

**Interdisciplinary Graduate Certificate in the
Adaptive Management of Environmental Systems
(AMES Certificate)**

A Proposal

September 30, 2002

It has been repeatedly argued that adaptive management should begin with a concerted effort to integrate existing interdisciplinary experience and scientific information into dynamic models that attempt to make predictions about the impacts of alternative policies. This modeling step is intended to serve three functions: (1) problem clarification and enhanced communication among scientists, managers, and other stakeholders; (2) policy screening to eliminate options that are most likely incapable of doing much good, because of inadequate scale or type of impact; and (3) identification of key knowledge gaps that make model predictions suspect.

Carl Walters, 1997.

A system is a whole that cannot be divided into independent parts or subgroups of parts. Therefore, it has properties that derive from the interactions of its parts that none of its parts have. ... From this it follows that when a system is taken apart it loses all of its essential properties and so do its parts. ... As a result, it becomes apparent that one cannot explain, and hence understand the properties and behavior of a system by analyzing it[s parts]; synthetic thinking is required.

Russell Ackoff, 2001.

System dynamics must be seen as a modeling approach which relies on assumptions about how human agents use information, how one can go about collecting data to construct models, how such models can be used to explore structural constraints, and how those models can help in creating understanding of social problems. This combination of mathematical core, scientific stance on the applicability of models, and craft skills relating to the ways of making such models useful, together constitute the system dynamics method.

David C. Lane, 2001.

0. The Request: A Summary

An interdisciplinary committee proposes the formation of a fifteen-credit hour graduate certificate program in the Adaptive Management of Environmental Systems (AMES). This certificate seeks to provide structured opportunities for graduate students in various disciplines to enhance their degree programs with an interdisciplinary course of study designed to:

- § Train students in the collaborative construction of dynamic models for use in the adaptive management of environmental resources – a process of computer-aided policy mediation.
- § Illustrate the complexities and conflicts of environmental management and the challenges these present to traditional disciplinary perspectives.
- § Develop communication and mediation skills suited to the variety of problems, methods, and perspectives in environmental science, engineering, law, and policy.
- § Demonstrate the power of collaborative problem solving through interdisciplinary team-based development of dynamic models that simulate the impacts of alternative policies.

These objectives are met through a schedule of curricular offerings in interdisciplinary communication, environmental science or engineering, and resource management law and policy within the unifying framework of systems thinking applied to team-based modeling of human-environmental dynamics.

1. Need

Complexity, information lags, feedback effects and conflicting interpretations of reality confound the development of laws and policies for the management of human-environmental systems. The dynamics of these systems are torturous. Decision makers frequently encounter complex interdependencies, lagged system responses, unanticipated feedback effects and counter-

intuitive results. Expected outcomes are often uncertain. Management decisions frequently precipitate indirect and unforeseen consequences.

The resulting scientific ambiguities and engineering uncertainties constitute a playground for special interest politics. Decision-makers encounter conflicting objectives, buried assumptions and hidden agendas. Alternative interpretations of problem contexts confound problem definition and complicate the assessment of policy outcomes. Functionally specialized bureaucratic arrangements slow the formation of multi-party agreements of any scientific subtlety or value complexity.

Traditional perspectives in environmental science and public policy neglect most of these troublesome considerations. To pursue higher levels of professional practice, post-baccalaureate students need to learn systematic ways to address conflicts and complexity.

The Interdisciplinary Certificate in the Adaptive Management of Environmental Systems (AMES) addresses these needs consistent with the goals of the National Science Foundation (NSF) program in Integrative Graduate Research and Traineeship.

“The [NSF] program is intended to catalyze a cultural change in graduate education, for students, faculty, and universities, by establishing new, innovative models for graduate education in a fertile environment for collaborative research that transcends traditional disciplinary boundaries.”

The proposed Certificate Program will enroll both matriculated graduate students and non-matriculated students with prior masters degrees who are interested in developing competency in meeting the interdisciplinary challenges of adaptive environmental management. The Program will train students to think systemically and communicate across disciplines within a structured, collaborative learning and modeling process. It will train students to integrate practical experience and scientific information into stock and flow models that simulate alternative policy impacts. It will train students to combine collaborative learning with model-based policy assessment to dissolve stakeholder contention and promote mutual agreement about system behavior and management options.

We expect that working professionals and matriculated graduate students will use certificate-based skills. We expect them to address multi-dimensional problems currently unresponsive to discipline-specific methods. We expect them to synthesize information from multiple disciplines into a systems-based understanding of system trajectories, management possibilities, and important knowledge gaps.

Student demand for the proposed certificate is difficult to predict with great precision. Two sources of information may be gleaned for indications of future student demand. The first is recent experience with enrollments in courses that will serve as core courses in the proposed program. The second is the history of enrollments at a comparable program at USU.

The proposed program's two core courses now regularly attract more than twenty-five students. If a quarter of these were program participants, then one would have a flow of six students per year. Assuming the average tenure of a student in graduate training to be three years, then one would have 18 students in the program by the third year.

The Utah State University Natural Resource and Environmental Policy Program (NREPP) offers an interdisciplinary graduate certificate that shares some similar academic objectives. Their Program Director, Prof. Joanna Enter-Wada suggests the likelihood of an enrollment buildup on par with that just indicated. She also indicates that possibilities beyond the early years are

substantial and depend upon both the quality of program management and the interest and support of collaborating faculty.

2. Educational Objectives

The Certificate Program addresses two different audiences. One is the matriculated graduate student pursuing a Master's or Ph.D. degree in the various disciplines that engage science, engineering or public affairs. The second is the non-matriculated students seeking to build upon previously obtained graduate or undergraduate degrees.

The Program will provide students with an interdisciplinary course of study designed to:

- § Train students in the collaborative construction of dynamic models for use in the adaptive management of environmental resources.
- § Illustrate the complexities and conflicts of environmental management and the challenges these present to traditional disciplinary perspectives.
- § Develop communication and mediation skills suited to the variety of problems, methods, and perspectives in environmental science, engineering, law, and policy.
- § Demonstrate the power of collaborative problem solving through interdisciplinary team-based development of dynamic models that simulate the impacts of alternative policies.

These objectives are met through a schedule of curricular offerings in interdisciplinary communication, environmental science or engineering, and environmental law and policy within the unifying framework of systems thinking applied to team-based modeling of human-environmental dynamics.

A key feature of the Certificate Program is the opportunity to, work, study and interact with students and faculty who, while trained in various disciplinary traditions, share a common interest in interdisciplinary education. Rather than becoming more specialized, AMES Certificate holders are expected to broaden the skills obtained in their other degrees.

The AMES Certificate Program will help students grapple with conflict and complexity. It will emphasize the cross-disciplinary integration of academic traditions relevant to the management of human-environmental interactions. It will do so while developing real-world problem-solving skills. The combination will be attractive to important audiences within and outside of academia.

3. Impact on Existing Programs

There are no other such programs in either Utah or the Intermountain West. Washington State University offers courses in environmental management, assessment, modeling and planning through its program in Environmental Science and Regional Planning. The University of Nevada at Las Vegas has a system dynamics component in their Environmental Studies degree. The Northern Arizona University has recently proposed an M.S. degree in Environmental Science and Policy that captures some of what we propose, but seems to lack both training in systems dynamics and the necessary inter-disciplinary integration. The Utah State University Natural Resource and Environmental Policy Program (NREPP) offers an interdisciplinary graduate certificate with the following goals:

From an educational perspective, the program's goals are to provide students with a more comprehensive educational framework for understanding complex natural resource and environmental concerns and to develop the critical thinking and analytical skills needed to address these issues. Students will develop familiarity with both disciplinary and interdisciplinary concepts and principles of the social, natural, and physical science approaches to natural resource policy.

Discussions with the Program's Director, Prof. Joanna Enter-Wada, suggest that, while our goals and objectives are similar, our approaches are distinct. Our focus is on the collaborative

construction of dynamic models as key to the dissolution of stakeholder conflict and the exploration of adaptive management policies. This distinguishes the current proposal from any other program now in operation.

In an attempt to learn from the efforts of others, we visited the following programs:

- § School of Public and Environmental Affairs, Indiana University,
- § Bren School of Environmental Science and Management, University of California, Santa Barbara,
- § Program in Environmental Science and Policy, University of California, Davis,
- § Department of Environmental Science, Policy and Management, University of California, Berkeley.

These programs function at a scale too large for emulation at the University of Utah. Yet they do offer numerous lessons in program scope and design. These were documented and incorporated into this proposal at an earlier stage in our deliberations.

The AMES Certificate Program's impact on other programs at the University of Utah will be positive, not competitive. The proposed Program promises to make many good graduate programs even more attractive. The administrators of the Urban Planning Program, the Conflict Resolution Certificate Program, the Environmental Engineering Graduate Program and the Professional Masters in Science and Technology Program are enthusiastic about the collaborative opportunities that have already begun to evolve for both faculty and students. Programs in engineering and environmental science will be able to offer training in the integration of scientific and engineering perspectives into policy decision processes. Programs in management and policy will be able to offer training in group-based modeling of alternative policy outcomes.

The AMES Certificate Program has begun to serve as a forum for cross-campus interdisciplinary discussions among faculty and students. The ideas inherent in the program have already provided a fulcrum for interdisciplinary research proposals, funded research projects and graduate theses. Collaborative model building is at the core of two campus-based research projects – A Systems Analysis of Welfare Reform in Utah and the Border +20 Project. The role of system dynamics in the interdisciplinary synthesis of information is central to the \$1.5 million grant recently awarded on campus by National Science Foundation's Bio-complexity Program. There is no reason to believe that further collaborative initiatives will not grow out of the continued organization of an interdisciplinary educational program.

4. Courses and Other Program Components

Workshops. Each year, a workshop will be organized for AMES candidates to introduce the interests, perspectives and institutional relations involved in the adaptive management of environmental systems. It will help them appreciate the scientific complexity, managerial conundrums, and inter-group conflict potential implicit in the design and management of any and all socio-environmental systems. It will help AMES candidates develop interpersonal communication skills and build relationships with fellow students. It will promote an awareness of the impact that problem complexity has on the need to work in teams and the need for team-related skills in the execution of program-specific research projects. It will serve as a showcase where advanced AMES candidates will present their works in progress as indicated in the requirements below.

Course Requirements. Fifteen hours of designated course work are required for the Proposed Certificate. No new courses are required. None of the proposed courses are currently delivered using distance education. For the convenience of those pursuing the certificate while working locally, many program courses will continue to be offered during the late afternoon and evening hours.

Program Requirements are organized into Core Courses, Electives in Planning, Law and Policy, and Negotiated Interdisciplinary Electives.

1.) Core Courses (6 cr hr required)

GEO 6340 System Dynamics and Environmental Policy (3) [cross-listed as CVEEN 6660, GEOGR 6370, POL S 6323, and URBPL 5370]

COMM 6150 Dialogue, Culture and Conflict Resolution (3)

2.) Electives in Planning, Law and Policy (3 cr hr required)

With the assistance and approval of the AMES Academic Advisor select one course from outside your discipline.

Planning *

FCS 5720 Community and Environmental Change (3)

URBPL 5240 Planning Theory and Ethics (4)

URBPL 5270 Metropolitan Regional Planning (3)

URBPL 5340 Urban Growth Management (3)

URBPL 5390 Community, Economy and Sustainability (3)

* A 6000-level course designation for selected URBPL courses is pending before the College Curriculum Committee.

Environmental Law **

LAW 7200 Natural Resources (3)

LAW 7240 Environmental Law and Policy (3)

LAW 7800/7810 SEM – selected topics in environmental law (2)

** Non-law students are admitted only with the permission of the instructor and only if space is available.

URBPL 5360 Environmental Planning Law and Policy (3)

Environmental Policy

COMM 6000 Resolving Environmental and Public Policy Disputes (3)

ECON 6250 Environmental and Natural Resource Economics (3)

GEOGR 5350/URBPL 5360 Public Lands and Environmental Policy (3)

CVEEN 6661 Practicum in Environmental Systems Sustainability (3) [cross-listed as GEO 6341, GEOGR 6371, POL S 6324, and URBPL 5371]

POL S 6320 Public Policy Theories and Applications (3)

POL S 6321 Health Policy (3)

POL S 6322 Environmental Policy (3)

3.) Negotiated Interdisciplinary Electives (6 cr hr required)

With the assistance and oversight of the AMES Academic Advisor, each student will select two elective courses at the 5-, 6-, or 7000 level. The first Interdisciplinary Elective must be selected from outside the college of the student's current degree program (or if non-matriculated, the college of the student's prior degree). The second Interdisciplinary Elective course may be a course from within the student's college. Yet each student is actively encouraged to select yet another course from outside his or her college.

In all cases, we strongly recommend that students without a science background take basic science and engineering elective courses to obtain a better understanding of the fundamental science underpinnings that govern the physical dimensions of environmental planning, law, and policy.

4.) Requirement in Applied Systems Thinking

A distinction is made in this requirement between matriculated and non-matriculated graduate students. Matriculated graduate students are advised to design a component of their graduate thesis, dissertation or major research paper around a systems theoretic concept or its use in adaptive management. The character and extent of this element will be developed in consultation with the student's research supervisory committee and the AMES Academic Advisor. The result of this effort will be presented at an annual meeting of faculty and students involved in the AMES Certificate Program.

Non-matriculated graduate students will be required to expand upon and present in the same forum either the systems model that they helped develop in the required course 'System Dynamics and Environmental Policy' or the systems communications project that they completed in the required course 'Dialogue, Culture and Conflict Resolution'. The character and extent of their expanded project will be developed in consultation with the AMES Academic Advisor or other AMES Committee Members.

Program Admittance. An applicant for admission may be a matriculated graduate student at the University of Utah or a non-matriculated student with a prior undergraduate degree. An applicant must submit a program application to demonstrate satisfaction of the following requirements:

1. Admission to candidacy in a master's or doctoral degree program at the University of Utah or a baccalaureate degree from a fully accredited university.
2. An undergraduate GPA of at least 3.0 (exceptions to this requirement may be granted for students with compensating professional experience or improved graduate level coursework),
3. A letter of application with a personal statement of intent.
4. A letter of recommendation preferably from an academic reference.

A final requirement will be the favorable recommendation of the AMES Advisory Committee upon review of the student's application.

5. Assessment

We will assess the success of the Program relative to previously stated educational objectives. We will monitor enrollments and course evaluations, have all graduates complete an exit survey, and circulate a post-graduate survey to alumni. The exit survey will be designed to assess levels of systems thinking, teamwork/communication skills and cross-disciplinary knowledge. A follow-up survey will be circulated to program alumni two years after graduation to assess how knowledge gained has helped in their professional careers or subsequent graduate degree programs. We will also comply with Graduate School annual reporting requirements during the first three years of the Certificate Program and with the program review cycles established by the Graduate Council.

External program review will be arranged on an informal basis after the third year of operation. Prof. Andrew Ford of Eastern Washington University Department of Environmental Science and Regional Planning, Prof. Eugene B. McGregor of Indiana University School of Public and Environmental Affairs, and Prof. Krystyna Stave of UNLV's Department of Environmental Studies have expressed a willingness to serve.

6. Faculty

With the support of the University Teaching Committee, a Committee on Environmental Systems and Management Policy was organized in July of 1998 to explore the possible design of an interdisciplinary program in environmental science and policy. It is currently composed of the following individuals:

Prof. David Chapman, Department of Geology and Geophysics and Graduate School Dean
Prof. Philip C. Emmi, Department of Geography and Chair of the Urban Planning Program
Res. Prof. Craig B. Forster, Department of Geology and Geophysics
Prof. Donald F. Hayes, Department of Civil and Environmental Engineering
Prof. Leonard C. Hawes, Department of Communications and Director of the Graduate Program in Conflict Resolution
Dr. James I. Mills, Idaho, Engineering and Environmental Laboratory (retired)

Prof. J. Steven Ott, Department of Political Science and Dean of the College of Social and Behavioral Science

Faculty members who contribute instructional services directly to the Program include selected members of this Committee plus those teaching the courses indicated above in Section 4.

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| Keith Bartholomew, FCS Ralph Becker, GEOGR/URBPL Robert Huefner, POL S | Gabriel Lozada, ECON Dan McCool, POL S Tarla Peterson, COMM |
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In addition, there are a number of other faculty members from Colleges and Departments throughout the University campus who are interested in supporting the Certificate Program and promote its development for use in activities to which they are already committed.

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| Milind Deo, CHFEN Saskia Dyvestyn, MET EN Andy Hong, CVEEN John Horel, METEO Bill Johnson, GG Paul Jewell, GG JoAnn Lighty, CHFEN/COE Joe Klewicki, ME EN | Peter Martin, CVEEN Jan Miller, MET EN Eric Pardyjak, ME EN Geoff Silcox, CHFEN Kip Solomon, GG Ed Trujillo, CHFEN Carol Werner, PSYCH |
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We anticipate no need for additional faculty hires. We do expect an ongoing need to find student credit hour dollar equivalent sufficient to reimburse Adjunct Professor James I. Mills, instructor of the variously cross-listed course, *System Dynamics and Environmental Policy*. Currently this need is being met by the mechanism described in section 9 below on the budget

7. Coordination

The Committee on Environmental Systems and Management Policy will be renamed as the AMES Advisory Committee. The Coordinator of the Certificate Program will be the Chair of the AMES Advisory Committee. The Coordinator will serve as the Program's Academic Advisor and implement program initiatives as developed by the Advisory Committee. The Coordinator's responsibilities will include substantive academic leadership, program recruitment, maintenance of lab site-licenses, coordination of the annual workshop, core course scheduling, maintenance of cooperating faculty/departmental relations, student advising, participation on student research committees, certification of program completion, design and administration of exit surveys, and the periodic assessment of program design and performance.

The first Coordinator will be Prof. Philip C. Emmi (curriculum vita attached). Currently Prof. Emmi chairs the Committee on Environmental Systems and Management Policy – the Committee responsible for the design of the current program proposal. The Coordinator position will rotate among the Advisory Committee members every six years through election within the committee. The program's academic office will be housed in the department of the Coordinator.

8. Advisory Committee

The Advisory Committee will comprise of five to seven faculty representatives drawn from the participating colleges and departments. Committee members will rotate on and off the committee with varying periods of tenure ideally at least three years in duration. New committee members will be nominated by members of the Advisory Committee and appointed through election by the committee. The first Advisory Committee will comprise members of the Committee on Environmental Systems and Management Policy as listed above. The Advisory

Committee will regularly review the status of the Certificate Program and develop any changes required to ensure that the program is meeting the needs of students, achieving programmatic goals and interfacing well with related programs.

9. Budget

Scholarship Stipends. As permitted by original 1998 University Teaching Committee grant, the AMES Advisory Committee will set aside an allocation of \$16,000 to be distributed as scholarship stipends to students participating in the AMES Certificate Program. This will encumber remaining reserves in that budget.

Training Facilities. In 1999, Professors, Emmi, Forster and Mills were trained in the use of Stella[®] System Dynamics Software. This is the computer program we now use to provide students with dynamic modeling capabilities. It offers a user-friendly visual graphic interface and a powerful set of analytical options based on the mathematics of simultaneous difference equations. It is the technical basis for the organization of team-based learning exercises in the collaborative construction of dynamic models and the adaptive assessment of management options.

We have secured a 10-seat site licenses for STELLA[®] in the Marriott Library Multi-Media Center using funds from the 1998 grant by the University Teaching Committee. We use the software in two courses, in *System Dynamics and Environmental Policy* and the *Practicum on Environmental Systems Sustainability*. We have offered these courses over the past three and a half academic years. Existing computer laboratory facilities and classroom equipment have served remarkably well. But, in the future, we will need to periodically upgrade our site licenses as new versions of the software are released and possibly expand the availability of licensed seats. We estimate that \$500 per year will be required to expand and upgrade the STELLA[®] licenses installed in the Marriott Library Multi-Media Center on an alternate-year basis.

Administrative Expenses. The AMES Coordinator will handle all of the day-to-day management tasks for the program as described above in section 7. Prior experience in administering such programs suggests that the AMES Program Coordinator (Chair of the AMES Advisory Committee) should receive, at a minimum, an annual stipend of \$2,400 that would be used preferably to offset on alternate years the teaching obligation for one course (a \$4,800 expense).

A \$500 budget allocation is required to help the host department defray the costs of secretarial assistance and administrative expenses such as web site maintenance, photocopying, postage and production of program descriptions and advertisements.

Funding Instructional Services. In the Fall Term of 1999 *System Dynamics and Environmental Policy* (3) was organized as a variously cross-listed course and offered simultaneously to students in four different departments in three different colleges. It was offered as a Special Topics course to 12 students. Formal listings as CVEEN 6660, GEOGR 5/6370, GEO 5/6340, POLSC 5/6323 and URBPL 5370 were secured for AY 2000-01. Eighteen students enrolled during the Fall Term of 2000 and 19 enrolled during the Fall Term of 2001. Presently 29 students are enrolled in the current Fall Term offering.

A variously cross-listed soft-sequel to this course was also organized with the intention of having it meet with another substantively-focused course and bringing to the other course the perspectives it has to offer. During the Spring Term of 2000, the *Practicum in Environmental Systems Sustainability* (3) met with a Geography Seminar on *Lake Systems*. Stock and flow models of lake levels and salinity were developed collaboratively. A combined total of 9 students

were in attendance. During the Spring Term of 2001, it met with URBPL 5390 *Community, Economy and Sustainability*. A model of urban sustainability was developed. Eighteen students were in attendance. During the spring of 2002, it met with URBPL 5270 *Metropolitan Regional Planning*. A model on the dynamics of urban sprawl was developed. Twenty-two students were in attendance.

Prof. Emmi and Prof. Forster and/or Prof Mills have jointly offered these courses. They are variously cross-listed to attract a diversity of students and to emphasize their interdisciplinary character. In addition to students from the four participating departments, students have attended from Architecture, Environmental Studies, Chemical Fuels Engineering, and Parks, Recreation and Tourism. In the future, Prof. Mills will offer the Fall Term course, *System Dynamics and Environmental Policy*. Either Prof Emmi or Prof. Mills will offer the Spring Term course, *Practicum in Environmental Systems Sustainability*, likely in conjunction with either URBPL 5270 or 5390.

These two courses are already of service to existing and proposed programs of education. They currently serve as core and elective courses in the Graduate Program in Environmental Engineering. The former is being proposed as a core course in the Environmental Engineering Certificate Program. Both serve as track cores in the new Professional Masters of Science and Technology degree program. They serve as electives within the Urban Planning Program.

The student credit hours generated by the courses have been distributed to the participating departments according to their enrollments. We have obtained written agreements from Civil and Environmental Engineering, Political Science and Geology and Geophysics to participate with Geography and Urban Planning in covering the costs of adjunct instructional services for the Fall Term of 2002. (Specifics of the agreements are found in the attached memos.) With enough students, this cost-sharing agreement will meet the need for Fall Term administrative course support. A similar arrangement is being pursued for the Spring Term and is now partially in place.

Support for Administrative Expenses. We have also secured commitments from the Deans of three participating colleges to underwrite \$3,400 in annual administrative costs with continuing annual or one-year reviewable contributions of \$850 each. In the fourth College, Civil and Environmental Engineering has committed half of the requested \$850 per year, but the second half remains to be committed. This ensemble of funding arrangements constitutes a show of good faith in the Program and a strong acceptance of the need for it to be self-supporting.

These considerations are summarized in the accounting details immediately below.

Program Expenses per Year

\$2,400 for Program Coordinator bi-annual course-release support
\$ 500 for administrative support
\$ 500 for bi-annual STELLA® software licenses and updates
\$3,400 TOTAL

Resources Currently Committed

\$ 850 from the College of Humanities
\$ 850 from the CSBS
\$ 850 from the College of Mines and Earth Science
\$ 425 from the Department of Civil and Environmental Engineering
\$2,975 TOTAL

The small shortfall is not a present concern and can be made up, if need be, by postponing STELLA software updates.

To be operationally effective, we propose that a budget account be established for the AMES program through which it can manage its various expenses and into which it can receive contributions from participating departments and Deans. The AMES Program Coordinator at the behest of the AMES Program Advisory Committee will be the signator on this account.

10. Significance

The significance of this proposal can be seen in terms of its promise relative to current dilemmas in the management of environmental systems. These are well defined by a recent report from the International Council for Science (2002).

The goal of sustainable development is to create and maintain prosperous social, economic, and ecological systems. These systems are intimately linked: humanity depends on services of ecosystems for its wealth and security. Moreover, humans can transform ecosystems into more or less desirable conditions. Humanity receives many ecosystem services. Yet human action can render ecosystems unable to provide these services, with consequences for human livelihoods, vulnerability, and security. Such negative shifts represent loss of resilience. New insights have been gained during the last ten years about the essential role of resilience for a prosperous development of society. ... Management can destroy or build resilience. ... More resilient social-ecological systems are able to absorb larger shocks without changing in fundamental ways. ... Resilience is often associated with diversity – of species, of human opportunity, and of economic options – that maintains and encourages both adaptation and learning. ... Management that builds resilience can sustain social-ecological systems in the face of surprise, unpredictability, and complexity. Resilience - building management is flexible and open to learning. It attends to slowly changing, fundamental variables that create memory, legacy, diversity, and the capacity to innovate in both social and ecological components of the system. It also conserves and nurtures the diverse elements that are necessary to reorganize and adapt to novel, unexpected, and transformative circumstances. Thus, it increases the range of surprises with which a socioeconomic system can cope.

The proposed curriculum provides students with basic tools for addressing concerns about “building adaptive capacity in a world of transformations.”

Core courses train students:

- To think constructively about feedbacks, lags and complex interdependencies,
- To work in teams to tease out and combine multiple perspectives on wicked problems, and
- To mediate conflicts over policies for adaptive management.

Interdisciplinary electives guarantee students sufficient breadth of perspective as to be competent beyond the specialized training of their graduate degrees.

Electives in planning, environmental law or environmental policy increase comprehension of the substantive conditions, institutional contexts and policy arenas that shape the interplay between science, engineering and policy.

Faculty who cooperate in the delivery of this program will be better prepared to pursue growing opportunities for interdisciplinary research. The results of early cooperation are already very encouraging.

Employers of our graduates will greatly appreciate working with individuals who understand the broader complexities of problem solving and are able to enhance their respective disciplinary competencies with this more comprehensive set of skills and capacities.

References Cited

Ackoff, Russell L. 2001. After OR: A post mortem. *System Dynamics Review*, 17(4): 341-346.

International Council for Science. 2002. ICSU Series on Science for Sustainable Development: Resilience and Sustainability: Building Adaptive Capacity in a World of Transformations, No. 3. URL: <<http://www.icsu.org/Library/WSSD-Rep/vol3.pdf>>.

Lane, David C. 2001. *Rerum cognoscere causas* Part 1 _How do the ideas of system dynamics relate to traditional social theories and the voluntarism/determinism debate? *System Dynamics Review*, 17(2): 97-118.

Walters, C. 1997. Challenges in adaptive management of riparian and coastal ecosystems. *Conservation Ecology* 1(2):1. URL: <<http://www.consecol.org/vol1/iss2/art1>>.

Attachments

Memo dated 4/2/02 from Prof. Ron Hrebenar, Chair, Department of Political Science regarding a cost-sharing agreement for *Environmental Systems and Management Policy*.

Memo dated 4/4/02 from Prof. Ron Bruhn, Chair, Department of Geology and Geophysics regarding a cost-sharing agreement for *Environmental Systems and Management Policy*.

Memo dated 4/9/02 from Prof. Lawrence D. Reaveley, Chair, Department of Civil and Environmental Engineering regarding a cost-sharing agreement for cross-listed courses.

Memo date 4/22/02 from Prof. Robert Newman, Dean, College of Humanities regarding an agreement to support administrative costs for the AMES Certificate Program.

Memo date 5/1/02 from Prof. Frank Brown, Dean, College of Mines and Earth Sciences regarding an agreement to support administrative costs for the AMES Certificate Program.

Memo date 5/6/02 from Prof. J. Steven Ott, Dean, College of Social and Behavioral Sciences regarding an agreement to support administrative costs for the AMES Certificate Program.

Memo dated 5/9/02 from Prof. Lawrence D. Reaveley, Chair, Department of Civil and Environmental Engineering regarding an agreement to support administrative costs for the AMES Certificate Program.

Letter dated 9/17/02 from Prof Robert B. Roemer, Associate Dean, College of Engineering, offering support of the AMES Certificate Program.

Letter dated 9/16/02 from Prof Prof. Ann L. Darling, Chair, Department of Communications, offering support of the AMES Certificate Program.

Letter dated 9/18/02 from Prof Ron Hrebenar, Chair, Political Science Department, offering support of the AMES Certificate Program.

Letter dated 9/19/02 from Prof Tom Kontuly, Chair, Geography Department, offering support of the AMES Certificate Program.

Letter dated 9/19/02 from Prof. Lawrence D. Reaveley, Chair, Department of Civil and Environmental Engineering, offering support of the AMES Certificate Program.