites: CE 20600

CE 40631 Construction Alternative Project Delivery Methods (3 Credit Hours)
Project delivery is a comprehensive process including planning, design, and construction required to execute and complete a facility or other type of project. Alternative project delivery methods include Design Build (DB), Construction Manager/General Contractor (CM/GC), Integrated Project Delivery (IPD), Public Private Partnerships (P3), and others. This course will focus on the various alternative project delivery methods application in the construction sector. Historical and current project delivery methods are explored. The course explores the latest project delivery techniques used to support achievement of project objectives, identifying constraints, and recognizing stakeholders. Procurement strategies, contractual arrangements, and compensation methods are also discussed in conjunction with risks, costs, and legal and ethical issues that need to be considered when determining which system is best for a particular project.

CE 40701 Principles of Practice (1 Credit Hour)
An integrated, multi-disciplinary civil engineering design experience. The course will include a review of the civil engineering design process, professional considerations and preliminary design aspects.

CE 40702 Senior Design (3 Credit Hours)
The second semester of an integrated civil engineering design experience. Student teams will work closely with industry professionals and faculty who act as consultants on a real-world design project to facilitate the student's understanding of the students' proposed final designs. This semester will culminate in a final design project including a report, drawings, and presentation.
Prerequisites: CE 40701
Enrollment limited to students in the Cvl & Envmntl Engr & Earth Sci department.

CE 40710 Capstone for Minor in Resiliency and Sustainability of Engineering Systems (1 Credit Hour)
In order to obtain hands-on experience with sustainability and resiliency issues focusing on implementation in a real-world setting, each student will complete a 1-credit capstone experience. Proposed by the student, each capstone experience will be approved by the Director of the Minor. Projects will vary among students, and it is expected that each experience will allow the student to pursue a topic of particular interest to him/her in much more depth than a single course might allow. Each experience will be accompanied by a Capstone Thesis Report. This report will be evaluated and graded by CEEES faculty with input from the student's internship advisor. Examples of suitable activities include: at least one semester or summer of undergraduate research in sustainability and resiliency; a senior level capstone design course involving multi-hazard mitigation with a defined project output relevant to the minor; a summer job or internship within a resiliency and sustainability related organization; independently undertaking a meaningful trip to investigate issues or technologies on resiliency and sustainability; a substantial and relevant experience on sustainable and resilient development shaped through either CSC 33902 - Social Concerns Seminar: Science Policy Ethics: Guiding Science through Regulation of Research and Funding or CSC 33985 - Social Concerns Seminar: Energy, Climate, and Social Change ; or summer internship within a U.S., Chilean, New Zealand or other country state government or research agency, immersed with law and policymakers, industry leaders, regulatory agencies, and/or environmental advocacy groups who discuss their efforts to resolve contemporary issues on sustainable and resilient development. The summer internship options may be paid experiences. The students will earn their capstone credit by submitting and presenting a Capstone Thesis Report on their internship activity after returning to campus.
Enrollment is limited to students with a minor in Rslncy & Sustnblty of EG Sys..

CE 41450 Hydraulics Lab (0.5 Credit Hours)
Lab component for CE 40450, required for CE students
Corequisites: CE 40450

CE 43600 Challenges and Innovations in Civil and Environmental Engineering (0.5 Credit Hours)
This course will focus on examining large scale civil and environmental engineering problems, the technological challenges encountered, and the resulting innovative solutions. The emphasis will be on the engineering systems and will include problems in structural, ocean, hydraulic, groundwater, soils and environmental engineering. Course format: 6-10 lectures per semester presented by senior project engineers, university faculty and researchers who are leaders in the field. Each lecture will be 75 minutes and consist of a 1 hour presentation with 15 minutes for discussion and questions. The lectures will be targeted to tie the problems discussed to concepts emphasized in the current curriculum.
Course offered: Each spring and fall semester
Course may be repeated.
Enrollment limited to students in the Cvl & Envmntl Engr & Earth Sci department.

CE 44350 Environmental Microbiology (3 Credit Hours)
In this course you will be introduced to microbiological concepts relevant to agricultural, environmental and food applications. Examples will relate microbiological theory to the production & spoilage of foods & fodders, water quality, microbiological regulation of nutrient cycles, animal and plant health, and biotechnology. You will be introduced to common microorganisms and will consider growth, classification, genetics, survival and control by sterilization, disinfection, immunization and antibiotics. As part of the theoretical and practical aspects of the course you will gain experience with microbiological laboratory methodologies such as microscopy, sterile technique & the isolation and identification of pure cultures. PA descr: The purpose of Introductory Microbiology MICR2208 is to present a view of the overall scope of microbiology, thus providing the basic background to understanding advanced medical and general microbiology subjects offered in third year.

CE 44450 Hydraulics (3 Credit Hours)
Hydraulics is a one semester module which provides students with the concepts of hydraulic engineering. The module reviews the relevant aspects of fluid flow developed in 2E5, such as Bernoulli's equation, and the momentum and continuity relationships and demonstrates how these are developed for use in Civil Engineering design. The module develops the concept of analysing time varying problems using quasi-steady state relationship and compares the results with some readily developed closed form solutions. The methods of developing head/discharge relationships for pipe flows which includes for friction loss are formulated. The principals involved in the flow of water in open channels are explained and relationships are developed to allow the estimation of the discharge in open channels and the depth variation behind control structures. The methods used to analyse pipe networks, with and without pumps within the system, are developed. The design of water distribution systems providing an adequate supply of water to consumers is also examined. Finally, the module examines the subject of Urban Drainage, initially comparing combined systems against separate systems. The calculation of hydraulic loads for the network is then demonstrated for both wastewater quantities and also storm water predictions from the analysis of rainfall events. The hydraulic design of the pipe network to these loads is then examined before moving onto the design of Combined Sewer Overflows which are used to relieve the system hydraulically under storm conditions. IR - Dublin, Ireland This module builds on the Stage 2 Hydraulics I (CVEN20130) module in which foundation material relating to fluid definitions, properties, application of the fundamental fluid principles (continuity, energy and momentum) were presented for steady flow closed conduit and open channel hydraulic systems. It is essential that this material is fully understood and retained at the commencement of the Hydraulics II module. The module itself will take place in the Spring trimester and will consist of 36 lectures (3 per week), 2 laboratory exercises, 4 tutorials, 2 in-class tests and an end of trimester examination. The course is broadly split between closed conduit (pipe) and open channel (rivers and streams) flow and will also present the principles of physical similarity in hydraulic systems in which experimental results from small scale models are applied to other conditions. The closed conduit analysis in this module develops the theory presented in Hydraulics I for single pipe systems to parallel and series systems and also to more complex branched and loop-type pipe networks. Energy is lost through friction and local losses in pipe systems but mechanical energy through hydrodynamic machines can overcome these losses. Hydrodynamic machinery (pumps) are investigated for a full range of pipe systems. The open channel flow component of Hydraulics I studied steady-uniform flow conditions in simple channels. The open channel flow component of Hydraulics II builds on this to include non-uniform flows that are both gradually and rapidly varied. Energy and momentum principles are applied in this analysis and the 'special' case of hydraulic jumps are analysed. Water surface GVF profiling using direct and standard step methods is presented and this OCF analysis is extended to river modelling (HEC-RAS). More complex compound channel geometries where floodplains are inundated present different challenges for engineers and these are presented and analysed. The concept of suntainability features throughout the module. The relationship of the module content to the UN SDGs is presented at the outset of the course and as students work through the the different course components, the relevence of that material to SDGs (particularly, SDG 6, 9, 11 and 14) is outlined.

CE 44460 Groundwater hydrology (3 Credit Hours)
This is an applied geology module aimed specifically at civil engineers. The hydrogeology component covers the analysis of groundwater flow, both regional flow and radial flow to wells, with an emphasis on teaching the student to compare and evaluate different methods of analysis, and to critically examine the underlying assumptions. Students are also taught how to plan groundwater investigations in a systematic manner, with the aid of case studies. The engineering geology component deals with the analysis of rock properties and their application to geotechnical problems (as such, this module component is complementary to compulsory modules in the students' third and fourth years which focus on geotechnical issues in soils).

CE 44600 Special Studies (1-5 Credit Hours)
Special studies course abroad. IC - Co. Galway, Ireland - University of Galway - CE 476: The Built Environment This module is designed to introduce Engineers and Project Managers to the basic principles of architecture, planning and the considerations and common challenges involved in the successful design of both. It enables students to take up a position within the construction (or related) industry armed with a meaningful understanding of how their individual role is critical to realising good design. It allows meaningful communication with architects and planners with the mutual benefits of same.
Course may be repeated.

CE 44860 Undergrad Research (1-10 Credit Hours)
A research project at the undergraduate level under the supervision of a faculty member.

CE 45200 Geology Field Trip (1 Credit Hour)
Field trip during the fall/spring vacation; emphasis on regional field geology and field relationships. Classic localities are studied in order to demonstrate geological concepts.

CE 45340 Fall Geology Field Trip (1 Credit Hour)
Field trip to the Upper Peninsula of Michigan during Fall Break; emphasis on understanding the regional geology before, during, and after the formation of Proterozoic banded iron formations and the Marquette Mineral District. A wide range of sedimentary, metamorphic, and igneous rock types and geologic structures are studied, and the trip includes a structural geology field exercise. Prior to the trip, there will be lectures on the regional geology, and each student will prepare a presentation on one aspect of the geology that is seen in the field.
Course may be repeated.
Enrollment is limited to students with a major in Environmental Earth Sciences.

CE 45620 Engineering for International Development II (1-10 Credit Hours)
Engineering for International Development II partners students with community organizations to put their engineering skills into service, in this case students work with Engineering2Empower (E2E). E2E started as an organization committed to exploring new approaches and solutions to the Haitian urban housing problem. Through its work with various university and non-university partners, the organization has broadened its focus to seek holistic solutions to hazard mitigation in developing settings. Undergraduate students lead all facets of Research and Development for the organization through this course, focusing on prototype frame and panel design and construction/production for the housing solutions promoted, but also programming for Community Awareness and Engagement. Through partnerships with the Kellogg Institute, students have the opportunity, on a case by case basis, to travel to Haiti to directly implement their work.
Course may be repeated.

CE 45640 Engineering for International Development I (1 Credit Hour)
Engineering for International Development I Engineering for International Development I partners students with community organizations to put their engineering skills into service, in this case Bridges2Prosperity, a nonprofit organization providing pedestrian bridges to communities worldwide who lack such basic infrastructure. Under the banner of the ND SEED (Notre Dame Students Empowering Engineering Development), up to a dozen students will be accepted each academic year for this course and will supervise all aspects of bridge design and construction, including fundraising and international study via site surveys over Fall Break and construction in May following the spring semester. To join this course in the fall of any academic year, students must apply and be accepted by ND SEED in the prior spring semester. Students are expected to participate in the course for a full academic year, through bridge construction in May. The project is also affiliated with the Center for Social Concerns International Summer Service Learning Program (ISSLP) and has additional curricular requirements through ISSLP. This section is for CEEES students using this course as their Capstone design project.
Enrollment is limited to students with a program in Cvl & Envmntl Eng & Earth Sci.

CE 47600 Special Studies (0-10 Credit Hours)
Individual or small group study under the direction of a faculty member in an undergraduate subject not concurrently covered by any University course.

CE 47603 Special Studies: Concrete Canoe (0-3 Credit Hours)
Students taking this course will be competing in the American Society of Civil Engineers's Concrete Canoe Competition. Students will create a mix design for the canoe in the fall semester according to the specific yearly rules of the competition. In the spring semester, students first create the mold for the canoe. The students then cast and finish the canoe before bringing the finished canoe to the regional conference for competition. Students also develop safety guidelines, requirements and plans in accordance with the department and university stakeholders.
Course may be repeated.

CE 48600 Undergraduate Research (1-10 Credit Hours)
A research project at the undergraduate level under the supervision of a faculty member.
Course may be repeated.