5b. Project Narrative

a. Project Overview.

The proposed project will establish the Burd Run Interdisciplinary Watershed Research Laboratory at Shippensburg University of Pennsylvania (SU). This cooperative effort among 13 faculty from the Departments of Geography-Earth Science, Biology, and Teacher Education will: (1) provide intensive undergraduate field training through collection and analysis of related hydrologic, geologic, biologic, and geographic data from a single watershed for thousands of students over the life of the project, (2) establish a comprehensive statistical and spatial watershed database using a geographic information system (GIS), (3) use the accumulated data for student investigations, quantitative analyses, and spatial studies in a wide variety of environmentally related courses across the curriculum, emphasizing interconnections of environmental processes in the earth system, and (4) facilitate similar approaches at other institutions through conference presentations, publications, and internet access to the database and related curricular materials.

A four-part organizational structure will be used to administer and implement the watershed research laboratory: (1) The 13 faculty directly involved in the project will continue to meet regularly to evaluate and guide the project. (2) For each major discipline involved (geography-earth science, biology, and teacher education) a curricular coordinator has been designated to oversee and evaluate curricular needs in their area of expertise. (3) "Module coordinators" will oversee data collection within geomorphology, hydrology / water quality, soils, meteorology, hydrogeology, geology, aquatic biology, vegetation, and land use. (4) Similarly, each of the major laboratory components--field equipment, computer laboratories, digital map library, instructional/curricular library and project web site--has a designated coordinator.

The project will involve equipment acquisition; continuous monitoring of hydrology, water quality, and meteorology; and data collection and analysis in various undergraduate courses. In 1999 the watershed database, curricular/instructional library, and project web site will be established. By 2001 a complete interdisciplinary library of watershed data and course instructional materials will be available across SU and at any institution with internet access.

SU draws students primarily from the immediate, largely rural region. Approximately 55% of undergraduates are first-generation college students. It is expected that the watershed laboratory will motivate an increased number of these students to pursue studies and careers in science

through exposing students to the application of scientific methods to local problems in familiar landscapes of farms, forests, streams, and small communities.

b. Goals and Objectives.

Shippensburg University recently recognized four means to improve undergraduate education: greater use of technology, increased support for student-faculty research, emphasis on innovative teaching strategies, and enhanced interdisciplinary study. Accordingly, the goal of the watershed laboratory is to improve the undergraduate science curriculum across the disciplines of geography, earth science, biology, and teacher education at SU by addressing each of these concerns. These objectives will be achieved by linking learning across courses and disciplines over several semesters, allowing students to build and integrate scientific skills throughout their education using the watershed as a common case study. Six specific needs will be addressed: (1) strengthen hands-on field and laboratory learning by emphasizing hypothesis generation and testing, research methodology, data collection, instrumentation, and environmental monitoring; (2) enhance students' quantitative skills through analyzing environmental data; (3) improve the teaching of complex, interdependent environmental systems by linking a variety of scientific perspectives to a common case study used throughout students' undergraduate education; (4) allow students to conduct long term monitoring of environmental change and impacts of human disturbance; (5) improve the earth-space science and biology education curricula by providing pre-service teachers intensive training in scientific methods as applied in a field and laboratory learning environment; and (6) provide field opportunities otherwise unavailable for a wide range of users, including public school systems and related university programs targeting women and minorities in science (see Appendix 1). Most importantly, the project seeks to instill an appreciation for innovation and cooperation within the faculty culture at SU.

The emphasis on environmental systems in this project mirrors national trends in both natural resources management and ecological sciences. The EPA (1996) has recently stressed coordination of natural resources management within entire watersheds, rather than focusing on components of hydrology, ecology, pollution, or water use. Similarly, ecologists are calling for management that integrates the physical, chemical, biological, and social environments (Talylor et al. 1995). Watershed scientists have also emphasized linkages between upland and downstream environments and between land use and water resources (Brooks et al. 1991).

Approaches emphasizing integrative, interdisciplinary studies of watersheds exist at several other institutions, including Pennsylvania State University (Ferreri et al. 1997), Skidmore College (Kirk et al. 1997), and Indiana University-Purdue University Indianapolis (Lindsey and Jewett 1997). Similarly, the SU approach uses an easily-accessible local watershed case study, facilitating involvement of local experts and planners in student learning. The use of case study methods in undergraduate education is supported by research finding that students are more likely to retain information when theories and methods discussed in the classroom have been applied to "real world" case studies (Watson 1975, Meyers and Jones 1993).

The proposed project is innovative in that it will integrate learning across the science curriculum. Many single courses use watershed case studies, often incorporating team teaching to support interdisciplinary studies (e.g. Kirk et al. 1997). The SU project goes a step further, linking faculty and scientific perspectives across several courses in geography, earth science, biology, and education. Using this approach, important linkages between watershed characteristics, water quality, and aquatic ecology can be emphasized.

Courses using the watershed laboratory will emphasize concepts and problem-solving procedures, rather than "cookbook" methods (McKeachie 1986). Small group assignments will be designed to foster positive interdependence and individual accountability, two basic tenets of effective teaching (Cooper and Mueck 1990, Meyers and Jones 1993). The watershed laboratory will also integrate faculty research, student research, and classroom instruction, which can provide benefits in terms of both student learning and faculty interest in student learning (Schratz 1990).

c. Project Description.

Purpose

The Departments of Geography-Earth Science, Biology, and Teacher Education at SU will develop the "Burd Run Interdisciplinary Watershed Research Laboratory," which will include field and laboratory equipment, computer laboratories, a digital map library (including a watershed database), and an instructional/curricular library. Each of these components are detailed below. The University already owns much of the necessary equipment (existing holdings are discussed in the Budget Justification). Funds are requested for additional equipment needed to support hands-on student experience in data collection, laboratory analysis, and field investigations. Curricular and

course improvements based on the watershed research laboratory are also discussed below.

Watershed description. The Burd Run watershed is an ideal setting for an environmental laboratory due to its proximity to SU (the stream flows through campus), its manageable scale, and its diverse physical characteristics. Burd Run at the SU campus drains a watershed of 51.8 km^2, identical in size to the Crooked Creek, Indiana watershed that has proven to work well as a teaching laboratory (Lindsey and Jewett 1997).

Burd Run heads atop South Mountain, the local name given to the northern part of the Blue Ridge, at an elevation of 591m. There, two mountain tributaries flow through the Michaux State Forest, an area of sandy soils developed on Cambrian quartzite. Near the base of South Mountain, these tributaries combine and flow across thick Pleistocene colluvial deposits that support mixed forestry and agriculture eventually emerging into the Cumberland Valley. As the colluvium thins with distance from the base of the mountain, several units of Ordovician and Cambrian limestone are exposed (Root 1965), some of which include solution cavities and other karst features (Shirk 1980). Agriculture is the primary land use on the silt loam and clay loam limestone soils until the stream flows into the Borough of Shippensburg. Urban land uses dominate the lower watershed, where the stream eventually flows across the SU campus at an elevation of 189m.

Water quality varies considerably with geology and land use. For example, pH readings in the forest/quartzite environment are acidic (pH = 4.5), whereas water flowing through the limestone terrain of the Cumberland Valley is buffered (pH = 7.5). Temperature, turbidity, dissolved oxygen, and other water quality parameters also vary considerably in the different watershed environments. This variability among topography, geology, land use, and water quality provides an excellent field laboratory for a wide range of course projects and investigations.

Field and laboratory equipment. The project will emphasize expanding field and laboratory learning in a wide variety of courses and student research projects (details provided below). Necessary equipment includes instruments for: (1) automated monitoring of stream discharge, water quality, and meteorologic variables; (2) student field studies in geomorphic mapping, surface and groundwater hydrology, wetlands, soils and sediments, aquatic biology, and land use; and (3) quantitative and spatial data analysis, presentation, and exchange.

Computer laboratories. Existing computer laboratories will be enhanced to facilitate student data analysis, including adding hardware and software supporting: (1) GIS mapping and

statistical analysis, (2) remote sensing image analysis of watershed land use and vegetation cover, and (3) access to the watershed database through the project internet site.

Digital map library. The map library will include spatial data covering the entire drainage area as well as point data of water quality, discharge, groundwater flow, and meteorologic variables. Spatial data will be publicly available via a web page in two forms, as graphical files that can be viewed and printed via any web browser and as GIS files that can be downloaded and manipulated with ArcView software. A GIS will be established to maintain the spatial database of watershed conditions. This will include digital maps produced through student course projects covering hydrography (stream network and wetlands), geomorphology (including floodplain mapping and sedimentology), topography, bedrock and surficial geology, groundwater, soils, vegetation, land use, urban water management, water quality, and aquatic biology.

The watershed database of point data will include continuously monitored discharge and basic water quality parameters (temperature, pH, dissolved oxygen, turbidity, conductivity) at the stream monitoring station to be established on campus under this grant. Meteorological data already routinely collected at the SU weather station (daily temperature, rainfall, and snowfall) will be made available in digital form and will be supplemented by student projects using grant-funded meteorological instruments that can be moved throughout the watershed. Both raw data in tabular form and processed data in statistical and graphical summaries will be included in the database.

Instructional / curricular library. This digital library will be available on the project web site, providing field and laboratory instructional materials developed under the proposed grant, results from courses and student research, and evaluations of course projects from students, faculty, and the project advisory board (described below). Instructional materials will emphasize field and laboratory methods, hypothesis development and testing, mapping and spatial analysis, quantitative analysis, and interdisciplinary analysis (e.g. ecological studies, watershed management plans). After the project is well established (2001-2002) field research methods will be compiled in a laboratory manual available on the web site and offered for publication.

Curricular and course improvements. Several courses in geography-earth science, biology, and teacher education will use the watershed laboratory. One of the project's most innovative aspects is the use of the watershed database as a common case study throughout students' undergraduate education to improve learning of complex, interdependent environmental

systems that are difficult to address within a single course. For example, ecology students will be able to integrate water quality, geology, soils, and land use data to test hypotheses of aquatic invertebrate distributions. Geomorphology students will be able to link research on floodplain development to upstream geology, soils, land use, and hydrology. Access to the watershed database will support numerous student research projects, addressing a university-wide initiative.

Significant improvements in individual courses focus on needs identified in surveys of undergraduate interns, their supervisors, alumni, and departmental advisory boards. These include: (1) increased field and laboratory research, (2) exposure to state-of-the-art equipment, (3) greater quantitative and spatial analysis of data, and (4) familiarity with long term environmental monitoring. Examples of individual course improvements are provided in the methods section.

Methods

Administration. The project will be administered by the Burd Run Interdisciplinary Watershed Research Laboratory Committee, a 13-member team of faculty from geography-earth science, biology, and teacher education (see Appendix 2). The committee formed in Spring 1998 and continues to meet regularly to generate and share ideas on project implementation. Curricular coordinators from each of the major disciplines involved in the laboratory (geography earth science-Dr. Christopher Woltemade, Biology -Dr. Tim Maret, and teacher education - Dr. Elaine Anderson) will work together to maximize use of project equipment and data. Project module coordinators will oversee administration and implementation of specific project components:

Project module	Coordinator
Field equipment	Dr. Christopher Woltemade
Computer laboratories	Dr. Daniel DeVitis and Dr. Tim Maret
Digital map librarian and GIS	Dr. Paul Marr
Instructional/curricular library and geomorphology	Dr. William Blewett
Project web site	Prof. Alison Philpotts
Hydrology / water quality instrumentation and soils	Dr. Christopher Woltemade
Meteorological instrumentation	Dr. Diane Stanitski-Martin
Hydrogeology	Dr. Thomas Feeney
Geology	Prof. Craig Oyen
Aquatic biology	Dr. Tim Maret
Vegetation	Dr. Larry Klotz
Land use	Dr. John Benhart

The heart of the project--the GIS-based map library, the watershed database, and the project web site--will be established and managed by a team of faculty (Drs. DeVitis, Marr, and Philpotts) and two half-time graduate assistants to be funded under this proposal. The faculty involved have extensive experience in GIS and web site development (see attached biographical sketches). The Departments of Geography-Earth Science, Biology and Teacher Education have a strong, collaborative working relationship. There are no barriers to further collaboration on this project.

Implementation strategy. Positive impacts of the watershed laboratory will be maximized through a four-part strategy: (1) developing the comprehensive watershed analysis methodology, (2) implementing course and curricular improvements, (3) improving faculty professional development, and (4) providing for long-term project review, modification, and enhancement.

(1) Developing the comprehensive watershed analysis methodology.
The design of data acquisition, monitoring, and field investigation in the Burd Run watershed will be an iterative process driven by faculty and students in geography, earth science, biology, and education courses. The research design will closely parallel National Water Quality Assessment (NAWQA) methods for watershed studies (Gilliom et al. 1995, Fitzpatrick et al. 1998), including: (A) watershed reconnaissance, (B) occurrence and distribution assessment, (C) assessment of long-term trends and changes, and (D) source, transport, fate, and effect studies.

(A) Watershed reconnaissance. This effort will focus on identifying major natural and human factors influencing hydrology, water quality, and aquatic habitat within the watershed. The baseline information provided--including mapping of groundwater and surface water hydrology, water quality, aquatic biology, bedrock and surficial geology, geomorphology, topography, soils, land use / land cover (including vegetation), and urban water management--will assist in locating sampling sites for further data collection. As described above, a GIS will be designed for data storage, analysis, and exchange. Faculty will become familiar with basin characteristics through interdepartmental field trips and GIS training sessions.

(B) Occurrence and distribution assessment. The subsequent, integrated sampling effort to monitor major watershed processes (meteorology, surface and groundwater hydrology, soil erosion, geomorphology, water quality, aquatic biology) and assess human impacts on the

watershed (land use change, forestry, agriculture, urban water management) will be designed based on the watershed reconnaissance. This will include a combination of continuous monitoring at the watershed outlet and periodic sampling at additional watershed locations.

Discharge and water quality will be continuously monitored at the watershed outlet, where the data collected will indicate the integrated inputs from the entire drainage basin. The convenience of this site (on the SU campus) will maximize student involvement in monitoring. One array of meteorological instruments will be located at this site to continuously monitor radiation inputs and outputs; water, soil and air temperature; precipitation and evapotranspiration; and wind speed and direction. Aquatic biology surveys will also be conducted annually at this site.

Additional undergraduate studies will be conducted throughout the watershed to characterize geographic and seasonal distributions of water-quality and biological (aquatic macroinvertebrates) conditions in relation to natural and human features. These studies will emphasize the range of watershed landscapes, with sampling across the various topography, land use, geology, geomorphology, and soils represented. Long-standing collaborative relationships with the Michaux State Forest, the Borough of Shippensburg, and key riparian landowners will facilitate site access. The sampling design will emphasize monitoring both spatial and temporal changes in water-quality and biological conditions.

(C) Assessment of long-term trends and changes. Long term monitoring sites will be established to detect temporal changes in hydrology, aquatic chemistry, biology, and geomorphology as related to changes in landscape features and human activities. Sites will be defined based on parts (A) and (B) above and will include the watershed outlet and sites capturing runoff from the forested upper watershed, the agricultural middle watershed, and the urban lower watershed.

(D) Source, transport, fate, and effect studies. Hypotheses will be developed and tested to determine the status and trends of particular water quality parameters, including temperature, pH, dissolved oxygen, turbidity, conductivity, and nitrate, as well as aquatic habitat suitability. These assessments will be linked to watershed characteristics, such as land use, geology, and soils.

(2) Implementing course and curricular improvements.

The concept of interdisciplinary watershed study driven by multiple courses sharing a common research site and field data is not new. In 1993 a similar approach at Millersville University (a Pennsylvania State System of Higher Education sister institution), supported by a NSF-ILI award, established a GIS database to integrate analysis in hydrology and water resources courses. At Skidmore College the "sense of purpose and continuity [provided by a watershed case study] has proven to be an ideal method for teaching environmental science" (Kirk et al. 1997, p.508). Successful projects at Ohio State University and Iowa State University also provide useful models.

While a much larger project, the Olentangy River Wetland Research Park at Ohio State University provides an example of a successful project with similarities to the proposed SU watershed laboratory. Teaching at OSU has been improved through the wetland park in much the same way that is proposed here--by exposing students in a range of courses to field and laboratory experience focused on sharing data from a common case study (Mitsch 1998). In 1997, 18 OSU classes involving 700 students used their research park. At SU, over 1000 students from 22 courses would receive intensive field training within the research watershed each year.

The Riparian Management Systems (RiMS) project at Iowa State also uses a common research site across multiple courses, facilitating comprehensive data collection and analysis and integrative student learning. While the ISU site is more intensively monitored than what is proposed for the SU project, the concept of facilitating a variety of studies, each sharing data and providing a unique perspective, is similar. Burd Run studies would be similar in scope to those at ISU and would focus not only on biogeophysical processes, but application of that information at the watershed level (Schultz et al. 1997).

An important distinction is that while the Ohio State and Iowa State projects emphasize graduate research, the SU effort would be driven by undergraduate students. Small group field projects in a range of courses would focus on field data collection. Individual and small group projects would analyze field data through quantitative methods and spatial analysis using GIS.

During the past 10 years, the Biology and Geography-Earth Science departments at SU have increasingly emphasized field research in undergraduate courses. For example, in 1995 a soils field site was developed for student studies of colluvial soil common to the Burd Run watershed, a site that continues to be used in soils and geomorphology courses. The Burd Run floodplain

serves as the basis for course field studies and student research in aquatic ecology, wetland delineation, soil description, and stream discharge. A pending separate grant proposal has been prepared to fund student-faculty research to develop a stream corridor restoration plan for this site. The watershed laboratory will improve these preliminary efforts by supporting new field and laboratory equipment and facilitating sharing of watershed data and curricular materials.

Several examples of individual course improvements facilitated by the watershed laboratory are detailed below. Improvements to additional courses (soils, groundwater, water resources management, mapping sciences, etc.) are described in Appendix 3. Perhaps most importantly, the project will also provide a conceptual link among disciplines, so that a student may utilize the watershed database in different ways in several courses and/or in independent research.

Hydrology. Students in this undergraduate geography course will delineate the watershed and surface water features on topographic maps and aerial photographs as the basis of the GIS hydrography coverage. Four new field laboratory exercises will be developed: (a) water quality data acquisition and interpretation (using the water quality sonde, colorimeter, and existing equipment) (b) stream current velocity and discharge measurement (using current meters to be purchased), (c) infiltration capacity of various watershed soils, and (d) rainfall-runoff computer modeling (using HEC-1 software already owned by SU and using the watershed database for input data). These exercises will emphasize watershed variability, incorporating maps of watershed characteristics generated in other courses to explain local hydrologic conditions. Two examples illustrate the enhancement of existing course projects with data made available through the watershed laboratory: (a) estimation of evaporation rates, currently based on hypothetical data, will be based on local data provided by students in other courses using the meteorological instruments; (b) flood probability analysis will focus on campus facilities located along Burd Run, utilizing rainfall-runoff modeling results, the record of discharges recorded at the stream monitoring station, and floodplain surveying to be conducted in geomorphology courses.

Ecology (biology majors and all pre-service biology teachers) and *Introduction to Ecology* (non-majors). These undergraduate biology courses currently include a laboratory section in which students intensively study the Burd Run watershed. Students visit watershed sites where they collect data on physical, chemical, and biological parameters, including water quality and macroinvertebrate community composition. The students then analyze and interpret the data,

investigating relationships among the various parameters. Using the watershed laboratory database and computers to be purchased for use in the biology department, students will not only be able to compare results among years and locations, but will also be able to explore relationships between their data and data collected in other courses on watershed hydrology, geology, geomorphology, soils, and land use. This integration will provide students with unique learning opportunities and a chance to explore the many factors that contribute to watershed processes. Biology students will also learn the latest in GIS/Arcview technology.

Meteorology and *Applied Meteorology and Climatology*. Two meteorological stations will allow students of Meteorology to measure precipitation, evaporation, and radiation and energy fluxes; the data will be incorporated into group laboratory exercises designed specifically for the watershed. Each small group will measure a different component of the energy or radiation balance, justify its importance to watershed processes, and present their results. Evaporation data will be provided to local farmers to incorporate into agricultural water budgets, thus encouraging students to use an applied approach to scientific investigation. The watershed laboratory will also facilitate the development of new field projects in Applied Meteorology and Climatology. Students will develop research projects using both the permanent instrument array located at the watershed outlet and a mobile station that will allow for comparisons of meteorological components across varying terrain, in and out of a forest, above and adjacent to water, etc.

Geomorphology. The proposed project will form the basis for an extensive revision of teaching and learning strategies in geomorphology, one emphasizing learning through direct experience, rather than lecture. Specific field applications for undergraduate students include: (a) using the total station (survey equipment) to map and identify floodplain landforms, (b) incorporating stream discharge data, stream current velocities, and sampling to determine channel conveyance capacity and sediment budgets, (c) applying an understanding of geomorphic processes within the watershed to local environmental problems, such as sinkhole development, and (d) using watershed data as a basis for group research projects, such as exploring soil genesis in various geologic and topographic environments.

Environmental Education Practicum. The teacher education program will be improved through increasing exposure of pre-service teachers to the scientific method applied in a field and laboratory learning environment. Several field studies will be developed as course improvements to

the environmental education practicum, providing extensive experience with water science to pre-service teachers. Water has been described as a particularly effective focus for future science teachers because: (a) few sciences can be taught without an understanding of water, (b) hydrology and water quality provide extensive data sets useful for developing mathematical skills, and (c) we all interact with water daily (Smith et al. 1997).

(3) Improving faculty professional development.

The benefits of the project will be broadened at SU through: (a) Campus-wide instructional innovation workshops emphasizing field and laboratory research, student data collection and analysis, use of the watershed case study, and the value of sharing this common research site across courses in a variety of disciplines. Faculty from additional departments, such as chemistry, mathematics, and physics will be encouraged to link their students and courses with the project. (b) Professional development seminars will be conducted to increase faculty skills in using project equipment, such as geographic information systems, field mapping, and water quality monitoring. (c) Future initiatives to expand the curricular impact of the research watershed at the university will be coordinated by the Burd Run Interdisciplinary Watershed Research Laboratory Committee.

(4) Providing for long-term project review, modification, and enhancement.

Project review will be conducted annually by an advisory board of outside evaluators, representing university educators and private industry analysts working in hydrology, water quality, wetlands, and aquatic biology (details in evaluation section below). Individual field investigations and the watershed monitoring program will be updated based on their recommendations.

While the initial Burd Run watershed database will be completed during the time frame of NSF support (1999-2001), the regular use of field and laboratory equipment will continue. The watershed database will continue to expand with ongoing monitoring and student research projects. If additional field sites are needed for basic data collection (e.g. mapping of soils), the project may eventually be expanded to include the Middle Spring watershed. This watershed also heads on South Mountain and combines with the Burd Run watershed approximately 3km downstream of the SU campus to form a 129km^2 watershed. This watershed includes the Shippensburg wastewater treatment plant, a site frequently used for water quality studies in biology courses.

Timetable for executing the project

Summer 1999	• begin project equipment acquisition and continuous meteorological, hydrological and water quality monitoring
	• establish web site, watershed database, and curricular / instructional library
1999-2001	• collect and analyze watershed reconnaissance data in undergraduate courses
	• complete watershed descriptive mapping
	• develop hypotheses on occurrence and distribution of watershed processes and human impacts; assessment of long-term trends and changes; and source, transport, fate, and effect of water quality parameters
	• develop field and laboratory exercises in individual courses to test hypotheses
	• meet with watershed laboratory advisory board annually to evaluate project
	• present curricular development and watershed research results in publications, conference presentations, and on project web site
Future years	• continue watershed monitoring and field studies to expand watershed database and curricular / instructional library

Facilities and resources available for realizing the project's objectives

The following SU facilities and equipment will support the watershed laboratory: the GIS and computer mapping laboratory, the soils / geomorphology laboratory, the university weather station (daily temperature, precipitation, and snowfall), portable water quality monitoring equipment, dissecting microscopes for invertebrate identification, aquatic biology field sampling equipment, and 3 departmental vans available for field trips (specific equipment holdings related to the project are detailed in the Budget Justification). While project funds are needed to enhance some facilities, the infrastructure to implement much of the project is already in place.

At the conclusion of NSF support, the laboratory will continue to support undergraduate education through student field investigations using project equipment and interdisciplinary analyses facilitated by the watershed database. Necessary maintenance of field and laboratory equipment will be funded through the regular university budget (see Appendix 4).

d. Experience and Capability of the Principal Investigators.

Drs. Woltemade and Blewett have practical experience with undergraduate students in all aspects of the proposed project, including teaching, research, and curriculum development. They have published in a diverse group of refereed journals including *Journal of the American Water Resources Association, Geological Society of America Bulletin, Annals of the Association of American Geographers, Physical Geography,* and *Journal of Geoscience Education,* and have

presented or supervised more than 30 papers at professional meetings since 1990. These activities have been augmented by three refereed publications with students (2 undergraduate, 1 graduate), plus several directed theses and Pennsylvania State System of Higher Education student-faculty research grants. Dr. Woltemade has developed undergraduate field exercises in hydrology, soils, and water resources management. Dr. Blewett has developed similar projects in geomorphology, soils, and physical geology. Curricular and course developments will benefit from the experience of Dr. Woltemade as Chair of the Geography-Earth Science Curriculum Committee. Likewise, pedagogy will be enhanced by Dr. Blewett's experience in earth science education and continued research interests in use of the scientific method in undergraduate education (Blewett 1993).

e. Evaluation.

Three existing assessment strategies will be modified to provide formative evaluation of watershed laboratory course and curricular improvements. These strategies include: (1) departmental advisory board reviews of undergraduate educational programs, (2) surveys of student interns and their supervisors working in environmental science fields, and (3) surveys of graduating seniors.

The "Burd Run Interdisciplinary Watershed Research Laboratory Advisory Board" will be developed following the model of the existing Geography-Earth Science Department Advisory Board, which includes educators independent of SU and government and industry representatives who provide guidance on department curricular matters. Example members willing to serve on the watershed laboratory advisory board include: Robert McClure (Executive Vice President, Skelley and Loy Environmental Consultants), Scott Sternberger (Wetland Scientist, KCI Technologies), Tony Ross (Biologist, Pennsylvania Game Commission), Kieth Taylor (GIS Specialist, Pennsylvania Department of Conservation and Natural Resources), and Dr. Tom Bott (Assistant Director, Stroud Water Research Center). The advisory board will be asked to critically review watershed laboratory annual reports that will be prepared to describe ongoing watershed monitoring efforts, student field and laboratory projects, and course and curricular materials.

Annually, approximately 100 SU students in biology and geography-earth science work as interns in environmental science fields. Each intern and their supervisor is surveyed by either site visit or telephone. Seniors are also surveyed to assess their educational experience before graduating from SU. These routine surveys will be updated with a new evaluation instrument.

Both the project advisory board and the evaluation instrument to be used in student and supervisor surveys will address the basic question: How could the watershed laboratory, as implemented in individual courses and across the science curriculum at SU, more effectively prepare students for careers or graduate education in science? In particular, the major educational objectives of the project will be addressed: student use of technology, student-faculty research, innovative teaching strategies, and enhanced interdisciplinary study. Three additional educational areas will be targeted: field and laboratory training, quantitative skills, and understanding of complex, interdependent environmental systems. Project implementation will be revised as needed based on comments of the advisory board and surveys.

f. Dissemination of Results.

The watershed laboratory model to be developed under this project could easily be adopted by other universities, such as SU's 13 sister institutions in the Pennsylvania State System of Higher Education (SSHE). During summer 2000 a conference and field workshop will be held at SU to share information with SSHE and other university faculty. Conference participants will be given a handbook of ideas for implementing a similar program at their home campus. In addition, results in the form of watershed data, interdisciplinary curricular initiatives, and course materials such as a manual of field and laboratory methods, small group projects, and student research results will be disseminated via publications, conference presentations, and an internet site.

Publication of curricular innovations such as case study data sharing across the science and education curricula will target science education journals such as *Journal of Geoscience Education, Journal of Environmental Education,Journal of Geography, Journal of College Science Teaching,* and *American Biology Teacher* . Findings will be disseminated through presentations at national meetings of the American Water Resources Association, Association of American Geographers, Geological Society of America, Ecological Society of America, and National Council on Geographic Education. Student presentations will be given at regional meetings of these organizations and meetings of the Pennsylvania Academy of Science and the Pennsylvania Geographical Society. The project internet site will make available watershed data and field and laboratory course materials suitable for adoption at other institutions. Project newsletters and annual reports will be widely distributed via internet and a project mailing list.