Discussion Draft:
Proposal for a Graduate Certificate in River Restoration
First version—April 10, 2006

Background:

In July 2005, a prospectus was developed to create a program to graduate Masters-level students at the University of Washington with professional-quality, interdisciplinary training in the principles and practice of river restoration. This effort was motivated by recognition of a growing need for trained entry-level professionals, and the value of responding to the high level of student interest that already exists in this subject area. It also was borne on the judgment that this field presents an ideal opportunity for the UW to move quickly into a role of national prominence, because interest and attention in this subject is high nationwide but credentialed academic programs do not currently exist.

As originally envisioned, the program would include the following elements:

- Available for students in any one of several departments, the most likely being Earth & Space Sciences, Civil & Environmental Engineering, Aquatic & Fishery Sciences, and Forest Resources;
- Administered as either a two-year (with thesis) or a 12-month (non-thesis) post-baccalaureate program, with the latter option as either a 5^{th}-year MS degree for undergraduate majors or as a professional MS for returning students who have already been active in the field;
- Granting a certificate in river restoration, akin to existing certification programs already offered across the university, to accompany the MS degree that would be earned in the student's home department (although a future stand-alone degree was not to be precluded); and
- Based on a curriculum of traditional coursework, field-based data collection and analysis, development of writing skills, and an integrative project ideally in conjunction with a project of an agency or private firm.

Implementing any such program requires a number of steps between initial conception and accepting its first students. Eight steps have been envisioned, of which the first six will be completed by June 2006:

1. Determine the need, opportunity, and current interest in a graduate river-restoration program.
2. Identify the educational content and desired outcome of this program.
3. Characterize one or more organizational frameworks that could successfully administer a program with this content and outcomes at the University of Washington.
4. Solicit feedback on the content, desired outcomes, and organizational framework(s) from students, faculty, and interested outside professionals; iterate through steps 2 and 3 (above) as needed to reach consensus among interested groups.
5. Determine existing and required resources to implement the program as developed through steps 1–4.

6. Document the outcomes of the first 5 steps, including needs and opportunities in the field, intended educational outcomes, preferred administrative framework, and required new resources.
7. To the extent new resources are needed, open discussions with University administrators and, potentially, outside funding sources.
8. If and when necessary new resources are identified, move to formal establishment of the program. Note that different desired outcomes and administrative frameworks (e.g., certificate vs. graduate degree program) would require different actions at this step.

To date, steps 1 and 2 have occurred; their outcomes are posted on the project website, http://depts.washington.edu/cwws/streams.html. In particular, a recent Science article noted that >$1B/year is being spent on "River Restoration" nationwide; of the activity represented by this total, a substantial amount is occurring in the Pacific Northwest and is already providing both post-graduate employment and research opportunities for many in the University community. "Restoration" is already an area of recognized University expertise (e.g., the Restoration Ecology Network), and the improvement of our region's watercourses is a topic of high public interest.

This report represent the first iteration of step 3, "Characterize organizational frameworks," and it is intended to provide a tangible basis for discussions to follow (step 4). This document thus explores *one* possible expression of a River Restoration program. It does not yet reflect the consensus view of the University community about the "best" such program, but it is at least consistent with informal conversations and discussions among many faculty, students, and outside professionals that have already occurred about what such a program might and should include. It is also informed by a recent workshop sponsored by the NSF-funded National Center for Earth-Surface Dynamics, where participants from the academic and consulting communities explored the options for improving the quality and rigor of stream-restoration training. A public distribution of that workshop's recommendations is anticipated May 2006, prior to the completion of the University of Washington proposal.

The purpose of the following discussion draft is to articulate choices that are still to be made about the form of the program, to show the tangible consequence of making some of those choices, and to provide the basis for further suggestions and discussions about how best to proceed (or, if to proceed at all). The structure of this presentation loosely follows that of existing graduate certificate programs, in particular the Environmental Management Certificate Program and the Interdisciplinary and Policy Dimensions of the Earth Sciences. General guidelines for certificate programs are specified by the Graduate School.

****DISCUSSION DRAFT****

PROPOSAL FOR A GRADUATE CERTIFICATE IN RIVER RESTORATION
First version—April 10, 2006

Program Structure and Requirements

This program is envisioned as a graduate certificate program, following the framework established by the Graduate School at the University of Washington. Under this framework, each student completes departmental degree requirements and designs a concurrent Certificate program to develop both background and selected technical skills in the field. Coursework is custom-tailored to the individual student but must include at least 15 credits, with a minimum of 9 credits in courses numbered 500 or higher (per Graduate School requirements). Also in accord with Graduate School requirements, certificate programs cannot be simply a subset of courses required for their degree, but courses taken for the certificate can also count as electives to fulfill departmental degree requirements. The program of study will be designed in consultation with an advisory committee and the Graduate Program Coordinator. As part of the 15 credits, all students will complete a capstone course.

Application and Enrollment

Students enrolled in or entering a graduate degree program in one of the following academic units are eligible to apply:

- Earth and Space Sciences
- Civil and Environmental Engineering
- Aquatic and Fishery Sciences
- Forest Resources

This is not necessarily an exhaustive or all-inclusive list. For example, students in Landscape Architecture, Urban Planning, or the Evans School might well have an interest and background appropriate for such a program. This proposal draft, however, is limited to these four units because of the similarities that commonly exist between the respective backgrounds and coursework of enrolled students.

As with other graduate certificate programs at the University, this is not a stand-alone degree program and does not offer admission to graduate students. Prospective graduate students interested in applying for graduate study in River Restoration at UW should apply to one of the four above-listed academic units. (The absence of admission-granting authority, although consistent with current university policies, may have undesired outcomes that should be explored during further discussions.) This program is also available for non-matriculated, non-degree courses of study, but it does not provide a graduate degree, only a certificate, and it does not automatically confer acceptance into a graduate degree program.

Advising and Administration

Administration of the Certificate program will be through an existing entity at the University of Washington. Obvious candidates are the Program on the Environment, which already administers two other graduate certificate programs, and the Water Center, which has a more focused mission that includes this topic and is co-sponsored by three of the four colleges envisioned to contribute students and courses to this program. No detailed conversations have occurred with either unit, however, and so these suggestions are neither final recommendations nor even confirmation of a willingness to proceed. They simply reflect that an administrative role is needed in order to provide guidance and other resources for prospective and ongoing students, and to help organize seminar series and the capstone course (see below). The Certificate is granted through the University of Washington Graduate School, and the associated Masters Degree through the student's home academic unit.

Core Courses

Five existing courses form the core of the River Restoration curriculum. They have been selected to provide students a fundamental background across the range of disciplines and perspectives important in the theory and practice of river restoration:

Risk Analysis and Decision Theory: QERM 514 Analysis of Ecological and Environmental Data I (4) (Quantitative Ecology & Resource Management) *or* Q SCI 482 Statistical Inference in Applied Research (5) (Quantitative Science)

Hydrology: CEE 476 Physical Hydrology (3) (Civil & Environmental Engineering) *or* CFR 525 Advanced Wildland Hydrology (4) (Forest Resources)

Fluvial Geomorphology: ESS 426 Fluvial Geomorphology (5) (Earth & Space Sciences)

Restoration Ecology: ESRM 473 Principles of Ecological Restoration (5) (Forest Resources)

Stream Ecology: FISH 547 Stream and River Ecology (5) (SAFS) *and/or* FISH 438 Biological Monitoring and Assessment (5) (SAFS)

Other recommended and/or worthwhile courses currently available at the University of Washington are summarized on the accompanying table (Appendix A).

Capstone Course

As part of the program, students in the program participate in a one-quarter capstone course on River Restoration. The capstone course is designed to integrate state-of-the-art research findings in combination with ongoing examples from the region. Were opportunities available from outside collaborators in government and (or) the private sector, internships or other field-site experiences would ideally be included. Such an integrative course is a requirement of the Graduate School for any certificate program, but it does not currently exist for this topic in any department at the University of Washington.

Implementation of course program for matriculated students

Because each of the four targeted academic units have somewhat different requirements for their own MS degrees (see Appendix B), the implementation of this program will be different for students in each unit. What follows is a discussion, organized by academic unit, of those implementation alternatives based on current published degree requirements. What this discussion does *not* take into account, however, are (1) impending changes to programs that have not yet been implemented but will occur before any new students could begin this proposed program; (2) formal waivers of departmental/school requirements that are available to students via the process of academic advising; and (3) informal practices that are carried out by common consent but not readily apparent from printed policies and procedures. As a result, the following almost certainly diverges from both present and future reality, although presumably not in its gross elements.

- Earth and Space Sciences: At present, departmental requirements are little different from those of the Graduate School, and so a non-thesis degree program could consist exclusively of courses from the recommended list for the River Restoration program. A sample curriculum for a student in ESS might therefore look like this:

  Risk Analysis and Decision Theory: QERM 514 Analysis of Ecological and Environmental Data I (4) (Quantitative Ecology & Resource Management) *or* Q SCI 482 Statistical Inference in Applied Research (5) (Quantitative Science) (CORE)

  Hydrology: CEE 476 Physical Hydrology (3) (CORE); CEE 574 Advanced Hydrology (3) (Civil & Environmental Engineering)

  Fluvial Geomorphology: ESS 426 Fluvial Geomorphology (5) (Earth & Space Sciences) (CORE)

  Restoration Ecology: ESRM 473 Principles of Ecological Restoration (5) (Forest Resources) (CORE)

  Stream Ecology: FISH 547 Stream and River Ecology (5) (SAFS) *and/or* FISH 438 Biological Monitoring and Assessment (5) (SAFS) (CORE)

  Sediment Transport: OCEAN 542 Sediment Dynamics and Boundary-Layer Physics (4) (Oceanography)

  Watershed Processes : FISH 447 Watershed Ecology and Management (3) (SAFS)

  Capstone course (3) (CORE)

These courses total 38 credits out of a minimum requirement of 45, and so additional coursework options are still available. Note that this curriculum includes only one ESS course, however, suggesting that such a graduate student might wish to explore other coursework outside of those listed here in order to maintain his or her disciplinary foundation (or, at least, to explore their disciplinary interests).

Proposed changes within the ESS department would significantly change this prospective program, insofar as a number of new courses would be required of all ESS students. The flexibility currently provided to students in this program, and the opportunities that this flexibility currently provides for exploring diverse topics within the field of river restoration, may thus be short-lived.

- Civil and Environmental Engineering: The primary curricular requirement for students in this department is the need for 15 credits at the 400 or 500 level from within the CEE offerings. In combination with the core courses for the River Restoration certificate, a sample program might include the following:

    Risk Analysis and Decision Theory: QERM 514 Analysis of Ecological and Environmental Data I (4) (Quantitative Ecology & Resource Management) *or* Q SCI 482 Statistical Inference in Applied Research (5) (Quantitative Science) (CORE)

    Hydrology: CEE 476 Physical Hydrology (3) (CORE); CEE 574 Advanced Hydrology (3) (Civil & Environmental Engineering)

    Sediment Transport: CEE 474 Hydraulics of Sediment Transport (3) (Civil and Environmental Engineering)

    Hydraulics: CEE 472 Introduction to Hydraulics in Water Resources (3); CEE 570 Hydrodynamics (4) (Civil & Environmental Engineering)

    Fluvial Geomorphology: ESS 426 Fluvial Geomorphology (5) (Earth & Space Sciences) (CORE)

    Restoration Ecology: ESRM 473 Principles of Ecological Restoration (5) (Forest Resources) (CORE)

    Stream Ecology: FISH 547 Stream and River Ecology (5) (SAFS) *and/or* FISH 438 Biological Monitoring and Assessment (5) (SAFS) (CORE)

    Capstone course (3) (CORE)

  This course of study totals 38 credits, and so additional coursework options remain available for students.

- Aquatic and Fishery Sciences: Of the 27 coursework credits required for the MS degree in this school, 15 are specified. Of those 15 credits, one of the courses (QSCI 482, Statistical Inference in Applied Research, 5 credits) is already part of the River Restoration core. The remaining core courses total 18 units:

    Hydrology: CFR 525 Advanced Wildland Hydrology (4) (Forest Resources) (CORE)

    Fluvial Geomorphology: ESS 426 Fluvial Geomorphology (5) (Earth & Space Sciences) (CORE)

    Restoration Ecology: ESRM 473 Principles of Ecological Restoration (5) (Forest Resources) (CORE)

    Stream Ecology: FISH 547 Stream and River Ecology (5) (SAFS) *and/or* FISH 438 Biological Monitoring and Assessment (5) (SAFS) (CORE)

…and the capstone adds an additional 3 units. This total, 21 credits, is 9 credits more than the departmental minimum. It constitutes a feasible course of study over a two-year MS degree program (already likely as a consequence of the school's thesis requirement) but renders a one-year alternative virtually impossible.

- Forest Resources: Of the 36 course credits required for the MS degree, 14 are specified. Of those 14, 4 that are targeted for "research design and quantitative analysis" are almost certainly satisfied by the River Restoration core (via QERM 514). Thus, a potential curriculum for a graduate student in this unit might include the following:

    Risk Analysis and Decision Theory: QERM 514 Analysis of Ecological and Environmental Data I (4) (Quantitative Ecology & Resource Management) *or* Q SCI 482 Statistical Inference in Applied Research (5) (Quantitative Science) (CORE)

    Hydrology: CFR 525 Advanced Wildland Hydrology (4) (Forest Resources) (CORE)

    Fluvial Geomorphology: ESS 426 Fluvial Geomorphology (5) (Earth & Space Sciences) (CORE)

    Restoration Ecology: ESRM 473 Principles of Ecological Restoration (5) (Forest Resources) (CORE)

    Stream Ecology: FISH 547 Stream and River Ecology (5) (SAFS) *and/or* FISH 438 Biological Monitoring and Assessment (5) (SAFS) (CORE)

    Capstone course (3) (CORE)

As with SAFS, a thesis is required (although the minimum number of credit-hours for this effort is only 9). This degree requirement also makes the likelihood of accomplishing the river restoration certification as part of a 1-year program rather low.

Discussion and Issues

Under the current structures of the four targeted academic units, the prospective certificate program could be accomplished by matriculated MS students while pursuing their primary degree. Students in Civil and Environmental Engineering would probably have the most straightforward time in satisfying both the degree and certificate requirements in a single year, subject only to course timing and availability (see below). One-year coursework-only MS degrees are already a well-established element of the department, and so there are no apparent "cultural" impediments. Indeed, many of the recent graduates from this department are already working professionally in the field of river restoration, suggesting that some informal implementation of this general approach is already taking place.

Students in Earth and Space Sciences are nominally presented with the greatest flexibility and opportunity to pursue this course of study, but as a practical matter virtually no graduate students are accepted into that department with the expectation of a coursework-only degree. It is also quite unusual for students with sufficient disciplinary interest and expertise in either geology or geophysics to embark on a course of graduate study that includes almost no coursework explicitly in their chosen discipline. This suggests the most likely alternative for future ESS graduate students in this program would be through the implementation of a 5th-year MS program that drew from recent BS graduates of the department. Under current written procedures there is no formal impediment to beginning such a program, but departmental policy allocates incoming graduate-student “slots” on the basis of RA or TA funding availability over a 3-year period; graduate students are not accepted into the department unless funding is available. That policy obviously has no relevance for a 1-year terminal degree program, but it nonetheless would have to be changed before such a program could begin. The department is also considering an increase in the specified coursework requirements for all incoming graduate students, which would not preclude the successful completion of this program but would probably add 1 or 2 additional quarters to a student’s residency.

Students in Forest Resources and SAFS have ample curricular flexibility, and substantial overlap in relevant courses offered through their respective units, to readily meet the proposed certificate requirements over the ~2 years normally required for a thesis-based MS program. A number of students already are pursing a de facto program in river restoration; for them, this proposal would provide them with greater coherence and formal recognition for what they are already accomplishing on their own. As with Earth and Space Sciences, graduate students in these units are not currently accepted with the expectation of a coursework-only degree.

The most obvious, significant obstacle to beginning this program is the lack of a “capstone” course (and the faculty available to create and to teach it). A set of less-apparent but related issues is the irregularity with which some of the key courses are taught, the currently limited coordination for scheduling and sequencing of courses to fit an individual student’s course of study, and the possible or impending departure of certain faculty without a matching institutional commitment to replace them in kind. These all point to the likely need for additional new resources, or permanent reallocation of existing faculty commitments, to support and implement this program as currently envisioned. Following broader discussions and further refinement of this proposal, that need can and will be quantified.

APPENDIX A

Listed Courses at the University of Washington Relevant to River Restoration

The following courses have been identified from the 2006 edition of the University of Washington's online course catalog (http://www.washington.edu/students/crscat/). The bold-faced categories in the table below were taken without modification from the top-ranked course topics solicited in a recent survey of private consultants, agency staff, and university students and faculty at the February 2006 River Restoration Northwest Design Symposium (see "Curriculum questionnaire" at http://depts.washington.edu/cwws/streams.html) for a complete description of this process and the full results of the survey). These categories do not necessarily encompass the final list of courses anticipated for a graduate program in river restoration, but they provide a useful starting point that is not biased by what is currently available at the University of Washington.

Several conclusions are suggested by inspection of this list:

1. Most of the categories are well represented by existing course offerings. This confirms a judgment from this project's initial proposal, namely that the University of Washington is well positioned to create such a program without beginning from scratch.
2. Based on the administrative home of the course offerings, students in the College of Forest Resources are most likely to find courses in their home department, i.e. under existing departmental structures, these students are likely to have the easiest time in meeting any home-unit course requirements for their current degree program. Those students from SAFS, Civil and Environmental Engineering, and Earth and Space Sciences would be progressively less able to satisfy such requirements, because more of the classes on this list are offered only in units other than their own.
3. Most of the courses listed here are not taught at the graduate level, and a number are only covered by those numbered 200 or 300, i.e. not available for graduate credit. These classes are not available for graduate students seeking to meet course-unit requirements.
4. The more "integrative" topics (e.g., Restoration Ecology and Environmental Problem Solving) are the least well covered at the graduate level, offering obvious new teaching opportunities.
5. Several aspects of this list are not self-evident but raise issues that will eventually require solutions. First, not every class in the course catalog is offered every year, or even regularly. In addition, several classes on this list are dependent on faculty that are likely to retire or otherwise leave the University in the next few years, with no certainty that their areas of expertise will be replaced. Finally, courses are spread over about a dozen separate units, including all three UW campuses. Although diversity and multidisciplinarity are both hallmarks of a credible program in environmental restoration, they also impose logistical complexities on students trying to move through a curriculum. They also diffuse the commitment and responsibility that any one unit may feel towards such a program.

This final topic will be revisited at a later time, but the institutional challenges that face interdisciplinary programs in general are well articulated in a recent report issued by the University of Washington's Graduate School, ""Seeding, Supporting, and Sustaining Interdisciplinary Initiatives at the University of Washington" (http://grad.washington.edu/Acad/interdisc_network/InterdisNetwork.htm). Balancing these challenges, however, is the commitment of many individual faculty members and the institution as a whole to make progress in this arena. The problems will not be solved simply by implementing a graduate program in river restoration, but the process engaged through this effort should be supported, and provide support in turn, for broader efforts university-wide.

A final note on this list is in order. The richness and diversity of academic opportunities at the University of Washington are much too great for any one compendium to capture fully. Some courses that should be on this list have surely been overlooked; conversely, others with promising-sounding names and descriptions that appear here may be wholly unsuited for this program. Comments, perspectives, and recommendations are welcomed and should be sent via the "Contact us" link on the project's web page.

In the following table, **bold, underlined** categories correspond to the ranked recommendation of mandatory courses for a graduate curriculum in river restoration, as compiled at the recent River Restoration Northwest conference. Each bulleted course shows its description as it appears in the UW course catalog, together with its home department or program (e.g., "QERM"), translated into plain English at the end of each entry, and the number of credits (in parentheses, after the title).

Risk Analysis and Decision Theory

- QERM 514 Analysis of Ecological and Environmental Data I (4) Overview of generalized linear models (GLMs), their use in forestry, fisheries, wildlife ecology, and environmental monitoring. Analysis of the statistical tests that fall under GLMS: chi-square tests on contingency tables, t-tests, analysis of variances, etc. Statistical software S+/R used throughout. (Quantitative Ecology & Resource Management)
- QSCI 482 Statistical Inference in Applied Research (5) Analysis of variance and covariance; chi square tests; nonparametric procedures multiple and curvilinear regression; experimental design and power of tests. Application to biological problems. Use of computer programs in standard statistical problems. (Quantitative Science)
- SPCI 508 Risk Assessment and Management (4) Introduction to processes and methods of risk assessment and management, focusing on how these principles can be integrated into strategic planning and decision making. (Architecture and Urban Planning)
- QMETH 501 Decision Support Models (2) Introduction to computer-based modeling techniques for management decision making. Linear programming, decision analysis, and simulation. Formulation and interpretation. (Business School)
- STAT 481 Introduction to Mathematical Statistics (5) NW Probability, generating functions; the d-method, Jacobians, Bayes theorem; maximum likelihoods, Neyman-Pearson, efficiency, decision theory, regression, correlation, bivariate normal. (Statistics)

Hydrology

- CEE 476 Physical Hydrology (3) Global water picture, data sources and data homogeneity, precipitation, evapotranspiration, hydrographs. Hydrologic data frequency analysis. Hydrologic design: flood mitigation, drainage. Introduction to deterministic and stochastic models. (Civil & Environmental Engineering)

- CEE 574 Advanced Hydrology (3) Detailed treatment of statistical methods used in hydrologic analysis. Stochastic hydrology, detailed examination and use of a deterministic watershed model (e.g., Stanford Watershed Model). (Civil & Environmental Engineering)
- CFR 525 Advanced Wildland Hydrology (4) Advanced treatment of hydrologic cycle and basic hydrologic methods as applied to wildlands. Effects of forest management activities on hydrologic processes. Graduate focus on a detailed field or modeling hydrologic analysis (Forest Resources)

Restoration Ecology

- ESRM 473 Principles of Ecological Restoration (5) Philosophy of restoration, structural components of ecosystem degradation, analysis of restoration projects and methods, and an ecosystem by ecosystem review of how systems are restored. An ecology courses that emphasizes applied scientific knowledge of ecosystems. Recommended: plant ecology, plant identification, horticulture, landscape ecology coursework. (Forest Resources)
- ESRM 462, 463, 464 (3 x 2) Restoration Ecology Capstone: Three-course capstone sequence in restoration ecology. Students review and assess project plans and installations. Class meets with members of previous capstone classes to review their projects. Student teams prepare proposals in response to requests for proposals (RFPs) from actual clients. Clients may be governments, non-profit organizations, and others. Upon acceptance of the proposal, teams prepare restoration plans. Teams take a restoration plan developed in ESRM 463 and complete the installation. Team participation may include supervision of volunteers. Teams prepare management guidelines for the client and conduct a training class for their use. (Forest Resources)

Sediment Transport

- CEE 474 Hydraulics of Sediment Transport (3) Introduction to sediment transport in steady flows with emphasis on physical principles governing the motion of sediment particles. Topics include sediment characteristics, initiation of particle motion, particle suspension, bedforms, streambed roughness analysis, sediment discharge formulae, and modeling of scour and deposition in rivers and channels. (Civil and Environmental Engineering)
- OCEAN 542 Sediment Dynamics and Boundary-Layer Physics (4) Theoretical descriptions of sediment transport processes constrained by laboratory demonstrations. The physics of boundary layers, initiation of motion, suspended load, bedload, bedforms, and continua transport (turbidity currents, debris flows, and suspensions) and its application to the geological record. (Oceanography)

Fluvial Geomorphology

- ESS 426 Fluvial Geomorphology (5) Hydraulic and morphological characteristics of streams and valley floors. Landscape evolution by stream erosion and deposition. Field exercises emphasize quantitative analysis of fluvial processes, channel forms, acquisition of various skills, such as mapping, topographic surveying, report writing. (Earth & Space Sciences)

<u>Environmental Problem Solving</u>

- BES 302 Environmental Problem Solving (5) Introduces different aspects of environmental problem solving. Uses real-world situations for thinking quantitatively and creatively about such environmental concerns as energy and water resources, food production, indoor air pollution, acid rain, and human influences on climate. (Bothell campus; Interdisciplinary Arts and Sciences)

<u>Environmental Economics</u>

- ESRM 465 Economics of Conservation (3) Economic principles and their use in the analysis of contemporary conservation problems. Particular emphasis directed toward the conservation of forest resources in the Pacific Northwest and related policy issues. (Forest Resources)
- ECON 235 Introduction to Environmental Economics (5) Introduces non-economics majors to environmental and natural resource economics. Discussion of fundamental economic concepts, including markets and private property. Students learn basic tools used in the economic assessment of environmental problems and apply these methods to key environmental issues. (Economics; Program on the Environment)
- ECON 435 Natural Resource Economics (5) Survey of the economics of renewable and nonrenewable resources including fisheries, forest, minerals, and fuels. Optimal trade-offs between benefits and costs of resource use, including trade-offs between current and future use. Effects of property rights on resource use. (Economics)
- ECON 436 Economics of the Environment (5) Microeconomic analysis of environmental regulation. The problem of social cost, policy instrument choice, enforcement of regulations, methods for damage assessment, and estimating benefits of environmental improvement. (Economics)

<u>Geographic Information Systems (GIS)</u>

- ESRM 250 Introduction to Geographic Information Systems in Forest Resources (5) Applications of GIS technology to forest science and management. Fundamentals of GIS systems: data sources, preprocessing, map analysis, output; remote sensing as a source of GIS data, image analysis, and classification. Emphasis on GIS as a source of management and technical information requests. (Forest Resources)
- URBDP 420 Database Systems and Planning Analysis (3) Applications of relational database management systems in urban design and planning. Emphasis on practical aspects of database design and use. Design, create, and modify databases and database applications, including spatial databases. Introduction to GIS. Use of personal computers linked to desktop mapping packages and relational database management systems. (Urban Design and Planning)
- GEOG 460 Geographic Information Systems Analysis (5) Methods of Analysis provided by geographic information systems (GIS). Operations on map information including map overlay, aggregation/disaggregation, and other spatial and attribute procedures. Exposure to raster and vector software. Review of capabilities of current available GIS software. (Geography)

<u>Ecorestoration Strategies: Case Studies</u> • ENVIR 203 Environmental Case Studies: Resources (5, max. 10) Exploration of resource environmental issues from natural science, historical, socioeconomic, legal, political, and ethical perspectives. Involves gathering information, analyzing data, applying mathematical and statistical reasoning and decision-making schemes, evaluating conflicting views based on cultural and philosophical frames of reference, and developing communications and research skills. (Program on the Environment)
<u>Environmental Policy and Management</u> • ESRM 470 Natural Resource Policy and Planning (5) Introduction to and analysis of environmental policy-making processes, with a focus on forest and land policy and law. Use of policy models to examine the interaction of agencies, interest groups, Congress, and the courts in the legislative process. Policy implementation, evaluation, and change are also addressed. (Forest Resources)
<u>Restoration of Aquatic Systems (freshwater)</u> • FISH 428 Restoration of Fish Communities and Habitats in River Ecosystems (5) Examines opportunities to encourage recovery through natural developmental processes that enhance the complexity of habitats and connectivity between habitats in the river basin. Class discussion and participation on field trips focuses on current restoration concepts for ecosystems, designs of projects, and case studies. Recommended: fish ecology and hydrology courses. (Fisheries)
<u>Environmental Impact Analysis</u> • SMA 476 Introduction to Environmental Law and Process (3) Use and application of key statues in marine living resources management. Overview of administrative law and process. Basic legal research, reading, and briefing selected judicial opinions. Participatory case study component. Designed for non-law graduate and advanced undergraduate students. (School of Marine Affairs) • TCSIUS 438 Environmental Law (5) Examines the historical and policy framework of major environmental laws and regulations. Takes a case law approach to evaluate laws in biological conservation, energy, land use, mineral rights, air and water quality, and other complex environmental arenas, and how courts (primarily in the United States) have interpreted such laws (Tacoma campus, Interdisciplinary Arts and Sciences)
<u>Geomorphology (general)</u> • ESS 326 Geomorphology (5) Introduction to landforms and surficial deposits. Emphasis on landscape-forming processes. Intended for students who wish to take additional courses in geomorphology. (Earth and Space Sciences)
<u>Watershed Processes</u> • FISH 447 Watershed Ecology and Management (3) Explores fundamental ecological processes at the watershed scale, identifies human-induced changes to ecological systems, and discusses approaches to improve watershed management. Includes lectures, field trips, and discussions with organizations and agencies about how they are addressing ways to improve watershed management. (Fisheries)

<u>Restoration Principles and Concepts</u> (overlaps with Restoration Ecology)
<u>Ecosystem Management</u> • ESRM 441 Ecosystem Management (5) Scientific and social basis for ecological forestry. Forest practices to achieve integrated environmental and economic goals based upon material models of disturbance and stand development including alternative harvesting methods; adaptive management and monitoring; certification and global issues. (Forest Resources)
<u>Watershed Analysis</u> (overlaps with Watershed Processes)
<u>Hydraulics</u> • CEE 345 Hydraulic Engineering (4) Extension and application of fluid mechanics principles to hydraulic engineering problems. Open channel flow, pipeline systems, turbomachinery, unsteady flow in pipes, diffusion and mixing processes, groundwater, surface water hydrology. (Civil & Environmental Engineering) • CEE 444 Water Resources and Hydraulic Engineering Design (4) Opportunity to effect design solutions for projects or major project components in such representative areas as reservoirs and associated systems for flood control, water supply, irrigation, and hydroelectric power, surface water control systems, fisheries related projects, small harbors, and coastal engineering problems. (Civil & Environmental Engineering) • CEE 472 Introduction to Hydraulics in Water Resources (3) Hydraulics related to environmental issues. Global hydrology; stratified flows; two-phase (bubble) flows; pollutant transport and mixing in reservoirs, lakes, coastal waters, and oceans; diffuser design and related case studies. (Civil & Environmental Engineering) • CEE 570 Hydrodynamics (4) Applications of the equations of motion to the flow of ideal and real fluids. Fundamentals of fluid potential motion. Viscous flows; Navier-Stokes equations and some exact solutions. Boundary-layer theory. Introduction to turbulence. Two- and three-dimensional examples, including free surface flows. Applications of field equations to problems of engineering significance. (Civil & Environmental Engineering)
<u>GIS in Environmental Restoration</u> (overlaps with Geographic Information Systems)
<u>Environmental Ethics</u> • TIBCG 456 Environmental Ethics (5) Critical exploration of selected philosophical and literary texts pertinent to ethics attending the natural environment. Topics for consideration may include animal and nature rights, social ecology, natural value (instrumental, inherent, intrinsic), anthropocentrism v. Deep Ecology, and environmental aesthetic theory. (Tacoma campus; Interdisciplinary Arts and Sciences)
<u>Riparian Management</u> • ESRM 328 Forestry-Fisheries Interactions (4) Characteristics of forestry-fisheries interactions in terrestrial and aquatic landscapes. Effects of changes in landforms on forest and aquatic communities. River basin and watershed features. Forest stand dynamics, forest hydrology, fish and wildlife histories and behavior. Resource conflicts and resolution. (Forest Resources)

Stream Ecology

- FISH 547 Stream and River Ecology (5) Characterizations of stream and river ecosystems from a watershed perspective. Emphasis on fundamental processes affecting the structure and dynamics of aquatic communities and the riparian zone. Resource conflicts, new technologies, field trips, and class projects. (Fisheries)
- FISH 438 Biological Monitoring and Assessment (5) Explores the technical questions (conceptual, sampling, and analytical), the rationale, policy relevance, and legal basis for tools -- existing and needed -- to assess ecological health. Prepares students to see the biological components of ecological systems in diverse ways. (Fisheries)

Biodiversity and Conservation Biology

- BIOL 476 Conservation Biology (5) Explores biological, managerial, economic, and ethical concepts affecting survival of species. Applications of ecology, biogeography, population genetics, and social sciences for the preservation of species in the face of widespread global habitat modification, destruction, and other human activities. (Biology)
- FISH 450 Salmonid Behavior and Life History (3/5) Marine distribution, homing migration, and spawning behavior of adult salmon: incubation, emergence, migration, and residence of fry; fingerling distribution and residence with reference to species interaction and population evolution. (Fisheries)

APPENDIX B

MS Degree Requirements
(March 2006; from academic unit web sites)

Earth and Space Sciences (Geology "track")

At least 18 credits of course work must be completed with a numerical grade for courses numbered 400 and 500. In the non-thesis option, a minimum of 45 credits must be earned. At least 18 must be in courses numbered 400 and above, and no more than 9 may be in Field Geology.

Civil and Environmental Engineering

A minimum of 42 quarter credits must be earned.

- At least 3 coursework credits outside the CEE program in which the student is enrolled.
- At least 15 credits of 400 or 500 level courses within the CEE department.
- At least 39 coursework credits.
- A maximum of 3 CEE 600 credits for a research project.
- At least 21 credits of 500 or 600 level courses.

Aquatic and Fishery Sciences

A minimum of 45 credits (27 coursework credits and 18 thesis credits), a thesis, and successful Final Examination in defense of that thesis are required.

Required courses (15 credits total) include:

- QSCI 482, Statistical Inference in Applied Research, 5 credits.
- FISH 510-514, Current Topics series (offered credit/no credit only), 2 credits each; students are required to complete at least two of these courses.
- FISH 521, Research Proposal Writing, 4 credits.
- FISH 522, Hot Topics in Aquatic & Fishery Sciences (offered credit/no credit only), 2 credits.
- FISH 700, Thesis Research, 18 credits.

In addition, at least 12 credits of coursework at the 400- or 500-level are required; four of those 12 credits must be in 500-level courses. SAFS core-required course may be waived, but students must substitute those missed credits with additional coursework.

College of Forest Resources

A minimum of 45 credits, a thesis (9 thesis credits minimum), and the following common coursework are required for graduation:

- CFR 500 (1 credit) Graduate Orientation Seminar
- CFR 509 (3 credits) Natural Resource Issues: Unspoken Basics
- Current Topics (2 credits)
- Minimum 8 credits (400-500 level) in research design and quantitative analysis
- At least 10 other credits at 400-500 level are required