

## DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

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Semester schedules, curriculum changes and new courses, visit us at <http://www.eng.uml.edu/Dept/civ>

## MASTER OF SCIENCE IN CIVIL & ENVIRONMENTAL ENGINEERING Program Description and General Requirements

**G**raduate study in Civil and Environmental Engineering is an intensive program of instruction at an advanced technical level. The program permits students to design, in consultation with their advisor, a plan of study that meets individual goals and career objectives. Program options include environmental engineering, geoenvironmental engineering, geotechnical engineering, structural engineering and transportation engineering. Admission to a particular engineering option is open to applicants with undergraduate degrees in engineering, mathematics or science.

The degree requires successful completion of 30 credit hours of course work, or 24 credit hours of instruction and a publishable thesis, or 27 hours of course work and preparation of a project report. Courses are scheduled in the late afternoon and evening to provide study opportunities for students with full-time employment. Successful completion of undergraduate prerequisite courses is required prior to registering for graduate courses. However, undergraduate prerequisites and selected graduate courses, that do not have prerequisites, may be taken during the first year of study, but only with the written permission of the student's advisor. Required undergraduate prerequisite courses are listed in descriptions of the core graduate courses shown below.

Applicants who satisfy the Graduate School admission requirements will be assigned to a faculty member who will serve as their academic advisor. Students receiving a teaching or research assistantship will normally be required to submit a publishable thesis. Those admitted to graduate study as non-degree students may apply for matriculated status. However, no more than 9 credits of work completed while in non-degree student status or transferred from another department or college will be used toward a degree. Matriculated status is preferred before initial registration and is mandatory prior to registration for second semester courses. Faculty will review a petitioner's performance in all courses attempted.

**M.S. in Civil Engineering  
(Environmental Engineering  
Option)**

The program offers an opportunity to pursue a broad range of interests in the fields of environmental and water resources engineering. The course of study is designed to meet an individual student's interests and career goals. Programs consist of civil engineering courses in water and wastewater treatment, environmental chemistry, hydrology, hydraulics, air pollution control, environmental law and policy and may include courses from allied disciplines such as biological and health sciences, environmental studies, chemistry and work environment. The program of study consists of four core courses and elective courses. Undergraduate core course prerequisites must be completed before beginning graduate course work.

**Core Courses**

- 14.561 Physical and Chemical Treatment Processes
- 14.562 Physical and Chemical Hydrogeology
- 14.567 Environmental Chemistry I
- 14.568 Environmental Chemistry II

**Elective Courses**

Individual student programs consist of a complement of elective courses usually taken from the following list:

- 14.509 Environmental Engineering Geology
- 14.527 Geotechnical Environmental Site Characterization
- 14.529 Engineering with Geosynthetics
- 14.564 Advanced Water Resources
- 14.590 Design and Analysis of Waste Containment Systems
- 14.592 Advanced and Innovative Concepts in Waste Containment
- 14.593 Physio-chemical Interactions in Earthen Barriers
- 14.570 Small and Alternative Waste Water Treatment
- 14.571 Surface Water Quality Modeling
- 14.572 Marine and Coastal Processes
- 14.573 Municipal, Industrial and Hazardous Waste Management
- 14.574 Air Quality Modeling
- 14.575 Groundwater Modeling
- 14.595 Hazardous Waste Site Remediation
- 18.501 Wetlands Ecology
- 18.505 Glacial Geology
- 18.510 Water Resources Management
- 18.511 Environmental Soil Science

- 18.523 Air Resources Management
- 18.530 Environmental and Natural Resource Economics
- 18.571 Air Pollution Phenomenology
- 18.581 Understanding the Massachusetts Contingency Plan

**M.S. in Civil Engineering  
(Geotechnical Engineering  
Option)**

The master's degree program in geotechnical engineering encompasses soil mechanics theory and applications in the fields of foundation and soil engineering. Course work emphasizes the engineering behavior of soil, soil property determination, and the use of advanced soil mechanics theory and soil-structure interaction in the solution of soil and foundation engineering problems. Elementary courses in soil mechanics, statics, strength of materials and fluid mechanics are required as prerequisites for graduate core courses. Students receiving a teaching or research assistantship are required to submit a publishable thesis.

The program of study consists of five required courses: 14.531 Advanced Soil Mechanics and any four core courses and four elective courses, selected with the consent of a student's faculty advisor. Program and course details are included in the graduate course list and the graduate catalog.

**Core Courses**

(select any four of the following as core courses, others may be used as electives)

- 14.529 Engineering with Geosynthetics
- 14.530 Deep Foundations
- 14.532 Theoretical Soil Mechanics
- 14.533 Advanced Foundation Engineering
- 14.534 Soil Dynamics and Earthquake Engineering
- 14.536 Soil Engineering
- 14.537 Experimental Soil Mechanics
- 14.538 Soil Behavior

**Additional Elective Courses**

- 14.504 Advanced Strength of Materials
- 14.507 Engineering Computation
- 14.509 Environmental and Engineering Geology
- 14.521 Reliability Analysis in Engineering
- 14.527 Geotechnical Environmental Site Characterization
- 14.529 Engineering with Geosynthetics
- 14.539 Ground Improvement
- 14.550 Behavior of Structures

- 14.562 Physical and Chemical Hydrogeology
- 14.581 Engineering Systems Analysis
- 14.583 Stochastic Concepts
- 14.590 Design and Analysis of Waste Containment Systems

**M.S. in Civil Engineering  
(Geoenvironmental Option)**

A field that encompasses the application of science and engineering principles to the analysis of the fate of contaminants in the ground; and design and implementation of schemes for treating, modifying, reusing or containing of wastes in the ground. A bachelor's degree in engineering, mathematics or science is required for admission to the program. The general areas of professional activities are:

- Characterization of geomedia with respect to stability and fluid flow properties.
- Assessment of response of terrains that host waste containment systems to natural and/or man-made hazards such as earthquakes, global warming, subsidence and floods.
- Analysis of contaminant generation and migration through porous and fractured geomaterials, and fabricated materials.
- Physico-chemical, chemical, thermal and biological treatment of wastes and contaminated geomaterials to reduce or eliminate pollutants.
- Design and analysis of surficial waste containment systems such as landfills, monofills, slurry walls, grout curtains and dewatering schemes; and deep disposal systems such as radioactive waste disposal chambers in rock.

**Core Courses**

- 14.562 Physical and Chemical Hydrogeology
- 14.590 Design and Analysis of Waste Containment Systems
- 14.593 Physio-chemical Interactions in Earthen Barriers and at least one of the following :
- 14.531 Advanced Soil Mechanics
- 14.529 Engineering with Geosynthetics
- 14.538 Soil Behavior
- 14.527 Geotechnical Environmental Site Characterization

**Elective Courses**

- (Optional core courses may be used as electives)
- 14.509 Environmental/Engineering Geology

- 14.521 Reliability Analysis in Engineering
- 14.530 Deep Foundations
- 14.532 Theoretical Soil Mechanics
- 14.533 Advanced Foundation Engineering
- 14.534 Soil Dynamics and Earthquake Engineering
- 14.536 Soil Engineering
- 14.537 Experimental Soil Mechanics
- 14.561 Physical and Chemical Treatment Process Engineering
- 14.564 Advanced Water Resources
- 14.567 Environmental Chemistry I
- 14.568 Environmental Chemistry II
- 14.573 Municipal, Industrial and Hazardous Waste Management
- 14.575 Groundwater Modeling
- 14.591 Geohazards and Waste Containment System Stability
- 14.592 Advanced and Innovative Concepts in Waste Containment
- 14.594 Fundamentals of Contaminated Site Treatment Techniques
- 14.595 Hazardous Waste Site Remediation
- 18.581 Understanding the Massachusetts Contingency Plan

### **M.S. Civil Engineering (Structural Engineering Option)**

The structural option within Civil and Environmental Engineering offers instruction and research in advanced concepts and techniques in the solution of complex structural engineering problems. A student seeking an M.S. Engineering in Structural Engineering must have a structural analysis course which includes statically indeterminate structures and junior or senior level courses in the design of steel and concrete structures. Student study programs in structural engineering are developed with a faculty advisor to meet the needs of the individual. These undergraduate courses are core graduate course prerequisites and students deficient in these areas must take these courses before they can take advanced courses.

#### **Core Courses**

- 14.504 Advanced Strength of Materials
- 14.551 Design of Steel Structures or
- 14.552 Design of Reinforced Concrete Structures
- 14.556 Finite Element Analysis (or equivalent)
- 14.557 Structural Dynamics

#### **Elective Courses**

- 14.507 Engineering Computation
- 14.521 Reliability Analysis in

- Engineering
  - 14.550 Behavior of Structures
  - 14.551 Design of Steel Structures
  - 14.552 Behavior of Concrete Structures
  - 14.553 Wood Structures
  - 14.554 Prestressed Concrete Design
  - 14.555 Bridge Design
  - 14.531 Advanced Soil Mechanics
  - 14.533 Advanced Foundation Engineering
  - 14.536 Soil Engineering
- Additional geotechnical and geoenvironmental courses and appropriate courses from the Departments of Mathematics and Mechanical Engineering may also be included in a degree plan.

### **M.S. In Civil Engineering (Transportation Engineering Option)**

The program in Transportation Engineering offers courses in planning, design and operation of multi-modal transportation facilities. It emphasizes the interdisciplinary nature of the subject, supplementing engineering concepts with techniques from management, economics, operations research and environmental studies. It is designed to provide students with advanced technical knowledge for addressing transportation problems in a variety of practical situations. Specialization in a specific area can be achieved through thesis and project work. Graduate study plans are designed based upon student interest, professional needs and undergraduate preparation. Students are expected to have completed or show proficiency in the following courses in partial fulfillment of degree requirements:

#### **Core Courses**

- 14.441 Traffic Engineering
- 14.540 Urban Transportation Planning
- 14.581 Engineering Systems Analysis
- 14.583 Stochastic Concepts (or equivalents)

Courses from other appropriate disciplines such as engineering, management, and pure and applied science may be taken to form a coherent program in Transportation Engineering. A graduate plan of study will be designed to meet the professional needs of each student; however, at a minimum, each student is expected to have completed or show proficiency in the following courses:

#### **Elective Courses**

- 14.521 Reliability Analysis in Engineering
- 14.543 Transportation Systems Analysis
- 14.545 Public Transit Planning and Design
- 14.547 Airport Planning and Design
- 14.549 Traffic Flow Theory Elective

### **THE FIVE-YEAR B.S./M.S. ENGINEERING PROGRAM**

A five-year B.S./M.S. Engineering program is available to undergraduates with a cumulative grade point average of at least 3.0 at the end of their junior year. See the front of the catalog for a complete description.

### **DOCTOR OF ENGINEERING PROGRAM WITH A SPECIALIZATION IN CIVIL AND ENVIRONMENTAL ENGINEERING Program Objectives**

The objective of the Doctor of Engineering Degree focus in Civil and Environmental Engineering is to develop decision-making, research-oriented engineers with the ability to produce new engineering knowledge and analyze complex, cross-disciplinary issues. Successful applicants are expected to perform advanced research in one or more areas of concentration within the Department of Civil and Environmental Engineering and successfully complete both core courses and electives that may be drawn from a variety of disciplines. Beyond the core courses, the program can be tailored to the needs of each student through a formal arrangement between the student and his or her research advisor.

#### **Areas of Specialization**

The areas of specialization within the Doctor of Engineering focus in Civil and Environmental Engineering are:

- Environmental Engineering
- Geoenvironmental Engineering
- Geotechnical Engineering
- Transportation Engineering
- Structural Engineering

#### **Program Curriculum**

Students enrolled in the Doctor of Engineering program with a focus in Civil and Environmental Engineering undertake a program of study that consists of graduate courses in engineering, sciences, mathematics, and management.

The program also includes oral and written qualifying examinations and a dissertation. A minimum of 63 credit hours is required beyond the bachelor of science degree. The distribution of credit hours within the curriculum is as follows:

Civil engineering and other advanced courses - 33 credit hours; Management courses - 9 credit hours; Doctoral research dissertation - 21 credit hours

Core Courses in each doctoral program focus area

*Environmental Engineering Core*

- 14.561 Physical and Chemical Treatment Processes
- 14.562 Physical and Chemical Hydrogeology
- 14.567 Environmental Chemistry I
- 14.568 Environmental Chemistry II
- 14.595 Hazardous Waste Site Remediation

*Geoenvironmental Engineering Core*

- 14.562 Physical and Chemical Hydrogeology
- 14.590 Design and Analysis of Waste Containment Systems
- 14.593 Physio-chemical Interactions in Earth's Barriers

and at least one of the following :

- 14.531 Advanced Soil Mechanics
- 14.529 Engineering with Geosynthetics
- 14.538 Soil Behavior
- 14.527 Geotechnical Environmental Site Characterization

*Geotechnical Engineering Core*

- 14.531 Advanced Soil Mechanics (and any four of the following:)
- 14.527 Geotechnical and Environmental Site Characterization
- 14.529 Engineering with Geosynthetics
- 14.530 Deep Foundations
- 14.532 Theoretical Soil Mechanics
- 14.533 Advanced Foundation Engineering
- 14.534 Soil Dynamics and Earthquake Engineering
- 14.536 Soil Engineering
- 14.537 Experimental Soil Mechanics
- 14.538 Soil Behavior
- 14.539 Ground Improvement

*Transportation Engineering Core*

- 14.541 Traffic Engineering
- 14.540 Urban Transportation Planning
- 14.581 Engineering Systems Analysis
- 14.583 Stochastic Concepts

*Structural Engineering Core*

- 14.504 Advanced Strength of Materials
- 14.551 Design of Steel Structures or
- 14.552 Design of Reinforced Concrete Structures

14.556 Finite Element Analysis or equivalent

14.557 Structural Dynamics

A maximum of 24 hours of graduate-level course work taken at another institution with a minimum grade of B will be accepted. A maximum of 12 credits of dissertation research can be transferred from another institution to the program.

**Admission to the Doctor of Engineering Program**

i. Admission of Engineering Degree holders: Admission of applicants who have at least one degree in engineering from an accredited university and department requires high academic standing in all prior course work. Applicants are requested to submit GRE (aptitude part only) scores to the Graduate School. In addition to GRE scores, international students must obtain a minimum score of 550 in the Test of English as a Foreign Language (TOEFL) examination.

ii. Admission of Non-Engineering Degree holders: Admission to the Doctor of Engineering in Civil and Environmental Engineering may be offered to applicants who have a Bachelor's and/or Master's degree in non-engineering fields. In such cases, the applicant must successfully complete all requirements for a master of science in Civil and Environmental Engineering prior to being considered a candidate for the Doctor of Engineering degree.

**Admission Application Process**

Interested applicants are urged to contact the Graduate School for application packages and should contact the Doctoral Program Coordinator of the Department of Civil and Environmental Engineering for information about the program. The Coordinator will refer applicants to faculty members in specialization areas for more detailed information about research focus areas and the availability of graduate research assistantships. Applicants should send application packages directly to the Graduate School. The Doctoral Coordinator will review all application files in the Graduate School and circulate a complete list of all applicants to all faculty members every two months. The Coordinator will convene an Admissions Panel.

**Plan of Study**

i. Assignment of an Advisor and Formation of a Doctoral Committee

Within about one academic year of initiation of doctoral study, each student must work with his/her research advisor to develop a Plan of Study that complies with doctoral program and Graduate School policies. Courses substitutions, in the Plan of Study, must be reviewed by the Departmental Graduate Committee. Formal requests for substitutions are made by the student's Research Advisor. The student's Research Advisor is the supervisor of the student's research activities. The Advisor will work with the student to develop Dissertation research focus and request the service of appropriately qualified persons in the student's Dissertation Committee. The Dissertation Committee will comprise a minimum of 4 persons of which at least 2 will be full time, regular faculty members of the Department of Civil and Environmental Engineering. The function of the Dissertation Committee is to ensure that the final edition of the student's dissertation meets the high technical standards expected in doctoral work and that the student successfully defends his/her findings prior to the award of the Doctor of Engineering degree. Dissertation Committee members are not necessarily co-investigators of the student's research topic.

ii. The Qualifying Examination

Upon the completion of a maximum of 45 credit hours of graduate work that count towards the Doctor of Engineering degree, the student will apply to the Dissertation Committee to take a Qualifying Examination. In addition, students who were admitted as non-engineering degree holders into the Doctor of Engineering program must satisfy all requirements for the award of the M.S. degree in Civil and Environmental Engineering before they are allowed to take the Qualifying Examination (see section E(ii)). The Qualifying Examination may be written and oral. The Dissertation Committee members will submit their grades to the Doctoral Program Coordinator who will tally them and report the overall grade on a pass/fail basis, to the student and his/her Advisor. Students who successfully complete the Qualifying Examination will be designated as Candidates for the Doctor of Engineering degree. For each doctoral student, a maximum of two Qualifying Examinations will be allowed. A doctoral student who fails the Qualifying Examination two times will not be

allowed to continue in the doctoral program. Shortly after passing the Qualifying Examination, the Doctor of Engineering degree candidate will be expected to develop a thesis plan in collaboration with his/her advisor, and defend it successfully before the Doctoral Committee.

iii. Residency Requirements

One year of full-time residence is required of all students in the program. Residency is defined herein as a continuous period of full-time enrollment in the program or research effort at a University of Massachusetts or any other facility approved by the Doctoral Committee. Prior to graduation, a residency verification form signed by the student's Research Advisor must be submitted to the Doctoral Program Coordinator.

iv. Dissertation

Prior to the award of the Doctor of Engineering degree, each Candidate is expected to author and defend a dissertation which must represent original contributions to the field of research focus. Defense of the thesis work will be held in a seminar that will be open to the public.

## COURSE DESCRIPTIONS

### 14.504 Advanced Strength of Materials

(3-0)3 Stress and strain at a point, curved beam theory, unsymmetrical bending, shear center, torsion of non-circular sections, theories of failure, introduction to the theory of elasticity. Prerequisite 14.204 Statics.

### 14.507 Engineering Computation

(3-0)3 Advanced software design and implementation for engineers. Structured programming using a modern language such as C. Theory and implementation of advanced data structures. Numerical algorithms for systems of equations and data manipulation. Emphasis on design and implementation of software for civil engineering purposes. Prerequisites: 25.101/102 Introduction to Engineering or equivalent.

### 14.509 Environmental Engineering

**Geology** (3-0)3 The evolution of contaminated site remediation techniques and the necessity to construct above-ground and underground structures on difficult terrains have generated the need to characterize sites and improve geomedias at such sites for both environmental and structural purposes. Whereas site selection requires the analysis of environmental conditions at large spatial scales, the use of a specific site requires detailed analysis of the characteristics of geomaterials that comprise the site at much smaller spatial scales. The scope of this

course covers techniques which can be applied in the analysis of geomedias with respect to their contaminant and moisture transport properties, as well as their capacity to serve as load-bearing foundations and durable construction materials. Prerequisites: Undergraduate course in physical geography, or geology/geomorphology, or 14.330 soil mechanics, or engineering geology.

### 14.521 Reliability Analysis in Engineering

(3-0)3 A review of the elementary principles of probability and statistics followed by advanced topics including decision analysis, Monte Carlo simulation, and system reliability. In-depth quantitative treatment in the modeling of engineering problems, evaluation of system reliability, and risk-benefit decision management. Prerequisite: 14.286 Probability and Statistics for Engineers or equivalent.

### 14.522 Statistical Applications in Civil Engineering

(3-0)3 Most of civil engineering applications must take into account the possibility of randomness. That is, the quantities that we are interested in exhibit an inherent variation that must be taken into account. This course develops a comprehensive framework in stochastic modeling, through many examples, applicable in analyses and decision making in all kinds of civil and environmental engineering problems. The emphasis in the course is placed on the application side of probabilistic techniques rather than their theoretical side with special emphasis in parametric and nonparametric statistics; reliability issues; stochastic processes; regression and simulation. Prerequisites: 14.286 Probability and Statistics for Engineers or equivalent.

**14.527 Geotechnical and Environmental Site Characterization** (3-0)3 This course is designed to give students a comprehensive understanding of various site investigation and site assessment technologies employed in geotechnical and environmental engineering. The course begins with introduction to site investigation planning and various geophysical methods including: seismic measurements, ground penetrating radar, electrical resistivity, electromagnetic conductivity, time domain reflectometry. Drilling methods for soil, gas and ground water sampling; decontamination procedures; and long term monitoring methods are studied. Emphasis in this course is placed on conventional and state-of-the-art in situ methods for geotechnical and environmental site characterization: standard penetration test, vane shear test, dilatometer test, pressuremeter test and cone penetration tests. Modern advances in cone penetrometer technology, instrumented with various sensors (capable of monitoring a wide range of physical and environmental parameters: load, pressure, sound, electrical resistivity, temperature, PH, oxidation reduction potential, chemical contaminants) are playing a major role in site characterization. Principles underlying these methods along with the interpretation of test

data will be covered in detail. The course will also look into emerging technologies in the area of site characterization. Prerequisites: 14.330 Soil Mechanics

### 14.529 Engineering with Geosynthetics

(3-0)3 Design, selection, testing, specifying, and constructing with geotextiles, geocomposite drains, geogrids and related geosynthetic materials for erosion control, embankment on soft soils, reinforced soil slopes (RSS), and mechanically stabilized earth walls (MSEW). Prerequisites: 14.431 Foundation and Soil Engineering or 14.531 Advanced Soil Mechanics.

### 14.530 Deep Foundations

(3-0)3 Design and analysis of deep foundations including: Cost analysis of foundations. Effects of pile installation. Static capacity and settlement analysis of single piles and a pile group under vertical and lateral loads. Interfacial friction. Pile load test standards, construction, interpretation, and simulation. Dynamic analysis of piles, the wave equation analysis, dynamic measurements during driving and their interpretation. Caisson design, construction, and integrity techniques. Prerequisite: 14.431 Foundation and Soil Engineering or 14.531 Advanced Soil Mechanics.

### 14.531 Advanced Soil Mechanics

(3-0)3 Theories of soil mechanics and their application. Drained and undrained stress-strain and strength behavior of soils. Lateral earth pressures, bearing capacity, slope stability, seepage and consolidation. Lab and in situ testing. Prerequisite: 14.531 Advanced Soil Mechanics or both 14.330 Soil Mechanics and 14.331 Foundation and Soil Engineering

### 14.532 Theoretical Soil Mechanics

(3-0)3 Development and solution of the theories important in geotechnical engineering. Analytical and approximate methods of solution including finite element and finite difference. Elasticity theory for stress distributions. Upper and lower bound theory applied to retaining structures and shallow foundations. Soil structure interaction. See page and consolidation theory. Prerequisite: 14.531 Advanced Soil Mechanics or both 14.330 Soil Mechanics and 14.331 Foundation and Soil Engineering.

### 14.533 Advanced Foundation Engineering

(3-0)3 Design and analysis of shallow foundations, excavations and retaining structures including: site exploration, bearing capacity and settlement theories, earth pressures, braced and unbraced excavations, rigid and flexible retaining structures. Prerequisite: 14.431 Foundation and Soil Engineering or 14.531 Advanced Soil Mechanics.

### 14.534 Soil Dynamics and Earthquake Engineering

(3-0)3 Effects of dynamic loading on foundations and earth structures. Single and multiple degree-of-freedom systems. Modal analysis. Basic seismology. Stress-strain and strength behavior of soils during cyclic and dynamic

loading, including liquefaction. Soil amplification. Effect of earthquakes on retaining walls and dams. Dynamically loaded foundations. Prerequisites: 14.531 Advanced Soil Mechanics and 92.231 Calculus III.

**14.536 Soil Engineering** (3-0)3

The study of soil as an engineering material and its use in earth dams, road embankments, flow control, compacted fills and landfill design. Topics include: stability of slopes, unconfined flow, drains and filters, dewatering, geotechnical instrumentation and ground improvement methods. Prerequisite: 14.431 Foundations and Soils or 14.531 Advanced Soil Mechanics.

**14.537 Experimental Soil Mechanics**

(3-0)3 Application of testing procedures to the evaluation of soil type and engineering properties. Testing for classification, permeability, consolidation, direct and triaxial shear and field parameters. The technical procedures are followed by data analysis, evaluation and presentation. Critical examination of standard testing procedures, evaluation of engineering parameters, error estimation and research devices. Prerequisite: 14.531 Advanced Soil Mechanics or 14.431 Foundations and Soils.

**14.538 Soil Behavior** (3-0)3 Study of the physico-chemical and mechanical behavior of soil. Topics include: soil mineralogy, formation, composition, concepts of drained and undrained stress-strain and strength behavior, frozen soils. Prerequisite: 14.531 Advanced Soil Mechanics.

**14.540 Urban Transportation Planning**

(3-0)3 Study the characteristics and current issues of urban transportation in the United States (both supply and demand). Develop an understanding of the objectives and procedures of the urban transportation planning process. Study techniques of analysis, prediction and evaluation of transportation system alternatives. Consider the importance of economic, environmental, ethical, social and safety impacts in the design and analysis of transportation systems. Prerequisite: 14.340 Transportation Engineering or equivalent.

**14.541 Traffic Engineering** (3-0)3

Traffic Engineering examines the planning, geometric design and traffic operations of roads, their networks, terminals, abutting lands, and relationships with other modes of transportation. It looks at measuring traffic and travel, the study of basic laws relating to traffic flow and generation, and the application of the knowledge to the professional practice of planning, designing and operating traffic systems to achieve safe and efficient movement of persons and goods. The practice of traffic engineering can be divided into five major functional areas: Transportation Planning, Study of Traffic Characteristics, Geometric Design, Traffic Operations and Control, and Administration. Prerequisites: 14.340 Transportation Engineering or equivalent.

**14.542 Intelligent Transportation Systems**

**Seminar** (3-0)3 In response to environmental, institutional, right-of-way, and fiscal constraints, intelligent transport systems embody a shift from the expansion of the transportation infrastructure to the optimization of the existing network generation through integration with advanced electronics, computers, and communications. Hallmark benefits include:

- Reduced congestion and improved traffic flow.
- Safer roads and faster emergency response.
- Seamless integration of transportation modes.

•More efficient and productive commercial transport sectors. The seminar on Intelligent Transportation Systems (ITS) focuses on the various new methods and technologies, from vehicle safety controls to traffic information and motorist assistance. The proposed technologies have important implications for the design, operation, and management of the transportation system. The state of the research, for the most mature technologies, has progressed from proposals to field tests. Experience with such systems in various countries is discussed. Prerequisites: 14.540 Urban Transportation Planning or 14.541 Traffic Engineering or permission of the instructor.

**14.543 Traffic Principles for Intelligent Transportation Systems** (3-0)3

The objective of this course is to introduce the student to the traffic principles that are pertinent for the planning, design and analysis of Intelligent Transportation Systems (ITS). The course is oriented toward students that come from different disciplines and who do not have previous background in traffic or transportation principles. It is designed as an introductory course that will enable the student to pursue more advanced courses in transportation systems subsequently. Prerequisites: 92.234 Differential Equations and 14.286 Probability and Statistics for Engineers or equivalent.

**14.544 Transportation Planning Practice**

This course reviews the characteristics and issues associated with transportation in the United States. It investigates the basic components of transportation systems and their relationship to land use activity. Principal topics covered: history of urban transportation; Capacity analysis; ISTE; Intermodal freight transportation; Public transportation; Intelligent transportation systems; travel demand forecasting concepts and techniques; Air quality requirements; Public involvement. The course includes a term project in which the student can practice the concepts covered in the course in a hypothetical situation. This course can substitute 14.540 for satisfying core course requirements.

**14.545 Public Transit: Planning & Design** (3-0)3

Planning and design of public transportation systems and the technical, operational and cost characteristics of the various transit

modes. Class discussions on: the impact of public transportation on urban development; the different transit modes, including regional and rapid rail transit (RRT), light rail transit (LRT), buses, and paratransit, and their relative role in urban transportation; performance of transit systems (service frequency and headway, speed, capacity, productivity, utilization, etc.); routes and networks; scheduling; terminal layout; innovative transit technologies and their feasibility. Prerequisites: 14.540 Urban Transportation Planning or 14.541 Traffic Engineering or permission of the instructor.

**14.548 Pavement Design** (3-0)3

Fundamentals of planning, design, construction and management of roadway and airport pavements. Introduction to the theory and the analytical techniques used in pavement engineering. Principal topics covered: pavement performance, analysis of traffic, pavement materials; evaluation of subgrade; flexible and rigid pavement structural analysis; reliability design; drainage evaluation; design of overlays; and pavement distresses. Prerequisites: 14.340 Transportation Engineering and 14.330 Soil Mechanics or equivalent.

**14.547 Airport Planning and Design** (3-0)3

An airport encompasses a wide range of activities with different and often conflicting requirements. This necessitates the development of different levels of planning and design of airport facilities, which are discussed in this course. Main topics covered: Forecasting of aeronautical demand; aircraft characteristics; analysis of wind data and runway orientation; runway capacity and air separation criteria; terminal system design; access system and parking lots; financing of airports and future aviation issues. The course includes a term project where the main features of an airport (airside and landside components) are designed. Prerequisites: 14.340 Transportation Engineering.

**14.548 Traffic management and Control**

(3-0)3 The course presents modern methods of traffic management, traffic control strategies and traffic control systems technology. Main topics covered, include: transportation systems management (TSM) strategies; available and emerging traffic control systems technology; control concepts - urban and suburban streets; control and management concepts - freeways; control and management concepts - integrated systems; traveler information systems; system selection, design and implementation; systems management; ITS plans and programs. The course will also include exercises in the use and application of traffic simulation and optimization models such as NETSIM, TRANSYT and MAXBAND/ MULTIBAND. Prerequisites: 14.541 Traffic Engineering or equivalent.

**14.549 Traffic Flow Theory** (3-0)3

Traffic flow theory seeks to describe through

precise mathematical models (a) the interactions between the vehicle and the roadway system and (b) interactions between vehicles. Traffic flow theory forms the basis of all the models and procedures used in design and operational analysis of streets and highways. The course examines the fundamental traffic flow characteristics: time headway, flow, time-space trajectories, speed, distance headway and density. In depth treatment of related analytical techniques including traffic stream modeling at both microscopic and macroscopic levels, supply and demand analysis, shock wave analysis, queuing analysis and simulation modeling of traffic systems.

Prerequisites: 14.541 Traffic Engineering and 14.522 Statistical Applications in Civil Engineering or 14.583 Stochastic Concepts.

#### **14.550 Behavior of Structures** (3-0)3

The use of classical and stiffness methods for analysis of structures under static loading, and the study of the effect of dynamic loading on structures. Behavior of structures, under static and dynamic loading, is emphasized in the course. Prerequisites: 14.350 Structural Analysis.

#### **14.551 Design of Steel Structures** (3-0)3

Elastic and plastic design of structural steel systems, residual stresses, local buckling, beam-columns, torsion and biaxial bending, composite steel-concrete members, load and resistance factor design. Prerequisites: 14.452 Steel Design.

#### **14.552 Behavior of Reinforced Concrete Structures** (3-0)3

Review of strength design methods for flexure and shear, anchorage, torsion, deep beams, slender columns and beam columns, deflections, slabs and walls. Prerequisites: 14.352 Reinforced Concrete Design.

#### **14.553 Wood Structures** (3-0)3

Review of properties of wood, lumber, glued laminated timber and structural-use panels. Review of design loads and their distribution in wood-frame buildings. Design of wood members in tension, compression and bending; design of connections. Prerequisites: 14.350 Structural Analysis.

#### **14.554 Prestressed Concrete Design**

(3-0)3 An introductory course in the analysis and design of prestressed concrete structures. ACI/PCI Code applications. Prerequisites: 14.352 Reinforced Concrete Design.

#### **14.556 Finite Element Analysis** (3-0)3

Direct and variational methods are used to derive equations for structural elements. Static and dynamic problems are analyzed. Prerequisites: 14.350 Structural Analysis.

#### **14.557 Structural Dynamics** (3-0)3

Analysis of typical structures subjected to dynamic force or ground excitation using direct integration of equations of motion, modal analysis and approximate methods. Prerequisites: 14.350 Structural Analysis, 14.352 Reinforced Concrete Design and 14.452 Steel Design.

**14.558 Bridge Design** (3-0)3 Analysis and design of modern bridges, using computer software for the 3-D modeling of sample bridges under dead and live loading and seismic excitation. AASHTO specifications are used for the design of superstructures and substructures (abutments, piers, and bearings) under group load combinations. Prerequisites: 14.350 Structural Analysis, 14.352 Reinforced Concrete Design and 14.452 Steel Design.

**14.559 Advanced Projects in Structural Engineering** (3-0)3 Studies of topics of special interest and need of the students in structural analysis and/or design. Prerequisites: Permission of the instructor.

#### **14.561 Physical Chemical Treatment Processes** (3-0)3

The course develops the theories of physical-chemical processes used in water and wastewater treatment. Topics include adsorption processes, solubility and precipitation, heavy metal removal, aeration and gas transfer, mixing and corrosion control. Students are encouraged to use computers in solving homework problems. Prerequisites: 84.121 Chemistry I, 84.122 Chemistry II, 14.301 Fluid Mechanics and 14.362 Environmental Engineering I.

Prerequisites: 84.121 Chemistry I, 84.122 Chemistry II, 14.301 Fluid Mechanics and 14.362 Environmental Engineering I.

#### **14.562 Physical and Chemical Hydrogeology** (3-0)3

Well hydraulics for the analysis of groundwater movement. A review of the processes of diffusion, dispersion, sorption, and retardation as related to the fate and transport of organic contaminants in groundwater systems. Factors influencing multi-dimensional contaminant plume formation and migration are addressed. It is the goal of this course to provide environmental scientists and engineers with the technical skills required to understand groundwater hydrology and contaminant transport within aquifers. A term paper and professional presentation in class regarding a relevant topic is required. Prerequisites: 84.121 Chemistry I, 84.122 Chemistry II, 92.131 Calculus I, 92.132 Calculus II and 95.141 Physics I.

#### **14.564 Computer Hydraulics and Hydrology** (3-0)3

Advanced course in civil engineering hydraulics and hydrology. Development of skills and familiarization with pressure conduit and open channel hydraulic models and Corps of Engineer and Soil Conservation Services, hydrology programs. Prerequisites: 14.301 Fluid Mechanics and 14.460 Water Resources Engineering.

#### **14.565 Industrial Waste Treatment Processes** (3-0)3

The course introduces the unit operations most commonly encountered in industrial waste treatment. Unit operation theory is first developed and then methods for data collection and data analysis are established. Specific industrial applications will be covered after an understanding of each unit operation has been developed. Each student will be required to select a specific industrial waste problem and conduct a literature search for information related to identify waste treatment problems and their solu-

tions regarding the selected industry. A formal research report will be generated and results will be presented in class. Prerequisites: 14.362 Environmental Engineering I.

#### **14.567 Environmental Chemistry I**

(3-0)3 The environmental chemistry course sequence, Environmental Chemistry I and II, provide the essentials of chemistry needed for the study and practice of environmental science and engineering. The courses are not sequential. Environmental Chemistry I is a foundation course in inorganic equilibrium chemistry needed for advanced study of water and wastewater treatment processes and an understanding of chemical processes that occur in ground and surface waters. Basic concepts are taught utilizing, as examples, conventional water and waste treatment processes, e.g. precipitation and disinfection and reactions that can occur in clean and polluted waters. Subjects include dilute aqueous solution chemistry of acid-base and oxidation-reduction reactions, chemical thermodynamics and kinetics and coordination chemistry. Prerequisites: 84.121 Chemistry I, 84.122 Chemistry II, 92.131 Calculus I and 92.132 Calculus II.

#### **14.568 Environmental Chemistry II**

(3-0) The fate of contaminants in the environment is controlled by transport processes within a single medium and between media. The similarities in contaminant dispersion within air, surface water and groundwater will be emphasized. Interphase transport processes such as volatilization and adsorption will then be considered from an equilibrium perspective followed by the kinetics of mass transfer across environmental interfaces. A professional presentation of a select paper or group of papers concerning a course topic is required. Prerequisites: 84.121 Chemistry I, 84.122 Chemistry II, 92.131 Calculus I, 92.132 Calculus II and 95.141 Physics I.

#### **14.569 Advanced Projects in Water Resources** (3-0)3

Studies of topics of special interest and need of students in environmental engineering and water resources design.

#### **14.570 Small and Alternative Waste Water Treatment** (3-0)3

The era of massive subsidies for construction of sanitary sewers and centralized publically operated treatment works (POTWs) has passed. Non-point pollution from sources such as onsite disposal systems has become a major focus of concern in our efforts to protect and improve ground and surface water quality. Much of the new construction in areas not already served by centralized collection and treatment must use the alternative technologies. The course is design oriented. The variously available technologies are studied in depth. Students evaluate various technologies as they may be applied to a complex problem for which information is available, and develop an optimum problem solution. Prerequisites: 14.362 Environmental Engineering I.

**14.571 Surface Water Quality Modeling** (3-0)3 Theory and application of surface water quality modeling will be combined interactively throughout the course. Data from a stream will be utilized in order to bring a public domain model into operation. Prerequisites: 14.362 Environmental Engineering I and 14.460 Water Resources Engineering.

**14.572 Marine and Coastal Processes** (3-0)3 This course focuses on the coastal dynamics of currents, tides, waves, wave morphology and their effects on beaches, estuaries, mixing and sediment transport/accretion processes. Generalized global aspects of atmospheric and hydrospheric interactions with ocean currents are also presented. Prerequisites: 84.121 Chemistry I, 84.122 Chemistry II, 92.131 Calculus I and 92.132 Calculus II.

**14.573 Municipal, Industrial and Hazardous Waste Management** (3-0)3 Characterization, handling and disposal of municipal, industrial and hazardous wastes. Technologies such as landfills, recycling, incineration and composting are examined. A term paper and professional presentation in class regarding a relevant topic is required. Prerequisites: 84.121 Chemistry I, 84.122 Chemistry II, 92.131 Calculus I, 92.132 Calculus II and 95.141 Physics I.

**14.574 Air Quality Modeling** (3-0)3 This course will focus on computer application of air dispersion models. A basic understanding of the processes governing air pollution is desirable but not essential. Students will be expected to exercise gaussian plume models developed by the U.S. Environmental Protection Agency; in addition, spreadsheet calculations will be used for some analyses.

**14.575 Groundwater Modelling** (3-0)3 Groundwater Modeling is designed to present the student with fundamentals, both mathematical and intuitive, of analytic and numeric groundwater modeling. An introductory course in groundwater hydrology is a prerequisite for Groundwater Modeling, and the student should be familiar with IBM computers in running text editors and spreadsheets. The semester will start with basic analytic solutions and image theory to aid in the development of more complex numeric models. Emphasis will then switch to numeric groundwater flow models (MODFLOW) and the use of particle tracking models (GWPATH) to simulate the movement of solutes in groundwater. The numeric modeling process will focus on forming the problem description, selecting boundary conditions, assigning the model parameters, calibrating the model, and preparing the model report. Course topics include: Analytic Methods, Numeric Methods, Conceptual Model and Grid design, Boundary Conditions, Sources, and Sinks, and Particle Tracking.

**14.581 Methods of Systems Analysis** (3-0)3 The course presents methods of operations

research, management science and economic analysis that are used in the design, planning and management of systems. Main topics covered, include: the systems approach, mathematical models of quantitative decision problems, optimization concepts, network models, project planning and scheduling, decision analysis, queuing systems, economic evaluation. The examples and problems presented in the course illustrate how the analysis methods are used in a variety of systems applications, such as: civil engineering, environmental systems, transportation systems, construction management, water resources, urban development, etc.

**14.583 Stochastic Concepts** (3-0)3 Effects of uncertainty in engineering design and decision making. Emphasis on practical applications of mathematical principles and tools of probability and statistics to problems in civil engineering. Prerequisites: 14.386 Statistics for Science and Engineering.

**14.590 Design and Analysis of Waste Containment Systems** (3-0)3 Proficiency in the design and analysis of systems for temporary storage and permanent disposal of wastes has become necessary for professionals involved in various technical aspects of environmental management. This course will cover the regulatory framework, design techniques and numerical analyses of several types of containment systems. The major sub-topics are: Regulations and Policies that Pertain to Containment System Design; Types and Functions of Containment Systems; Selection of Potentially Effective Systems; Design and Analysis of Landfills; Storage Tanks and Surface Impoundments; Slurry Walls and Grout Curtains; Other Containment Systems, e.g., Cryogenic Barriers, Peripheral Compaction and Ground Covers.

Prerequisites: Students are expected to be proficient in simple computational methods, undergraduate level statistics, soil mechanics or engineering geology. Prior experience of practicing environmental personnel in relevant projects provides a good background for this course.

**14.591 Geohazards and Environmentally Sensitive Facilities and Environments** (3-0)3 Geohazards such as storms, earthquakes, floods, subsidence and global warming have significant impacts on the stability of constructed waste management facilities. This course is focused on the analysis of the characteristics of geohazards and sensitive environments in which they may occur. Approaches to mitigating environmental damages are also analyzed. The major sub-topics are: Types and distribution of sensitive geological environments; Spatial and temporal risk analysis for site zonation and selection, and facility design; Analysis of potential failure modes in seismic zones, permafrost, wetlands, floodplains, karst and subsiding areas; Airphoto interpretation and site characterization techniques; Design modifications to

counteract geohazards. Prerequisites: Successful completion of an undergraduate course in physical geography, or geology/geomorphology, and soil mechanics (or geotechnical engineering) or engineering geology.

**14.592 Advanced and Innovative Concepts in Waste Containment** (3-0)3 The development of effective schemes for controlling human and environmental exposure to stored contaminants in constructed systems such as landfills, radioactive waste repositories and liquid waste storage tanks requires integrated analyses. This course covers: Integration of ecosystem, toxicological and geotechnical risks; Modeling of one-dimensional extraction of contaminants in barriers; Application of reliability techniques; Principles and design of biokinetic, cryogenic, rhizo, reactive (attenuative), capillary and electrokinetic barriers; Analysis and design of mitigative geotechnical foundations for radon intrusion control, and buildings on contaminated/reclaimed sites. Prerequisites: Successful completion of 14.590, Calculus I and an undergraduate course in soil mechanics is required prior to enrollment in this course.

**14.593 Physico-Chemical Interactions in Earthen Barriers** (3-0)3 This course focuses on the mechanisms by which chemical contaminants react with earthen components of containment systems. The objective is to explore physico-chemical phenomena that may occur at the microscopic scale but have macroscopic physical manifestations which could determine the long term performance of waste containment systems. The effects of physico-chemical interactions on barrier characteristics such as permeability, contaminant distribution coefficient and diffusion coefficient are analyzed. Some of the major sub-topics covered are: Earthen barrier mineralogy and crystal chemistry; Thermodynamic basis for contaminant retardation, barrier material flocculation, dissolution, leaching and weathering; Application of microscopy and other imaging techniques; Hydrothermal alteration and mercury porosimetry. Prerequisites: Students are expected to have completed an advanced undergraduate class in physical chemistry or soil chemistry. Prior completion of 14.567, Environmental Chemistry I or concurrent enrollment is encouraged.

**14.594 Fundamentals of Contaminated Site Treatment Techniques** (3-0)3 This course focuses on the principles of hazardous waste site assessment and treatment using physical and chemical remediation technologies. Both established and emerging remediation technologies will be addressed. Among the topics covered are: Site contamination scenarios; Site characterization techniques; Contaminant release mechanism; Exposure assessment; Site ranking techniques; Waste classification; Solidification/stabilization; Oxidation/reduction; Thermal treatment; In-situ vitrification; and Hydraulic fracturing.

(Additional technologies are covered in Course 14.595.) Prerequisites: Completion of two semesters of Introductory Chemistry is required. Previous completion of courses in basic-level environmental engineering, soil science, or engineering geology is also an advantage. Students are expected to be proficient in basic computational methods. Prior experience of practicing environmental personnel in relevant projects provides a good background for this course.

**14.595 Hazardous Waste Site Remediation** (3-0)3 This course focuses on the principles of hazardous waste site remediation (with an emphasis on organic contaminants) using physical, chemical or biological remediation technologies. Both established and emerging remediation technologies including: bioremediation, intrinsic remediation, soil vapor extraction (SVE), in situ air sparging (IAS), vacuum-enhanced recovery (VER), application of surfactants for enhanced in situ soil washing, hydraulic and pneumatic fracturing, electrokinetics, in situ reactive walls, phytoremediation, and in situ oxidation, will be addressed. A term paper and professional presentation in class regarding a relevant topic is required. Prerequisites: 84.121 Chemistry I, 84.122 Chemistry II, 92.131 Calculus I, 92.132 Calculus II, 95.141 Physics I and 14.562 Physical and Chemical Hydrogeology is highly recommended.

**14.651 Special Topics in Civil Engineering** (3-0)3 Course content and credits to be arranged with instructor who agrees to direct the student.

**14.693 Individual Projects in Civil & Environmental Engineering** (3-0)3

**14.705 Supervised Teaching in Civil & Environmental Engineering** (3-0)3

**14.733 Master's Project in Civil Engineering** (3-0)3

**14.743, 6 Master's Thesis in Civil Engineering** (3-0)3, (6-0)6

## MASTER OF SCIENCE IN ENVIRONMENTAL STUDIES

*Department Head and Graduate Coordinator*

**William B Moeller**

Professor of Civil Engineering; B.S., Villanova University; M.S., Ph.D., University of Connecticut, P.E.

*Associated Faculty:*

**Clifford J. Bruell**

Professor of Civil Engineering, B.S., Lowell Technological Institute; M.S., University of Lowell; Ph.D., University of Connecticut.

**Michael Carter**

Associate Professor of Economics, Ph.D., Stanford University

**Frank P Colby, Jr.**

Associate Professor of Environmental and Atmospheric Sciences; B.S., University of Michigan; M.S., Ph.D., Massachusetts Institute of Technology.

**Michael J. Ellenbecker**

Professor of Work Environment, SC.D., Harvard School of Public Health.

**Clayton S. French**

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**Kenneth Geiser**

Associate Professor of Work Environment; B.Arch., University of California, Berkeley; M.C.P., Ph.D., University of Massachusetts.

**Robert Gamache**

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**Dan S. Golomb**

Associate Professor of Environmental, Earth and Atmospheric Sciences; M.Sc., Ph.D., Hebrew University, Jerusalem.

**Hillary I. Inyang**

University Professor; B.S.,(Geology), University of Calabar; B.S. (C.E.), M.S., North Dakota State University; Ph.D., Iowa State University.

**Supriya Lahiri**

Associate Professor of Economics, B.A., Presidency College (India); M.A., Ph.D., University of Delhi.

**Arnold L. O'Brien**

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**Charles R. Ott**

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**Stephen A. Pennell**

Associate Professor of Mathematics; B.S., Rensselaer Polytechnic Institute; Sc.M., Ph.D., Brown University.

**Burton A. Segall**

Professor of Civil Engineering; B.C.E., Polytechnic Institute of Brooklyn; M.S., M.P.H., University of North Carolina; Ph.D., New York University, P.E.

**Susan Woskie**

Associate Professor of Work Environment, Ph.D., Clark University.

(Semester schedules, curriculum changes and new courses visit us at <http://www.eng.uml.edu/Dept/civ>)

**MASTER OF SCIENCE DEGREE PROGRAM**

This interdisciplinary program offers a Master of Science in Environmental Studies with a thesis or a non-thesis track. Enrollment in the program is open to individuals with a baccalaureate degree in technology, biology or a physical science. Others may be admitted with the approval of the Graduate Coordinator. Such students may make up course prerequisite deficiencies while in the program, although those credits will not count toward the total required for the master's degree. Frequently, students entering the program are required to take a number of undergraduate courses to develop analytical skills and to prepare for advanced level course work. Undergraduate courses may include calculus, statistics, chemistry, computer programming or courses designed to develop problem-solving skills. Course requirements are determined by discussion with the Program Coordinator.

The thesis track requires completion of an approved program of study involving a minimum of 24 credits of core courses and electives, and 6 credits of thesis, consisting of laboratory research or scholarly investigation, for a total of 30 credits. Students may only register for thesis research with the prior approval of a thesis advisor. The thesis work is to be guided by a principal advisor who is a member of the University of Massachusetts Lowell faculty and by two additional committee members, at least one of whom must be a member of the faculty. Committee selection and the thesis topic are subject to the approval of the graduate coordinator.

The non-thesis track requires completion of an approved program of study involving 30 credits of core courses and electives. All individual programs of study must include the core courses listed below:

**Core Courses**

- 18.510 Water Resources Management
- 14.573 Municipal, Industrial and Hazardous Waste Management
- 18.523 Air Pollution Control or
- 18.571 Air Pollution Phenomenology

**Elective Courses**

- 14.509 Environmental/Engineering Geology
- 14.561 Physical and Chemical

- Treatment Processes
- 14.562 Physical and Chemical Hydrogeology
- 14.564 Advanced Water Resources
- 14.567 Environmental Chemistry I
- 14.568 Environmental Chemistry II
- 14.570 Small and Alternative Wastewater Treatment
- 14.571 Surface Water Modeling
- 14.572 Marine and Coastal Processes
- 14.574 Air Quality Modeling
- 14.575 Groundwater Modeling
- 14.595 Hazardous Waste Site Remediation
- 18.501 Wetlands Ecology
- 18.502 Limnology
- 18.503 Environmental Toxicology and Risk Assessment
- 18.505 Glacial Geology
- 18.511 Environmental Soil Science
- 18.512 Geology and Evaluation Techniques
- 18.516 Topics in Geomorphology
- 18.517 Soil Physics
- 18.519 Introduction to Microbiology
- 18.525 Epidemiology for Environmental Studies
- 18.527 Environmental Laws
- 18.530 Environmental and Natural Resource Economics
- 18.571 Air Pollution Phenomenology
- 18.572 Energy and the Environment
- 18.575 Physical Chemistry for Environmental Studies
- 18.576 Boundary layer Meteorology
- 18.577 Remote Sensing of the Atmosphere
- 18.578 Advanced Synaptic Meteorology
- 18.580 Implementation of Environmental Policy
- 18.581 Understanding the Massachusetts Contingency Plan
- 84.519 Environmental Chemistry III

**PH.D. PROGRAM IN CHEMISTRY ENVIRONMENTAL STUDIES OPTION**

A Ph.D. in Chemistry with an option in Environmental Studies is offered jointly by the Department of Chemistry and the Department of Civil Environmental Engineering. The program is described in detail in the Chemistry Department section of this catalog.

**COURSE DESCRIPTIONS**

**18.501 Wetland Ecology** (3-0)3  
Types, characteristics and definitions, func-

tions and values, regulation and management of wetlands; with due regard given to geology, soils and hydrology, and biological/ecosystem interactions.

**18.502 Limnology** (3-0)3 Study of functional relationships and productivity of freshwater communities as affected by physical, chemical and biological components of the environment. Emphasis on lakes and ponds, man-made stresses on systems, tools for diagnosis and restoration.

**18.503 Environmental Toxicology and Risk Assessment** (3-0)3 Basic toxicological principles, spectrum of effects with emphasis on mammals, predicting fate of chemicals, assessing potential exposure, prediction of exposures. Case studies of major health hazards, issues of regulation. Strong interdisciplinary approach.

**18.505 Glacial Geology** (3-0)3 The course will examine how study of nature, origin and history of glacial events can allow the residual soils and landforms to be dealt within a meaningful comprehensive manner in investigations of groundwater, environmental and engineering problems.

**18.510 Water Resources Management** (3-0)3 Concepts and methodologies of hydrology, constraints and objectives of water resources management, and the interrelationship between hydrologic and managerial components of water resource issues. Case studies are reviewed and discussed.

**18.511 Environmental Soil Science** (3-0)3 Prerequisite: introductory chemistry. Discussion of physical, chemical and biological soil properties in relation to environmental issues. Principles of soil physics, soil mineralogy, soil formation and classification, soil fertility, soil management and mineralogy. Role of soils in agronomic systems, wastewater disposal, and wetland delineation. Impact of land use and associated practices on soil pollution and related water quality issues.

**18.512 Geology and Evaluation Techniques** (3-0)3 The course will examine the application of techniques such as seismic, resistivity, and gravimetric testing for the analysis and evaluation of various geologic conditions.

**18.516 Topics in Geomorphology** (3-0)3 A study of selected physical and chemical processes at work on the earth's surface which result in the formation and development of landforms. Emphasis is placed on understanding processes and the application of that knowledge to environmental problems.

**18.517 Soil Physics** (3-0)3 Physical properties of soils and how they relate to the movement of water, solutes, and contaminants in saturated and unsaturated soils. Methods of measuring and characterizing physical properties of soils. Applications to environmental problems, including land-based disposal systems, hazardous waste site investigation and remediation, and soil-water management.

**18.519 Introduction to Microbiology** (3-0)3 An introductory course focusing on

the significance of micro-organisms in man's environment, and the physical, chemical and biological processes governing their behavior and fate in ecosystems.

**18.523 Air Pollution Control** (3-0)3

Air pollutants, their sources, emission rates, ambient concentrations, effects on health, animals and vegetation including aquatic life. The Clean Air Act, National Ambient Air Quality Standards, New Source Performance Standards, Prevention of Significant Deterioration. Monitoring at emission sources and in the ambient; exceedances and enforcement. Air pollution modeling as a tool of permitting and enforcement. Emission control technologies and strategies. Local, regional and global air resources management.

**18.525 Epidemiology for Environmental Studies** (3-0)3

The study of the distribution and determinants of disease in human population and how these diseases are disseminated by environmental changes. The methods used in conducting epidemiological investigations including descriptive analytical and experimental studies, patient care and cohort studies.

**18.527 Environmental Laws** (3-0)3

The large body of law which has developed since the early 1960's is examined in considerable detail. Federal laws relating to the environment, particularly with the Environmental Protection Agency and the Occupational Safety and Health Acts. State and local laws and ordinances are discussed where pertinent.

**18.530 Environmental and Natural Resource Economics** (3-0)3

The development of concepts and methods of economic analysis with a view toward their application for preserving the environment. An analysis of economic growth and the usage of depletable resources. Appraisal of quantitative methods for measuring environmental damage and the cost of abatement.

**18.571 Air Pollution Phenomenology** (3-0)3

Air pollutants: their sources, emission rates, ambient concentrations and trends. National and international standards for emissions and ambient concentrations. Air pollution meteorology: atmospheric structure and dynamics. Air pollutant dispersion and transport. Photo-oxidant pollutants: precursors and products. Particular matter: primary and secondary particles, their dispersion, transport and deposition on a local and regional scale, including regional haze (visibility impairment). Acid deposition: precursors and products, their transport, dispersion, dry and wet deposition. Global air pollution, e.g. stratospheric ozone depletion and greenhouse effect.

**18.572 Energy and the Environment**

(3-0)3 Laws that govern the conversion of energy from one form to another. Flow of energy in our present industrial society from extraction through transport and conversion to end use. Electricity: generation from fossil

fuel, nuclear, hydro, solar and other sources; its distribution and end use. Air, water and soil pollution from all sources of energy on a local, regional and global scale. Amelioration of environmental effects by emission control, fuel switching, renewable energy and conservation.

**18.573 Air Pollution Laboratory** (1-4)3

Instruments and apparatus applied to monitoring and chemical analysis of air pollutants, gaseous and particles (aerosols). Physico-chemical fundamentals of air pollutant monitoring and analysis. Standard monitoring of "criteria" pollutants (CO, O<sub>3</sub>, NO<sub>x</sub>, SO<sub>2</sub>, total hydrocarbons, size-fractioned particles) and other pollutants (lead and other metal vapors, speciated organic compounds). Analytical techniques (gas chromatography, chemiluminescence, mass-spectrometry, flame ionization, atomic and molecular emission and absorption spectroscopy). Data collection, archiving and analysis. Use of data in air pollution modeling.

**18.575 Physical Chemistry for**

**Environmental Studies** (3-0)3 Physical chemistry principles related to environmental systems, processes and measurements. Topics include thermodynamics, thermochemistry, collision processes, chemical kinetics in the gaseous phase and solution, including heterogeneous reactions and catalysis, oxidation-reduction, electrochemistry, changes of state, adsorption, absorption, diffusion and osmosis, atomic and molecular structure, atomic and molecular spectroscopy.

**18.580 Implementation of Environmental Policy** (3-0)3

Development and analysis of information on policy issues; development of strategies for implementation. Case studies, practitioner seminars and student projects employed.

**18.581 Understanding the Massachusetts Contingency Plan** (3-0)3

The Massachusetts Contingency Plan (MCP) is a body of regulations designed to streamline and accelerate the assessment and cleanup of releases of oil and hazardous materials to the environment. This course serves as an introduction to the MCP and will explore the intent and use of key aspects of this working document. Though primarily a regulatory course, some topics to be covered are technical by nature. Prerequisites: None. Though not required, some familiarity with relevant environmental science and/or engineering principles is desirable.

Semester schedules, curriculum changes and new courses: visit the Department of Civil and Environmental Engineering's web site at <http://www.eng.uml.edu/Dept/civ>.

**MASTER OF SCIENCE IN ENVIRONMENTAL STUDIES (ATMOSPHERIC SCIENCES CONCENTRATION)**

Enrollment in this program is open to individuals with a baccalaureate degree in sciences, mathematics and engineering.

Others may be admitted with the approval of the Graduate Coordinator. Such students may make up course prerequisite deficiencies while in the program, although these credits will not count toward the total required for the master's degree. Frequently, students entering the program are required to take a number of undergraduate courses to develop the analytical skills, and to prepare for the advanced level courses.

The M.S. program requires the completion of 30 credits, 9 in core courses, and 15 in elective courses listed below. Six credits are achieved by completing a Masters Thesis. The thesis involves original laboratory or theoretical work, usually publishable in accredited and peer reviewed technical journals. With the Graduate Coordinator's approval, the thesis work may be performed at home or at the student's employment facilities. The thesis advisory committee will consist of a Principal Advisor who is the member of EEAS faculty, and two members from CEE, associated faculty or external advisor, the latter with the approval of the Graduate Coordinator. Most of the courses will be offered in the evening, usually from 6 to 9 pm, once per week. This enables working students to complete the course requirements while the student is employed. A maximum of 5 years is allowed for completion of the master's degree, including the thesis.

**Core Courses**

- 85.501 Boundary Layer Meteorology
- 87.575/ Physical Chemistry for Environmental Studies
- 84.575 Chose one of the two following courses:
- 19.527 Environmental Law and Policy
- 49.615 Environmental and Natural Resources Economics

**Elective Courses**

- 85.502 Advanced Synoptic Meteorology
- 85.503 Remote Sensing of the Atmosphere
- 85.511 Solar Terrestrial Relations
- 85.515 Atmospheric Structure and

- Dynamics
- 85.523 Air Pollution Control
- 85.571 Air Pollution Phenomenology
- 85.673/19.617 Air Pollution Laboratory/Measurement of Airborne Contaminants
- 85.674 Air Quality Modeling
- 87.572 Energy and the Environment
- 19.514 Aerosol Science
- 92.550 Mathematical Modeling
- 98.613 Environmental Monitoring and Surveillance (Radionuclides)

## COURSE DESCRIPTIONS

**85.501 Boundary Layer Meteorology** (3-0)3 This course will draw upon the equations of motion in the atmosphere to develop a theoretical understanding of the atmospheric boundary layer. This understanding will be compared with real observations, both taken with the Department's rawinsonde equipment, as well as published data. The emphasis will be on blending theory and practice to enhance the student's understanding of the behavior of the atmosphere.

**85.502 Advanced Synoptic Meteorology** (3-0)3 This course is designed for graduate students who have a strong background in mathematics and physics, but whose meteorology preparation is weak. The basic concepts of weather forecasting and analysis on synoptic scales will be covered both theoretically as well as in application to case studies and current weather. Each student will be required to make 25 forecasts during the course of a semester. This will encourage the development of three-dimensional visualization techniques and an appreciation of weather systems.

**85.503 Remote Sensing of the Atmosphere** (3-0)3 This course is a survey of ground based, balloon, rocket probe, radar and satellite remote sensing techniques. Optical and radio frequency remote sensing techniques are surveyed. The focus is on the determination of physical, chemical and dynamical quantities by remote sensing measurements. The theory presented is used to interpret data obtained by remote sensing techniques.

Various inversion methods discussed are used to obtain spatial discrete quantities from line-of-sight observations. Modeling and simulation techniques are described and practiced.

**85.511 Solar Terrestrial Relations** (3-0)3 As part of the solar system the earth and its atmosphere is coupled through the earth's plasmasphere and magnetosphere to the sun's electromagnetic and corpuscular radiation. Starting with a discussion of the upper atmosphere (mesosphere and thermosphere) the course will develop the photo-ionization processes in the ionosphere, and the ground-based and space techniques for the

exploration of the upper atmosphere. An introduction will be given to the collisionless plasma processes in the magnetosphere leading to the concept of space weather. Solar activity, coronal mass ejection and solar wind effects on the magnetosphere will be introduced, and the phenomena of magnetic storms and their effects on electrical power systems will be explained.

**85.515 Atmospheric Structure and Dynamics** (3-0)3 The temperature, pressure and density structure of the atmosphere are reviewed, as well as the chemical composition. Topics include atmospheric and solar radiation, atmospheric heat budget and the hypsometric equation. Dynamics of the atmosphere explores the behavior of fluids on a rotating earth, global circulation, synoptic scale motions, perturbation theory of wave motions. Elements of climatic change and the effects of anthropogenic emissions on climate and weather will also be discussed.

**85.523 Air Pollution Control** (3-0)3 This course describes air pollutants, their characterization, ambient concentrations, effects on human health and the ecology, and the environmental laws and regulations that set standards on emission rates and ambient concentrations. The basics of air pollutant dispersion and transport are also covered. The main focus of the course is on emission control technologies for particulate matter, carbon monoxide, sulfur oxides, nitrogen oxides, organic and inorganic toxic pollutants. The following technologies are discussed: cyclones, scrubbers, electrostatic precipitators, bag-houses, adsorption, absorption and incineration. The automobile and its emission control are reviewed. Alternative methods are also discussed, such as fuel substitution, conservation and efficiency improvement.

**85.571 Air Pollution Phenomenology** (3-0)3 The course centers on transport, dispersion and transformation of air pollutants in the atmosphere. The atmospheric structure and dynamics are reviewed. The atmospheric dispersion equation is developed for instantaneous and steady state releases of pollutants, including the Gaussian Plume Equation for point, line and area sources. The sources and transport of particulate matter are discussed, including haze and visibility impairment. Other topics are photo-oxidants (ozone), acid deposition, stratospheric ozone depletion and the greenhouse effect.

**85.673/19.617 Air Pollution Laboratory/Measurement of Airborne Contaminants** (3-0)3 Prerequisite: 85.571 Air Pollution Phenomenology. This laboratory course is jointly offered by the Departments of EEAS and Work Environment. The student gains practice in operating standard apparatuses for measuring air pollutants in the outdoor and indoor air. The techniques employed are photometry, spectroscopy, chemi-luminescence, mass-spectrometry, gas chromatography and particle collection and analysis.

**85.674 Air Quality Modeling** (3-0)3 This course focuses on computer applications of air dispersion models. Students will be expected to exercise the Gaussian plume models developed by EPA. Also, reactive-dispersion modeling will be practiced, that is, models in which primary pollutants react with themselves, or with atmospheric species to produce secondary pollutants. Examples are acid deposition, photo-oxidant and aerosol models. In addition, spreadsheet calculations will be used for some analyses. A prerequisite to this course is 85.571 Air Pollution Phenomenology.

**87.572 Energy and the Environment** (3-0)3 This course discusses the world and U.S. primary energy resources and consumption, including fossil, nuclear and renewable energy sources. Principles of thermodynamics are reviewed, especially in regard to energy usage efficiency improvement. A significant part of the course is devoted to electricity production, including site visits to fossil and nuclear power plants. The environmental effects are discussed of energy extraction and consumption, such as SO<sub>x</sub>, NO<sub>x</sub> and particulate matter emissions, acid deposition, the greenhouse effect, radioactive waste disposal. Also the risks of accidents are discussed in fossil and nuclear fuel usage.

**87.575/84.575 Physical Chemistry for Environmental Studies** (3-0)3 This course covers the physical chemistry principles that are related to environmental systems, processes and measurements. Topics include fundamental aspects of thermodynamics, thermochemistry, collision processes, chemical kinetics in solution and the gas phase, heterogeneous reaction and catalysis, water chemistry (drinking, ground and waste water), oxidation-reduction, electrochemistry, changes of state, adsorption, absorption, diffusion, osmosis, atomic and molecular structure, atomic and molecular spectroscopy, and radioactivity.

**19.514 Aerosol Science** (3-0)3 This course describes the basic properties of airborne particles, with particular regard to properties important to health. Content includes uniform particle motion, particle collection mechanisms, filtration, particle sampling and analysis, respiratory deposition, particle statistics, electrical and optical properties. The course includes lectures and laboratory practice.

**92.550 Mathematical Modeling** (3-0)3 This course is devoted to studying the application of mathematics to real life problems from the physical, biological, social and behavioral sciences. Experience is provided with a wide variety of models (deterministic, stochastic, simulation, continuous, discrete, axiomatic). Computer use in solving problems is encouraged.

**19.550 Environmental Law and Policy** (3-0)3 Survey of relevant environmental laws and their application to public policy. A framework for understanding environmental

policy will be developed. The course focuses particularly on laws and regulations pertaining to environmental and work place protection. State and local laws and ordinances are also discussed.

**49.615 Environmental and Natural Resources Economics** (3-0)3 This course introduces students to the economic and policy aspects of environmental quality and natural resources issues. Standard benefit cost and efficiency criteria are used to analyze a wide variety of environmental and natural resources problems. Topics covered include basic theory of environmental and natural resource economics; sustainable development; economics of pollution control; economics of renewable and recyclable resources; energy economy and environmental interaction models.

**98.613 Environmental Monitoring and Surveillance (Radionuclides)** (3-0)3 Sources of environmental radioactivity; design of monitoring programs; sampling and analytical measurement programs for specific radionuclides and external radiation sources; analytical equipment and procedures; design of an environmental laboratory; and quality assurance programs.

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