# ENVIRONMENTAL ENGINEERING, SCIENCE, MANAGEMENT, AND SUSTAINABILITY PROGRAMS

The part-time programs in Environmental Engineering, Science, Management and Sustainability programs address an array of modern environmental and health issues while capitalizing on environmental protection and remediation solutions made possible by technology. Students enhance their knowledge in these areas through a quantitative program built around the common theme of engineering, science, and health in support of environmental decision-making and management. The strength of the programs lies in a faculty of working professionals and from the nationally renowned full-time Department of Environmental Health and Engineering hosted jointly in the Whiting School of Engineering and the Bloomberg School of Public Health at Johns Hopkins University.

## Program Committee

**Hedy Alavi, Program Chair**
Associate Dean for International Programs
Teaching Professor, Department of Environmental Health and Engineering
JHU Whiting School of Engineering

**Chris Overcash, Program Manager**
Lecturer, Department of Environmental Health and Engineering
JHU Whiting School of Engineering

**Kirsten Koehler**
Associate Professor, Department of Environmental Health and Engineering
Bloomberg School of Public Health

**Megan Weil Latshaw**
Associate Scientist and Director, MHS and ScM Master's Programs, Department of Environmental Health and Engineering
Bloomberg School of Public Health

**Scot Miller**
Assistant Professor, Department of Environmental Health and Engineering
JHU Whiting School of Engineering

**Carsten Prasse**
Assistant Professor, Department of Environmental Health and Engineering
Bloomberg School of Public Health

**Gurumurthy Ramachandran**
Professor and Deputy Chair, Department of Environmental Health and Engineering
Bloomberg School of Public Health

This committee ensures that instruction in the part-time program is of the highest quality and is continually enhanced in a manner consistent with parallel developments in the full-time program.

## Programs

### Environmental Engineering

- Environmental Engineering, Graduate Certificate (https://e-catalogue.jhu.edu/engineering/engineering-professionals/environmental-engineering-science-management-programs/environmental-engineering-graduate-certificate/)
- Environmental Engineering, Master of Environmental Engineering (https://e-catalogue.jhu.edu/engineering/engineering-professionals/environmental-engineering-science-management-programs/environmental-engineering-master/)
- Environmental Engineering, Post-Master's Certificate (https://e-catalogue.jhu.edu/engineering/engineering-professionals/environmental-engineering-science-management-programs/environmental-engineering-post-masters-certificate/)

### Environmental Engineering and Science

- Environmental Engineering and Science, Graduate Certificate
- Environmental Engineering and Science, Master of Science (https://e-catalogue.jhu.edu/engineering/engineering-professionals/environmental-engineering-science-management-programs/environmental-engineering-science-master/)
- Environmental Engineering and Science, Post-Master's Certificate (https://e-catalogue.jhu.edu/engineering/engineering-professionals/environmental-engineering-science-management-programs/environmental-engineering-science-post-masters-certificate/)

### Environmental Planning and Management

- Environmental Planning and Management, Graduate Certificate (https://e-catalogue.jhu.edu/engineering/engineering-professionals/environmental-engineering-science-management-programs/environmental-planning-management-graduate-certificate/)
- Environmental Planning and Management, Master of Science (https://e-catalogue.jhu.edu/engineering/engineering-professionals/environmental-engineering-science-management-programs/environmental-planning-management-master-science/)
- Environmental Planning and Management, Post-Master's Certificate (https://e-catalogue.jhu.edu/engineering/engineering-professionals/environmental-engineering-science-management-programs/environmental-planning-management-post-masters-certificate/)

### Climate, Energy, and Environmental Sustainability

- Climate Change, Energy, and Environmental Sustainability, Graduate Certificate (https://e-catalogue.jhu.edu/engineering/engineering-professionals/environmental-engineering-science-management-programs/climate-change-energy-environmental-sustainability-graduate-certificate/)
- Climate, Energy, and Environmental Sustainability, Master of Science (https://e-catalogue.jhu.edu/engineering/engineering-professionals/environmental-engineering-science-management-programs/climate-energy-environmental-sustainability/)

## Faculty

The program features highly qualified instructors who are distinguished and experienced professionals. Each holds the highest academic degree in their field of expertise and has demonstrated a strong commitment to excellence in teaching. Many of the outstanding full-time faculty from the renowned full-time Department of Environmental Health and Engineering serve as instructors. The program also includes directors, senior scientists, engineers, researchers, and attorneys affiliated with the US

Environmental Protection Agency, American Academy of Environmental Engineers and Scientists, Maryland Department of the Environment, Nuclear Regulatory Agency, National Institute of Health, US Department of Energy, US Department of Defense, and many leading environmental consulting companies.

# Courses

## Environmental Engineering

**EN.575.604. Principles of Environmental Engineering. 3 Credits.**
This course provides knowledge of environmental elements with insight into quantitative analysis and design where applicable. Topics include an introduction to environmental engineering and design process, professional associations, engineering licensure, engineering ethics, and environmental justice; dimensional analysis, mass and energy transfer and balances; environmental chemistry; mathematics of growth and decay; risk assessment and management; surface water pollutants, biological and chemical oxygen demands; eutrophication; water supply systems and drinking water standards; wastewater treatment systems and effluent standards; groundwater flow, contaminant transport, and remediation technologies; remedial and corrective actions at contaminated sites; air pollution sources, control technologies, and atmospheric stability; ambient air quality standards and indoor air quality; global temperature, greenhouse effect and warming potential; global energy balance, carbon emission, and stratospheric ozone depletion; hazardous and solid waste management, landfill disposal, combustion, composting, and recycling; medical waste. Overviews of pertinent environmental laws and regulations will be presented where applicable. The course encompasses conceptual design projects for environmental systems and infrastructures. Course Note(s): This is a required course for all students in the Environmental Engineering, Science, and Management Programs who do not possess an undergraduate degree in Environmental Engineering.

**EN.575.605. Principles of Water and Wastewater Treatment. 3 Credits.**
Water quality objectives and the chemical, physical, and biological processes necessary for designing and managing modern drinking water and wastewater treatment plants are described in the course. The principles of coagulation, flocculation, sedimentation, filtration, biological treatment, solids handling, disinfection, and advanced treatment processes are presented. The course serves as a basis for the more advanced courses: EN.575.745 Physical and Chemical Processes for Water and Wastewater Treatment, EN.575.706 Biological Processes for Water and Wastewater Treatment, and EN.575.746 Water and Wastewater Treatment Plant Design.
**Prerequisite(s):** EN.575.601 Fluid Mechanics or an equivalent course in fluid flow or hydraulics; two semesters of undergraduate chemistry.

**EN.575.606. Water Supply and Wastewater Collection. 3 Credits.**
This course covers the fundamental but practical issues of water distribution systems and wastewater/stormwater collection systems. Specific topics of interest in water supply include water supply master planning; design of water storage facilities, water mains, and pumping stations; distribution-system water quality; and service connection issues. Topics covered under wastewater/stormwater collection include hydrology and hydraulics of stormwater/wastewater conveyance systems; design of stormwater detention and retention facilities; and collection system control technologies including green infrastructure. Also covered are regulations governing sanitary sewer overflows (SSOs) and combined sewer overflows (CSOs); public health, environmental, and economic impacts of SSOs and CSOs; sewer system evaluation and rehabilitation methods; stormwater best management practices; and the benefits and challenges of water reuse. Through research papers and discussion forums, students examine case studies that illustrate diverse practical situations and stimulate creative ideas for solving real-life design problems.
**Prerequisite(s):** EN.575.601 Fluid Mechanics or an equivalent course in fluid flow or hydraulics.

**EN.575.607. Radioactive Waste Management. 3 Credits.**
This course covers fundamental aspects of radioactive substances in the environment; remediation processes for these substances; and their eventual storage, processing, and disposal. It provides a basic understanding of radioactivity and its effect on humans and their environment, as well as the techniques for their remediation and disposal. Topics include radioactivity, the nucleoids, interaction of radiation with matter, shielding, dosimetry, biological effects, protection standards, sources of environmental radiation, risk evaluation, fate and transport analysis, cleanup standards, legal requirements, cleanup technologies, waste disposal, and case studies.

**EN.575.620. Solid Waste Engineering & Management. 3 Credits.**
This course covers engineering and scientific concepts and principles applied to the management of municipal solid waste (MSW) to protect human health and the environment and the conservation of limited resources through resource recovery and recycling of waste material. Topics include regulatory aspects and hierarchy of integrated solid waste management; characterization and properties of MSW; municipal wastewater sludge utilization; hazardous waste found in MSW; collection, transfer, and transport of solid waste; separation, processing, combustion, composting, and recycling of waste material; and the landfill method of solid waste disposal, which encompasses guidelines for design, construction, operation, siting, monitoring, remedial actions, and closure of landfills. Permitting and public participation processes, current issues, and innovative approaches are also addressed.

**EN.575.703. Environmental Biotechnology. 3 Credits.**
This course examines current applications of biotechnology to environmental quality evaluation, monitoring, remediation, and mitigation of contaminated environments. The scale of technology ranges from the molecular to macrobiotic. Relevant topics of microbiology and plant biology are presented. These provide a foundation for following discussions of microbial removal and degradation of organics, phytoremediation of soil and water contaminated with toxic metals and radionuclides, wetlands as treatment processes, biofilms/biofilters for vapor-phase wastes, and composting in alignment with sustainable development goals considering climate change. Emphasis is placed on modeling and design. Advantages and disadvantages of each application are compared. Case studies are presented in the areas of biosensors in environmental analysis, molecular biology applications in environmental engineering, and genetic engineering of organisms for bioremediation. Prerequisites: Prior coursework in environmental microbiology, molecular Biology, or biochemical engineering is recommended but not required.

**EN.575.706. Biological Processes for Water & Wastewater Treatment. 3 Credits.**
This course develops the fundamentals and applications of aerobic and anaerobic biological unit processes for the treatment of municipal and industrial wastewater. The principles of activated sludge, aeration and clarifier design, fixed film reactors, anaerobic treatment, solids handling and treatment, land treatment, and nutrient removal are presented. This course uses concepts from microbiology and the basic principles of stoichiometry, energetics, and microbial kinetics are used to support the design of biological unit processes.
**Prerequisite(s):** EN.575.605 Principles of Water and Wastewater Treatment.

**EN.575.715. Environmental Contaminant Dispersion and Transport. 3 Credits.**
This course will provide an overview of the basic foundations of pollutant transport and dispersion phenomena in the environment including surface water, atmosphere, and groundwater media. The emphasis of the course will be on mathematical formulation of transport equations, analytical solutions, physical insights, methods of analysis of tracer breakthrough curves, spatial and temporal moments analysis. Although numerical modeling is not the primary objective of the course, the students will be provided with the knowledge to build a modest computational toolbox using random-walk particle tracking to visualize and quantify transport processes. Computation of analytical solutions presented in the course will require some knowledge of scientific programming. However, the students will gain such competency during the course.Prerequisites: Undergraduate fluid mechanics (570.351 or equivalent) and differential equations.

**EN.575.741. Membrane Filtration Systems and Applications in Water and Wastewater Treatment. 3 Credits.**
This course covers fundamentals of membrane filtration technology and application in municipal and industrial water and wastewater treatment. Topics include membrane classification, mechanism of separation/filtration, principle of operation, performance monitoring, maintenance, pilot scale testing, residual disposal, emerging and developing membrane separation technologies, and regulations governing treatment objectives and residual disposal in membrane filtrations systems. This course provides students with in-depth knowledge of the theory, application, and design of membrane filtration systems by engaging them in group assignments and design projects.

**EN.575.742. Hazardous Waste Engineering and Management. 3 Credits.**
The course addresses traditional and innovative technologies, concepts, and principles applied to the management of hazardous waste and contaminated sites to protect human health and the environment. Topics include regulatory requirements; hazardous waste generators and transporters; permitting and enforcement of hazardous waste facilities; closure and financial assurance requirements; RCRA Corrective Action and CERCLA/Superfund/Brownfields site remediation processes; groundwater flow and fate and transport of contaminants; physical, chemical, and biological treatment; land disposal restrictions; guidelines for design, construction and closure of hazardous waste landfills; environmental monitoring systems; management of medical waste and treatment options; management of underground and aboveground storage tanks; toxicology and risk assessment; and pollution prevention and waste minimization.

**EN.575.745. Physical and Chemical Processes for Water and Wastewater Treatment. 3 Credits.**
In this course, mass and momentum transport, aquatic chemistry, and chemical reaction engineering are applied to physical and chemical processes used for water and wastewater treatment. Students also learn the theory and practice of various unit processes including disinfection, oxidation, coagulation, sedimentation, filtration, adsorption, gas transfer, and membrane filtration. The goal is to provide a theoretical understanding of various chemical and physical unit operations, with direct application of these operations to the design and operation of water and wastewater treatment systems. Students will use the concepts learned in this class to better understand the design and operation of engineered and natural aquatic systems.
**Prerequisite(s):** EN.575.605 Principles of Water and Wastewater Treatment.

**EN.575.746. Water and Wastewater Treatment Plant Design. 3 Credits.**
This course familiarizes students with appropriate design criteria and the design process for water and wastewater treatment plants. This includes design of treatment processes, cost estimates, and a working design team under project managers. Additional course requirements include oral presentations and writing engineering reports.
**Prerequisite(s):** EN.575.605 Principles of Water and Wastewater Treatment and either EN.575.706 Biological Processes for Water and Wastewater Treatment or EN.575.745 Physical and Chemical Processes for Water and Wastewater Treatment.and Wastewater Treatment)

**EN.575.749. Water Quality of Rivers, Lakes, and Estuaries. 3 Credits.**
Sustainably managing aquatic environments for ecosystem restoration/maintenance and protection of public health in a changing climate requires us to understand the combined effect of multiple physical, chemical, and biological stressors and processes. This class will equip students to apply their understanding of environmental engineering principles to real-world water quality issues using computer simulation models. Emphasis will be placed on gaining insight by understanding fundamental principles, assumptions, equations and methods used to develop water quality models. Physical, chemical and biological processes related to the classical water pollution problem of oxygen demand will be covered. Students will use a public domain model widely used in industry to develop a real-world case study application as a Course Project. Through the project the students will get experience assessing the impact of wastewater discharges of organic matter and nutrients on dissolved oxygen and to evaluate TMDL compliance. Selected advanced topics including eutrophication and toxic chemicals may also be introduced. Prerequisite(s):?Environmental Engineering Principles and Applications (EN.570.303 or equivalent) Area: Engineering, Natural Sciences. Undergraduate or Graduate level course(s) in Differential Equations.

**EN.575.761. Measurement and Pseudo-measurement in the Environmental Arena. 3 Credits.**
In this course, students will be provided with the knowledge to critically investigate practical, theoretical, mathematical, philosophical, sociological, and legal aspects of measurement and pseudo-measurement in environmental science and related disciplines. Students will explore the theoretical and mathematical bases for quantification and trace the relationship between these bases and the expanding role of quantification and pseudo-quantification in environmental research, policy, and decision making. Three theories of measurement (traditional, representational, and operational) will be presented from historical, technical, and philosophical perspectives. Claims to quantification arising in a number of environmental contexts (such as river systems and hydrology) will be closely examined in light of these divergent measurement paradigms.

## Environmental Engineering and Science

**EN.575.601. Fluid Mechanics. 3 Credits.**
This course introduces the principles of continuity, momentum, and energy applied to fluid motion. Topics include fluid properties, cavitation and phase changes, hydrostatics, applications of Reynold Transport Equation to control volume analyses, laminar and turbulent flow, viscous boundary layers, form and surface resistance with applications to flow in conduits and channels, pumps, and turbines. This course requires a team project evaluating the design and operational parameters for fluid systems under safety and environmental constraints.

**EN.575.615. Ecology. 3 Credits.**
The course examines an introduction to the organization of individual organisms into populations, communities, and ecosystems and interactions between organisms, humans, and the environment. Topics include causation and prediction in ecology; evolution and natural selection; populations and competition; biodiversity, extinction, and conservation; the impact of forest fragmentation and deforestation on diversity, erosion and sedimentation; wetland ecology and restoration; succession, stability, and disturbance; eutrophication and the Chesapeake Bay; island biogeography; and global climate change. An independent project will be required regarding a field site visited by the student; the student will examine an ecological, conservation, or restoration event or issue about that site.

**EN.575.619. Principles of Toxicology, Risk Assessment & Management. 3 Credits.**
Risk assessment and risk management have become central tools in continued efforts to improve public safety and the environment within the limited resources available. This course introduces the basic concepts of environmental risk assessment, relative risk analysis, and risk perception, including identifying and quantifying human health impacts and evaluating ecological risk. The course describes legislative and regulatory initiatives that are attempting to base decisions on risk assessment, along with the controversy that surrounds such approaches. It also addresses specific federal requirements for risk analysis by industry. The course discusses the realities of using risk assessments in risk management decisions, including the need to balance costs and benefits of risk reduction, issues of environmental equity, accounting for the uncertainties in risk estimates, effective risk communication, and acceptable risk.

**EN.575.626. Hydrogeology. 3 Credits.**
This course is an introduction to groundwater, geology, and to the interactions with contaminant transport between the two. It provides a basic understanding of geologic concepts and processes, focusing on understanding the formation and characteristics of water-bearing formations. The course also addresses the theory of groundwater flow, the hydrology of aquifers, well hydraulics, groundwater resource evaluation, and contaminant fate and transport in groundwater. The relationship between the geologic concepts/processes and the groundwater resource are discussed. Examples include a discussion of the influence of the geologic environment on the availability and movement of groundwater and on the fate and transport of groundwater contaminants. Geotechnical engineering problems associated with groundwater issues are also covered.Prerequisites: Calculus I, Calculus II, Ordinary Differential Equations.

**EN.575.629. Modeling Contaminant Migration through Multimedia Systems. 3 Credits.**
This course addresses contamination in several physical media as chemical species that migrate through an integrated environment. Contaminants can be released into air, subsurface or surface water from which chemicals can migrate between these media. Predicting the movement as well as human health and ecological impacts of contaminants between the air, groundwater and surface water media requires consideration of transport and fate processes that occur separately within each medium as well as linkages of contaminant interactions between media. The course presents the basic principles and computational methods for simulation of contaminant transport and kinetic fate processes in air, groundwater and surface water. Course assessments include interactive discussion topics, assignments and a course project. Screening level models will be used to evaluate transport and fate of contaminants in the air, groundwater and surface water media for a course project based on a hypothetical yet realistic case study of an industrial facility in the Washington DC region. Students will be responsible for data setup and coding of equations to create Excel spreadsheet models for contaminant fate and transport in the air and surface water and will be responsible for data setup for application of a public-domain Excel spreadsheet model for subsurface contaminant fate and transport in groundwater. Although there are no formal prerequisites for this course, the instructors strongly recommend that the student have a college-level understanding of calculus and fluid mechanics and have good quantitative skills with engineering calculations. Proficiency with the Microsoft Excel spreadsheet program is critical for data setup, coding of equations for model calculations and creating graphic plots of data and multi-media model results.

**EN.575.643. Chemistry of Aqueous Systems. 3 Credits.**
This course examines the chemical principles necessary to understand water quality and contaminant fate in natural and engineered aqueous systems. Quantitative problem-solving skills are emphasized. Specific topics include acid-base reactions, carbonate chemistry, oxidation-reduction reactions, and metal speciation. Case studies applying fundamental principles to important environmental phenomena (e.g., water disinfection, lead contamination of drinking water, soil/subsurface pollution, ocean acidification, and geoengineering) are key components of this course.

**EN.575.645. Environmental Microbiology. 3 Credits.**
This course covers fundamental aspects of microbial physiology and microbial ecology. Specific areas of focus include energetics and yield, enzyme and growth kinetics, cell structure and physiology, metabolic and genetic regulation, microbial/ environmental interactions, and biogeochemical cycles. The goal of this course is to provide a basic understanding and appreciation of microbial processes that may be applicable to environmental biotechnology.

**EN.575.704. Applied Statistical Analysis and Design of Experiments for Environmental Applications. 3 Credits.**
This course introduces statistical analyses and techniques of experimental design appropriate for use in environmental applications. The methods taught in this course allow the experimenter to discriminate between real effects and experimental error in systems that are inherently noisy. Statistically designed experimental programs typically test many variables simultaneously and are very efficient tools for developing empirical mathematical models that accurately describe physical and chemical processes. They are readily applied to production plant, pilot plant, and laboratory systems. Topics covered include fundamental statistics; the statistical basis for recognizing real effects in noisy data; statistical tests and reference distributions; analysis of variance; construction, application, and analysis of factorial and fractional-factorial designs; screening designs; response surface and optimization methods; and applications to pilot plant and waste treatment operations. Particular emphasis is placed on analysis of variance, prediction intervals, and control charting for determining statistical significance as currently required by federal regulations for environmental monitoring.Prerequisite: Undergraduate statistics is strongly recommended

**EN.575.708. Open Channel Hydraulics. 3 Credits.**
The course covers application of the principles of fluid mechanics to flow in open channels. Topics include specific energy and momentum basics, uniform flow, flow resistance, gradually varied flow, flow transitions, channel design, channel stability and erosion protection, and hydraulic structures. The course also addresses 1D flow numerical computations in irregular and natural channels, and gradually varied flow modeling using HEC-RAS computer software.
**Prerequisite(s):** EN.575.601 Fluid Mechanics or an equivalent course in fluid flow or hydraulic and basic geometry and basic calculus.

**EN.575.713. Field Methods in Habitat Analysis, Wetland Delineation, and Restoration. 3 Credits.**
This course provides students with practical field experience in the collection and analysis of field data needed for wetland delineation, habitat restoration, and description of vegetation communities. Among the course topics are sampling techniques for describing plant species distributions, abundance and diversity, including the quadrat and transect-based, pointintercept, and plot-less methods; identification of common and dominant indicator plant species of wetlands and uplands; identification of hydric soils; and the use of soil, topographic and geologic maps and aerial photography in deriving a site description and site history. Emphasis is placed on wetland vegetation, delineation and restoration. While many of the field examples are centered in the Maryland and Washington, DC region, the format is designed so that the student performs field work in the state, country or region in which he or she would like to specialize.
**Prerequisite(s):** EN.575.615 Ecology.

**EN.575.716. Principles of Estuarine Environment: The Chesapeake Bay Science and Management. 3 Credits.**
The course examines the basic physical, chemical, and biological components of the Chesapeake Bay ecosystem and how they interrelate in both healthy and degraded states of an estuary. The course focuses on the tidal waters of the Chesapeake Bay and its tributaries. It also covers the relationships of the bay with the surrounding watershed, atmosphere, and ocean as well as relevance to other coastal systems. Particular emphasis is on to anthropogenic stresses such as nutrient and contaminant pollution, habitat modification, and harvest of fish and shellfish. The most current Chesapeake Bay management issues and policies being pursued at the federal, state, and local levels of government are discussed in depth, including their scientific foundation.

**EN.575.717. Hydrology. 3 Credits.**
This course introduces the fundamental physical principles that are necessary to understand the occurrence, distribution, and circulation of water near Earth's surface. Students will be introduced to the global hydrological cycle and the influence of climate, geology, and human activity. Students will study the processes of precipitation and evapotranspiration; surface water flow, floods, and storage in natural and artificial reservoirs; groundwater flow; and whole-cycle catchment hydrology. Although less emphasized, water-quality and water resources management issues will be discussed and case studies presented. Throughout the course, a quantitative approach is taken in which mathematical descriptions of hydrological phenomena will frequently be an objective. The course will also provide an introduction to hydrological data acquisition and analysis.
**Prerequisite(s):** EN.575.601 Fluid Mechanics or an equivalent course in fluid flow or hydraulics.

**EN.575.727. Environmental Monitoring and Sampling. 3 Credits.**
Environmental monitoring and sampling provides the information needed for assessments of compliance with environmental criteria and regulatory permits, and status/trends to evaluate effectiveness of regulatory controls. Students will prepare a Sampling and Analysis Plan (SAP) as a course project to support a site-specific field data collection study for environmental sampling of air, surface water, groundwater, and soils. An overview of historical/current environmental issues, including public health and environmental impacts, for air, surface water, groundwater, and soil, is presented. An overview of regulatory requirements of federal environmental statutes and assessments of effectiveness of the Clean Water Act, Clean Air Act, Safe Drinking Water Act, CERCLA, and RCRA is presented. The course describes pollutant sources and physical, chemical, biological processes that govern transport and fate of contaminants in air, surface water, groundwater, and soils. The course examines the principles, methods, and strategies for monitoring and sampling of air, surface water, groundwater, and soil. Sampling methods are presented for discrete sampling, automated data acquisition, and remote sensing for air, surface water, groundwater, and soils. SAP requirements for the course project will be presented, including key elements of Quality Assurance Project Plans and Field Sampling Plans. The course presents selected concepts of environmental statistics; an overview of data sources available from EPA, USGS and other agencies for air, surface water, groundwater, and soils; and interpretation of environmental data sets with GIS/mapping, data analysis, and statistical methods to support decision-making, site characterization, and evaluation of status/trends. Students will research online opportunities for “virtual” field trips to observe field sampling methods for air, surface water, groundwater, and soils media.

**EN.575.728. Sediment Transport and River Mechanics. 3 Credits.**
This course examines the processes of sediment entrainment, transport, and deposition and the interaction of flow and transport in shaping river channels. Topics reviewed include boundary layer flow; physical properties of sediment; incipient, bed-load, and suspended-load motion; bed forms; flow duration; sediment loads; hydraulic roughness; scour and deposition of bed material; bank erosion; sediment budgets; channel classification, and size, shape, planform, and migration of river channels. In addition, the course develops techniques of laboratory, theoretical, and sediment modeling and applies them to problems of sediment transport, channel morphology, and channel change. Prerequisite(s): A course in fluid mechanics or an equivalent course in fluid flow or hydraulics. A course in statistics is strongly encouraged

**EN.575.730. Geomorphic and Ecologic Foundations of Stream Restoration. 3 Credits.**
This course presents principles from hydrology, sedimentation engineering, geomorphology, and ecology relevant to the design and evaluation of stream restoration projects. A watershed context is emphasized in developing the background needed to assess different design approaches. After developing a common foundation in stream dynamics, the course considers trade-offs among restoration objectives, the merits of analog and predictive approaches, the role of uncertainty in restoration design, and metrics for assessing ecological recovery. The course includes online discussions, design exercises, and review papers and finishes with an assessment of a stream in students’ geographic regions.

**EN.575.744. Environmental Chemistry. 3 Credits.**
This course focuses on the environmental behavior and fate of anthropogenic contaminants in aquatic environments. Students learn to predict contaminant properties influencing contaminant transfers between hydrophobic phases, air, water, sediments, and biota, based on a fundamental understanding of physico-chemical properties, intermolecular interactions, and basic thermodynamic principles. Mechanisms of important transformation reactions and techniques and quantitative models for predicting the environmental fate or human exposure potential of contaminants are discussed.

**EN.575.763. Nanotechnology and the Environment: Applications and Implications. 3 Credits.**
This course explores the positives and negatives of nanotechnology: the benefits to use in commercial and environmental applications, as well as considering nanoparticles as an emerging environmental contaminant. The course will analyze nanotechnology through an interdisciplinary outlook for a life-cycle analysis. This analysis will begin with synthesis, manufacturing, unintentional releases, and disposal. We will consider ecological consequences and public health implications of the use of nanotechnology. Students will learn the science behind nanotechnology and how nanoparticle characteristics impact transport in the environment, including human exposure assessment, and a discussion of current measurement tools. Policies regulating nanotechnology and risk assessment will be addressed.

**EN.575.801. Independent Project. 3 Credits.**
This course provides students with an opportunity to carry out a significant project in the field of environmental engineering, science, technology, planning, or management as a part of their graduate program. The project is individually tailored and supervised under the direction of a faculty member and may involve conducting a semester-long research project, an in-depth literature review, a non-laboratory study, or application of a recent development in the field. The student may be required to participate in conferences relevant to the area of study. To enroll in this course, the student must be a graduate candidate in the Environmental Engineering, Science, and Management Program within the latter half of the degree requirements and must obtain the approval and support of a sponsoring faculty member in the Department of Environmental Health and Engineering. The proposal description and completed required forms must be submitted prior to registration for approval by the student’s advisor and the program chair. A maximum of one independent project course may be applied toward the master’s degree or post-master’s certificate.

## Environmental Planning and Management

**EN.575.608. Optimization Methods for Public Decision Making. 3 Credits.**
This course is an introduction to decision support models used in environmental planning and management. We will develop and apply analytical methods and mathematical models that help decision makers solve complex environmental and socio-economic problems and formulate associated policies. There is a focus on real-world problems in the public sector, including urban facility location, transportation planning, water resources management, biological conservation, and landscape resources management. You will learn how to structure and analyze problems and formulate optimization models to make the most of limited resources and achieve specified objectives related to efficiency, cost-effectiveness, environmental protection, public health, and fairness to stakeholder groups and to the public. The types of models covered in this course are linear programming, integer programming, and multi-objective models. Algorithmic solution methods are reviewed, and computer-based solution methods are applied in the context of a course project. Prerequisite: pre-calculus mathematics including algebra with multiple variables.

**EN.575.611. Economic Foundations for Public Decision Making. 3 Credits.**
The course examines intermediate-level price theory and surveys applications to public-sector decision making. Topics include demand, supply, behavior of the market, and introductory welfare economics. Applications include forecasting, cost-benefit analysis, engineering economics, and public sector pricing.

**EN.575.628. Business Law For Engineers. 3 Credits.**
This course introduces engineers to the basic legal principles they will encounter throughout their careers. Course discussions cover contracts (formation, performance, breach, and termination), corporations and partnerships, insurance, professional liability, risk management, environmental law, torts, property law, and evidence and dispute resolution. The course emphasizes those principles necessary to provide engineers with the ability to recognize issues that are likely to arise in the engineering profession and introduces them to the complexities and vagaries of the legal profession. This course also affords a proper foundation for students interested in law-related ancillary careers such as forensic consulting.

**EN.575.635. Environmental Law for Engineers & Scientists. 3 Credits.**
This course explores fundamental legal concepts relevant to environmental issues, including the relationship between statutes, regulations, and court decisions. Also included are various forms of enforcement used in environmental rules: command and control, liability, and information disclosure. Specific issues include criminal enforcement, a survey of environmental statutes, regulations and case law, the purpose and misconceptions surrounding environmental audits and assessments, the concept of attorney-client privilege, unauthorized practice of law, and ethical conflicts between the attorney and engineer/scientist roles.

**EN.575.637. Environmental Impact Assessment. 3 Credits.**
This course provides a thorough review and application of the Environmental Impact Assessment (EIA) process and the National Environmental Policy Act (NEPA.) It covers selection of scientific, engineering, and socioeconomic factors in EIA; identification of quantitative and qualitative environmental evaluation criteria; EIA life cycle application of techniques for assessing impacts of predicted changes in environmental quality; approaches for identifying, measuring, predicting, and mitigating environmental impacts; modeling techniques as employed in EIA; environmental standards in the EIA process; sustainable development goals (SDG) as applied to EIA, methodologies for incorporating EIA into management decision-making. EIA alignment with climate change and Diversity, Equity, and Inclusion (DEI) as related to EIA are addressed. Case studies of EIA for several types of engineering projects are employed. Students acquire the knowledge to prepare an EIA, critically review and analyze an EIA, apply EIA as an important tool in management decision-making processes and develop a comprehensive analytical example of an Environmental Impact Statement (EIS).

**EN.575.640. Geospatial Intelligence: the art and science for better understanding our world. 3 Credits.**
Through lectures and laboratory exercises, this course illustrates the fundamental concepts of GIS and remote sensing technologies in the context of environmental engineering. Topics include the physical basis for remote sensing, remote sensing systems, digital image processing, data structures, database design, and spatial data analysis. The course is not intended to provide students with extensive training in particular image processing or GIS packages. However, handson computer laboratory sessions re-enforce critical concepts. Completion of a term project is required.

**EN.575.707. Environmental Compliance Management. 3 Credits.**
The course covers compliance with environmental laws and regulations by industry, small business, government facilities, and others. It includes legal responsibilities, environmental management systems, and practices such as audits and information systems and development of corporate policies and procedures that rise to the daunting challenge to harmonize the institution's primary goals with its environmental obligations. Several dimensions of environmental management are discussed: federal, state, and local regulation; scientific/technical factors; public relations and the press; and institutional objectives including economic competitiveness.

**EN.575.710. Financing Environmental Projects. 3 Credits.**
This course treats the financing of projects from two complementary perspectives: that of a government agency funding source, and that of an environmental utility (water, wastewater, solid waste) that needs funds for its project. It discusses grants, concessionary loans, market loans, and loan guaranties, along with their relative desirability and efficiency. Since grant funding is never available for all projects, the course deals extensively with borrowing/lending. It discusses strategies for maximizing utility income, including appropriate tariff structures and the reform of government subsidy policy from supply-based general subsidies to demand-based targeted subsidies. Operational strategies to maximize income are also discussed, such as techniques to improve billing and collections, reduce losses, and reduce energy costs. Traditional cash flow analyses are used to determine debt service capabilities. Various project cost reduction strategies, such as staging and scaling, are introduced. Grants in the form of upfront project cost buy-downs vs. annual debt service subsidies are compared. Finally, several examples of project financing combining many of the elements introduced during the course are presented and analyzed. Advocacy skills for financing environmental projects and obtaining funding sources are major areas of focus.

**EN.575.714. Water Resources Management. 3 Credits.**
This course examines the technical, economic, and social aspects of managing water resources. A review of water fundamentals involving physical, chemical, and biological systems provides a foundation. Students are given a historical basis for thinking about and resolving contemporary challenges. Observed and predicted climate change impacts on water resources are explored along with management implications and responses. Key water law concepts, their roots in social institutions, and current traditional institutions are covered. The course surveys regulatory instruments, like permits, and their operation across federal, state, and local levels of government. Funding and financing issues are covered. The course addresses the management of water supply and demand in the United States. Fundamentals of flood and drought management are covered, with attention given to climate change. Water quality-based management under the federal Clean Water Act includes the topics of water quality standards, water quality assessments, total maximum daily loads (TMDLs), and implications for permit requirements. Regional ecological water resources management is addressed by contrasting the Chesapeake Bay case with other cases. The topic of natural environmental flows explores the benefits of natural flow variability and the interrelationships among five key functions that characterize the health of a stream and support stream restoration design. Water resource management decision making is addressed in terms of structured techniques involving economic analyses, multi-objective analyses, and collaborative decision making with a focus on the role of public involvement. Students will be led in the development of a well-defined, substantive water resources management research question as part of a course project.

**EN.575.731. Water Resources Planning. 3 Credits.**
The course will discuss the application and interrelationships among microeconomics, ecology, hydrology, and fields related to the planning and management of water systems. Topics will include flood control, navigation, hydroelectric power, water supply, environmental restoration, multi-objective planning, and urban water resource management. The course will demonstrate the process for planning a water resource project, including identifying the problems and opportunities, inventorying and forecasting conditions, formulating alternative plans, evaluating alternative plans, comparing alternative plans, and selecting a plan. Particular attention will be paid to the appropriate interdisciplinary approach to plan formulation.

**EN.575.737. Environmental Security with Applied Decision Analysis Tools. 3 Credits.**
This multi-disciplinary course examines current and emerging environmental security issues at multinational, national, and regional scales. These issues are approached from the perspective of decision-making for policy, planning, and management. The course begins with an overview and definitions of environmental security within the context of present global demographic patterns, use of natural resources, and climate change. The theory and principles of multi-criteria decision analysis (MCDA) are reviewed, using environmental security examples to illustrate concepts. Three MCDA methodologies are presented, including multi-attribute weighting, Analytic Hierarchy Process, and outranking, which are commonly used to assist decision makers. The MCDA approach is critiqued from the perspective of measurement theory and guidelines for MCDA use are suggested. With both the social sciences and natural sciences providing a framework, several specific environmental security topics are covered in greater depth: energy; air quality; ecosystems and biodiversity; fresh water; agriculture and food; and sea level rise. Within these topics, students will develop MCDA models for particular policy, planning, and management problems under the guidance of the instructors. The course concludes by considering the prospects for environmental security and sustainability in the coming decades.

**EN.575.747. Environmental Project Management. 3 Credits.**
This course provides students with the knowledge for an integrated approach to environmental project management, applying pertinent scientific, engineering, legal, public policy, and project management disciplines. Emphasis is placed on factors that are common to an environmental project, such as external impacts, stakeholder conflicts, scope uncertainty, and the evolving environmental regulatory environment. The students learn the elements of environmental project plans, including project organization and staffing, schedule dependencies and optimization, cost estimating and control, and communication with internal and external stakeholders. The types of environmental projects addressed include infrastructure, restoration and remediation, program development, and alternatives analysis. Project Management Institute materials are utilized, along with case studies, to illustrate actual project conflicts, necessary adjustments, and successes.

**EN.575.751. Environmental Justice, Climate, and Health Equity. 3 Credits.**
Environmental planners are uniquely positioned to address climate change, environmental health, and health equity. The will course lectures and applied exercises will offer students a first-hand experience assessing the impact of environmental planning on climate and public health and the impact of environmental justice movements in the United States and globally. Students will harness evidence-based practices with community stakeholders to address emerging environmental and public health challenges. These applied exercises with community stakeholders will reinforce seminal course concepts.

**EN.575.753. Communication of Environmental Information and Stakeholder Engagement. 3 Credits.**

This course provides students with the skills for communicating scientific environmental data and sustainable engineering design to stakeholders, including scientists in different fields, policy decision makers, and the interested public. The course covers the importance of clear communication of complex scientific information for the development and acceptance of technologies, public policy, and communitybased environmental initiatives. The key stakeholders for environmental engineers, scientists, and managers are specified. Methods of engagement and designing key messages are defined for global, national, and local issues of student interest. Major types of communication media are covered, including written communication and graphics, online communications in short- and long-form new media, and interactive communications such as surveys and citizen science to involve stakeholders in the creation and analysis of big data and dispersed information. The emphasis of the course is from the point of view of an environmental professional (not a marketing professional) and developing an effective sciencebased communications portfolio to share complex scientific information with a broad range of interested parties.

**EN.575.759. Environmental Policy Analysis. 3 Credits.**

The course explores the process of analyzing environmental policies to ensure human health, that environmental needs are protected, and that the physical environment is preserved, protected, and restored, if necessary. Emphasis is placed on the need to evaluate and make decisions regarding environmental science, human health, sociopolitical, technological, legal, and economic considerations in a context of incomplete information and uncertain futures. Case studies and policies relating to various contemporary environmental issues, for example hazardous waste disposal, natural resource extraction and preservation of natural resources, are critiqued during the semester. The course will lead students through the various steps of the policy analysis process. Students are expected to evaluate policy alternatives, develop evaluation criteria, and apply qualitative and quantitative methods to determine consequences, trade-offs, and potential synergies relating to these environmental issues. Students will then use these skills to create and execute an individual research project that analyzes an environmental policy relating to a specific issue of interest to them, evaluating potential responses to environmental management problems through analyzing the impacts of each policy alternative.