

# Environmental Science (ENSCI)

## Courses primarily for undergraduates:

### ENSCI 110. Orientation to Environmental Science.

(1-0) Cr. 1. F. *Prereq:* Freshman classification in EnSci

Overview of Environmental Science curriculum and discussion of professional opportunities. Offered on a satisfactory-fail basis only.

### ENSCI 201. Introduction to Environmental Issues.

(Cross-listed with BIOL, ENV S). (2-0) Cr. 2. F.S.

Discussion of current and emerging environmental issues such as human population growth, energy use, loss of biodiversity, water resources, and climate change.

### ENSCI 250. Environmental Geography.

(Cross-listed with ENV S). (3-0) Cr. 3. F.

The distribution, origins and functions of the earth's physical systems and the spatial relationship between human activity and the natural world.

### ENSCI 301. Natural Resource Ecology and Soils.

(Cross-listed with NREM). (3-3) Cr. 4. F. *Prereq:* BIOL 211, BIOL 211L; FOR 201 or a second course in biology

Effects of environmental factors on ecosystem structure and function using forest, prairie and agricultural ecosystems as models. Special emphasis is given to soil-forming factors and the role of soil in nutrient and water cycling and ecosystem dynamics. Additional emphasis is given to human influences on natural ecosystems and the role of perennial plant communities in agricultural landscapes. Nonmajor graduate credit.

### ENSCI 312. Ecology.

(Cross-listed with A ECL, BIOL). (3-3) Cr. 4. F.SS. *Prereq:* BIOL 211L and BIOL 212L

Fundamental concepts and principles of ecology dealing with organisms, populations, communities and ecosystems. Laboratory and field exercises examine ecological principles and methods as well as illustrate habitats.

### ENSCI 312I. Ecology.

(Cross-listed with A ECL, IA LL). Cr. 4. SS.

An introduction to the principles of ecology at the population, community and ecosystem level. Field studies of local lakes, wetlands and prairies are used to examine factors controlling distributions, interactions, and roles of plants and animals in native ecosystems.

### ENSCI 345. Natural Resource Photogrammetry and Geographic Information Systems.

(Cross-listed with NREM). (2-3) Cr. 3. F. *Prereq:* Junior classification

Measurement and interpretation of aerial photos in resource management. Introduction to Geographic Information Systems (GIS) using ArcGIS including digitizing, development and query of attribute tables, georeferencing, and use of multiple GIS layers in simple spatial analyses. Nonmajor graduate credit.

### ENSCI 360. Environmental Soil Science.

(Cross-listed with AGRON). (2-3) Cr. 3. S. *Prereq:* AGRON 154 or ENSCI 250 or GEOL 201

Burras. Application of soil science to contemporary environmental problems; comparison of the impacts that different management strategies have on short- and long-term environmental quality and land development. Emphasis on participatory learning activities.

### ENSCI 381. Environmental Systems I: Introduction to Environmental Systems.

(Dual-listed with ENSCI 581). (Cross-listed with BIOL, ENV S, MICRO). Cr. 3-4. F. *Prereq:* 12 credits of natural science including biology and chemistry

Introduction to the structure and function of natural environmental systems. Emphasis on the analysis of material and energy flows in natural environmental systems and the primary environmental factors controlling these systems. Nonmajor graduate credit.

### ENSCI 382. Environmental Systems II: Analysis of Environmental Systems.

(Dual-listed with ENSCI 582). (Cross-listed with BIOL). (2-2) Cr. 3. S. *Prereq:* ENSCI 381

Continuation of EnSci 381. Systems approach to the analysis of material and energy flows in natural environmental systems and the primary environmental factors controlling these systems. Nonmajor graduate credit.

### ENSCI 390. Internship in Environmental Science.

Cr. arr. Repeatable. F.S.SS. *Prereq:* Approval of the Environmental Science coordinator

Supervised off-campus work experience in the field of environmental science. Offered on a satisfactory-fail basis only.

### ENSCI 391. Apprenticeship.

Cr. arr. Repeatable. F.S.SS. *Prereq:* Approval of the Environmental Science Coordinator

Practical experience in an approved setting such as a research laboratory, government office, or private office. Offered on a satisfactory-fail basis only.

### ENSCI 402. Watershed Hydrology.

(Dual-listed with ENSCI 502). (Cross-listed with GEOL, MTEOR, NREM). (3-3) Cr. 4. F. *Prereq:* Four courses in physical or biological sciences or engineering; junior standing

Examination of watersheds as systems, emphasizing the surface components of the hydrologic cycle. Combines qualitative understanding of hydrological processes and uncertainty with quantitative representation. Laboratory emphasizes field investigation and measurement of watershed processes. Nonmajor graduate credit.

### ENSCI 402I. Watershed Hydrology and Surficial Processes.

(Cross-listed with AGRON, IA LL). Cr. 4. SS. *Prereq:* Four courses in physical or biological sciences or engineering

Effects of geomorphology, soils, and land use on transport of water and materials (nutrients, contaminants) in watersheds. Fieldwork will emphasize investigations of the Iowa Great Lakes watershed. Nonmajor graduate credit.

### ENSCI 404. Global Change.

(Dual-listed with ENSCI 504). (Cross-listed with AGRON, MTEOR, ENV S). (3-0) Cr. 3. S. *Prereq:* Four courses in physical or biological sciences or engineering; junior standing

Recent changes in global biogeochemical cycles and climate; models of future changes in the climate system; impacts of global change on agriculture, water resources and human health; ethical issues of global environmental change. Nonmajor graduate credit.

### ENSCI 405. Environmental Biophysics.

(Dual-listed with ENSCI 505). (Cross-listed with MTEOR, AGRON). (3-0) Cr. 3. Alt. S., offered 2013. *Prereq:* MATH 165 or MATH 182 or equivalent and some computer programming experience (any language)

Hornbuckle. A description of the physical microenvironment in which organisms live. Emphasis on the movement of energy (heat and radiation) and mass (water and carbon) among organisms, the soil, and atmosphere. Applications to humans, other animals, plants, and plant communities. Nonmajor graduate credit.

### ENSCI 406. World Climates.

(Cross-listed with MTEOR, AGRON). (3-0) Cr. 3. F. *Prereq:* AGRON 206/MTEOR 206

Arritt. Distribution and causes of different climates around the world. Effects of climate and climate variations on human activities including society, economy and agriculture. Current issues such as climate change and international efforts to assess and mitigate the consequences of a changing climate. Semester project and in-class presentation required. Nonmajor graduate credit. Meets International Perspectives Requirement.

### ENSCI 407. Watershed Management.

(Dual-listed with ENSCI 507). (Cross-listed with NREM, ENV S). (3-3) Cr. 4. S. *Prereq:* A course in general biology

Managing human impacts on the hydrologic cycle. Field and watershed level best management practices for modifying the impacts on water quality, quantity and timing are discussed. Field project includes developing a management plan using landscape buffers.

### ENSCI 408. GIS and Natural Resources Management.

(Dual-listed with ENSCI 508). (Cross-listed with A E). (2-2) Cr. 3. F. *Prereq:* Working knowledge of computers and Windows environment

Introduction to fundamental concepts and applications of GIS in natural resources management with specific focus on watersheds. Topics include: basic GIS technology, data structures, database management, spatial analysis, and modeling; visualization and display of natural resource data. Case studies in watershed and natural resource management using ArcView GIS.

**ENSCI 409. Field Methods in Hydrogeology.**

(Dual-listed with ENSCI 509). (Cross-listed with GEOL). (0-4) Cr. 3. Alt. SS., offered 2012. *Prereq:* GEOL/ENSCI 402 or GEOL/ENSCI 411 or C E 473 Introduction to field methods used in groundwater investigations. In-field implementation of pumping tests, slug tests, monitoring well installation and drilling techniques, geochemical and water quality sampling, seepage meters, minipiezometers, stream gaging, and electronic instrumentation for data collection. Field trips to investigate water resource, water quality, and remediation projects.

**ENSCI 411. Hydrogeology.**

(Dual-listed with ENSCI 511). (Cross-listed with GEOL). (3-2) Cr. 4. F. *Prereq:* Four courses in biological or physical sciences Physical principles of groundwater flow, nature and origin of aquifers and confining units, well hydraulics, groundwater modeling, and contaminant transport. Lab emphasizes applied field and laboratory methods for hydrogeological investigations. Nonmajor graduate credit.

**ENSCI 414. Applied Groundwater Flow Modeling.**

(Dual-listed with ENSCI 514). (Cross-listed with GEOL). (2-2) Cr. 3. Alt. S., offered 2012. *Prereq:* GEOL 411 or C E 473; MATH 165 or MATH 181 Introduction to the principles of modeling groundwater flow systems. Finite-difference and analytic-element methods, spreadsheet models, boundary conditions, calibration, sensitivity analysis, parameter estimation, particle tracking, and post-audit analysis. Application of MODFLOW to regional flow-system analysis. Computer laboratory emphasizes assigned problems that illustrate topics discussed in the course. Nonmajor graduate credit.

**ENSCI 415. Paleoclimatology.**

(Dual-listed with ENSCI 515). (Cross-listed with GEOL). (3-0) Cr. 3. Alt. S., offered 2013. *Prereq:* Four courses in biological or physical science Introduction to mechanisms that drive climate, including the interplay between oceanic and atmospheric circulation and fluctuation in Earth's orbital parameters. Examination and analysis of past climate records ranging from historical documentation to ecological and geochemical proxies (e.g. tree ring analysis; O and C isotopes of skeletal carbonates and soils). Dating methods used to constrain and correlate climatic periods; utility of computer models to reconstruct past climates and predict future climate change. Emphasis placed on paleoclimatology and paleoecology of the late Quaternary (last ~1 million years). Nonmajor graduate credit.

**ENSCI 416. Hydrologic Modeling and Analysis.**

(Dual-listed with ENSCI 516). (Cross-listed with MTEOR, GEOL). (2-3) Cr. 3. Alt. S., offered 2013. *Prereq:* Four courses in Earth science, meteorology, or engineering; junior standing Study of the basic principles of hydrologic modeling, including rainfall-runoff analysis, lumped and distributed modeling, conceptual and physical models, parameter estimation and sensitivity analysis, input and validation data, uncertainty analysis, and the use of models in surface water hydrology. A range of common models are applied to study hydrologic topics such as flood forecasting and land use change impacts. Previous experience with Matlab or other programming language is needed. Nonmajor graduate credit.

**ENSCI 418. Stream Ecology.**

(Dual-listed with ENSCI 518). (Cross-listed with A ECL). (2-3) Cr. 3. Alt. F., offered 2011. *Prereq:* 486 Biological, chemical, physical, and geological processes that determine the structure and function of flowing water ecosystems. Current ecological theories as well as applications to stream management for water quality and fisheries.

**ENSCI 419. Environmental Geochemistry.**

(Dual-listed with ENSCI 519). (Cross-listed with GEOL). (2-2) Cr. 3. F. *Prereq:* GEOL 402 or GEOL 411 or equivalent Geochemistry of natural waters and water-rock interactions. Acid-base equilibria, carbonate chemistry and buffer systems, mineral dissolution and precipitation, sorption, ion exchange, and redox reactions. Introduction to thermodynamics and kinetics. Laboratory emphasizes chemical analysis of waters and computer modeling. Nonmajor graduate credit.

**ENSCI 422I. Prairie Ecology.**

(Cross-listed with IA LL). Cr. 4. SS. *Prereq:* Familiarity with basic principles in biological sciences and ecology Basic patterns and underlying physical and biotic causes of both regional and local distributions of plants and animals of North American prairies; field and laboratory analyses and projects. Nonmajor graduate credit.

**ENSCI 424. Air Pollution.**

(Dual-listed with ENSCI 524). (Cross-listed with C E, A E). (1-0) Cr. 1. *Prereq:* Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above 1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

**ENSCI 424A. Air Pollution: Air quality and effects of pollutants.**

(Dual-listed with ENSCI 524A). (Cross-listed with C E, A E). (1-0) Cr. 1. *Prereq:* Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above 1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

**ENSCI 424B. Air Pollution: Climate change and causes.**

(Dual-listed with ENSCI 524B). (Cross-listed with C E, A E). (1-0) Cr. 1. *Prereq:* Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above 1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

**ENSCI 424C. Air Pollution: Transportation constraints.**

(Dual-listed with ENSCI 524C). (Cross-listed with C E, A E). (1-0) Cr. 1. *Prereq:* Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above 1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

**ENSCI 424D. Air Pollution: Off-gas treatment technology.**

(Dual-listed with ENSCI 524D). (Cross-listed with C E, A E). (1-0) Cr. 1. *Prereq:* Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above 1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

**ENSCI 424E. Air Pollution: Agricultural sources of pollution.**

(Dual-listed with ENSCI 524E). (Cross-listed with C E, A E). (1-0) Cr. 1. *Prereq:* Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above 1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

**ENSCI 426. Stable Isotopes in the Environment.**

(Dual-listed with ENSCI 526). (Cross-listed with GEOL). (3-0) Cr. 3. Alt. F., offered 2011. *Prereq:* Four courses in biological or physical science Introduction to the theory, methods and applications of stable isotopes. Primary focus on the origin, natural abundance, and fractionation of carbon, hydrogen, oxygen, nitrogen isotopes. Applications of isotopic occurrence for elucidation of physical, chemical, biological, and environmental processes. Effects of plant physiology, photosynthesis, trophic structure, diffusion, evaporation, chemical precipitation, soil and atmospheric processes, and environmental factors on isotope abundance. Nonmajor graduate credit.

**ENSCI 434. Contaminant Hydrogeology.**

(Dual-listed with ENSCI 534). (Cross-listed with GEOL). (3-0) Cr. 3. S. *Prereq:* GEOL 411 or equivalent Theory and practical considerations of fate and transport of solutes through porous geologic materials. Organic and inorganic contaminants in industrial and agricultural settings. Subsurface microbiology and biodegradation of aromatic and chlorinated hydrocarbons. Investigation of coupled processes (diffusion, advection, dispersion, sorption, and biodegradation) using computer models. Soil and groundwater monitoring and remediation strategies. Nonmajor graduate credit.

**ENSCI 446. Integrating GPS and GIS for Natural Resource Management.**

(Dual-listed with ENSCI 546). (Cross-listed with NREM). (2-3) Cr. 3. S. *Prereq:* 12 credits in student's major at 300 level or above, NREM 345 or equivalent experience with ArcGIS Emphasis on the use of GPS as a data collection tool for GIS. Basic theory of GPS. Use of Global Positioning System technology for spatial data collection and navigation. Post-processing and real-time correction of GPS data. GPS data transfer to GIS for mapping applications. Use of GIS to construct waypoints for use in GPS navigation.

**ENSCI 451. Applied and Environmental Geophysics.**

(Dual-listed with ENSCI 551). (Cross-listed with GEOL). (2-2) Cr. 3. Alt. S., offered 2012. *Prereq:* GEOL 100 or GEOL 201, MATH 181 or equivalent experience Seismic, gravity, magnetic, resistivity, electromagnetic, and ground-penetrating radar techniques for shallow subsurface investigations and imaging. Data interpretation methods. Lab emphasizes computer interpretation packages. Field work with seismic - and resistivity-imaging systems and radar. Nonmajor graduate credit.

**ENSCI 452. GIS for Geoscientists.**

(2-2) Cr. 3. F. *Prereq:* GEOL 100, GEOL 201 or equivalent Introduction to geographic information systems (GIS) with particular emphasis on geoscientific data. Uses ESRI's ArcGIS Desktop Software and extension modules. Emphasizes typical GIS operations and analyses in the geosciences to prepare students for advanced GIS courses. Nonmajor graduate credit.

**ENSCI 459. Environmental Soil and Water Chemistry.**

(Dual-listed with ENSCI 559). (Cross-listed with AGRON). (3-3) Cr. 4. F. *Prereq:* Two semesters of college-level chemistry, MATH 140, AGRON 154 or AGRON 360; GEOL 100 and AGRON 354 recommended.

Thompson. An introduction to the chemical properties of soils, chemical reactions and transformations in soils and surface waters, and their impact on the environment. Topics include solution chemistry in soils and surface waters, solid-phase composition of soils, reactions at the solid-solution interface, and applications to contemporary environmental issues. Nonmajor graduate credit.

**ENSCI 461I. Introduction to GIS.**

(Cross-listed with IA LL, ENV S, L A). Cr. 4. SS.

Descriptive and predictive GIS modeling techniques, spatial statistics, and map algebra. Application of GIS modeling techniques to environmental planning and resource management. Nonmajor graduate credit.

**ENSCI 463. Soil Formation and Landscape Relationships.**

(Dual-listed with ENSCI 563). (Cross-listed with AGRON). (2-4) Cr. 4. S. *Prereq:* AGRON 154 or AGRON 260

Burras. Relationships between soil formation, geomorphology, and environment. Soil description, classification, geography, mapping, and interpretation for land use. Two weekend field trips. Nonmajor graduate credit. Credit for one of AGRON 463 or AGRON 463I may be applied for graduation.

**ENSCI 463I. Soil Formation and Landscape Relationships.**

(Dual-listed with ENSCI 563I). (Cross-listed with AGRON, IA LL). Cr. 4. Alt. SS., offered 2012. *Prereq:* AGRON 154 or AGRON 260

Burras. Relationships between soil formation, geomorphology, and environment. Soil description, classification, geography, mapping, and interpretation for land use. Credit for only Agron 563 or 563I may be applied for graduation.

**ENSCI 477. Soil Physics.**

(Dual-listed with ENSCI 577). (Cross-listed with AGRON). (3-0) Cr. 3. S. *Prereq:* Recommended: AGRON 154 MATH 166

Horton. The physical soil system: the soil components and their physical interactions; transport processes involving water, air, and heat.

**ENSCI 479. Surficial Processes.**

(Dual-listed with ENSCI 579). (Cross-listed with GEOL). (2-2) Cr. 3. F. *Prereq:* GEOL 100 or GEOL 201 or equivalent experience

The study of physical processes that shape Earth's surface. Topics include weathering, sediment transport, and landform genesis with emphasis on fluvial, glacial, hillslope, eolian, and coastal processes. Applications to engineering and environmental problems. Laboratory includes topographic map interpretation and local field trips. Nonmajor graduate credit.

**ENSCI 480. Engineering Analysis of Biological Systems.**

(Cross-listed with BSE). (2-2) Cr. 3. F. *Prereq:* BSE 216; MATH 266; BIOL 211 or BIOL 212; ME 231

Systems-level engineering analysis of biological systems. Economic and life-cycle analysis of bioresource production and conversion systems. Global energy and resource issues and the role of biologically derived materials in addressing these issues. Nonmajor graduate credit.

**ENSCI 484. Ecosystem Ecology.**

(Cross-listed with BIOL). (3-0) Cr. 3. S. *Prereq:* Combined 12 credits in biology and chemistry

Introduction of the study of ecosystems and the factors that influence their properties and dynamics. Conceptual foundations for ecosystem studies. Quantitative analyses of accumulations, transformations, and fluxes of nutrients, water, and energy within and among ecosystems.

**ENSCI 485. Soil and Environmental Microbiology.**

(Dual-listed with ENSCI 585). (Cross-listed with AGRON, MICRO). (2-3) Cr. 3. F. *Prereq:* AGRON 154 or AGRON 402, MICRO 201 (MICRO 201L recommended)

Loynachan. The living organisms in the soil and what they do. Emphasis on soil biota composition, the carbon cycle and bioremediation, soil-plant-microbial relationships, and environmental issues. Nonmajor graduate credit.

**ENSCI 486. Aquatic Ecology.**

(Dual-listed with ENSCI 586). (Cross-listed with BIOL). (3-0) Cr. 3. F. *Prereq:* Biol 312 or EnSci 381 or EnSci 402 or NREM 301

Dual-listed with EEOB 586. Structure and function of aquatic ecosystems with application to fishery and pollution problems. Emphasis on lacustrine, riverine, and wetland ecology. Nonmajor graduate credit.

**ENSCI 486L. Aquatic Ecology Laboratory.**

(Cross-listed with BIOL, A ECL). (0-3) Cr. 1. F. *Prereq:* Concurrent enrollment in BIOL 486

Dual-listed with EEOB 586L. Field trips and laboratory exercises to accompany 486. Hands-on experience with aquatic research and monitoring techniques and concepts. Nonmajor graduate credit.

**ENSCI 487. Microbial Ecology.**

(Dual-listed with ENSCI 587). (Cross-listed with BIOL, MICRO). (3-0) Cr. 3. F. *Prereq:* Six credits in biology and 6 credits in chemistry

Dual-listed with EEOB 587. Introduction to major functional groups of autotrophic and heterotrophic microorganisms and their roles in natural systems. Nonmajor graduate credit.

**ENSCI 488. GIS for Geoscientists II.**

(Dual-listed with ENSCI 588). (Cross-listed with AGRON, GEOL). (2-2) Cr. 3. Alt. S., offered 2013. *Prereq:* GIS course, such as GEOL 452, CRP 451, CRP 452, NREM 345, NREM 446, AE 408 or equivalent

GIS course with focus on the spatial analysis and modeling of raster data and triangulated irregular network (TIN) data. Uses ArcGIS and various extensions, such as Spatial Analyst, 3D Analyst, and ArcScene. Includes practical exercises during lectures, lab exercises, homework assignments, and (for GEOL 588) a class project. Nonmajor graduate credit.

**ENSCI 490. Independent Study.**

Cr. arr. Repeatable. F.S.SS. *Prereq:* Permission of the instructor and approval of the Environmental Science coordinator

**ENSCI 495. Current Topics and Case Studies in Environmental Science.**

Cr. 1-3. *Prereq:* Junior classification in Environmental Science, permission of instructor

Current topics and case studies related to the analysis and management of environmental systems. Individual and/or group projects.

**ENSCI 496. Travel Course.**

Cr. arr. Repeatable. *Prereq:* Permission of instructor

Extended field trips to study environmental topics in varied locations. Location and duration of trips will vary. Trip expenses paid by students. Check with department for current offerings. A. International Tour B. Domestic Tour.

**ENSCI 498. Cooperative Education.**

Cr. R. Repeatable. F.S.SS. *Prereq:* Permission of Environmental Science Coordinator

Required of all cooperative education students. Students must register prior to commencing each work period.

**Courses primarily for graduate students, open to qualified undergraduates:****ENSCI 502. Watershed Hydrology.**

(Dual-listed with ENSCI 402). (Cross-listed with GEOL, MTEOR, NREM). (3-3) Cr. 4. F. *Prereq:* Four courses in physical or biological sciences or engineering; junior standing

Examination of watersheds as systems, emphasizing the surface components of the hydrologic cycle. Combines qualitative understanding of hydrological processes and uncertainty with quantitative representation. Laboratory emphasizes field investigation and measurement of watershed processes. Nonmajor graduate credit.

**ENSCI 504. Global Change.**

(Dual-listed with ENSCI 404). (Cross-listed with AGRON, MTEOR, ENV S). (3-0) Cr. 3. S. *Prereq:* Four courses in physical or biological sciences or engineering; junior, senior, or graduate standing

Recent changes in global biogeochemical cycles and climate; models of future changes in the climate system; impacts of global change on agriculture, water resources and human health; ethical issues of global environmental change.

**ENSCI 505. Environmental Biophysics.**

(Dual-listed with ENSCI 405). (Cross-listed with MTEOR, AGRON). (3-0) Cr. 3. Alt. S., offered 2013. *Prereq:* MATH 165 or MATH 182 or equivalent and some computer programming experience (any language)

Hornbuckle. A description of the physical microenvironment in which organisms live. Emphasis on the movement of energy (heat and radiation) and mass (water and carbon) among organisms, the soil, and atmosphere. Applications to humans, other animals, plants, and plant communities. Nonmajor graduate credit.



**ENSCI 507. Watershed Management.**

(Dual-listed with ENSCI 407). (Cross-listed with NREM, ENV S). (3-3) Cr. 4. S. Prereq: A course in general biology

Managing human impacts on the hydrologic cycle. Field and watershed level best management practices for modifying the impacts on water quality, quantity and timing are discussed. Field project includes developing a management plan using landscape buffers.

**ENSCI 508. GIS and Natural Resources Management.**

(Dual-listed with ENSCI 408). (Cross-listed with A E). (2-2) Cr. 3. F. Prereq: Working knowledge of computers and Windows environment

Introduction to fundamental concepts and applications of GIS in natural resources management with specific focus on watersheds. Topics include: basic GIS technology, data structures, database management, spatial analysis, and modeling; visualization and display of natural resource data. Case studies in watershed and natural resource management using ArcView GIS. In addition to other assignments, graduate students will prepare research literature reviews on topics covered in class and develop enterprise applications.

**ENSCI 508I. Aquatic Ecology.**

(Cross-listed with IA LL, NREM). Cr. 4. SS. Prereq: Courses in ecology, chemistry, and physics

Analysis of aquatic ecosystems; emphasis on basic ecological principles; ecological theories tested in the field; identification of common plants and animals.

**ENSCI 509. Field Methods in Hydrogeology.**

(Dual-listed with ENSCI 409). (Cross-listed with GEOL). (0-4) Cr. 3. Alt. SS., offered 2012. Prereq: GEOL/ENSCI 402 or GEOL/ENSCI 411 or C E 473

Introduction to field methods used in groundwater investigations. In-field implementation of pumping tests, slug tests, monitoring well installation and drilling techniques, geochemical and water quality sampling, seepage meters, minipiezometers, stream gaging, and electronic instrumentation for data collection. Field trips to investigate water resource, water quality, and remediation projects.

**ENSCI 511. Hydrogeology.**

(Dual-listed with ENSCI 411). (Cross-listed with GEOL). (3-2) Cr. 4. F. Prereq: Four courses in biological or physical sciences

Physical principles of groundwater flow, nature and origin of aquifers and confining units, well hydraulics, groundwater modeling, and contaminant transport. Lab emphasizes applied field and laboratory methods for hydrogeological investigations.

**ENSCI 514. Applied Groundwater Flow Modeling.**

(Dual-listed with ENSCI 414). (Cross-listed with GEOL). (2-2) Cr. 3. Alt. S., offered 2012. Prereq: GEOL 411 or C E 473; MATH 165 or MATH 181

Introduction to the principles of modeling groundwater flow systems. Finite-difference and analytic-element methods, spreadsheet models, boundary conditions, calibration, sensitivity analysis, parameter estimation, particle tracking, and post-audit analysis. Application of MODFLOW to regional flow-system analysis. Computer laboratory emphasizes assigned problems that illustrate topics discussed in the course.

**ENSCI 515. Paleoclimatology.**

(Dual-listed with ENSCI 415). (Cross-listed with GEOL). (3-0) Cr. 3. Alt. S., offered 2013. Prereq: Four courses in biological or physical science

Introduction to mechanisms that drive climate, including the interplay between oceanic and atmospheric circulation and fluctuation in Earth's orbital parameters. Examination and analysis of past climate records ranging from historical documentation to ecological and geochemical proxies (e.g. tree ring analysis; O and C isotopes of skeletal carbonates and soils). Dating methods used to constrain and correlate climatic periods; utility of computer models to reconstruct past climates and predict future climate change. Emphasis placed on paleoclimatology and paleoecology of the late Quaternary (last ~ 1 million years).

**ENSCI 516. Hydrologic Modeling and Analysis.**

(Dual-listed with ENSCI 416). (Cross-listed with MTEOR, GEOL). (2-3) Cr. 3. Alt. S., offered 2013. Prereq: Four courses in earth science, meteorology, or engineering; junior standing

Study of the basic principles of hydrologic modeling, including rainfall-runoff analysis, lumped and distributed modeling, conceptual and physical models, parameter estimation and sensitivity analysis, input and validation data, uncertainty analysis, and the use of models in surface water hydrology. A range of common models are applied to study hydrologic topics such as flood forecasting and land use change impacts. Previous experience with Matlab or other programming language is needed.

**ENSCI 518. Stream Ecology.**

(Dual-listed with ENSCI 418). (Cross-listed with A ECL). (2-3) Cr. 3. Alt. F., offered 2011. Prereq: A ECL 486

Biological, chemical, physical, and geological processes that determine the structure and function of flowing water ecosystems. Current ecological theories as well as applications to stream management for water quality and fisheries.

**ENSCI 519. Environmental Geochemistry.**

(Dual-listed with ENSCI 419). (Cross-listed with GEOL). (2-2) Cr. 3. F. Prereq: GEOL 511 or equivalent

Geochemistry of natural waters and water-rock interactions. Acid-base equilibria, carbonate chemistry and buffer systems, mineral dissolution and precipitation, sorption, ion exchange, and redox reactions. Introduction to thermodynamics and kinetics. Laboratory emphasizes chemical analysis of waters and computer modeling.

**ENSCI 520. Environmental Engineering Chemistry.**

(Dual-listed with ENSCI 420). (2-3) Cr. 3. Prereq: CHEM 177 and CHEM 178, MATH 166

Principles of chemical and physical phenomena applicable to the treatment of water and wastewater and natural waters; including chemical equilibria, reaction kinetics, acid-base equilibria, chemical precipitation, redox reactions and mass transfer principles. Individual laboratory practicals and group projects required. Term paper and oral presentation for graduate level only.

**ENSCI 521. Environmental Biotechnology.**

(Dual-listed with ENSCI 421). (2-2) Cr. 3. Prereq: C E 326

Fundamentals of biochemical and microbial processes applied to environmental engineering processes, role of microorganisms in wastewater treatment and bioremediation, bioenergetics and kinetics, metabolism of xenobiotic compounds, waterborne pathogens and parasites, and disinfection. Term paper and oral presentation.

**ENSCI 522. Water Pollution Control Processes.**

(Cross-listed with C E). (2-2) Cr. 3. Prereq: C E 521

Fundamentals of biochemical processes, aerobic growth in a single CSTR, multiple events in complex systems, and techniques for evaluating kinetic parameters; unit processes of activated sludge system, attached growth systems, stabilization and aerated lagoon systems, biosolids digestion and disposal, nutrient removal, and anaerobic treatment systems.

**ENSCI 523. Physical-Chemical Treatment Process.**

(Cross-listed with C E). (2-2) Cr. 3. Prereq: C E 520

Material and energy balances. Principles and design of physical-chemical unit processes; including screening, coagulation, flocculation, chemical precipitation, sedimentation, filtration, lime softening and stabilization, oxidation, adsorption, membrane processes, ion exchange and disinfection; recovery of resources from residuals and sludges; laboratory exercises and demonstrations; case studies in mineral processing and secondary industries.

**ENSCI 524. Air Pollution.**

(Dual-listed with ENSCI 424). (Cross-listed with C E, A E). (1-0) Cr. 1. Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics.

Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

**ENSCI 524A. Air Pollution: Air quality and effects of pollutants.**

(Dual-listed with ENSCI 424A). (Cross-listed with C E, A E). (1-0) Cr. 1. Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics.

Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

**ENSCI 524B. Air Pollution: Climate change and causes.**

(Dual-listed with ENSCI 424B). (Cross-listed with C E, A E). (1-0) Cr. 1. Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics.

Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

**ENSCI 524C. Air Pollution: Transportation constraints.**

(Dual-listed with ENSCI 424C). (Cross-listed with C E, A E). (1-0) Cr. 1. Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics.

Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

**ENSCI 524D. Air Pollution: Off-gas treatment technology.**

(Dual-listed with ENSCI 424D). (Cross-listed with C E, A E). (1-0) Cr. 1. Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics.

Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

**ENSCI 524E. Air Pollution: Agricultural sources of pollution.**

(Dual-listed with ENSCI 424E). (Cross-listed with C E, A E). (1-0) Cr. 1. *Prereq:* Either *PHYS 221* or *CHEM 178* and either *MATH 166* or 3 credits in statistics. Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

**ENSCI 526. Stable Isotopes in the Environment.**

(Dual-listed with ENSCI 426). (Cross-listed with GEOL). (3-0) Cr. 3. Alt. F., offered 2011. *Prereq:* Four courses in biological or physical science

Introduction to the theory, methods and applications of stable isotopes. Primary focus on the origin, natural abundance, and fractionation of carbon, hydrogen, oxygen, nitrogen isotopes. Applications of isotopic occurrence for elucidation of physical, chemical, biological, and environmental processes. Effects of plant physiology, photosynthesis, trophic structure, diffusion, evaporation, chemical precipitation, soil and atmospheric processes, and environmental factors on isotope abundance.

**ENSCI 527. Solid Waste Management.**

(Cross-listed with C E). (3-0) Cr. 3. *Prereq:* C E 326

Planning and design of solid waste management systems; includes characterization and collection of domestic, commercial, and industrial solid wastes, waste minimization and recycling, energy and materials recovery, composting, incineration, and landfill design.

**ENSCI 529. Hazardous Waste Management.**

(Cross-listed with C E). (3-0) Cr. 3. *Prereq:* C E 326

Regulatory requirements for the classification, transport, storage and treatment of hazardous wastes. Analysis and design of alternatives for treatment and disposal technologies, including physical, chemical, and biological treatment, solidification, incineration, and secure landfill design. Regulatory requirements and procedures for hazardous waste contaminated site investigations and risk analysis. Analysis and design of remedial action alternatives for site restoration.

**ENSCI 531. Design and Evaluation of Soil and Water Conservation Systems.**

(Dual-listed with ENSCI 431). (2-3) Cr. 3. F. *Prereq:* E M 378 or CH E 356

Hydrology and hydraulics in agricultural and urbanizing watersheds. Design and evaluation of systems for the conservation and quality preservation of soil and water resources. Use and analysis of hydrologic data in engineering design; relationship of topography, soils, crops, climate, and cultural practices in conservation and quality preservation of soil and water for agriculture. Small watershed hydrology, water movement and utilization in the soil-plant-atmosphere system, agricultural water management, best management practices, and agricultural water quality. Graduate students will prepare several research literature reviews on topics covered in the class in addition to the other assignments.

**ENSCI 533. Erosion and Sediment Transport.**

(Cross-listed with A E). (3-0) Cr. 3. Alt. F., offered 2012. *Prereq:* A E 422 or C E 372, MATH 266

Soil erosion processes, modified universal soil loss equation and its application to conservation planning, sediment properties, initiation of sediment motion and over land flow, flow in alluvial channels and theory of sediment transport, channel stability, reserves sedimentation, wind erosion, BMPs for controlling erosion.

**ENSCI 534. Contaminant Hydrogeology.**

(Dual-listed with ENSCI 434). (Cross-listed with GEOL). (3-0) Cr. 3. S. *Prereq:* GEOL 511 or equivalent

Theory and practical considerations of fate and transport of solutes through porous geologic materials. Organic and inorganic contaminants in industrial and agricultural settings. Subsurface microbiology and biodegradation of aromatic and chlorinated hydrocarbons. Investigation of coupled processes (diffusion, advection, dispersion, sorption, and biodegradation) using computer models. Soil and groundwater monitoring and remediation strategies.

**ENSCI 535. Restoration Ecology.**

(Cross-listed with NREM, EEOB). (2-3) Cr. 3. F. *Prereq:* BIOL 366 or BIOL 474 or graduate standing

Theory and practice of restoring animal and plant diversity, structure and function of disturbed ecosystems. Restored freshwater wetlands, forests, prairies and reintroduced species populations will be used as case studies.

**ENSCI 535I. Restoration Ecology.**

(Cross-listed with A ECL, IA LL, EEOB). Cr. 4. Alt. SS., offered 2012. *Prereq:* A course in ecology

Ecological principles for the restoration of native ecosystems; establishment (site preparation, selection of seed mixes, planting techniques) and management (fire, mowing, weed control) of native vegetation; evaluation of restorations. Emphasis on the restoration of prairie and wetland vegetation.

**ENSCI 546. Integrating GPS and GIS for Natural Resource Management.**

(Dual-listed with ENSCI 446). (Cross-listed with NREM). (2-3) Cr. 3. S. *Prereq:* 12 credits in student's major at 300 level or above, NREM 345 or equivalent experience with ArcGIS

Emphasis on the use of GPS as a data collection tool for GIS. Basic theory of GPS. Use of Global Positioning System technology for spatial data collection and navigation. Post-processing and real-time correction of GPS data. GPS data transfer to GIS for mapping applications. Use of GIS to construct waypoints for use in GPS navigation.

**ENSCI 551. Applied and Environmental Geophysics.**

(Dual-listed with ENSCI 451). (Cross-listed with GEOL). (2-2) Cr. 3. Alt. S., offered 2012. *Prereq:* GEOL 100 or GEOL 201, MATH 181 or equivalent experience

Seismic, gravity, magnetic, resistivity, electromagnetic, and ground-penetrating radar techniques for shallow subsurface investigations and imaging. Data interpretation methods. Lab emphasizes computer interpretation packages. Field work with seismic - and resistivity-imaging systems and radar. Nonmajor graduate credit.

**ENSCI 552. GIS for Geoscientists.**

(Dual-listed with ENSCI 452). (Cross-listed with AGRON). (2-2) Cr. 3. F. *Prereq:* GEOL 100, GEOL 201 or equivalent

Introduction to geographic information systems (GIS) with particular emphasis on geoscientific data. Uses ESRI's ArcGIS Desktop Software and extension modules. Emphasizes typical GIS operations and analyses in the geosciences to prepare students for advanced GIS courses.

**ENSCI 553. Soil-Plant Relationships.**

(Cross-listed with AGRON). (3-0) Cr. 3. F. *Prereq:* AGRON 354

Composition and properties of soils in relation to the nutrition and growth of plants.

**ENSCI 558. Laboratory Methods in Soil Chemistry.**

(Cross-listed with AGRON). (2-3) Cr. 3. Alt. F., offered 2012. *Prereq:* AGRON 354 and CHEM 211

Experimental and descriptive inorganic and organic analyses. Operational theory and principles of applicable instruments, including spectrophotometry, atomic and molecular absorption and emission spectroscopy, mass spectrometry, X-ray diffraction and fluorescence, gas and ion chromatography, and ion-selective electrodes.

**ENSCI 559. Environmental Soil and Water Chemistry.**

(Dual-listed with ENSCI 459). (Cross-listed with AGRON). (3-3) Cr. 4. F. *Prereq:* Two semesters of college-level chemistry, MATH 140, AGRON 154 or AGRON 360; GEOL 100 and AGRON 354 recommended.

Thompson. An introduction to the chemical properties of soils, chemical reactions and transformations in soils and surface waters, and their impact on the environment. Topics include solution chemistry in soils and surface waters, solid-phase composition of soils, reactions at the solid-solution interface, and applications to contemporary environmental issues. Nonmajor graduate credit.

**ENSCI 563. Soil Formation and Landscape Relationships.**

(Dual-listed with ENSCI 463). (Cross-listed with AGRON). (2-4) Cr. 4. S. *Prereq:* AGRON 154 or AGRON 260

Burras. Relationships between soil formation, geomorphology, and environment. Soil description, classification, geography, mapping, and interpretation for land use. Two weekend field trips. Credit for one of Agron 563 or 563I may be applied for graduation.

**ENSCI 563I. Soil Formation and Landscape Relationships.**

(Dual-listed with ENSCI 463I). (Cross-listed with AGRON, IA LL). Cr. 4. Alt. SS., offered 2012. *Prereq:* AGRON 154 or AGRON 260

Burras. Relationships between soil formation, geomorphology, and environment. Soil description, classification, geography, mapping, and interpretation for land use. Credit for only Agron 563 or 563I may be applied for graduation.

**ENSCI 564. Wetland Ecology.**

(Cross-listed with EEOB). (3-0) Cr. 3. S. *Prereq:* 15 credits in biological sciences Ecology, classification, creation and restoration, and management of wetlands. Emphasis on North American temperate wetlands.

**ENSCI 564I. Wetland Ecology.**

(Cross-listed with IA LL, EEOB). Cr. 4. SS. *Prereq:* IA LL 312I

Ecology, classification, creation, restoration, and management of wetlands. Field studies will examine the composition, structure and functions of local natural wetlands and restored prairie pothole wetlands. Individual or group projects.

**ENSCI 571. Surface Water Hydrology.**(Cross-listed with C E). (3-0) Cr. 3. *Prereq: C E 372*

Analysis of hydrologic data including precipitation, infiltration, evapotranspiration, direct runoff and streamflow; theory and use of frequency analysis; theory of streamflow and reservoir routing; use of deterministic and statistical hydrologic models. Fundamentals of surface water quality modeling, point and non-point sources of contamination. Design project.

**ENSCI 572. Analysis and Modeling Aquatic Environments.**(Cross-listed with C E). (3-0) Cr. 3. *Prereq: C E 372*

Principles of surface water flows and mixing. Introduction to hydrologic transport and water quality simulation in natural water systems. Advection, diffusion and dispersion, chemical and biologic kinetics, and water quality dynamics. Applications to temperature, dissolved oxygen, primary productivity, and other water quality problems in rivers, lakes and reservoirs. Deterministic vs. stochastic models.

**ENSCI 573. Groundwater Hydrology.**(Dual-listed with ENSCI 473). (3-0) Cr. 3. *Prereq: C E 372*

Principles of groundwater flow, hydraulics of wells, super-position, slug and pumping tests, streamlines and flownets, and regional groundwater flow. Contaminant transport. Computer modeling. Individual and group projects.

**ENSCI 575. Soil Formation and Transformation.**(Cross-listed with AGRON). (3-0) Cr. 3. Alt. F., offered 2012. *Prereq: AGRON 463 or equivalent*

Advanced study of soil formation, emphasizing relationships among soils, landscapes, environment, humans, and land use.

**ENSCI 577. Soil Physics.**(Dual-listed with ENSCI 477). (Cross-listed with AGRON). (3-0) Cr. 3. S. *Prereq: Recommended: AGRON 154 and MATH 166*

Horton. The physical soil system: the soil components and their physical interactions; transport processes involving water, air, and heat.

**ENSCI 578. Laboratory Methods in Soil Physics.**(Cross-listed with AGRON). (0-3) Cr. 1. S. *Prereq: concurrent enrollment in AGRON 477 or 577*

Horton. Methods of measuring soil physical properties such as texture, density, and water content, and transport of heat, water, and gases.

**ENSCI 579. Surficial Processes.**(Dual-listed with ENSCI 479). (Cross-listed with GEOL). (2-2) Cr. 3. F. *Prereq: GEOL 100 or GEOL 201 or equivalent experience*

The study of physical processes that shape Earth's surface. Topics include weathering, sediment transport, and landform genesis with emphasis on fluvial, glacial, hillslope, eolian, and coastal processes. Applications to engineering and environmental problems. Laboratory includes topographic map interpretation and local field trips.

**ENSCI 581. Environmental Systems I: Introduction to Environmental Systems.**(Dual-listed with ENSCI 381). (Cross-listed with BIOL, ENV S, MICRO). Cr. 3-4. F. *Prereq: 12 credits of natural science including biology and chemistry*

Introduction to the structure and function of natural environmental systems. Emphasis on the analysis of material and energy flows in natural environmental systems and the primary environmental factors controlling these systems.

**ENSCI 582. Environmental Systems II: Analysis of Environmental Systems.**(Dual-listed with ENSCI 382). (Cross-listed with BIOL). (2-2) Cr. 3. S. *Prereq: ENSCI 581*

Continuation of EnSci 581. Systems approach to the analysis of material and energy flows in natural environmental systems and the primary environmental factors controlling these systems.

**ENSCI 584. Ecosystem Ecology.**(Cross-listed with EEOB). (3-0) Cr. 3. Alt. S., offered 2012. *Prereq: Combined 12 credits in biology and chemistry*

Introduction to the study of ecosystems and the factors that influence their properties and dynamics. Conceptual foundations for ecosystem studies. Quantitative analyses of accumulations, transformations, and fluxes of nutrients, water, and energy within and among ecosystems.

**ENSCI 585. Soil and Environmental Microbiology.**(Dual-listed with ENSCI 485). (Cross-listed with AGRON, MICRO). (2-3) Cr. 3. F. *Prereq: AGRON 154 or AGRON 402, MICRO 201 (MICRO 201L recommended)*

Loynachan. The living organisms in the soil and what they do. Emphasis on soil biota composition, the carbon cycle and bioremediation, soil-plant-microbial relationships, and environmental issues.

**ENSCI 586. Aquatic Ecology.**(Dual-listed with ENSCI 486). (Cross-listed with EEOB). (3-0) Cr. 3. F. *Prereq: ENSCI 301 or ENSCI 312 or ENSCI 381 or ENSCI 402*

(Dual-listed with Biol 486.) Structure and function of aquatic ecosystems with application to fishery and pollution problems. Emphasis on lacustrine, riverine and wetland ecology.

**ENSCI 586L. Aquatic Ecology Laboratory.**(Dual-listed with ENSCI 487). (Cross-listed with EEOB). (0-3) Cr. 1. F. *Prereq: Concurrent enrollment in EEOB 586*

(Dual-listed with Biol 486L.) Field trips and laboratory exercises to accompany 586. Hands-on experience with aquatic research and monitoring techniques and concepts.

**ENSCI 587. Microbial Ecology.**(Dual-listed with ENSCI 487). (Cross-listed with EEOB, MICRO). (3-0) Cr. 3. F. *Prereq: Six credits in biology and 6 credits in chemistry*

(Dual-listed with Biol 487.) Introduction to major functional groups of autotrophic and heterotrophic microorganisms and their roles in natural systems.

**ENSCI 588. GIS for Geoscientists II.**(Dual-listed with ENSCI 488). (Cross-listed with AGRON, GEOL). (2-2) Cr. 3. Alt. S., offered 2013. *Prereq: GIS course, such as GEOL 452, CRP 451, CRP 452, NREM 345, NREM 446, AE 408 or equivalent*

GIS course with focus on the spatial analysis and modeling of raster data and triangulated irregular network (TIN) data. Uses ArcGIS and various extensions, such as Spatial Analyst, 3D Analyst, and ArcScene. Includes practical exercises during lectures, lab exercises, homework assignments, and (for GEOL 588) a class project.

**ENSCI 590. Special Topics.**Cr. arr. Repeatable. F.S.SS. *Prereq: Permission of major professor in Environmental Science faculty*

Literature reviews and conference in accordance with needs and interest of the student.

**ENSCI 599. Creative Component.**Cr. arr. Repeatable. F.S.SS. *Prereq: Permission of major professor in Environmental Science faculty*

Creative component for nonthesis master of science degree.

**Courses for graduate students:****ENSCI 685. Advanced Soil Biochemistry.**(Cross-listed with MICRO, AGRON). (2-0) Cr. 2. Alt. S., offered 2012. *Prereq: AGRON 585*

Chemistry of soil organic matter and biochemical transformations brought about by microorganisms and enzymes in soils.

**ENSCI 690. Seminar in Environmental Science.**

Cr. R. Repeatable. F.S.

Reports and discussion of recent research and literature.

**ENSCI 699. Research.**

Cr. arr. Repeatable. F.S.SS.