Ph.D. in Engineering Program

Degree:

Doctor of Philosophy (Ph.D.) in Engineering

Emphasis areas:

Civil Engineering
Coastal Engineering
Environmental Engineering

Program Description

The Civil Engineering Program at JSU offers the Ph.D. in Engineering degree with emphasis areas in 1) Civil Engineering; 2) Coastal Engineering; and 3) Environmental Engineering. The mission statement, objectives, admission requirements, and degree requirements are described below.

Mission

To provide students with the necessary advanced knowledge, research skills, creativity, ethics, critical thinking, and problem solving to be able respond to engineering challenges and needs of our ever-changing world for professional competence and life-long and inquiry-based learning.

Objectives

The primary educational objective of the Ph.D. in Engineering Program is to produce engineers with terminal degrees to meet the needs for highly educated engineers with advanced technical and research skills in the workforces. The specific objectives of the three emphasis areas are as following:

Civil Engineering: to prepare students for continued professional and scholarly development consistent with their technical interests in civil engineering by conducting a major independent and original research study with critical thinking.

Coastal Engineering: to prepare students with advanced knowledge and skills in coastal engineering, (including coastal natural disasters) and produce graduates with competencies in advanced original research, education, and professional practice in coastal engineering.

Environmental Engineering: to equip students with advanced knowledge and skills in the environmental engineering field and produce graduates with competencies in advanced original research, education, and professional practice in the area of environmental engineering.

Admission Requirements

The applicants must meet all admission requirements set by the Division of Graduate Studies. In addition, the applicants must meet the following admission requirements.

a) A Bachelor of Science (B.S.) degree in civil engineering, environmental engineering, computer engineering, or electrical engineering or closely related engineering disciplines from accredited colleges and universities, or a Master of Science (M.S.) in related engineering field.

b) Applicants who do not have a B.S. or M.S. in an engineering field will be required to satisfy the articulation courses.

c) Minimum undergraduate grade point average (GPA) of 3.0 on a 4.0 scale and minimum graduate GPA of 3.50 on a 4.0 scale are required. In special cases, exceptional applicants

with B.S. degrees in engineering will be considered. These applicants must have a minimum GPA of 3.5.

d) Applicants with Minimum undergraduate grade point average (GPA) of 2.90 on a 4.0 scale and minimum graduate GPA of 3.250 on a 4.0 scale may be considered for conditional admission. These applicants must achieve a minimum graduate GPA of 3.50 during the first year of the Ph.D. Program to be eligible for consideration for regular admission.

e) International students must meet the English requirements as outlined by the Division of Graduate Studies.

f) Applicant must submit three letters of recommendation from professionals who are knowledgeable with applicant's credentials.

g) Applicant must submit a one-page statement on career goals and objectives, as well as research experience and interests.

Degree Requirements

The applicants must meet all degree requirements set by the Division of Graduate Studies. In addition, the applicants must meet the following degree requirements.

To obtain the Ph.D. in Engineering Degree, the students are required to complete a minimum of 72 credit hours beyond B.S. or 36 credit hours beyond M.S. degree. The program includes core courses, elective courses, and 24 hours of dissertation research. The adviser or the advising committee may recommend additional courses based on the students background and proposed research plan. Students have to maintain a graduate GPA of 3.0 or above to avoid academic probation.

A comprehensive qualifying exam is given to the student after six months of the study beyond the M.S. degree, but no later than after 2 years of study. Academic advisor and engineering faculty in a student's area of research determine the coursework needed for a student to prepare for the comprehensive qualifying examination. The comprehensive qualifying examination includes a written part and oral exam. During the comprehensive qualifying examination, students must demonstrate a sufficient depth and breadth of knowledge in their major to pursue independent and original research. However, the student must consult with their advisor and/or the exam coordinator in the major area of study for the schedule and specific procedures. A signature form, verifying that a student has passed the comprehensive qualifying exam, must be signed by the student's advisor and returned to the departmental office. After passing the comprehensive qualifying exam, the students will be admitted to Ph.D. Candidacy. If a student fails to pass the comprehensive qualifying exam, he/she will be allowed to take it again between one and six months after the first attempt. If the student fails twice on this exam, he/she will be dropped from the PhD program.

When at least 80% of coursework is completed and the comprehensive qualifying exam is successfully passed, the students are able to take a preliminary exam administered by the advising committee and academic advisor. Students should take the preliminary exam within 3 years of residence beyond the MS degree and at least two semesters before their final dissertation defense. This exam is based upon an oral exam and a written proposal and a detailed plan to carry out the

Ph.D. dissertation. Students must consult with their advisors for specific details of the requirements for the preliminary exam.

The defense of dissertation is the final exam of the Ph.D. program. An oral defense and a written Ph.D. dissertation demonstrating original and independent research and major contributions to an engineering field have to be approved by the advising committee before graduation. Recognizing the importance of high quality graduates, each graduate is expected to publish at least 2 papers based on the results of his/her research in high quality refereed engineering journals. A summary of minimum degree requirements is shown in Table 1.

Table 1. Summary of Minimum Degree Requirements for Ph.D. in Engineering

Minimum Requirements	Comments
Credit Hours	A minimum of 72 credit hours beyond B.S. or 36 credit hours beyond M.S. degree. Must complete 24 hours of dissertation research, the required core courses, and elective courses. The adviser or the advising committee may recommend additional courses based on the students background and the proposed research area.
Comprehensive Qualifying Exam	Successful completion of written and oral Comprehensive Qualifying Exam, given after six months of the study beyond the M.S. degree, but no later than after 2 years of study.
Preliminary Exam	Successful completion of the preliminary exam within 3 years of residence beyond the MS degree and at least two semesters before their final dissertation defense.
Final Dissertation and Defense	An oral defense and a written Ph.D. dissertation demonstrating original independent research and major contributions. Each graduate is expected to publish at least 2 papers based on the results of his/her research in high quality refereed engineering journals.

Time Limit

All work toward a Ph.D. in Engineering must be completed within a 10- calendar year period from the date of first entering the graduate program.

Degree Program: Ph.D. in Engineering
Emphasis Area: Civil Engineering
Department: Civil & Environmental Engineering and Industrial Systems & Technology

Core Courses

1. Choose three from the following list after consultation and approval of the student's advisor

Course	Title	Semester Hours
CIV 530	Advanced Pavement Analysis and Design	3
CIV 531	Traffic Engineering	3
CIV 532	Pavement Materials and Design	3
CIV 540	Advanced Structural Analysis	3
CIV 541	Structural Dynamics	3
CIV 542	Advanced Design of Concrete Structures	3
CIV 550	Engineering Hydrology	3
CIV 551	Advanced Fluid Mechanics	3
CIV 652	Hydraulic Engineering Design	3
CIV 672	Advanced Geomechanics	3
CIV 673	Advanced Foundation Engineering	3
CIV 674	Soil Dynamics	3

2. In addition, each student is required to take one graduate level advanced mathematics course after consultation and approval of the student's adviser

Elective Courses

CIV 520 Advanced Engineering Analysis I. (3 Hours)
CIV 521 Advanced Engineering Analysis II. (3 Hours)
CIV 533 Evaluation, Maintenance, & Rehabilitation of Public Works Infrastructure (3 Hours)
CIV 534 Urban Transportation Engineering System Design (3 Hours)
CIV 535 Pavement Design (3 Hours)
CIV 536 Highway Engineering (3 Hours)
CIV 543 Advanced Mechanics of Materials (3 Hours)
CIV 544 Advanced Design of Steel Structures (3 Hours)
CIV 545 Design of Wood and Masonry Structures (3 Hours)
CIV 552 GIS Applications in Civil and Environmental Engineering (3 Hours)
CIV 553 Experimental Methods in Civil Engineering (3 Hours)
CIV 554 Water Resources Engineering Planning and Management (3 Hours)
CIV 556 Groundwater Engineering (3 Hours)
CIV 557 Computational Fluid Dynamics (3 Hours)
CIV 558 Sedimentation and River Engineering (3 Hours)
CIV 559 Environmental Hydraulics (3 Hours)
CIV 562 Hazardous Waste Engineering (3 Hours)
CIV 564 Surface Water (3 Hours)
CIV 565 Wetland Management for Environmental Engineering (3 Hours)

CIV 567 Environmental Remediation (3 Hours)
CIV 568 Land Disposal of Waste (3 Hours)
CIV 571 Principles of Geoenvironmental Engineering (3 Hours)
CIV 572 Applied Geotechnical Engineering Design (3 Hours)
CIV 578 Applied Geophysics (3 Hours)
CIV 631 Linear Theory of Ocean Waves. (3 Hours)
CIVL 631 Linear Theory of Ocean Waves' Laboratory. (1 Hour)
CIV 632 Tides and Long Waves. (3 Hours)
CIV 633 Airport Planning and Design (3 Hours)
CIV 640 Finite Element Method (3 Hours)
CIV 642 Prestressed Concrete Design (3 Hours)
CIV 645 Plates and Shells (3 Hours)
CIV 650 Small Watershed Hydrology (3 Hours)
CIV 653 Advanced Design of Hydraulic Structures (3 Hours)
CIV 654 Water Resources Systems Engineering (3 Hours)
CIV 655 Stochastic Hydrology (3 Hours)
CIV 659 Advanced Topics in Water Resources Engineering (Variable 1-4 Hours)
CIV 663 Design of Environmental Engineering Facilities (3 Hours)
CIV 670 Rock Mechanics (3 Hours)
CIV 675 Earth Dams and Slopes (3 Hours)
CIV 676 Tunneling (3 Hours)
CIV 677 Design and Construction with Geosynthetics (3 Hours)
CIV 678 Soil Bioengineering (3 Hours)
CIV 679 Advanced Topics in Geotechnical Engineering (Variable 1-4 Hours)
CIV 680 Unsaturated Soil Mechanics (3 Hours)
CIV 695 Scientific Writing Seminar (1 Hour)
CIV 696 Seminar (1 Hour)
CIV 697 Internship (Variable 1-3 Hours)
CIV 698 Independent Study (Variable 1-4 Hours)
CIV 899 Dissertation Research (Variable 1-6 Hours)

Degree Program: Ph.D. in Engineering
Emphasis Area: Coastal Engineering
Department: Civil & Environmental Engineering and Industrial Systems & Technology

Core Courses

1. Choose four from the following list (CIV 520 is mandatory) after consultation and approval of the student's adviser.

Course No.	Title	Semester Hours
CIV 520	Advanced Engineering Analysis	3
CIV 538	Coastal Structures	3
CIV 539	Advanced Coastal Engineering Design	3
CIV 558	Sedimentation and River Engineering	3
CIV 631	Linear Theory of Ocean Waves	3
CIV 632	Tides and Long Waves	3
CIV 636	Spectral Wave Analysis	3
CIV 637	Advanced Design for Breakwater Rehab.	3

2. In addition, each student is required to take one graduate level advanced mathematics course after consultation and approval of the student's adviser.

Elective Courses

CIV 521 Advanced Engineering Analysis II**.** (3 Hours)
CIV 532 Pavement Materials and Design (3 Hours)
CIV 533 Evaluation, Maintenance, & Rehab. of Public Works Infrastructure (3 Hours)
CIV 534 Urban Transportation Engineering System Design (3 Hours)
CIV 540 Advanced Structural Analysis
CIV 542 Advanced Design of Concrete Structures
CIV 550 Engineering Hydrology (3 Hours)
CIV 551 Advanced Fluid Mechanics (3 Hours)
CIV 552 GIS Applications in Civil and Environmental Engineering (3 Hours)
CIV 553 Environmental. Methods in Civil Engineering
CIV 554 Water Resources Engineering Planning and Management
CIV 556 Groundwater Engineering
CIV 557 Computational Fluid Dynamics 3
CIV 558 Sedimentation and River Engr.
CIV 559 Environmental Hydraulics
CIV 562 Hazardous Waste Engineering
CIV 564 Surface Water (3 Hours)
CIV 633 Airport Planning and Design
CIV 640 Finite Element Method
CIV 650 Small Watershed Hydrology (3 Hours)
CIV 652 Hydraulic Engineering Design (3 Hours)
CIV 659 Advanced Topics in Water Resources Engineering

CIV 670 Rock Mechanics
CIV 680 Unsaturated Soil Mechanics
CIV 695 Scientific Writing Seminar
CIV 696 Seminar (3 Hours)
CIV 697 Internship (1-3 Hours)
CIV 698 Independent Study (1-4 Hours)
CIV 899 Dissertation Research (Variable 1-6 Hours)

Degree Program: Ph.D. in Engineering
Emphasis Area: Environmental Engineering
Department: Civil & Environmental Engineering and Industrial Systems & Technology

Core Courses

1. Choose three from the following list after consultation and approval of the student's adviser.

Course No.	Title	Semester Hours
CIV 561	Chemistry for Environmental Engineering	3
CIV 562	Hazardous Waste Engineering	3
CIV 660	Physiochemical Processes in Water and Wastewater	3
CIV 661	Biological Processes in Wastewater Engineering	3

2. In addition, each student is required to take one graduate level advanced mathematics course after consultation and approval of the student's adviser.

Elective Courses

CIV 520 Advanced Engineering Analysis I. (3 Hours)
CIV 521 Advanced Engineering Analysis II**.** (3 Hours)
CIV 550 Engineering Hydrology (3 Hours)
CIV 551 Advanced Fluid Mechanics (3 Hours)
CIV 552 GIS Applications in Civil and Environmental Engineering (3 Hours)
CIV 560 Environmental Engineering II (3 Hours)
CIV 563 Microbiology for Environmental Engineering (3 Hours)
CIV 564 Surface Water (3 Hours)
CIV 565 Wetland Management for Environmental Engineering (3 Hours)
CIV 566 Air Pollution and Control (3 Hours)
CIV 567 Environmental Remediation (3 hours)
CIV 568 Land Disposal of Waste (3 Hours)
CIV 569 Environmental Systems Modeling (3 Hours)
CIV 571 Principles of Geoenvironmental Engineering (3 Hours)
CIV 573 Environmental Geology for Engineers. (3 Hours)
CIV 574 Engineering Hydrogeology. (3 Hours)
CIV 575 Applied Geological Engineering. (3 Hours)
CIV 631 Linear Theory of Ocean Waves. (3 Hours)
CIV 631L Linear Theory of Ocean Waves' Laboratory (1 Hour)
CIV 632 Tides and Long Waves. (3 Hours)
CIV 650 Small Watershed Hydrology (3 Hours)
CIV 652 Hydraulic Engineering Design (3 Hours)
CIV 653 Advanced Design of Hydraulic Structures (3 Hours)
CIV 663 Design of Environmental Engineering Facilities (3 Hours)
CIV 664 Limnology for Environmental Engineering (3 Hours)

CIV 665 Environmental Law (3 Hours)
CIV 666 Advanced Waste Treatment Processes in Environmental Engineering (3 Hours)
CIV 667 Biological Process Engineering (3 Hours)
CIV 668 Bioenvironmental Engineering (3 Hours)
CIV 669 Advanced Topics in Environmental Engineering (Variable1-4 Hours)
CIV 680 Unsaturated Soil Mechanics (3 Hours)
CIV 695 Scientific Writing Seminar (1 Hour)
CIV 697 Internship (Variable 1-3 Hours)
CIV 698 Independent Study (Variable 1-4 Hours)
CIV 899 Dissertation Research (Variable 1-6 Hours)

Description of Courses

CIV 520 Advanced Engineering Analysis I. (3 Hours) A comprehensive course to familiarize engineering professionals with advanced applied mathematics as it relates to solving practical engineering problems. The course of intensive study blends the theoretical underpinnings of advanced applied mathematics with an understanding of how these powerful tools can be used to solve practical engineering problems. The material covered includes Ordinary Differential Equations; Linear Algebra, Vector Calculus; Fourier Analysis and Partial Differential Equations.

CIV 521 Advanced Engineering Analysis II. (3 Hours) A comprehensive course to familiarize engineering professions with advanced and applied mathematics as it relates to solving practical engineering problems. The course of intensive study blends the theoretical and advanced applied mathematics with an understanding of how these powerful tools can be

CIV 530 Advanced Pavement Analysis and Design. (3 Hours) Development of models for and analysis of pavement systems; use of transfer functions relating pavement response to pavement performance; evaluation and application of current pavement design practices and procedures; analysis of the effects of maintenance activities on pavement performance; and economic evaluation of highway and airport pavements. Prerequisite: CIV 475 or permission of Department.

CIV 531 Traffic Engineering. (3 Hours) Study of fundamentals of traffic engineering; analysis of traffic stream characteristics; capacity of urban and rural highways; design and analysis of traffic signals and intersection; traffic control; traffic impact studies; and traffic accidents. Prerequisite: CIV 390 or permission of Department.

CIV 532 Pavement Materials and Design. (3 Hours) Properties and control testing of bituminous materials, aggregates for bituminous mixtures, and analysis and design of asphalt concrete and liquid asphalt cold mixtures; structural properties of bituminous mixes; surface treatment design; and recycling of mixtures. Introduction to Superpave mix design and applications. Prerequisite: CIV 390 or permission of Department.

CIV 533 Evaluation, Maintenance, and Rehabilitation of Public Works Infrastructure. (3 Hours) Evaluation, maintenance, and rehabilitation of deteriorated infrastructure systems by considering live cycle costs and long-term performance. Understanding rehabilitation alternatives using in the practical field and designing rehabilitation based on the non-destructive testing methods and economic considerations. Prerequisite: CIV 390 and CIV475. (Cross Reference: CIV 479)

CIV 534 Urban Transportation Engineering System Design (3 Hours) Advanced design of highway systems, vehicle and driver characteristics, highway capacity, design of urban streets and expressways. Design constraints. Individual and team design projects oriented toward the solution of local urban transportation problems, societal and economic considerations. Prerequisite: CIV 390, CIV 310 and CIVL 310 or permission of Department. (Cross reference: CIV 470)

CIV 535 Pavement Design. (3 Hours) Aggregate, binder systems. Theory and design of pavement

structures, rigid and flexible pavement designs, subgrade materials, pavement management, nondestructive testing, pavement maintenance, design constraints, infrastructure maintenance, major design project. Prerequisite: CIV 380 and CIV 390. (Cross reference: CIV 475)

CIV 536 Highway Engineering. (3 Hours) Analysis of factors in developing a highway transportation facility; traffic estimates and assignment; problems of highway geometrics and design standards; planning and location principles; intersection design factors; street systems and terminal facilities; programming improvements; drainage design; structural design of surface; concepts of highway management and finance; and highway maintenance planning. Prerequisite: CIV 390 or permission of Department.

CIV 538 (3) Coastal Structures. The types and functions of coastal structures will be studied including, seawalls, groins, revetments, bulkheads, dikes, detached breakwaters, reef breakwaters, storm surge barriers and others. A coastal structure will be assigned to each student to provide the class a lecture to and prepare a term paper on the coastal structure assigned. Determination of the design wave climate for coastal structures is investigated as it pertains to the functional types of coastal structures. Invited guest lecturers will appear as available.

CIV 539 (3) Advanced Coastal Engineering Design. This course provides a comprehensive advanced investigation of the coastal engineering design process. It includes the Planning and Design Process, Site Characterization, Shore Protection Projects, Beach Fill Design, Navigation Projects, Sediment Management at Inlets and Environmental Enhancement. A design project will be assigned to each student to provide the class a power point presentation and to prepare a term paper on the design project assigned. Invited guest design professionals will appear and present lectures as available.

CIV 540 Advanced Structural Analysis. (3 Hours) A unified formulation of displacement and force methods of analysis including the topological view of the structure as an assemblage of members; matrix techniques of formulation; considerations for automatic computations; and evaluation of truss, grid, and frame models for the response of real structures. Prerequisite: CIV 320 or permission of Department.

CIV 541 Structural Dynamics. (3 Hours) Analysis of the dynamic response of structures and structural components to transient loads and foundation excitation; single-degree-of-freedom and multi-degree-of-freedom systems; response spectrum concepts; simple inelastic structural systems; and introduction to systems with distributed mass and flexibility. Prerequisite: CIV 320 or permission of Department.

CIV 542 Advanced Design of Concrete Structures. (3 Hours) Theory and design of reinforced concrete continuous beams, slender columns, two-way-slabs, footings, retaining walls, shear walls and multi-story buildings. Design for torsion and design constraints. Framing systems and loads for buildings and bridges, design constraints and a major design project. Prerequisite: CIV 420. (Cross reference: CIV 477)

CIV 543 Advanced Mechanics of Materials. (3 Hours) Study of beams under lateral load; beams with combined lateral load and thrust; beams on elastic foundations; applications of Fourier series

and virtual work principles to beam-type structures; stress and strain in three dimensions; applications to flexure of beams and plates; elements of the engineering theory of plates; and torsion of thin-walled open sections. Prerequisite: CIV 320 or permission of Department.

CIV 544 Advanced Design of Steel Structures. (3 Hours) Behavior and design of members subjected to fatigue, dynamic, combined loading. Methods of allowable design stress, and load resistance factor design. Design of continues beams, plate girders, composite beams, open-web joists, connections, torsion and plastic analysis and design. Framing systems and loads for industrial buildings and bridges, design constraints and a major design project. Prerequisite: CIV 360. (Cross reference: CIV 476)

CIV 545 Design of Wood and Masonry Structures. (3 Hours) Engineering properties and behavior of wood for analysis and design of wooden beams, walls and diaphragms. Engineering properties and behavior of masonry for analysis and design of masonry walls, columns and shear walls. Framing systems and loads for multi-story buildings, design constraints and a major design project. Prerequisite: CIV 420. (Cross reference: CIV 478)

CIV 550 Engineering Hydrology. (3 Hours) Principles and theory of surface water and groundwater flow and quality; understanding and determination of water budget, hydrologic cycle, Darcy's law, and water resources management at the watershed scale. Water quality parameters including data analysis and interpretation, laboratory tests, and maintenance of water quality. Applications in engineering design, Prerequisite: CIV 370 or permission of Department.

CIV 551 Advanced Fluid Mechanics. (3 Hours) Kinematics of fluid flow; plane irrotational and incompressible fluid flow; Navier-Stokes equations; two-dimensional boundary layers in incompressible flow; dimensional analysis and dynamic similitude; hydrodynamic stability; turbulence; real life problems; Engineering applications and system approach. Prerequisite: CIV 330 or permission of Department.

CIV 552 GIS Applications in Civil and Environmental Engineering. (3 Hours) This course introduces students to the basic concepts and skills necessary to engage applied Geographic Information Systems (GIS) in the field of Civil and Environmental Engineering. Students will gain basic theoretical knowledge required for development and successful use of GIS and practical training on use of GIS software. This course will consist of lecture sessions, lab exercises and a GIS project. While the principles taught will be general in nature, the students will be taught how to use the ArcView GIS software program, and working through several exercises that emphasize its use in Civil and Environmental Engineering. Selected topics include: GIS analysis procedures, integration of survey control for data acquisition and rectification, hardware software selection criteria, and error propagation analyses, Global Positioning Systems (GPS) and their use with GIS. Prerequisite: permission of the Department.

CIV 553 Experimental Methods in Civil Engineering. (3 Hours) Introduction to experimental methods, instrumentation, data acquisition and data processing; experimental aspects of static and dynamic testing in the various areas of civil engineering; overview of laboratory work with several hands-on applications in the laboratory. Prerequisite: permission of Department.

CIV 554 Water Resources Engineering Planning and Management. (3 Hours) Managing water resources; the planning process, systems analysis methods; institutional framework for water resources engineering; comprehensive integration of engineering, economic, environmental, legal and political considerations in water resources development and management. Prerequisite: permission of the Department.

CIV 556 Groundwater Engineering. (3 Hours) Groundwater hydrology, theory of groundwater movement, steady-state flow, potential flow, mechanics of well flow, multiple-phase flow, saltwater intrusion, artificial recharge, groundwater contamination and models. Prerequisite: CIV 370 or permission of Department.

CIV 557 Computational Fluid Dynamics. (3 Hours) Finite-difference and finite-volume methods and basic numerical concepts for the solution of dispersion, propagation and equilibrium problems commonly encountered in real fluid flows; theoretical accuracy analysis techniques. Prerequisites: CIV330 and knowledge of one programming language.

CIV 558 Sedimentation and River Engineering. (3 Hours) Hydraulics of sediment transport; erosion and sedimentation problems; river mechanics and morphology; mathematical modeling of river hydraulics; sediment transport and river channel changes. Design and environmental problems; erosion control and river training. Prerequisites: CIV465 or permission of Department.

CIV 559 Environmental Hydraulics. (3 Hours) The application of fluid mechanics principles in the analysis of environmental flows. Topics include Stratified flows, turbulent jets and plumes, wastewater and thermal diffusers, cooling ponds and cooling channels and the control of environmental problems. Prerequisites: CIV330 or permission of Department.

CIV 560 (3) Environmental Engineering II. The physical, chemical, and biological environmental engineering systems that are used to protect health and the environment. Examples include drinking water treatment, wastewater treatment, hazardous waste treatment, and air pollution control. Prerequisite: permission of the department.

CIV 561 (3) Chemistry for Environmental Engineering. The principles of physical, equilibrium, inorganic, and organic chemistry as they apply to drinking water treatment, wastewater treatment, natural water quality, air quality, and air pollution control. Applications in engineering design. Prerequisite: CIV 340, or CIV 560, or permission of the department.

CIV 562 Hazardous Waste Engineering. (3 Hours) Comprehensive study of the complex, interdisciplinary engineering principles involved in hazardous waste handling, collection, transportation, treatment, and disposal. Also covered are waste minimization, site remediation, and regulations important for engineering applications. Design constraints, engineering judgment, and ethical responsibility are covered. Contemporary hazardous waste issues and urban issues are also addressed. Prerequisite: CHEM 241, CHML 241, CIV 340, CIVL 340, or permission of Department. (Cross reference: CIV 468)

CIV 563 Microbiology for Environmental Engineering. (3 hours) The microbiological principles that apply to wastewater treatment, drinking water protection, water quality, and disease

transmission. Applications in engineering design. Prerequisite: CIV 560 or permission of the department.

CIV 564 Surface Water. (3 Hours) Water quantity, water quality, regulation of, and management of rivers, lakes, and wetlands. Applications in engineering design. Prerequisite: permission of Department.

CIV 565 Wetland Management for Environmental Engineering. (3 Hours) (3 Hours) The physical, chemical, biological, and regulatory aspects of wetland ecosystems. The impacts of engineered structures on wetland systems, and the factors involved with developing specifications for wetland creation and restoration. Prerequisite: permission of Department.

CIV 566 Air Pollution and Control. (3 hours) The sources of and engineering principles to prevent or control air pollution and to design and operate processes. Topics include the risks of air pollution to which the public is exposed, the principle and factor underlying the generation of pollutants, physical principles describing how pollution affects the atmosphere and human well-being, regulations which engineers will be expected to understand and comply with. The engineering aspects include principles governing pollutant production from stationary and mobile combustion systems, modeling of the generation and transport of pollutants in the atmosphere, methods for separation and removal of gasses and particulates from a process gas stream. Prerequisite: permission of the department.

CIV 567 Environmental Remediation. (3 Hours) The course covers current engineering solutions for the remediation of soils and waters contaminated by hazardous waste or spills. The technologies to be covered include bioremediation, oxidation, soil vapor extraction, soil washing, surfactant-enhanced remedy, thermal treatment, air stripping, solidification/stabilization, electrokinetic decontamination, underground barriers, permeable reactive treatment walls, and other newly-emerging technologies. The engineering principles behind the remediation technologies are emphasized. Examples of successful applications of the remediation technologies are discussed. Prerequisite: permission of Department.

CIV 568 Land Disposal of Waste. (3 hours) Theoretical, regulatory, and practical aspects of the disposal of waste on lands. Decontamination and reclamation of lands contaminated by industrial activities and spills of industrial chemicals. The usefulness and environmental impact of the disposal of municipal and industrial wastes via land treatment and land filling. Design considerations and engineering problems associated with the land disposal of septic tank effluent, municipal garbage, sewage sludge, sewage effluent, industrial and hazardous waste, and radioactive wastes. Prerequisite: permission from the department.

CIV 569 Environmental Systems Modeling. (3 hours) Mathematical modeling of environmental systems, including rivers, lakes, estuaries, and air. Prerequisite: permission from the department.

CIV 570 Regional Geological Engineering. (3 hours) Geological engineering problems unique to specific geomorphic and physiographic regions based on terrain, rock type, and geologic structure will be addressed. Examples will be presented to show how site-specific conceptual geologic models are necessary for successful engineering design in unique geologic regions of the

United States. Prerequisite: permission from the department.

CIV 571 Principles of Geoenvironmental Engineering. (3 Hours) Topics in geoenvironmental engineering in an urban environment. landfill design and incineration options. Stability of landfills, geotechnical characteristics of landfills, liner systems. Waste characterization, minimization, collection, treatment, transport and disposal. Leachate characteristics and potential groundwater contamination, design constraints. Legal and ethical considerations. Prerequisite: permission of Department. (Cross reference: CIV 471)

CIV 572 Applied Geotechnical Engineering Design. (3 Hours) Practical real life urban projects and advanced laboratory experience in geotechnical engineering, construction dewatering, construction issues, safety and economy, urban geotechnical engineering issues, preparation of subsurface investigation and geotechnical engineering reports, ethical considerations, oral presentation. Pre or co-requisite: CIV 430 or permission of Department. (Cross reference: CIV 472)

CIV 573 Environmental Geology for Engineers. (3 Hours) Defines the role of Environmental Geology in the engineering design of remedial activities dealing with a wide range of geotechnical engineering problems. Fundamental concepts of environmental unity and the rising human population will be addressed. Topics will range from earthquakes to coastal processes with particular emphasis on landslides and water problems. Prerequisite: permission from the Department.

CIV 574 Engineering Hydrogeology. (3 hours) Defines the role of Hydrogeology in the engineering design of activities dealing with the interaction of ground and surface water. The course will address a wide range of topics including the role of water in earthquakes and landslides, land subsidence, swelling clay foundations, geothermal energy, engineered wetlands, cave and karst formation, contaminant transport, and water resources with emphasis in engineering design. Prerequisite: permission from the Department.

CIV 575 Applied Geological Engineering. (3 hours) Applications of geological concepts including geomorphology and structural geology in solving geological engineering problems. Study of engineering principles and properties of earth materials. Exploration during engineering design and methods of site investigations. Applications of instrumentation and equipment used for soil, rock, and water analyses. Prerequisite: permission from the Department.

CIV 576 Geological Engineering Analysis. (3 hours) Computer applications to geological engineering, analysis, design, and use of computers for geological engineering projects. Computer-aided engineering facilities and use of general productivity and engineering software. Numerical methods in the solution of geological engineering and related problems. Case study of a complex project and a large- scale engineering analysis. Prerequisite: permission from the Department.

CIV 577 Air-Photo Interpretation for Terrain Evaluation. (3 hours) Determination of soil, bedrock, and drainage characteristics of land areas by air-photo interpretation and analysis; physical characteristics of landforms; application of air-photo interpretation for engineering soil surveys, land use suitability evaluation, and land use planning, applications in engineering design.

Prerequisite: permission from the Department.

CIV 578 Applied Geophysics. (3 Hours) Gravity and magnetic theory and methods. Gravitational field of earth and gravity measurements applications to geological engineering problems. Imaging subsurface features of earth using basic principles of physics, namely elastic, electric, magnetic, and density properties of earth material. Applications in engineering design. Prerequisite: permission of Department.

CIV 579 Engineering Seismology. (3 hours) Theory and applications in earthquake seismology, earthquake mechanics, wave propagation, earth structure, instrumentation, interpretation of seismograms, focal mechanisms, faults, paleoseismology, seismotectonics, earthquake locations and magnitudes, selection of ground motion parameters. Applications in engineering design. Prerequisite: permission from the Department.

CIV 631 Linear Theory of Ocean Waves. (3 Hours) A systematic theoretical development of the linear theory of simple harmonic ocean gravity waves, water particle kinematics, shoaling, refraction, diffraction, and reflection.

CIVL 631 Linear Theory of Ocean Waves' Laboratory. (1 Hour) Laboratory for linear ocean wave theory generation and propagation of linear waves, measurement of wave properties and observation of wave transformations in shallow water.

CIV 632 Tides and Long Waves. (3 Hours) A systematic development of the theory of ocean tides, tidal forcing functions, near shore tidal transformations and tidal

CIV 633 Airport Planning and Design. (3 Hours) Basic principles of airport facilities design to include aircraft operational characteristics, noise, site selection, land use compatibility, operational area, ground access and egress, terminals, ground service areas, airport capacity, and special types of airports. Prerequisite: CIV 390 or permission of Department.

CIV 636 Spectral Wave Analysis. (3 hours) Measurement techniques of ocean waves. Introduction and basic concept of wave spectrum. Harmonic analysis and mathematical formulation of wave spectrum. Maximum entropy and maximum likelihood methods. Idealized wave spectral models. Wave energy balance equation and its applications. Nonlinear wave-wave interaction and diffraction. Wave hindcast and forecast modeling in coastal waters. Prerequisite: CIV 330, CIV 631 or permission of the Department.

CIV 637 Advanced Design for Breakwater Rehabilitation. (3 hours) Advanced analysis and design considerations for breakwaters are investigated for the most complex challenges. These challenges are associated with rehabilitation and/or reconstruction of damaged breakwaters. Design considerations are explored from an analysis of breakwater failures at Sines, Nawiliwili, Kahului and others. Toe design, crest elevation, crown design, core alternatives, runup, overtopping, design waves, head design, constructability and functionality are explored. Prerequisite: permission of Department

CIV 640 Finite Element Methods. (3 Hours) Theory and application of the finite element method;

stiffness matrices for triangular, quadrilateral, and isoparametric elements; two- and three-dimensional elements; algorithms necessary for the assembly and solutions; direct stress and plate bending problems for static, nonlinear buckling and dynamic load conditions; displacement, hybrid, and mixed models together with their origin in variational methods. Prerequisite: CIV 540 or permission of Department.

CIV 642 Prestressed Concrete Design. (3 Hours) Study of strength, behavior, and design of prestressed reinforced concrete members and structures, with primary emphasis on precast, prestressed construction; emphasis on the necessary coordination between design and construction techniques in prestressing. Prerequisite: CIV 420 or permission of Department.

CIV 645 Plates and Shells. (3 Hours) Classical bending theory of plates and shells; emphasis on methods of solution including series expansions, finite element and finite difference methods; application of theories to commonly encountered structures in practice; and consideration of in plane loads, large deflections, buckling, and anisotropy. Prerequisite: CIV 640 or permission of Department.

CIV 650 Small Watershed Hydrology. (3 Hours) The role of land conditions in dealing with engineering problems of applied hydrology with emphasis on the small watershed, limited data, and land management situations Gain a physically-based understanding of hydrologic processes that define the functions of small watersheds; Effects of natural and human disturbances on the components of the hydrologic cycle; Investigate special characteristics of small watersheds; Approaches for dealing with limited data; Use the understanding of applied hydrology to predict the impacts of various land use activities on terrestrial and aquatic ecosystems; Develop analytic tools to integrate land use and catchments characteristics to predict catchments response and guide watershed management. Topics include stream flow generation, hill slope hydrology, stream channel hydraulics, hydrograph separation, evapotranspiration, hydrologic tracers, riparian zone hydrology, and hyporheic zone hydrology. Applications in engineering design. Prerequisite: CIV 550 or permission of Department.

CIV 652 Hydraulic Engineering Design. (3 Hours) Design of water supply and transport systems; Design and analysis of structures for controlling and conveying water in both the built and natural environment; Engineering applications of hydraulic and hydrologic engineering; Analytic methods and computer models for the design and evaluation of water resource projects such as flood control and river basin development; Common models, and typical applications for water resource systems; Reservoir design, flood routing; and design of water distribution and storm water management systems, and sanitary sewers. Prerequisite: CIV 370 or permission of Department.

CIV 653 Advanced Design of Hydraulic Structures. (3 Hours) Analysis and characteristics of flow in open channels (natural and artificial); channel design considerations including uniform flow (rivers, sewers), flow measuring devices (weirs, flumes), gradually varied flow (backwater and other flow profiles, flood routing), rapidly varied flow (hydraulic jump, spillways), and channel design problems (geometric considerations, scour, channel stabilization, sediment transport); analysis and design of hydraulic structures such as dams, spillways etc. based on economic, environmental, ethical, political, societal, health and safety considerations. Prerequisite:

CIV 370 or permission of Department. (Cross-Reference: CIV 466)

CIV 654 Water Resources Systems Engineering. (3 hours) Linear and non-linear optimization models and simulation models for planning and management of water systems; single- and multi-objective analysis and deterministic and stochastic techniques. Prerequisites: CIV 554 or permission of Department.

CIV 655 Stochastic Hydrology. (3 Hours) Advanced applications of statistics and probability to hydrology, time series analysis and synthesis, and artificial neural network methods. A combination of theory and application to the field of hydrology, environmental and water resources engineering, climatic modeling and other natural resources modeling. Prerequisites: CIV 550, MATH 307 or permission of Department.

CIV 659 Advanced Topics in Water Resources Engineering. (Variable 1-3 Hours) Course will focus on a variety of topics in the field of water resources engineering. May be repeated for credit. Prerequisite: permission of Department.

CIV 660 Physicochemical Processes in Water and Wastewater Treatment. (3 hours) Fundamental principles, analysis, modeling, and design considerations of physical and chemical processes for water and wastewater treatment processes and operations. Drinking water treatment processes will be focused on while parallel wastewater treatment schemes are also being discussed. Relevant water quality characteristics, standards, and regulations in engineering design will be reviewed. Prerequisite: CIV 561 or permission from the Department.

CIV 661 Biological Processes in Wastewater Treatment. (3 hours) Theory and applications of the biological processes available for the treatment of wastewaters. Fundamentals of biological degradations and transformation of pollutants. Microbial growth kinetics and modeling. Wastewater treatment processes, both aerobic and anaerobic, including suspended growth biological processes and attached growth processes. Emphasis on engineering design considerations and parameters. Prerequisite: CIV 660

CIV 663 Design of Environmental Engineering Facilities. (3 Hours) Analysis and design considerations and constraints for environmental engineering facilities such as water and wastewater treatment plants, solid and hazardous waste landfills, and resources recovery facilities. Design of municipal wastewater treatment plant including site selection, plant layout, hydraulic profile, preliminary treatment processes (screening, sedimentation, flow equalization, etc.), secondary treatment processes (activated sludge, trickling filter), waste stabilization ponds/constructed wetland), and sludge treatment and disposal (thickening, centrifugation, belt press, anaerobic digestion, thermal process and land disposal). Completion of one major design project and two minor design projects. Prerequisite: CIV 661 or permission of Department. (Cross reference: CIV 460)

CIV 664 Limnology for Environmental Engineering. (3 hours) The study of aquatic ecosystems, with an emphasis on lakes. The physical characteristics of water and lakes; the chemical characteristics of aquatic systems; the dominant plants and animals in lakes, streams, and wetlands. The impacts of pollution on engineered structures, and man-made alterations of lakes

and streams. Prerequisite: permission from the Department.

CIV 665 Environmental Law. (3 hours) The major federal statutes and regulations that govern environmental protection. Included are the National Environmental Policy Act, the Clean Air Act, the Clean Water Act, Superfund, and others. Prerequisite: permission from the Department.

CIV 666 Advanced Waste Treatment Processes in Environmental Engineering. (3 hours) An in-depth study of the biological processes used to treat wastewater, with an emphasis on recently published information. Prerequisite: CIV 661 or permission from the Department.

CIV 667 Biological Process Engineering. (3 hours) Applications of the principles of microbial kinetics and heat transfer to the analysis and design of biological engineering processes. Emphasis on applications in environmental engineering processes or projects. Prerequisite: permission from the Department.

CIV 668 Bioenvironmental Engineering. (3 hours) Engineering principles for the design of systems for the biological treatment and utilization of organic by- products from animal and crop production and from industrial processes such as food and crop processing industries. Design of best management practices to protect bioenvironmental resources by minimizing non- point pollution (off-site movement of sediment, nutrients and other constituents) and by minimizing nuisance odors associated with land-applied organic residues, inorganic fertilizers and pesticides. Economic utilization of beneficial components of typical wastes. Prerequisite: permission from the Department.

CIV 669 Advanced Topics in Environmental Engineering. (1-4 hours) This course will focus on a variety of topics in the field of environmental engineering. May be repeated for credit. Prerequisite: permission from the Department.

CIV 670 Rock Mechanics. (3 Hours) Classification of rock masses, stress and strain in rock, elastic and time-dependent behavior of rock, state of stress in rock masses, failure mechanisms, construction applications, geological and engineering applications. Prerequisite: permission of Department.

CIV 671 Advanced Topics in Geological Engineering. (1-4 hours) Course will focus on a variety of topics in the field of geological engineering. May be repeated for credit. Prerequisite: permission from the Department.

CIV 672 Advanced Geomechanics. (3 Hours) Theoretical and quasi-theoretical approaches for advanced soil mechanics including stress analysis, consolidation theory, immediate settlement, and saturated and partially saturated soils; problem idealization; introduction to rock mechanics; engineering judgment. Prerequisite: CIV 380 or permission of Department.

CIV 673 Advanced Foundation Engineering. (3 Hours**)** Advanced topics in foundations design, special cases of shallow foundations; horizontal load capacity of pile foundations; battered piles, load calculation of pile groups. Drilled caissons; design and construction of sheet piles including cantilever and anchored sheet piles; earth pressures and stability of retaining structures; design of

braced supports, cofferdams; design examples. Prerequisite: CIV 430 or permission of Department.

CIV 674 Soil Dynamics. (3 Hours) Study of soil behavior under various dynamic loadings including earthquakes. Laboratory & field techniques for determining dynamic soil properties and liquefaction potential. Factors affecting liquefaction; dynamic soil-structure interaction. Engineering design examples. Prerequisite: CIV 380 or permission of Department.

CIV 675 Earth Dams and Slopes. (3 Hours) Stability of natural and man-made slopes under various loading conditions, slope protection. Selection and measurement of pertinent soil parameters. Engineering design and construction of earth dams and embankments. Practical aspects of seepage effects and ground water flow. Flow net and its use; wells; filters; total and effective stress methods of slope analysis. Prerequisite: CIV 380 or permission of Department.

CIV 676 Tunneling. (3 Hours) Overview of tunneling practice in rocks and soft ground. Underground construction techniques. Geological aspects and major technical problems in tunneling. Various tunneling methods and selections. Design and support of tunnels in soft ground and rock. Prerequisite: Permission of Department.

CIV 677 Design and Construction with Geosynthetics. (3 Hours) Properties and behavior of geosynthetics including geotextiles, geogrids and other fabrics; applications in geotechnical and geo-environmental engineering; quantify hydraulic behavior; applications in remediation, retaining structures, and foundations construction. Prerequisite: permission of Department.

CIV 678 Soil Bioengineering. (3 Hours) Engineering practices and ecological principles for the assessment, design, construction and maintenance of living vegetation systems. Slope stabilization against shallow mass movement and erosion through vegetated reinforcement. Root reinforcement, erosion control, aesthetics and environmental factors in engineering design are considered. Prerequisite: permission of Department.

CIV 679 Advanced Topics in Geotechnical Engineering. (Variable 1-4 Hours) Course will focus on a variety of topics in the field of geotechnical engineering. May be repeated for credit. Prerequisite: permission of Department.

CIV 680 Unsaturated Soil Mechanics. (3 Hours) Introduction of unsaturated soil, stress-state variables, soil water suction and soil water characteristic curves, hydraulic function curves, flow in unsaturated soil, shear strength and slope stability analysis, lateral earth pressure and retaining structures design, and compressibility and volume change analysis for unsaturated soils. Prerequisites: CIV 380 or Departmental Permission.

CIV 681 Excavation Support Systems and Retaining Structures. (3 Hours) Earth pressure theory used in the design of temporary and permanent earth retaining structures, guidelines for the selection of retention method, retaining wall design and associated construction issues of gravity walls, concrete retaining walls, MSE wall, sheet pile wall, soldier pile and diaphragm walls, braced and tie back excavation support systems. Prerequisites: CIV 380 or permission from the Department.

CIV 682 Computational Geotechnics. (3 Hours) Introduction to numerical and finite element

modeling, analyses of embankments, earth dams, slopes, excavation support systems including soldier pile and diaphragm walls, shallow and deep foundation systems, and other geo-structures using advanced geotechnical software. Prerequisites: CIV 380 or permission from the Department.

CIV 683 Soil Structure Interactions. (3 Hours) Introduction to geotechnical earthquake engineering and fundamental understanding of soil behavior under dynamic loading, finite element analysis of soil structure interaction due to dynamic loading and structural response, seismic slope stability analysis, seismic design of retaining wall and buried structures, case studies. Prerequisites: CIV 380 or permission from the Department.

CIV 684 Advanced Site Characterization and Instrumentation. (3 Hours) In situ test methods, advantages and limitations, SPT, CPT, DCPT, CPTU or piezocone, DMT, pressure meter, shear vane and other field test methods, non-destructive seismic, res1stiv1ty, electromagnetic methods, soil property interpretation procedures, geotechnical instrumentation types, monitoring and applications. Prerequisites: CIV 380 or permission from the Department.

CIV 695 Scientific Writing Seminar. (1 Hour) Exercises in scientific writing format and style, with particular emphasis on writing abstracts and manuscripts for publication in referred archival journals.

CIV 696 Seminar. (1 Hour) Presentation of papers, projects and reports by visiting lecturers, graduate students, engineers, and community leaders.

CIV 697 Internship. (Variable 1-3 Hours) Supervised graduate internship and externship in various areas. Prerequisite: permission of Department.

CIV 698 Independent Study. (Variable 1-4 Hours) Intensive study of a special project including research and literature review selected in accordance with student interests and arranged in consultation with the adviser. Topics will vary. Students will make period reports, and will prepare a scholarly paper at the end of semester. Prerequisite: permission of Department.

CIV 899 Dissertation Research. (Variable 1-6 Hours) Dissertation representing independent and original research.