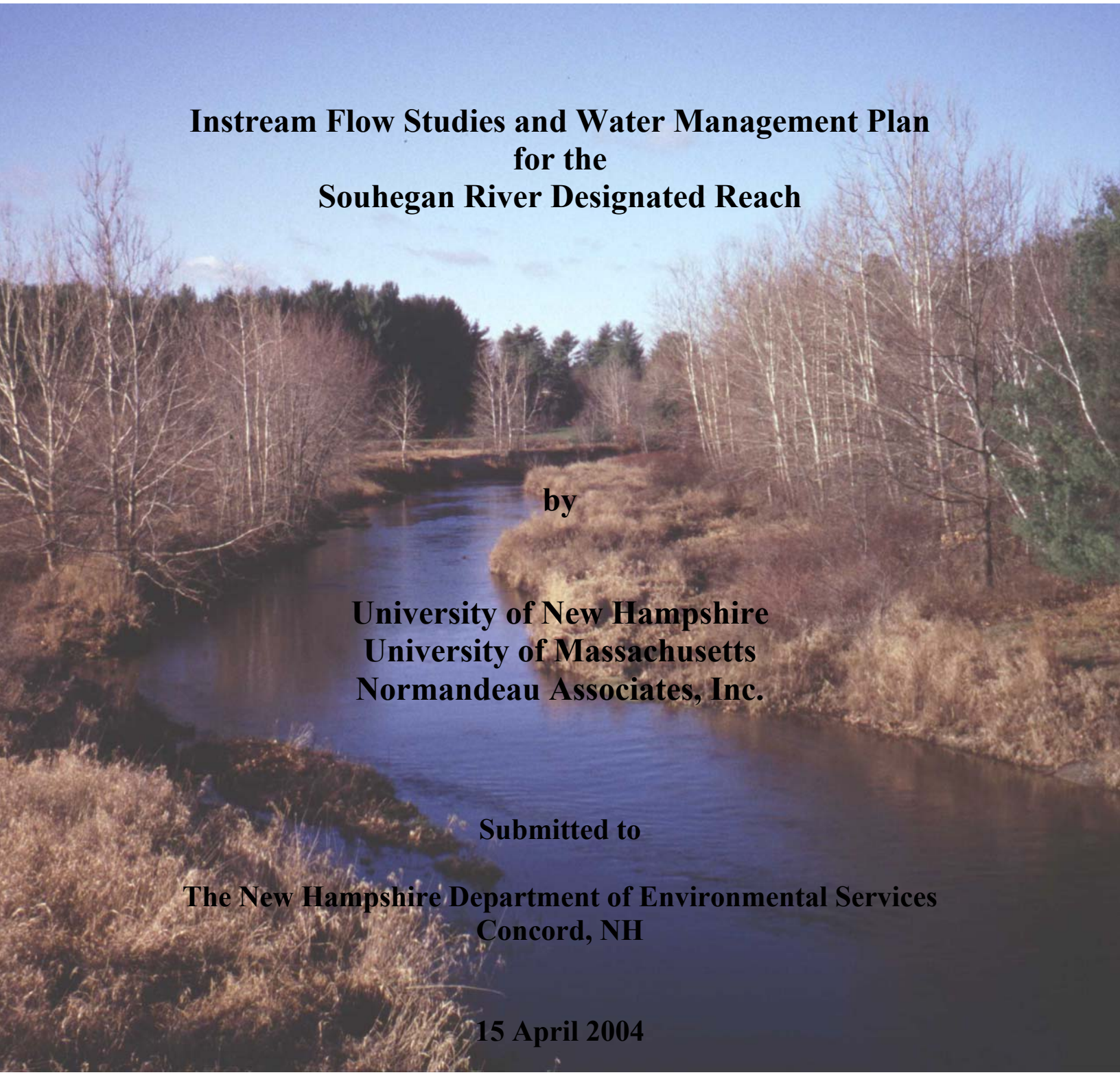

Instream Flow Studies and Water Management Plan for the Souhegan River Designated Reach

by

University of New Hampshire
University of Massachusetts
Normandeau Associates, Inc.

Submitted to

The New Hampshire Department of Environmental Services
Concord, NH

15 April 2004

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I. Specialized Experience of the Project Team

The project Team of the University of New Hampshire, Normandeau Associates, and the University of Massachusetts has worked together in the past and therefore possesses the ability to work in a unified and well-integrated manner to successfully meet project objectives. The team fields experience in: field and model development of instream flows, water resources management strategies, involvement of the public and stakeholders during the performance of technical projects, state and federal permitting, stream restoration, hydrologic field methods and simulation, and biologic characterization of aquatic systems. The team is highly qualified to perform all aspects of the Souhegan Instream Flow Study and Water Management Plan. Brief descriptions of relevant past projects of team members are found in the following paragraphs. More detailed descriptions of these projects appear in Appendix A.

Ecohydrology Study on the Quinebaug River: The Ecohydrology study on the Quinebaug River in Massachusetts and Connecticut focused on the assessment of the river's bio-physical conditions, the identification of ecological deficits, and the determination of potential improvement measures including determination of protected instream flows and potential flow augmentation methods. It was part of a multidisciplinary investigation required by the US Army Corps of Engineers Section 404 permit and by the Massachusetts Department of Environmental Protection Section 401 Water Quality Certification for the Millennium Power Project in Charlton, Massachusetts. The results of the study provided a basis for future decision-making processes and for the design of a long-term implementation plan.

Developing a Sustainable Management Plan for the Pomperaug River Watershed: Because of its relatively high ecological integrity, the Pomperaug River serves as a model of a healthy river ecosystem that could be used as a reference river for other river systems in the region. However, rapid population growth in the region and higher per capita water use has caused an increase in water demand, putting considerable pressure on the Pomperaug aquifer. Thus, the growing water demand could jeopardize the quality of the Pomperaug ecosystem.

This pilot project (performed in collaboration with the local USGS) covered the concept development and the first stage of the habitat component of the comprehensive study of the river ecosystem. A watershed-wide instream habitat survey was conducted in order to develop a quantitative instream habitat model. This model provided a general overview of available fish habitat. Recently the Connecticut Senate allocated additional funding to continue the study.

Measuring River Ecosystem Health in Western Massachusetts: The study investigated the availability of suitable habitat and dwarf wedgemussel under low flow conditions. The primary tools used for this effort were the MesoHABSIM habitat simulation model and the target fish community developed specifically for the Mill River.

Fish habitat assessment on Stony Clove Creek, NY using MesoHABSIM: From a physical standpoint, the Stony Clove Creek faces river management problems due to historical hydrological alterations, impaired aquatic fauna and fisheries, and dramatic seasonal fluctuations in flow. The New York City Department of Environmental Protection (DEP), in partnership

with the Greene County Soil and Water Conservation Districts, is restoring stream channel stability in priority sub-basins in order to improve water quality in city reservoirs. This study was therefore prompted by the need to develop a comprehensive, multi-objective Stream Management Plan.

Instream habitat evaluation of Santee River below Wilson Dam: This instream habitat evaluation study is developing a quantitative relationship between flow releases and fauna composition in the upper 37 mile reach of the Santee River. The goal is to develop recommendations for an ecologically sound flow regime and other measures to enhance the downstream section. These recommendations will then be evaluated by the FERC along with the other competing interests of the overall project.

Merrimack River Watershed Assessment Study: The study is developing a watershed management plan that will guide investments to achieve conditions that support feasible beneficial uses. This will be accomplished by conducting a water resources and ecosystem restoration investigation of the Merrimack River.

Aziscohos Dam Minimum Flow Study: Computer modeling procedures of the Instream Flow Incremental Methodology (IFIM) were used to quantify the amount of habitat available for brook trout and landlocked Atlantic salmon over a range of alternative stream flows in the tailrace and bypass area for a proposed hydroelectric station. Habitat suitability curves were developed for landlocked salmon in cooperation with the Maine Department of Inland Fisheries and Wildlife. In addition, Habitat Evaluation Procedures (HEP), developed by the U.S. Fish and Wildlife Service, were used to determine the amount of habitat for the evaluation species in the bypass reach and in a compensation area. This was done to assist in the development of a plan to mitigate for losses in habitat associated with the project.

Farmington River IFIM: Instream flow needs for fisheries within the Connecticut section of the West Branch and mainstem of the Farmington River were assessed using the Instream Flow Incremental Methodology (IFIM). The effects of alternate flows on recreational opportunities and aesthetics were assessed based on: 1) a user survey of recreationists on the river during spring, summer, and fall, 2) a field evaluation of recreational conditions conducted by experts and local volunteers, and 3) an evaluation of how scenic conditions are affected by flows based on videotapes and panel review.

Snowmaking Needs vs. Minimum Flow Requirements: Diversion of water from small, headwater streams for snowmaking purposes has resulted in serious concerns by state and federal fisheries and wildlife officials regarding potential impacts to aquatic biota. This project required the evaluation of minimum flows to sustain native coldwater fisheries in small headwater streams, negotiations with state fisheries and wildlife biologists, and presentation of expert testimony at Vermont Act 250 hearings. Winter minimum flows negotiated for two of these projects have yielded minimum flows substantially less than initial agency standards based on summer flow requirements. The third project, which is ongoing, involves the use of the U.S. Fish & Wildlife Service developed Instream Flow Incremental Methodology (IFIM) on Vermont's Ottauquechee River.

A Geographic Information System for Aquatic Resource Characterization and Management in the Upper Ohio River Basin of Western Pennsylvania: The study area covered approximately 110 miles of the Ohio, Allegheny, and Monongahela Rivers. The project was a joint venture of the Pennsylvania Department of Environmental Protection (PA DEP), the Pennsylvania Fish and Boat Commission (PFBC), and the Ohio River Valley Water Sanitation Commission (ORSANCO). The objectives of the project were to: 1) characterize aquatic habitat and develop GIS-based representations of the habitat variables used in classification, and 2) develop and implement GIS-based resource inventory and management applications.

Modeling Instream Habitat and Water Temperature Regimes in Marsh Creek at the Eisenhower National Historic Site, Pennsylvania. Marsh Creek is one of only two permanent streams flowing through Eisenhower National Historic Site (EISE)**.** The ecological integrity of these streams, and particularly Marsh Creek, has been an ongoing concern for many years due to increased human development and disturbance of the upper watershed. The largest and most direct threat to Marsh Creek was the issuance of a permit to Gettysburg Municipal Authority (GMA) to withdraw surface water just upstream from the EISE boundary and augment withdrawals with well water (a novel permit situation within Pennsylvania). Water withdrawal and augmentation could comprise a significant fraction of the total stream flow in Marsh Creek through EISE, altering available habitat quantity or water quality. The proximity of the GMA activity (adjacent and just upstream of EISE), coupled with the relatively short length of stream within the Park boundary, are of great concern because the activity may substantially degrade the ecological integrity of a unique Park resource. To address these ecological concerns instream flow modeling and water temperature monitoring of the stream were employed. A detailed study map of instream habitat units was constructed using a GPS unit with sub-meter accuracy and then plotted using ArcView software which also served as a spatially explicit data library for project samples.

Feasibility of Main Stem Reservoir Developments - Powder River, Wyoming: The project objective was to determine the maximum sustainable water resources development of the Powder River Basin to meet the demands of mining, public supply, irrigation, recreation, and instream flow. The Powder River extends from the Bighorn Mountains eastward to the state boundary with Nebraska and northward to the state line with Montana. The river is characterized by very clear, cold water from the west, and salty, turbid, warm water from the south and east. Hydrologic characterization of the flow regimes on ungaged tributaries and the mainstem were performed by statistical methods reinforced by concurrent flow measurements. Water development strategies considered the effect of both removing fresh water and sediment. A very significant issue on the mainstem was sediment transport and sedimentation in any proposed mainstem dam. Results of this study were recently employed in the assessment of the coal-bed methane extraction in the same watershed.

Legal, Environmental, and Hydrological Consequences of Missouri River Diversions: A very large water withdrawal from the mainstem Missouri River was proposed by a private interest and approved by the federal government. The diversion would take water from the Missouri River at the Oahe Dam in South Dakota and pump it to eastern Wyoming. The objection by the downstream states to this proposal brought the matter before the US Supreme Court. To support the concerns of the downstream states required: developing long term flow statistics for the river (including flow duration curves and 7Q10), identifying critical stream

reaches of habitat adversely affected by the withdrawals, reviewing system-wide reservoir operation strategies and how these strategies would be affected by the diversion, delineating how diversions would impact existing users, preparation of the hydrology in the context of the governing water law, preparing legal briefs, and supplying deposition testimony.

Hydrogeology of the Spruce Hole Formation: The Spruce Hole formation is a stratified drift aquifer located in Lee and Durham, NH. The formation was under development pressure. The formation also included one of the few remaining undisturbed kettle-hole bogs in New England, and as such, it was classified as a unique ecological area by the US National Park Service and is a registered National Natural Landmark. The primary objectives of the study were: aquifer delineation; determination of the safe ground water yield; evaluation of water quality; location of water supply well(s); wellhead delineation, assessment of the potential for artificial recharge; determination of the baseline vegetation of the bog; and establishing permanent long-term vegetation monitoring plots. The performance of the study included well installation of the following types of wells: production well, monitoring wells, small diameter wells, and miniature piezometers. The small diameter wells and the miniature piezometers were instrumental in clearly delineating the connection between the bog and the aquifer below.

Ground Water Well Supply and Wellhead Delineation, Pembroke, NH: The stratified drift formation along the Soucook River, at the Concord/Pembroke town line, was investigated for its suitability as a water supply source for the town of Pembroke. Monitoring wells and a production well were located and constructed. The production well is within 250 feet of the Soucook River. A pumping test was performed to help identify the well head area as well as to define the fraction of water pumped from the well that was induced to infiltrate from the river. Miniature piezometers were used to assist defining the river water pumped by the production well. This information was then built into the well head delineation.

Interaction of Surface and Ground Water, Fort Wainwright, AK: The large aquifer below Fairbanks AK was being studied with respect to water supply and contamination issues. A large part of this study was the computer simulation of the formation. This computer simulation relied on precipitation and surface water as boundary conditions to drive ground water flow in the aquifer. UNH used small diameter wells and miniature piezometers to determine river bed hydraulic conductivity in the Chena and Tanana Rivers. In addition, the miniature piezometers were used to define the ground water gradients used in the computer model during model calibration.

Movement of Contaminants and the Effects of Ground Water Pumping, Eielson Air Force Base, AK: Large volume ground water wells (> 4,000 gpm) were used for power plant cooling at Eielson AFB. Due to the very high transmissivity of the aquifer at the base (>100,000 ft^2/day) the effects of this pumping were far reaching. The base had various sites of ground water contamination, and the movement of contaminants was affected by the ground water pumping. Some contamination was moving towards the base water supply wells. The objective of this project was to study the effects of ground water withdrawals and propose management strategies or water supply options. Part of the performance of this project included the use of miniature piezometers on cooling ponds near to the power plant wells, in order to define the extent of short-circuiting of water from ponds to wells.

The Effects of Cochiti Dam on Sedimentation and Erosion in the Mainstem Rio Grande, New Mexico: The construction and operation of Cochiti Dam created a sink for river-borne sediments. The clear water discharge of the dam resulted in 20 miles of river-bed degradation below the dam, that was propagating downstream. Degradation generally resulted in 4 to 10 feet of scour before the river bed would armor. The objective of this project was to model the river bed scour process and to recommend strategies to arrest its progression. To do this, first the system hydrology was developed, then hydraulics, then sediment transport. Since most of the tributaries were ungaged, the hydrologic step required the generation of tributary stream flows, on a daily basis, for a 100-year horizon. These tributary hydrograph time series were developed by using aerial weighting schemes, regression relations, and concurrent flow data collection.

Assessing Cocheco River Contaminated Sediment Management Alternatives from Multiple Stakeholder Perspectives: This study characterized the priorities of different stakeholder groups in relation to novel contaminated sediment management alternatives. Stakeholder values were elicited in an interview-questionnaire-verification interview format and combined with expert assessments of the performance of the technological alternatives in relation to the decision criteria identified by stakeholders. An MCDA framework was employed to identify potential conflicts or opportunities for compromise among different stakeholder groups.

II. Project Personnel

To provide the best, scientifically defensible Instream Flow Study (IFS) and Water Management Plan (WMP), we have assembled a team of scientists and engineers who have significant experience in the evaluation of water resources issues. The team will be led by Dr. Tom Ballestero of the University of New Hampshire (UNH). Collaborating with Dr. Ballestero will be Dr. Piotr Parasiewicz of the University of Massachusetts (UMass) and Donald Kretchmer of Normandeau Associates, Inc. (Normandeau) in Bedford, New Hampshire. In addition to leading the team, Dr. Ballestero assumes the lead technical role in the preparation of the WMP. Dr. Parasiewicz assumes lead technical role for the IFS. Normandeau will provide additional technical assistance with both the IFS and the WMP as well as field support for the IFS and the WMP through Dr. Matthew Chan (Normandeau) and Don Kretchmer. Mr. Kretchmer will lead the public participation portion of the project and all Normandeau efforts. Details and resumes for all project personnel appear in Appendix B. Brief descriptions of the three lead personnel follow. These lead personnel are committing a minimum of 20% of their time to this project for the duration of the project. An organization chart may be found in Figure 1.

Dr. Thomas P. Ballestero has been involved in water resources engineering projects for 23 years. He has managed multi-million dollar projects that included diverse teams of professionals. Dr. Ballestero is a hydrologist and water resources engineer presently on the Civil Engineering faculty at the University of New Hampshire, where he has been employed since 1983. For 13 years Dr. Ballestero was the Director of the NH Water Resources Research Center. This position required that he be knowledgeable of NH water resources issues/laws, interact with the legislature, and integrate the public into the water resources issues that faced the state. Dr. Ballestero has been involved in a number of projects that directly or indirectly involve instream flow issues, such as: water resources development of the Powder River Basin, WY; evaluation of the impacts of trans-basin diversions on the Missouri River from South Dakota to the confluence with the Mississippi River; waste load allocation study for the Contoocook River below Jaffrey, NH; ground water resources evaluations, and hydropower optimization along the lower Cocheco River, NH. In addition, Dr. Ballestero has had formal training in strategies for water resources allocation during times of deficit. His dissertation research developed stochastic strategies to forecast deficits, thereby providing reaction time for management strategies prior to the deficit. He has taught courses on water resources allocation strategies. Dr. Ballestero has experience in public forums, especially those involving complicated and controversial issues. His advice was sought during the development of the New Hampshire instream flow rules.

Dr. Piotr Parasiewicz is a civil and environmental engineer educated at the University of Agricultural Sciences in Vienna. He started his career in 1988 as a research associate on an interdisciplinary team of biologists, water engineers, and landscape ecologist in the Department of Hydrobiology, Fisheries, and Aquaculture of the same university. This position strongly influenced his professional development and provided him with expertise on riverine ecology, ecosystem management and restoration, river morphology, physical habitat assessment, statistical and numerical modelling, as well as remote sensing. From 1997 to 1999 Piotr was a member of the Austrian Network for Environmental Research, a governmental institution actively participating in development of EU environmental and research policy. Since 1999 to 2004 Piotr has been leading the Instream Habitat Program at the Department of Natural

Resources of Cornell University. He is also an adjunct assistant professor in the Department of Natural Resources Engineering of the University of Connecticut. One of the key tasks of the Instream Habitat Program is to develop methodologies for basin-wide assessment of flow needs as a tool for water use planning and regional legislation. Recently, the University of Massachusetts proposed to relocate the Instream Habitat Program to Amherst with the ambition of creating a national and international center of excellence in instream habitat studies. Consequently last March, Piotr took a position of Research Associate Professor at the Department of Natural Resources Conservation at the University of Massachusetts, Amherst. The center will build upon intensive collaboration with organizations such as the USGS (Conte Anadromous Fish Laboratory), US Army Corps of Engineers (Waterways Experimental Station), Iowa Institute of Hydraulic Research, regional state Universities as well as the International Aquatic Modelling Group. Development of state-wide instream flow rules is one of the key tasks of the center.

The team leader for Normandeau Associates will be Mr. Donald W. Kretchmer. He has over 20 years of experience in water resource investigations as a principal investigator and project manager. He is currently managing a long-term water quality monitoring project on the Yadkin River System in North Carolina as a part of re-licensing of four hydropower dams. The alternative licensing process employed on this project relies on extensive input from stakeholders during study scoping, data collection and data interpretation. The stakeholder group includes regulatory agency personnel, NGO's, residents, fishermen and watershed groups. He is also currently managing a variety of water quality studies on the Lower Merrimack River to support the development of a comprehensive model of nutrients, bacteria and metals for the system. He recently evaluated the water quality implications of alternative reservoir operating scenarios on the entire TVA system as a part of a programmatic environmental impact statement. He has managed water quality investigations on the Middle and Lower Merrimack, the Pemigewasset, the Androscoggin, the Connecticut, the Salmon Falls, and the Piscataqua Rivers in New Hampshire which focused on flow, bathymetry, nutrients, temperature, dissolved oxygen and municipal and industrial withdrawals and discharges. Nationwide, he has participated in or managed water quality investigations at over 50 hydroelectric sites. He has assisted Manchester, New Hampshire and Portland, Maine in protecting their water supplies. Other areas of investigation during his career include lake restoration, natural resource damage assessment, water resource planning, groundwater, fisheries, food web interactions and watershed management.

Other Personnel

Resumes of all other team members may be found in Appendix B.

Organization Chart

Project Personnel and their efforts are organized in the following diagram.

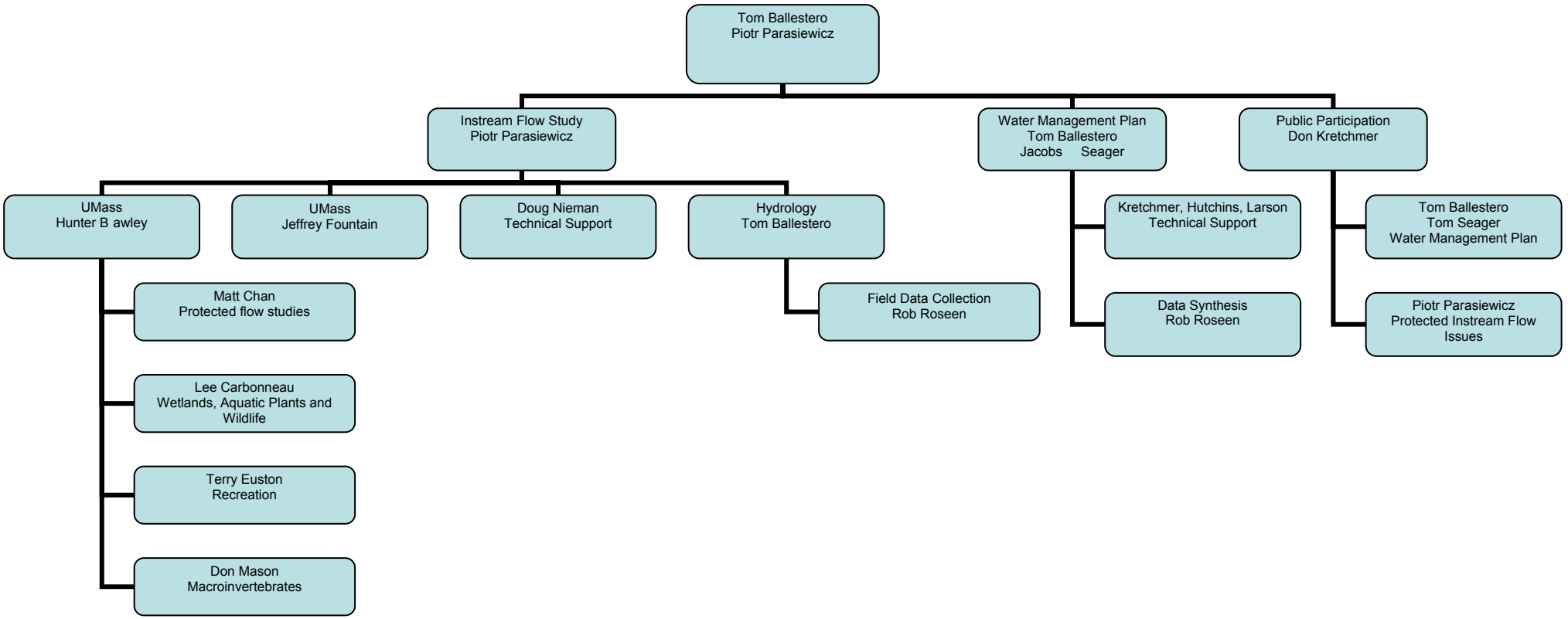


Figure 1. Project Personnel Organization Chart.

III. Project Approach

Protected Instream Flow Study

Background

A major goal of the Souhegan River instream flow assessment and Water Management Plan is the determination of Protected Instream Flow (PISF) values for designated reaches and strategies to achieve them. PISF values must be established that protect legislatively mandated Instream Public Uses, Outstanding Characteristics, and Resources (IPUOCR) entities, which may constrain water use by Affected Water Users (AWUs) in the Souhegan River basin. Consideration of PISF levels in relation to current and projected water use patterns in the basin will be an integral component of the Water Management Plan (WMP), as discussed elsewhere in this proposal (Section 10).

In order to foster public understanding and acceptance of recommended PISF levels, it is critical that they be based on defensible scientific principles and methodologies. NHDES has established a series of tasks that will provide the technical background, fulfill legal mandates, and meet Public Trust responsibilities that are needed for the Agency to establish the PISF regulations that it deems necessary. Briefly, these tasks are as follows: 1) identify IPUOCR entities, 2) conduct a targeted field verification survey of IPUOCR entities, 3) develop and apply a method to assess well withdrawal impacts on surface water, 4) describe IPUOCR entities and propose methods that would be used to assess their flow needs, 5) apply selected PISF method(s) and develop quantified PISF values that protect IPUOCR entities and, within the context of applicable regulatory frameworks, promote compliance with water quality standards.

Following completion of these five primary technical tasks, two additional tasks must be accomplished in order to satisfy public participation mandates included in the legislation that establishes the pilot instream flow protection program. First, details of the study and recommendations from it must be made available to the public through a public hearing, delivery of draft reports to public outlets in the study area, and posting of documentation to the NHDES website. Second, feedback from public review of study reports and recommendations will be used to revise conclusions and recommendations, if necessary, and document how such comments were considered. Results of these tasks, in conjunction with the previous technical components, will be used to prepare a final PISF report for the Souhegan River.

Recent studies have shown that the flow variability and dynamics in a fluvial ecosystem are critical for the viability of the adapted fauna (Jowett and Duncan 1990; Poff and Allen 1995; Richter *et al.* 1997). Natural ecosystems are much more resilient and better able to withstand short-term stress than systems with persistent habitat limitations (Niemi *et al*. 1990; Yount and Niemi 1990). Therefore, when evaluating environmental thresholds, it is essential to consider not only the magnitude of an impact, but also its duration and frequency, especially when estimating the impacts to the fauna resulting from habitat and flow changes.

Regulated flow regimes are characteristically different from more natural systems and affect biota in both direct and indirect ways. Persistent low flows modify the hydraulic character of an

ecosystem (by lower velocities and depths), creating habitat that is more suitable for pool-dwelling than flowing water fauna, giving pool dwellers a competitive advantage (Poff and Ward 1989, Kinsolving and Bain 1993). Low flows may also lead to increased temperatures and pollution levels, introducing additional stress for the entire aquatic community (Parasiewicz and Goettel, 2003). Hydrological modifications are also caused by watershed land use; these changes are not always easily reversible at the source of alteration. Mitigating or reducing land use impacts usually requires pro-active, long-term planning and sometimes substantial limitations on human activities within the watershed.

Protecting natural and anthropomorphic resources through water resources planning requires a broad based approach, including using the presence of dams in a system as a unique tool to mitigate impacts to instream flow resources (via flow regulation) while sustaining human use of resources. One way to protect river resources is by adapting regulated and altered flow regimes to mimic patterns like those of an un-impacted watershed condition. Dams can play an important role in adapting flow regimes to protect and conserve river ecosystem resources.

The following narratives describe the processes and proposed activities to be accomplished for the PIFS phase that, in conjunction with the WMP, will enable NHDES to adopt rules for protected instream flows on the Souhegan River. These actions follow the basic strategy of first conducting studies to develop PISF standards that protect IPUOCR entities, and then planning water management strategies that will maintain those standards.

1. Identification and Draft List of IPUOCR Entities

The primary objective of this task is to establish a comprehensive baseline of flow dependent IPUOCR entities for the designated reach of the Souhegan River. Based on their seasonal flow requirements, these entities will serve as basis for designating protected instream flows. The IPUOCR to be evaluated and the preliminary list of entities for the Souhegan River that have already been defined by the Department in RFP Appendices A and B will provide a starting point for completing this task. Accordingly, the main focus for this work will be to evaluate the information in RFP Appendices A and B for appropriateness and to refine and augment it for the designated reach. This will be accomplished by means of a comprehensive review of existing available data and information and by interviewing knowledgeable authorities, organizations, and individuals. Such information will include but not be limited to designated river nomination reports, river corridor management plans, natural resources studies, natural heritage inventories and environmental assessments and impact statements.

There presently exists a variety of reports for the Souhegan River including a nomination report, watershed study, river corridor study and a water monitoring report. Other available information includes NRCS soil maps, National Wetland Inventory maps, geologic resource maps, and aerial photos. Many of these sources are available on the UNH GRANIT database as GIS layers. Agencies and organizations to be interviewed will include groups such as the Souhegan Technical Review Committee and Water Management Area Advisory Committee members, New Hampshire Natural Heritage, Nashua Regional Planning Commission, Souhegan River Watershed Association, New Hampshire Fish and Game, and the relevant conservation commissions.

The reviews of available information and interviews will be structured so as to develop the information base necessary to prepare a list of IPUOCR entities for the designated reach and to annotate each entity on the basis of river location and dependence on flow conditions. This list will be confirmed to the extent possible and supplemented, if necessary, through the field survey to be conducted under Task III. The list and supporting information will be refined following review and comment by the advisory committee and general public and presented in a draft IPUOCR report. Ultimately, for each IPOUCR, there will be a database of primary contact information and contact person(s), contact information, and descriptions of relevance to the PIFS.

We will review local fisheries data bases and interview local and regional fisheries biologists in order to establish a list of native fish species representative to the Souhegan River. Depending on the quality of available data, we will develop a Resident Target Fish Community as described by Bain and Meixler (2000). For migratory species and specific life stages of resident fauna, we will determine biological periods when they are particularly dependent on appropriate flows. Consequently we will divide the year into seasons designating the most vulnerable "users" (species or life stages) for each period. We will use existing habitat data base and literature to establish habitat selection criteria for each of these species.

2. Assessment of Well Withdrawal Impacts on Surface Water

Ground water supply wells in proximity to surface water bodies can often draw water directly from the surface water body into the well. This is known as induced infiltration or induced recharge. This constitutes a direct withdrawal from surface water that is masked as a withdrawal from an aquifer. In these scenarios, simple analytical techniques exist to estimate the fraction of water from the aquifer versus surface water. Some of these techniques are available in public domain computer models (WHPA and WhaEM, both supported by the US EPA). In order to use such models, some basic information about the well (construction specifications, pump, pumping rate, pumping schedule), the formation (transmissivity, saturated thickness, porosity, storage parameter, gradient) and the surface water (distance to well, depth, volume, flowrate) are necessary. There are also field techniques for estimating the fraction of surface water drawn into the well. These methods include fingerprinting water sources (using dissolved water chemistry, for example), pumping tests, and field monitoring of water levels and flows (for example a dilution study of the river to measure river flow with distance). A very inexpensive field technique is to use miniature piezometers (1/4-inch ID plastic wells) at the banks of the surface water body near the pumping well. The miniature piezometers clearly delineate the footprint of where surface water is drawn into the aquifer. Interpretation of the miniature piezometer data quantifies the amount of water drawn into the well.

The first step in the performance of this task is to investigate which of the subject wells (delineated in the RFP) have previously had a well head delineation study performed. It is quite likely that these well head studies have addressed this topic, for example see the well head protection report for the Pembroke, NH well by the Soucook River.

Next, in the cases of wells without a well head protection study, the USGS maps and studies of the New Hampshire stratified drift aquifers will be used to obtain the necessary information to use in an analytical model to estimate the fraction of surface water pumped by the wells. For two or three of these wells, in cooperation with the well owners and riparian landowners, miniature piezometers will be installed along the Souhegan River, and field measurements will be taken to validate the estimates from the analytical models. The detailed methodology employed here will be written into a guidance manual in the event that this method is to be employed in the future at other locations or in the event the method is to be employed in verification efforts.

If no well head protection study and no USGS data are available for the subject wells, static and dynamic well water levels will be measured. Aquifer hydraulic characteristics will be estimated for the sites, and analytical models again will be employed to estimate the amount of surface water pumped by each well. For two or three of these wells, in cooperation with the well owners and riparian landowners, miniature piezometers will be installed at the Souhegan River, and field measurements will be taken to validate the estimates from the analytical models. The detailed methodology employed here will be written into a guidance manual in the event that this method is to be employed in the future at other locations.

The sites that are selected for field techniques will be preferentially those that appear to be in the more critical areas regarding instream flow needs.

The result of this task will be an estimate of the amount of induced Souhegan river infiltration by ground water wells within 500 feet of the river, as designated in the RFP.

3. On-Stream Survey for IPUOCR Entities

An on-stream survey will be conducted to verify the existence and occurrence of the IPUOCR entities identified in Task 1. This will be completed through a three day field survey of the designated reach with stops at specific locations to document the presence of each entity or the presence of conditions or habitat suitable for each entity. A pre-screening of likely locations will be conducted prior to the field survey. The first step in this process will divide the designated reach into segments. Data sources such as Landsat, GRANIT, and stereo pairs of aerial photos will be reviewed for their utility in identifying IPUOCR locations; any entities located by those sources will be placed on GIS maps of the designated area reach segments. Stakeholders will be invited and encouraged to participate in the planning for this survey and, if circumstances allow, participate in the survey. Two groups that will be very important to involve will be white-water enthusiasts and anglers, among others.

After known and potential IPUOCR entities have been mapped, representative locations of each entity will be selected for a detailed on-stream survey. The selection of sampling locations will prioritize the known occurrences to the extent they have been documented. Each proposed sampling location will be referenced with GPS coordinates on the map to insure efficiency in the field. Prior to the survey a Standard Operating Procedure (SOP) for conducting the survey will be prepared. This SOP will address the survey methods and schedule for the full range of IPUOCR entities developed in Task 1, and may include fisheries surveys, recreation surveys,

rare plant surveys, spawning habitat evaluations, etc. Both the sampling locations and the SOP will be presented to DES (the Department) for review and finalized to incorporate comments. The Department's Photo Documentation Procedure will be followed in taking photos to document IPUOCR entities. Notes will be taken at each location that will include pertinent information to describe each entity and its condition. We believe that participation of representatives of the local watershed groups, stakeholders and the DES during the field survey will be critical to the success of the effort. This effort will be conducted as soon as possible after contract award and is anticipated to be primarily a float trip with stops at critical points. Depending on river flows, the float trip may need to be augmented with some walking or vehicle access surveys.

We will employ a state-of-the-art laser-based field delineation system during the field survey. This system allows the operator to delineate habitats and important features within a line of sight from a boat, canoe, or vehicle with the laser. The system is integrated with a Trimble differential GPS system so the coordinates of all features pointed at by the laser and selected, are recorded. The end result is either point or polygon data that is immediately available as a GIS data layer. The advantages of this method are the speed and accuracy at which the resources can be mapped and the reduction in time spent digitizing and post-processing field data. Using this technique, Normandeau field crews successfully mapped aquatic habitat within a 15-foot drawdown zone along 370 miles of shoreline in three weeks. On the Souhegan, it is estimated that the field crew can cover 10-15 miles of river per day. Electronic data will be checked and backed-up daily during data collection phases. Field notes will be taken in waterproof field notebooks. Photocopies of field notebooks will be made monthly, and copies catalogued and maintained in files.

Throughout this process, coordination will occur with the Department and with the advisory committees. Photo documentation together with supporting text will be presented for each representative IPUOCR entity visited in the field. The IPUOCR report will be centered on an IPUOCR matrix. Potential categories in the matrix will include but not be limited to: the resource, the reason for inclusion, the local, regional and national importance of the resource, the flow requirement of the resource including seasonality and duration, the specific location of the resource in the study area and representative photos of the resource. The specific locations of resources that are rare, threatened, or endangered will be kept confidential; the Department and/or the advisory committee will make the ultimate decision on whether or not to publish these locations. The matrix of IPUOCR entities and accompanying report provides the organized, essential information to assist screening candidate methods for the determination of protected instream flow.

Prior to the survey we will prepare digital data entry forms that will include all information on IPUOCRs gathered in the Task 1 and habitat attributes expected to have importance for fish. The survey will be conducted from canoe (or kayaks) in June 2004.

During the survey we will also record fish habitat and hydro-morphological patterns at the reach scale. This will include the frequency of hydro-morphological units, density of fish cover, channel form as well as intensity and character of habitat alteration caused by other IPUOCRs. The aerial photographs and GIS layers encompassing data on existing IPUOCRs will be

uploaded into handheld computers equipped with Global Positioning System (GPS). The GIS coverages will allow verifying and updating the information on IPUOCR entities. Fish habitat characteristics will be entered into the digital data entry forms each time the physical character of the segment changes significantly, and the location of the changes will be geo-referenced on the aerial photographs.

After the survey, the data will be transferred into a GIS model and used to divide the river into uniform habitat reaches by generalizing obtained habitat information and superimposing it over other IPUOCRs. The reaches will be further grouped into reach types, and for each reach type we will select representative sites to be surveyed in more detail during PISF assessment phase.

4. Report Describing IPUOCR Entities and Proposed PISF Methods

This task requires that IPUOCR entities be identified and results of field verification be documented in the form of an initial report that, among other things, locates those entities geographically. Some uses and characteristics in need of protection may apply to the whole system, such that operationalizing their needs (that is, identifying what they are and how they can be attained) becomes a focus of investigation that is less dependent on location, other than accounting for natural spatial variation in flow across the drainage network. Otherwise, geographic differentiation of PISF recommendations can be seen as an added component of any study that addresses the needs of IPUOCR entities having well-defined spatial attributes (that is, they relate to specific locations or stream reaches). The IPUOCR assessment thus defines the context and requirements for methods that will quantify attributes of the River's flow regime needed to protect those entities.

It is clear from the diversity of potential IPUOCR entities listed in Attachment V of the RFP that no single evaluation method is adequate to address all the questions that must be answered in order to arrive at defensible PISF recommendations. Indeed, the realization of this problem by DES is evident in the structure of the RFP, in that the report addressed by this task is intended to document the process by which assessment methods are proposed. Therefore, because specific IPUOCR entities (and initial evaluation of their flow needs) have yet to be identified, a firm commitment to any one method or set of methods at the proposal stage is premature. Methods should be viewed as tools for assessing instream flow needs; what is most important at this stage is the adoption of a sound conceptual framework to guide not only the selection of appropriate methods, but also to provide a basis for asking relevant questions, interpreting results, and developing recommendations.

Early efforts to protect instream flow values arose primarily in the context of water-use allocation in western streams, many of which were already over-appropriated (i.e., demand often exceeded supply). As a result, early stream flow protection measures focused on the *minimum* flow that allowed for *maximum* use while preserving some (often only one or a few) critical aspect(s) of the stream system deemed necessary for survival of aquatic biota (often judged by relationships between flow, water temperature, and indices of suitable habitat for a few "indicator" species or species of management interest). Advances in understanding of relationships between stream flow and the biophysical structure and function of lotic systems led to the realization that stream system integrity depends on more than just the maintenance of a

single, persistent low minimum flow. The "natural flow paradigm" (Poff et al. 1997) has emerged as a widely accepted framework for describing the roles played by stream flow in shaping ecological characteristics of streams and understanding the consequences of modifications to natural stream flow patterns by human activity.

The natural flow paradigm (NFP) recognizes the importance of considering stream flow in terms of a *regime*, that is, a dynamic quantity that naturally varies over time in response to changes in many driving variables (precipitation, runoff, groundwater interactions, and evapotranspiration, to name a few) that occur over a broad range of spatial and temporal scales. Flow regimes can be described in terms of five general attributes that characterize temporal patterns and invoke conceptual linkages to other ecological variables. These include flow *magnitude* (which is used to distinguish between low, normal, and high flow conditions), the *timing* of high and low flow events (the predictability of which may select for or against various life history characteristics of resident biota), their *frequency* and *duration* (which interact to define disturbance intensity), and the *rate of change* in flow conditions (which interacts with organism mobility and availability of refuge from intolerable physical conditions to further characterize the intensity and consequences of disturbance).

We propose to adopt the NFP as an organizing framework for developing PISF recommendations for the Souhegan River. Note that the NFP is not a "method" in and of itself. Rather, it is an over-arching philosophy that will be used to assess and prioritize efforts to understand the instream flow needs of various IPUOCR entities and devise or select among methods needed to answer questions raised by that understanding when placed in a water management framework. For example, a "piece of the puzzle" that must be determined initially is to characterize the existing Souhegan River flow regime and estimate to what extent it may already deviate from "natural" conditions. Statistical tools such as the Indicators of Hydrologic Alteration (Richter et al. 1996) and related indices like those used by Poff and Ward (1989) can be used to characterize patterns of stream flow variation across temporal scales. Due to geographic variation in IPUOCR entities and existing water use patterns, methods will likely be needed to estimate stream flow records for un-gauged locations of interest in the watershed (see Richter et al. 1998). There could well be a need to compare flow regime attributes to those of a nearby reference stream, or between two time periods that bracket a significant change in water use within the basin. Consequences of such deviations, or of projected future water use scenarios, would then be evaluated with other methods specific to the nature of each IPUOCR entity, which could be grouped into classes, reducing the number of methods ultimately required to address all pertinent issues (examples of such methods are given later in this section).

It is important to recognize that adoption of the NFP as a conceptual framework does not mean that PISF studies will automatically result in recommendations to restore a "pristine" hydrograph to the Souhegan River. For one thing, total restoration of an unaltered hydrograph allows for no water usage at all, and is generally technically impossible (due to human-induced changes in watershed characteristics) and socially infeasible (due to human demands on flowing water resources). The challenge is in devising water management strategies (including PISF levels) that effectively balance human needs for water with those of the natural systems which provide the water and other forms of "natural capital".

Adding to this problem is the fact that the flow needs required to support multiple IPUOCR entities very often will conflict, raising issues of fairness and inter-generational equity among present and future stakeholders. Noting that the draft list of IPUOCR "types" in Appendix V of the RFP includes a mix of both anthropocentric (human-oriented) and "natural" uses to be protected, the NFP leads one to conclude that the latter are best served by an unaltered flow regime, inasmuch as the natural hydrology is a major component of the habitat template within which native biota evolved, often mediated through effects of stream flow on channel geometry, habitat diversity, and the timing and intensity of disturbance from droughts and floods. On the other hand, human demands on water resources are often continuous or display spatiotemporal patterns that do not correspond to the "natural delivery schedule".

Thus, from a water management perspective, it is important to ask, "How far can flow regime deviate from natural pattern before a system degrades?" To answer this question, assessment methods must use appropriate indicator variables that link flow regime alteration to changes in the biophysical properties of stream systems and their watersheds. Although it is unlikely that evaluation methods for this study will incorporate direct study of systems other than the Souhegan, comparative information is likely available from watershed assessments for other New England rivers, instream flow studies, and ecological profiles associated with hydropower projects, and monitoring reports associated with other water resource development projects. Such analogs would contribute to the credibility of PISF recommendations by providing much-needed perspectives from which to judge the consequences of departures from natural flow patterns in the Souhegan River.

Even if much redundancy exists in the flow needs among IPUOCR entities, the set of issues to be considered remains diverse enough that no single methodology is likely to address all relevant questions. However, the IPUOCR entities can broadly be divided into those having natural or anthropocentric origins, and then further into sub-sets. Natural use categories for the Souhegan River have been identified by DES and include wildlife, conservation, maintenance, and enhancement of aquatic and fish life, fish and wildlife habitat, and aquatic life and wildlife uses designated under the federal Clean Water Act. Natural outstanding characteristics and resources requiring protection are categorized as wildlife, natural, hydrological, geological, environmental, and ecological. Some IPUOCR entities, including fishing, fisheries, protection of water quality and public health, pollution abatement, aesthetic beauty, scenic resources, scientific resources, and consumption of fish and shellfish, are defined in ways that blur the distinction between natural and anthropocentric uses. In fact the flow needed may vary broadly across IPUOCR categories. Finally, IPUOCR definitions for navigation, recreation and recreational resources, water storage, cultural and archaeological resources, significance of community resources, agriculture, and hydroelectric energy production are clearly anthropocentric. Natural and anthropocentric resources can vary widely with respect to their dependence on the natural flow regime. However, such dependence, as well as the impact of deviations, will often be similar among sub-sets, suggesting that methodological approaches for one entity will usually be applicable or contribute to understanding of the flows needed to protect several.

Furthermore, all flow assessment tools have assumptions and limitations, and variation in their application costs must be evaluated against finite budget and time constraints. Some tools, such as models of system hydrology and statistical analyses of flow regime attributes, are common to

more than one "methodology". The IPUOCR and methods evaluation report will identify such interrelationships and account for them when selecting particular approaches to address the various instream flow needs of specific entities.

Nevertheless, as all IPUOCRs are related to the same entity, a running water ecosystem that evolved over thousands of years of adaptation and evolution, which needs to be left functional and integer to sustainably support all IPUOCR. Even if short term economic benefits could create the appearance of some IPUOCR having contrary objectives (e.g. fisheries vs. water withdrawals), in the long run, maintenance of a self-sustaining, balanced system extends the longevity of all uses and is in mutual interest of the entire society. Therefore, application of the PISF setting approach that balances anthropocentric water uses against maintenance of ecological integrity, as a measure of ecosystem sustainability, should address the objectives of the majority of uses and users.

Because analyzing all components of the aquatic ecosystem would be an enormous and overwhelming task, we propose to focus on resident fish as a primary indicator of ecological integrity.

A report by the American Institute of Hydrology (see Dunbar, M.J., et. al., 1998) identified three types of methods applied world-wide for purpose of PISF setting.

"Look up" or standard-setting techniques, based upon simple hydrological indices such as percentage of the natural mean flow or an exceedance percentile on a natural flow duration curve are the most commonly applied. They generally aim to determine some sort of minimum ecological discharge, sometimes with seasonal considerations, sometimes with other thresholds (desirable, optimum). "Such methods require considerable resources to set up initially; but once developed require a relatively low level of resources per site. These standards can play an important monitoring and strategic role and provide interim objectives, where further investigation is justified. Good examples of look-up techniques include the Tennant and Texas methods, and the Basque method."

The other set of methods is called "Discussion-based approaches and hydrological analysis**".** These methods use "structured consideration of expert opinion". "The methods are able to consider broad ecological functioning, plus species requirements at an intermediate level of detail. They may include elements such as hydraulic modeling, but the key assessment is undertaken at an expert panel workshop. This would be of particular use for setting more specific interim flow objectives, especially in the absence of clear species-related management targets, and ensuring effective targeting of further study."

The third category is "Biological response modeling", that refers to the Instream Flow Incremental Methodology (IFIM), and variations. "This type of approach is considered to be the most resource-intensive and defensible. Some countries have incorporated elements of the holistic approaches into their IFIM-equivalent framework, another common approach is to incorporate multivariate classification of river sector types and their biotic communities."

The IFIM uses habitat simulation models as a basis for an integrative decision making process. It is frequently misunderstood and falsely set equivalent with the Physical Habitat Simulation model (PHABSIM), which was the first modeling technique used for IFIM. The last twenty years have involved the application and further improvement of such models, along with heated discussion as to their validity (for a review see Gore and Nestler, 1988). Since the elaboration of the original PHABSIM habitat modeling software (Bovee, 1982) there have been a number of important developments (see Parasiewicz and Dunbar, 2001).

Physical habitat models quantitatively describe the functional relationship between the physical environment and aquatic fauna. These models are based on the observation that aquatic biota respond to physical habitat patterns within a stream (Wright et al., 1993). Spatial distributions of physical attributes (e.g., depth or velocity) in combination with observation of biological response to their patterns provide the basis for a predictive analysis of the consequences of ecosystem alteration (Milner et al., 1985; Stalnaker, 1995).

PHABSIM and other related techniques use high precision measurements of physical conditions to predict flow-based alteration of habitat, together with habitat suitability data for fish. The underlying approach of PHABSIM is to describe these changes with a deterministic hydraulic model as described above. Originally, one-dimensional hydrodynamic models provided the basis for habitat analysis. Implementation of two-dimensional models (along and across a river) for hydraulic description of physical habitat is currently under intensive evaluation. It has become a standard procedure in modeling systems such as RSS from Norway (Alfredsen, et al, 1997) and HABIOSIM (Lafleur and Leclerc, 1997) from Canada. Furthermore, it is expected that the new version of the standard PHABSIM model will include 2-D hydraulics.

The biological component of the PHABSIM model builds upon univariate response functions that individually consider the suitability of each hydraulic (depth, velocity) and geomorphological attributes. Subsequently, *a priori* selected algorithms (e.g., average) are applied to create composite suitability. In recent years, multivariate approaches, most notably logistic regression, have been developed that better take into account the interactive nature of habitat descriptors (Parasiewicz and Schmutz, 1999, Guay et al, 2000). A recent comparative study conducted on the Quinebaug River demonstrated substantial discrepancies between the results of multivariate and univariate models (Parasiewicz and Goettel, 2003).

PHABSIM was originally designed for applications related to individual water use facilities. It was not intended to be used as a standard settings tool for entire rivers and watersheds. Attempts to apply the technique as a broad, planning tool have generated criticism (Williams, 1996) because of violation of the principle of scale. Application of precision measurements on only a few selected locations (i.e. cross-sections) and drawing conclusions at the river or watershed scale generates large extrapolation errors stripping the technique of its defensibility.

MesoHABSIM (Parasiewicz, 2001) is an improvement of PHABSIM developed in response to these concerns and to address needs of community based, systems scale, integrative assessment of ecological status.

MesoHABSIM (Parasiewicz, 2001) is a recently developed habitat modeling technique in the northeastern United States which addresses the requirements of a watershed management of running waters. MesoHABSIM modifies the data acquisition technique and analytical approach of earlier efforts by changing the scale of resolution from micro- to meso-scales. Mesohabitats are described by hydro-morphological units (e.g., riffles, pools and runs) as well as associated hydrologic and cover characteristics. When applying the MesoHABSIM survey approach, mesohabitats are mapped at different flows along extensive sections of a river. The suitability of each mesohabitat for a target fish community is assessed using fishing surveys. These survey data are subsequently analyzed using multivariate statistics. The variation in cumulative area of suitable habitat is a measure of environmental quality associated with alterations in flow and channel structure.

The physical habitat analysis is only one, but an important element, applied in the IFIM framework. It provides quantitative values of habitat availability at various flow conditions creating a base for negotiations and alternatives analysis. Many studies make it a part of a broader integrative approach that also incorporates biological and chemical status assessment as well as temperature monitoring/modeling as additional decision support factors and components of habitat evaluation. Those are very important as modifications

In this report we will describe fish species that use the instream habitat of the Souhegan River and describe their habitat needs, life cycle, and seasons of particular dependence on adequate flows. For each season, we will also propose the indicator species to guide prescribed instream flows. In addition, the report will describe the outstanding morphological characteristics of the river corridor, instream public water uses, identified reaches, and reach types in Designated Segments.

Based on the review of instream flow assessment methods we will identify the detail of methods selected for each reach type. To assure the highest confidence level, the selection of methods will be driven by the value of instream flows for the native fish fauna. In river areas of high river habitat value (e.g. free flowing portions) the preference will be given to application of a quantitative habitat simulation model, such as MesoHABSIM. In areas such as impoundments or other artificial water bodies other quantitative, but non-modeling, analysis will be recommended.

5. PISF Assessments and Proposed PISF Report

Selection of models

Our approach is to develop criteria for a flow regime that protects aquatic and riparian life while balancing those needs with public and private water uses. Methods for accomplishing this task are numerous and vary greatly in their appropriateness to specific situations, as reviewed by the Eco-hydrological data base of the International Water Management Institute[1] and the Instream Flow Council. Intensive analysis of techniques leads to the conclusion that physical habitat simulations provide the most desirable results and have the greatest potential for broad

[1] Environmental flow assessment for aquatic ecosystems: a database of methodologies. http://www.lk.iwmi.org/ehdb/WetLand/index.asp

application. The diversity of approaches can be clustered into a few groups based on the required effort, resolution (scale), and accuracy of the results. One possible grouping of common instream flow methods is presented in Figure 2.

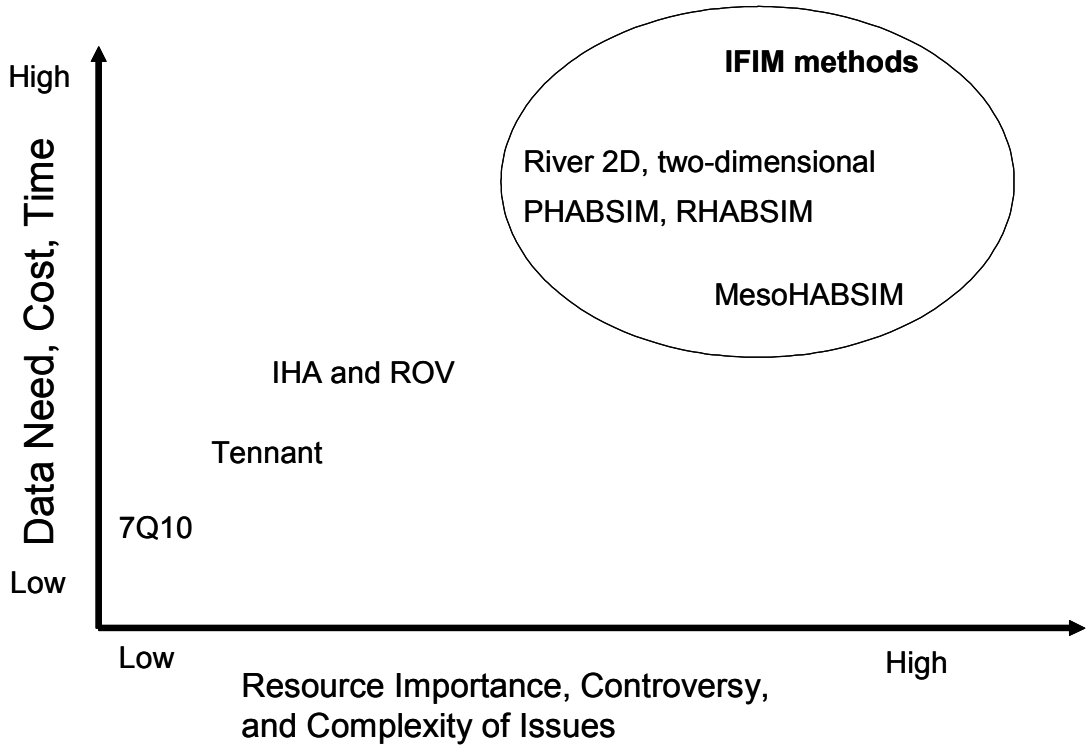


Figure 2. Example of qualitative comparison of Instream Flow Methods. The names represent the clusters of similar approaches.

The most common approach for establishing instream flow levels has been physical habitat modeling using PHABSIM techniques and software, or analogous procedures (e.g., RHABSIM or EVHA). Physical habitat models link a small number of hydraulic (depth, velocity) and habitat variables (cover, substrate) to models of suitability for target biota (habitat suitability criteria) and are useful for establishing criteria when a specific site or sites have high importance to an IPUOCR. However, these techniques are limited in their resolution and applicability when extrapolated to many river miles.

Over the last four years Dr. Parasiewicz has been developing a new physical habitat model with special emphasis on its application by state resource agencies which typically are responsible for establishing instream flow criteria. The result of this effort is an assessment framework called MesoHABSIM which improves the concept of habitat modeling by addressing the requirements for watershed management of running waters.

MesoHABSIM modifies the data acquisition technique and analytical approach of earlier efforts by changing the scale of resolution from micro- to meso- scales, providing a mechanism that allows the assessment of habitat changes at the watershed scale. When applying the

MesoHABSIM survey approach, mesohabitats (e.g. riffles, runs, and pools) are mapped at different flows along many miles of a river. The suitability of each mesohabitat for a target fish community is assessed using field surveys, and field data are subsequently analyzed using multivariate statistics. The variation in cumulative area of suitable habitat is a measure of environmental quality associated with alterations in flow and channel structure (Figure 3).

Our team has broad experience applying the traditional suite of site-specific microhabitat models as well as the strength of watershed-level MesoHABSIM studies. We will use tools appropriate for developing PISF solutions as determined by the value of the resource in comparison with funding constraints. The selection of an appropriate model will depend on the relative value for establishing PISF for any given IPUOCR. Adjustments in the use of available resources can be made within each evaluation method by various strategies, such as limiting the number of transects, using representative sites, and using existing data and literature-based models.

Because of our experience working in the Northeast, we already have a well-developed habitat database on adult and early life stages of resident native fish for regional river systems (Quinebaug River, Mill River, Fort River, Manhan River, Pomperaug River, Fenton River, Stony Clove Creek, etc.) collected from instream surveys; this database will provide a basis for determining fish-habitat relationships. For species which are not included in our data base, we will develop habitat selection criteria using literature values, e.g. Parasiewicz and Goettel (2004).

Because free flowing river segments provide higher quality habitat for river species, we believe our primary method, essential for addressing free flowing river segments, will be MesoHABSIM. This method can be applied for a wide range of known IPUOCRs, including fish, mussels, and other aquatic invertebrates. This approach would include an instream community survey (typically fish) to verify data from our habitat database and be combined with mesohabitat mapping for three or four study flows as the primary approach to describing the resource. Several representative sites will be used, covering approximately 5 miles of river in each site. Results are integrated into a GIS database and time series analysis, including frequency, seasonality, duration, and magnitude, are used to produce maps of suitable habitat for applicable IPUOCRs (Figure 3).

For IPUOCR resources with site-specific requirements, detailed methods such as physical habitat modeling with PHABSIM software, River 2D software (two dimensional) modeling, or other methods can be incorporated based on available resources. PHABSIM methods use transect based representation of microhabitat areas and changes at transects are extrapolated to the site they represent. PHABSIM methods require stage-discharge relationships at one or more transects (measurements from at least three flows), habitat measurements along transects, and fish habitat criteria. River 2D involves two-dimensional topographic modeling of instream areas. Combined with multivariate fish habitat criteria it can generate detailed maps of suitable habitat for a site.

Development of PISF recommendations

Using habitat rating curves developed from any method, in conjunction with flow time series for each river segment or IPUOCR site, we will create a time series of baseline habitat conditions

which will be analyzed for flow levels critical to the protected use. We will apply continuous under threshold habitat duration curves (CUT-curves) using the technique described by Capra et al. (1995). The process is illustrated in Figure 4. Using this method we identify four habitat levels that correspond with different protection thresholds. These levels divide the flow regime characteristics along a gradient of potential impact and are named *absolute minimum, trigger, critical, and typical*.

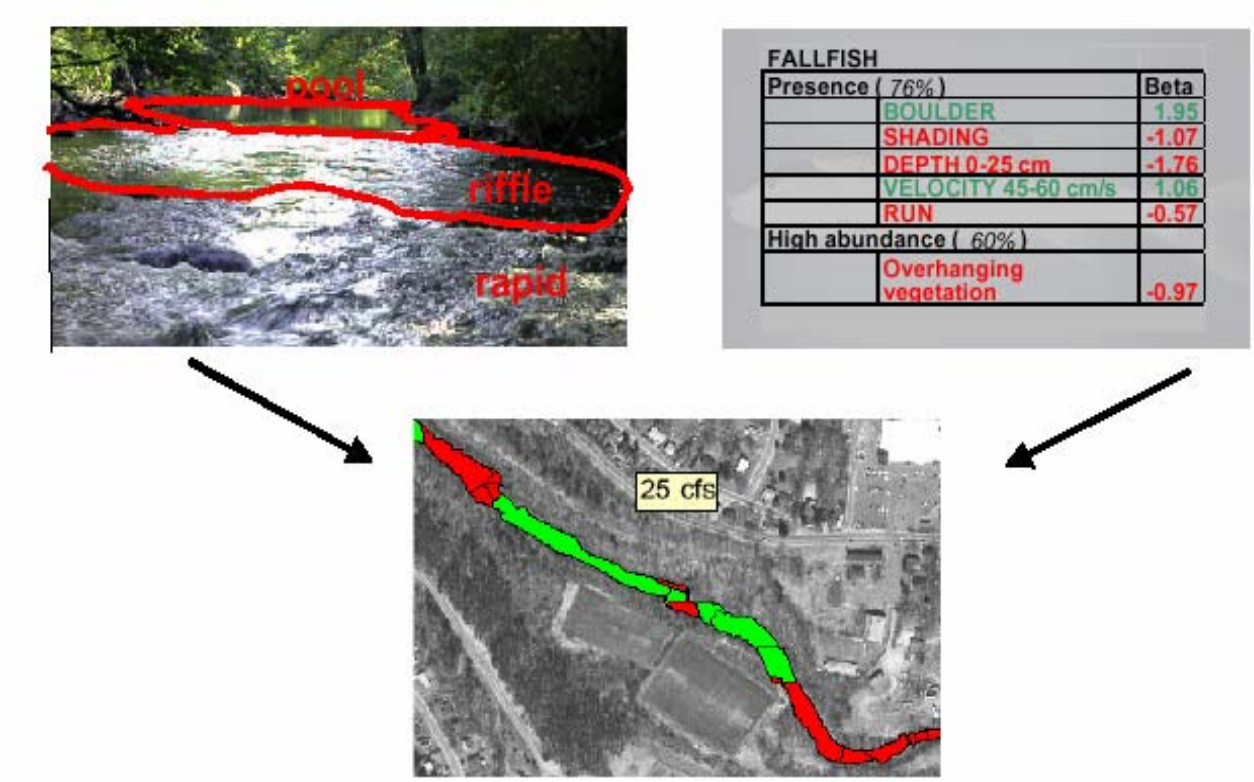


Figure 3. The habitat survey delineates hydromorphologic units and their physical attributes (top left). The fish survey identifies key habitat attributes affecting fish (top right). The model calculates the probability of fish presence in each habitat and delineates areas of suitable and unsuitable habitat.

The result will be recommendations for seasonal habitat regimes consisting of allowable habitat quantity together with duration and frequencies of flow events with habitat under specific thresholds. In addition, the amount of water necessary to fulfill the above criteria will be defined for every season. Eventually we will develop a concept for the application of these criteria by introducing dynamic flow management rules. This will include flows that trigger protective actions, allowable durations of these flows, together with duration and magnitude of protective flow pulses.

Simulation of habitat improvements

Results of assessment methods will be integrated into a GIS model that can be used to test alternative management scenarios. Based on known habitat needs of aquatic species,

geomorphological settings, and historical information, we can simulate river channel improvements due to flow or other habitat manipulations (e.g. bank stabilization, or connecting side arms). This will create a limited synthetic model of the base-line habitat conditions and when coupled with hydrologic data, identify flow related habitat fluctuations. The GIS model allows for improved visualization and computation of flow-habitat relationships at various scales, which will be of value when assessing the habitat needs of resident fauna and devising flow rules that are protective of instream needs.

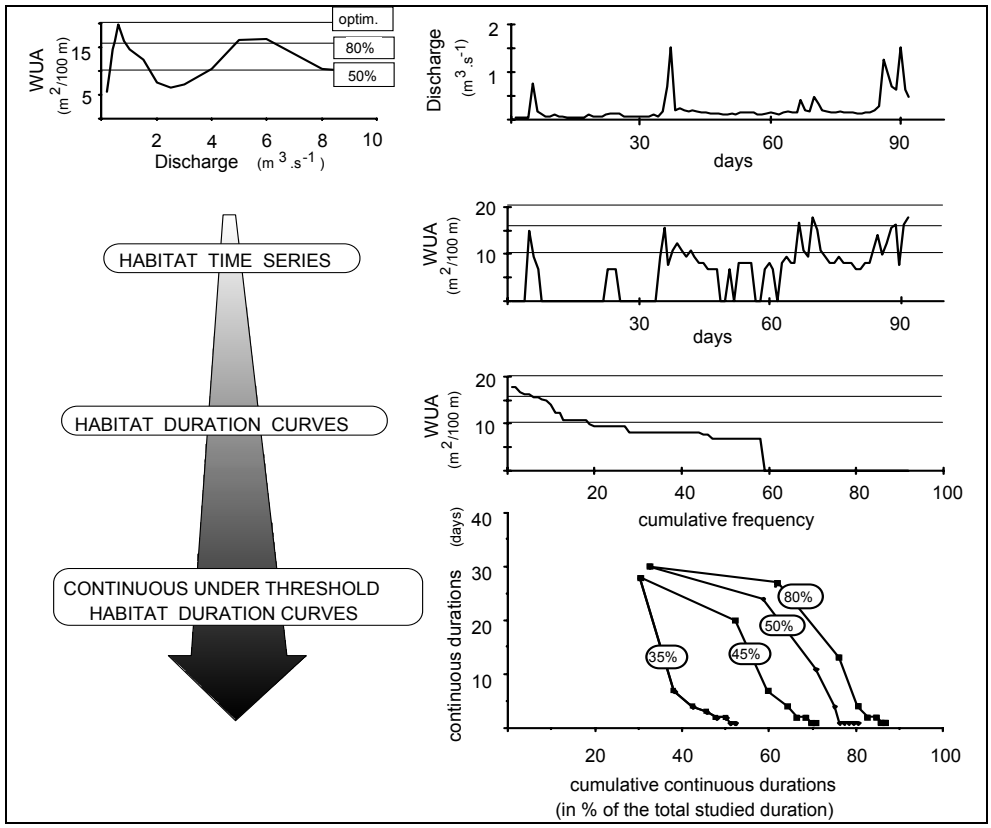


Figure 4. CUT curves from habitat time series (source: Capra et al., 1995)

In subsequent steps we will list river channel improvement opportunities by identifying areas where such measures could be more easily applied than on private property (e.g. public parks). The potential of these measures can be analyzed by simulation of the gain in fish habitat. This step will assist in the evaluation of potential water management vs. restoration trade-off options in the water management plan. The water management plan will build upon simulation results and determine how water can be allocated in order to satisfy the above flow recommendations.

The report describing this phase will consist of the description of completed work, and conclusions with regard to PISF. It will be organized into following sections:

- Locations and the protection goals for IPUOCR entities,
- Description of PISF methods chosen to meet these goals,
- PISF results and their scientific basis:
    - Proposed PISFs will refer to the individual reaches and the study area as a whole.

    - Detailed habitat maps for all surveyed sites and all analyzed species
    - Results of habitat simulation.
    - Matrix of methods, sites, and prevailing criteria
- Discussion of how the proposed PISF values meet the criteria in RSA 483:1 and 483:2 and water quality standards
- Description of the factors for reviewing the PISF found under Env-Ws 1905.03(b) and the results of PUC's assessment.
- Preliminary determination of DR reaches

In the report we will also determine aggregate water use versus stream flow on a daily basis using the draft proposed PISF and the aggregate water use versus stream flow assessment as requested in RFP. We will present the draft proposed PISF values before the advisory committees for review and comment. After the consultation we will revise the report.

6. PISF Public Hearing

The project team will support NHDES in the preparation for and the presentation of the proposed PISF in a public hearing as specified in the RFP. This will include delivery of a draft report 30 days prior to the meeting and the preparation of presentation materials based on the draft report. Team members will be present at the public hearing to present the proposed PISF as well as to answer questions. A copy of all presentation materials will be submitted to the NHDES prior to the meeting and will be available for posting to the DES instream flow website after the meeting. The public comments will be addressed and potentially could alter the PISF recommendations due to consideration of factors not included in the draft assessment.

7. PISF Report for the Souhegan River

Following the comment period, we will revise the Proposed PISF report, in consultation with the Department, based on the comments received. We will prepare the final PISF Report from the Proposed PISF report with the addition of a section describing how the comments affected the final PISF values [Env-Ws 1905.04 (b)(5-6)].

8. Assessment of Water Use with the Established PISF

There are several areas in which multi-criteria decision analysis (MCDA) could inform the project. The first of these is in assessing conflicts between different IPUOCR needs. It may be naïve to assume that all the instream flow needs can be met simultaneously when the demands are so varied. For example, it may be necessary to balance withdrawal needs with rate of change needs (e.g., if certain species depend upon seasonal cycles such as a spring flush). MCDA can help decision-makers understand how to assess different management strategies when IPUOCR needs must be prioritized. When combined with a stakeholder value elicitation process such as used in the Cocheco River contaminated sediments study, MCDA can help establish a set of intercriteria weightings that represent the preferred prioritization schemes of different instream stakeholder groups. A partially or non- compensatory goal-aspiration method may be appropriate for most instances that call for meeting a PISF specification (such as a minimum or maximum), but places no additional value on exceeding the PISF standard. (Partially

compensatory means that overperformance on one criterion might partially compensate for underperformance in another, whereas non-compensatory methods do not recognize any value in overperformance).

Secondly, MCDA could be applied at the level of the Water Use Plan. The Conservation and Dam Management Plans identify the *alternatives* (or decision variables), whereas the Water Use Plan identifies the *merit* or criteria by which all the alternatives may be judged. Lastly, the Water Management Plan could take the form of a set of operating recommendations for different hydrologic conditions such as plentiful flows, normal flows, or drought. MCDA is directly applicable at the level of the Water Use Plan. A mixed partially compensatory goal aspiration and utility maximization framework may be applicable. In the case of the AWUs and ADOs, utility maximization (of economic benefits) is most applicable. However, the *distribution* of benefits (and costs) may not be perceived as being fairly appropriated in a simple total utility maximization scheme. If some stakeholders are perceived to be disproportionately impacted, a partially compensatory or constrained compensatory utility maximization model may be most appropriate. On the other hand, the nature of the IPUOCR criteria are fundamentally different from the AWU and ADO criteria, and exceedances in IPUOCR criteria are unlikely to be tolerated by negatively impacted AWU or ADO users. Therefore, only partially or non-compensatory models interaction between IPUOCR and the AWU / ADO criteria and should be considered.

9. Development of WMP Sub Plans

The water management sub-plans have been defined to describe: supply, demand, and management. Since none evolves in a vacuum, they are synthesized into the overall strategy to meet the needs of users and instream flow. It should be recognized that supply, demand, and system operation can work in concert to satisfy competing objectives. However when a system is oversubscribed (excessive demands) or undersupplied (extreme low river flow) or possesses insufficient storage, all needs cannot be met simultaneously. Moreover, the competing objectives or perspectives of different stakeholders groups make it likely that no single "best" alternative is likely to emerge that will satisfy all stakeholders. Therefore, the basic approach to analysis must accommodate multiple decision criteria, perspectives, and a variety of quantitative and qualitative scales. This study proposes to employ multi-criteria decision analysis (MCDA), which has been used successfully in previous watershed management problems in North America and Europe (e.g., Borsuk, et al., 2001; , Gregory and Failing 2002; and, McDaniels, et al., 1999). Several software packages, such as *Decision Lab* (Visual Decision 2000), are available to both speed calculations and clearly present results.

MCDA can help decision-makers understand how to assess different management strategies when IPUOCR needs must be prioritized. When combined with a stakeholder value elicitation process such as used in the Cocheco River contaminated sediments study (Rogers, Seager, and Gardner, 2004), MCDA can help establish a set of intercriteria weightings that represent the preferred prioritization schemes of different instream stakeholder groups. A partially or non-compensatory goal-aspiration method may be appropriate for most instances that call for meeting a PISF specification (such as a minimum or maximum), but places no additional value on exceeding the PISF standard. (Partially compensatory means that overperformance on one

criterion might partially compensate for underperformance in another, whereas non-compensatory methods do not recognize any value in overperformance). In this case, a goal aspiration model in which in-stream ecological needs such as maintenance of fish habitat must be satisfied first, followed by mixed use needs such as water quality, and lastly in-stream anthropocentric needs satisfied last.

There are two areas in particular in which multi-criteria decision analysis (MCDA) could inform the project: development of the PISF specifications, and development of the Water Use and Water Management Plans. Figure 5 depicts the tiered approach proposed, in which information gathered at the lowest levels (such as the in stream survey, stakeholder interviews, and stream flow data) are synthesized at increasing higher levels. MCDA is called for when contrasting objectives or stakeholder values must compete for scarce resources.

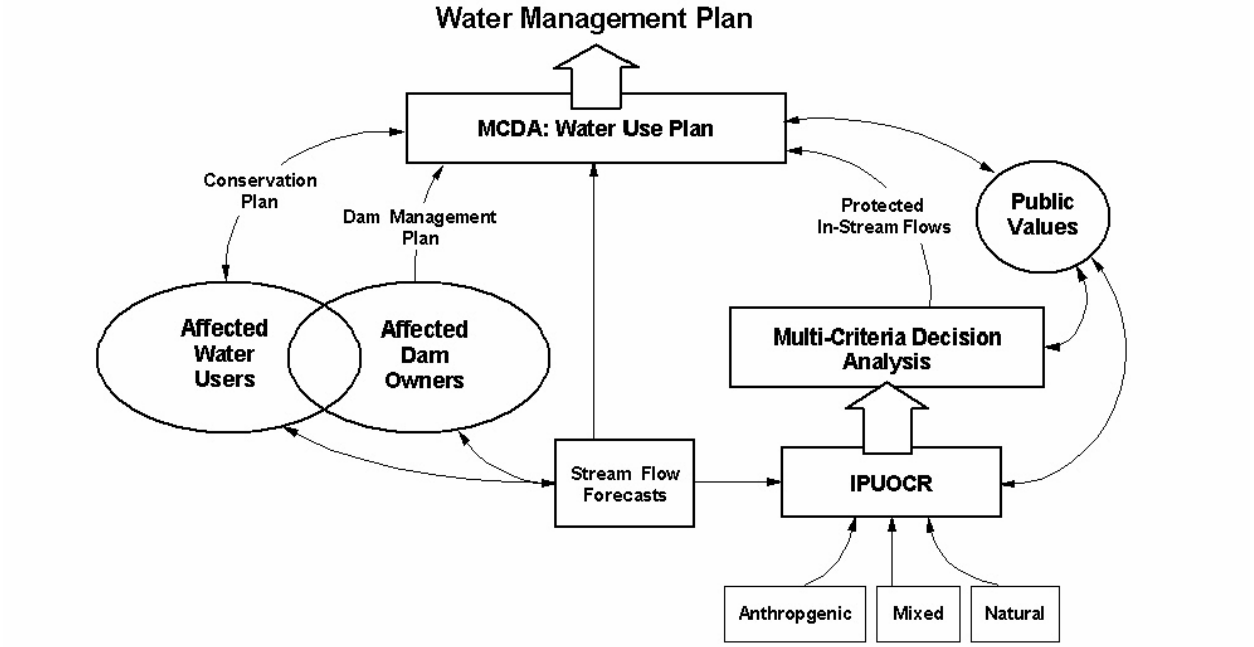


Figure 5: Synthesis of multiple information sources, stakeholder perspectives, and decision criteria using multi-criteria decision analysis.

The initial tasks of this PISF project will clearly delineate the water needs characteristics of the various entities in the system, including the instream flows. A silent but important aspect of management is forecast information. It is possible to avoid projected deficits or user needs going

unmet if proper attention and reactions are made to forecasts (for example, see Anderberg, 1980 or Ballestero, 1981). Forecasts and reactions to forecasts were not explicitly mentioned in the Request for Proposals, however, since there are near real-time stream gages on the Souhegan River and regionally, forecast information (trend in hydrograph recession, meteorological forecasts) can be employed to minimize or even prevent cutbacks to water users. The water management sub-plan strategies operate in concert to maximize the benefit to all needs while at the same time minimize negative consequences.

Normandeau Associates will take primary responsibility for meeting with each AWU and ADO to discuss the PISF and to query them about water use and management. All information obtained through these meetings will be held in confidence. Normandeau can accomplish this task very efficiently as most of the users are within 15 miles of the Normandeau office in Bedford. Don Kretchmer will lead this effort. The basis for the interviews will be a standard questionnaire. The questionnaire developed will be submitted to the DES for comment prior to conducting interviews. Normandeau proposes to send the questionnaire to each user after an initial contact is made prior to the interview and then meet with each user to discuss the questionnaire. This approach may reduce the amount of follow up that is required after the interview. The information requested from each water user will include but not be limited to the following:

- historical withdrawal records
- future plans for withdrawals
- configuration and location of intakes including depth
- estimated amount of return flow
- stream gaging in the vicinity of withdrawal points
- seasonal, weekly and diurnal variation in water needs
- current conservation measures employed
- potential conservation measures
- staffing related to water use (daytime, 24 hour, weekdays, weekends, seasonal)
- ability to store water and volume available
- ability to reuse water
- timing of planned shutdowns during water use season
- time required to respond to a change in water withdrawal and use
- known conflicts related to water use
- known sensitive IPUOCRs in vicinity of intakes or outflow areas
- estimated costs associated with changing water use

The interviewer will then discuss with each AWU the PISF in detail and have a two-way discussion on the universe of conservation measures that may be available to each AWU to meet

the PISF, if any is required. If possible, the interviewer and the representative of the AWU will then visit each in order to understand the relevant aspects of the operation. The site visit will be documented with photos. The result of this task will be a summary of the operation of each AWU and a description of the options available to meet the PISF.

The ADOs will be handled in a similar manner as AWUs with a questionnaire. Owners who are also on the AWU list will be asked questions from both questionnaires. Again, Don Kretchmer will lead this effort. The information requested from each dam owner will include but not be limited to the following:

- FERC operating orders, if any
- Mode of operation by season (run of river, peaking, store/release)
- Estimated amount of storage under their control
- Routes of water past dam and capacities at different water levels (turbines, spillways, overflow sections, fishways)
- Existence of bypass reaches
- Ability to change flows
- Historical flow records and ability to gage flows
- Staffing related to flow management (automated vs. part time attendant vs. full time attendant)
- Time lags in implementing changes in flow at dams
- Projected changes in operation or upgrades to facilities
- Known conflicts related to dam operations
- Known IPUOCRs in vicinity of dams
- Estimated costs associated with changing operations

The interviewer will then discuss with each ADO the PISF in detail and have a two-way discussion on the universe of conservation and or operational measures that may be available to each ADO to meet the PISF. If possible, the interviewer and the representative of the ADO will then visit the dam and other relevant aspects of the operation. The site visit will be documented with photos. The team has worked on numerous dam and hydropower projects throughout the country and is intimately familiar with operations of such facilities. The team will draw this experience to interface with the users on this project. The result of this task will be a summary of the operation of each ADO and a description of the options available to meet the PISF. These will form the starting point for the development of the Dam Management Plan.

a. Conservation Plan

The conservation plan aims to determine, for each water user, how their needs can be met, altered, or reduced when instream flow needs prevail. The individual water use characteristics (average water use, temporal characteristics of water use, variability of water use, duration of

water use, return flows for the water use) will be delineated along the river. Each user will define preferable options in the event that their full water Souhegan River need cannot be met. For example, using alternative water sources, ability to use less water, using water during offpeak water demand hours, maximizing use during periods of maximum return flows, capacity to store water (including aquifer storage and recovery), and/or alternative locations of Souhegan River withdrawal. These alternatives will not be undertaken in a vacuum but in concert with water use actions, forecasts, and reservoir management.

In addition, each AWU will be audited in its water use with the objective of identifying how their use may occur more efficiently. This can include: leak detection programs, metering, process modification, plumbing modifications, schedule modification, etc. Based on the audit, cost estimates to achieve more efficient water use, as well as the estimates of the water savings. The future projected water uses for each AWU will also be estimated, if records of past use exist, or if data for projection is available. This will allow the water management plan to also address future critical developments with respect to the PISFs.

The river channel improvement measures (e.g. creating cover and habitat structure) will be listed indicating the most desirable locations and the areas of highest opportunity (e.g. public lands) associated with AWUs. These measures will be incorporated in the catalog of conservation measures for each AWU giving the opportunity for trade offs between water use and habitat restoration. The habitat simulation model and elaborated habitat rating curves computed during PISF determination phase will be used as a measure of ecological costs and benefits of proposed strategies.

Ultimately, conservation measures and strategies for all AWUs will be compiled into one data base, including: costs, timing, water savings, and payback period.

b. Water Use Plan

A water use plan will be developed according to the guidance developed in the RFP. The first stage in the development of the water use plan will be a comparison of the PISF proposed for each relevant IPUOCR and the flow regime of the river. The hydrologic model will be run under a scenario that includes all users withdrawing at the maximum rate and a minimum amount of natural rainfall and runoff. This will represent a worse case water use scenario for each IPUOCR. Similarly conservation will be minimized and a worst case scenario for dam operations will be developed. If there is insufficient water to meet the needs of the IPUOCRs and the AWU's and ADO's, a MCDA strategy will be developed to address the shortfall that satisfies the highest priority needs first. PISF values may vary in terms of timing of flow required, quantity of flow required and duration of the required flow. To address the conflicts between water required for instream flow and water use, proposed plans or scenarios will be developed to eliminate or reduce the conflict. Because there may be several ways to eliminate or reduce the conflict including elements of the conservation plan as discussed above and dam management as discussed below, the water use plan must incorporate elements of those plans. Examples of specific water use changes that might be considered for incorporation in the water management plan include:

- change in the timing or duration of withdrawals

- sharing or trading water (by agreement or by market forces)
- storage of water during high river flows (for example in aquifers)
- reductions in withdrawal shared among all users during critical times
- re-use of water or returning flow after use
- process changes
- temporary shutdowns

Whereas the Conservation and Dam Management Plans identify the *alternatives* (or decision variables) available, the Water Use Plan identifies the *merit* or criteria by which all the alternatives may be judged. Consequently, the WUP is required to balance the needs of AWU, ADO, and IPUOCR (as specified in the PISF) and will describe the pros and cons of each scenario including the cost and the potential impact on the IPUOCRs if the required PISF cannot be met. Feasible water use scenarios which may include a number of changes in conservation, withdrawals, and dam operations will be run through the hydrologic model that forms the basis of the PISF to insure that they will meet the PISF throughout the designated reach. A mixed partially compensatory goal aspiration and utility maximization framework may be applicable. In the case of the AWUs and ADOs, utility maximization (of economic benefits) is most applicable. However, the *distribution* of benefits (and costs) may not be perceived as being fairly appropriated in a simple total utility maximization scheme. If some stakeholders are perceived to be disproportionately impacted, a partially compensatory or constrained compensatory utility maximization model may be most appropriate. On the other hand, the nature of the IPUOCR criteria are fundamentally different from the AWU and ADO criteria, and exceedances in IPUOCR criteria are unlikely to be tolerated by negatively impacted AWU or ADO users. Therefore, only partially or non- compensatory models interaction between IPUOCR and the AWU / ADO criteria shall be considered.

c. Dam Management Plan

If the comparison of the PISF and flow regime of the river as described above indicates a shortage of river flow in order to meet the PISF for each of the IPUOCRs, dam management will be evaluated along with conservation and changes in water use. Some of the dam management strategies that may be included are:

- change in the timing of releases from storage
- change in the mode of hydropower operations
- release of water through spill gates when insufficient flow is available to generate power
- coordinate the timing of releases to match the demands of water users and IPUOCRs
- change dams physically to gain better control of water releases
- dam removal
- temporary drawdown of impoundments

As described above for the Water Use Plan any dam management scenario considered should be integrated with conservation and water use alternatives and run through the hydrologic model to ensure the PISF requirements are met.

10. Proposed WMP

The Conservation, Water Use, and Dam Management Plans will be synthesized into a Proposed Water Management Plan (WMP) that takes the form of a set of operating recommendations for different hydrologic conditions such as plentiful flows, normal flows, or drought. This synthesis will be a spatial and temporal delineation of critical instream flow as the Souhegan River hydrograph recedes. The implementation of strategies within the plan is first predicated on the accuracy of forecast information: that is, rather than being reactive to real-time low flows that press AWUs and ecosystems into stressed status, forecast information (for example continued dry, hot weather) allows the river system some anticipated decision influence period when strategies can be employed to react to the potential for the stressed state yet minimize disruption to AWUs and ADOs. For example, reducing dam releases when water withdrawals are high, and increasing releases when withdrawals reduce, or maximizing water in off channel storage. The proposed WMP is a choreography of supply and demand to minimize impacts to all stakeholders. The WMP may highlight the most vulnerable stakeholders (the first to feel the pressure of low flows). In fact just the development of the WMP may prompt certain stakeholders to embark on proactive measures to make them less vulnerable in times of low flow, for example through habitat or stream restoration, or through conservation/use modifications.

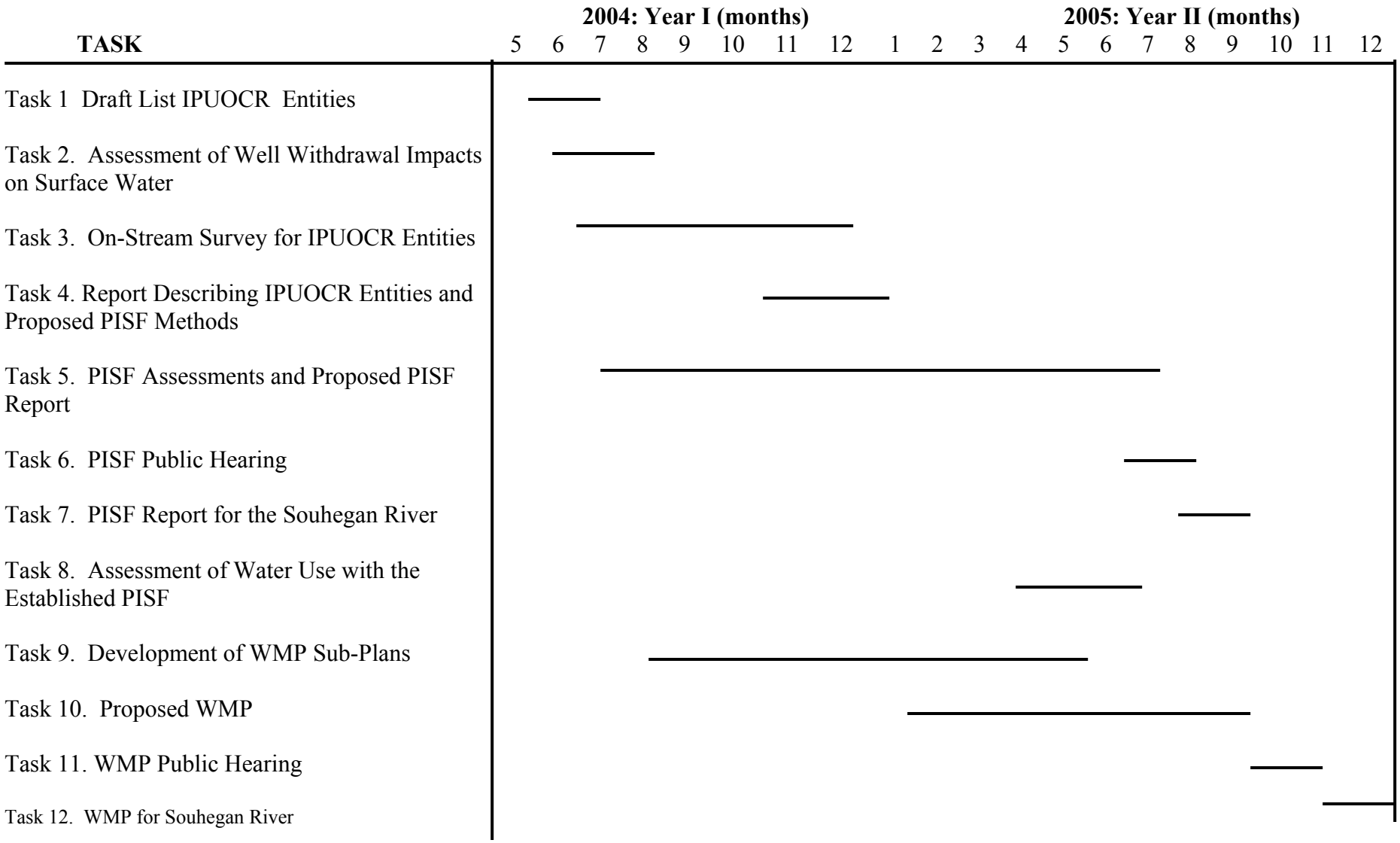
11. WMP Public Hearing

The project team will support the NHDES in the preparation for and the presentation of the proposed WMP in a public hearing as specified in the RFP. This will include delivery of a draft report 30 days prior to the meeting and the preparation of presentation materials based on the draft report. Team members will be present at the public hearing to present the proposed WMP as well as to answer questions. A copy of all presentation materials will be submitted to the NHDES prior to the meeting and will be available for posting to the DES instream flow website after the meeting. The public comments will be addressed and potentially could alter the WMP recommendations due to consideration of factors not included in the draft assessment.

12. Water Management Plan for the Souhegan River

Following the comment period, we will revise the Proposed WMP report based on the comments, in consultation with the Department. We will prepare the final WMP Report from the Proposed WMP report with the addition of a section describing how the comments affected the final WMP. We will submit the WMP Report to the Department to assist the Department meet the deadlines of Env-Ws 1906.07(a).

IV. Proposed Project Performance Schedule



V. Confidentiality Statement

Signed Confidentiality Statements by a representative of each team member may be found on the pages after the references.

VI. Conflict of Interest Statement

Signed Conflict of Interest Statements by a representative of each team member may be found on the pages after the Confidentiality Statements.

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Appendix A – Project Experience and Descriptions

On the following pages may be found short project description of the projects representing the most relevant experiences of the project team in reference to the Souhegan PIFS and WMP project.

Ecohydrology Study on the Quinebaug River
Massachusetts and Connecticut
Millennium Power
(copy of the report previously provided on CD)

The Ecohydrology study on the Quinebaug River in Massachusetts and Connecticut focuses on the assessment of the river's bio-physical conditions, the identification of deficits, and the determination of potential improvement measures. It is part of a multidisciplinary investigation required by the US Army Corps of Engineers Section 404 permit and by the Massachusetts Department of Environmental Protection Section 401 Water Quality Certification for the Millennium Power Project in Charlton, Massachusetts. The study began in Fall 1999 and was conducted by the Instream Habitat Program of the Department of Natural Resources at Cornell University. The results of the study provide a basis for future decision-making processes and for the design of a long-term implementation plan.

The mesohabitat simulation model for the target fish community is one of the principal tools used in this investigation. In summer and fall 2000, 34 km of the river were mapped for their habitat distribution at low flow. A sensitivity analysis of the quantitative distribution of hydro-morphological units was used to identify the representative sites. The sites (combined length - 9.2 km) were then surveyed at three different flow situations ranging from 0.3cfsm (cubic feet per second per square mile drainage) to 1cfsm.

Fish community-specific habitat/flow rating curves provided an assessment tool for simulating various management options, such as temporal and spatial manipulation of flows and improvements to the riverbed structure. It also facilitated in defining seasonal recommendations for flow augmentation. Hydro-morphology, fish habitat, fish density, invertebrate samples, and temperature data were analyzed in every section to determine the present condition of the river and its restoration potential. The model has then been used to evaluate the remaining 30 miles of the Quinebaug River of the same stream order.

The Quinebaug River is a fourth-order river with multiple impoundments and a history of industrial use very similar to the Souhegan River. Within the study area, the different river sections demonstrate a wide range in condition, type, and degree of environmental impact. A number of deficits in fish habitat, river morphology, flow and thermal regime, as well as the presence of pollution, have been identified. Extended duration of low flow conditions combined with channel alteration have been identified as key sources of these deficits.

Comparison of habitat models
As a part of this study the use of different habitat models and their influence on the results of instream habitat assessment and therefore the conclusions for river management, was investigated. The experiment conducted for this purpose was to develop, for the same portion of the Quinebaug River, three types of models: a microhabitat model with univariate habitat suitability criteria (PHABSIM), a microhabitat model using multivariate criteria (HARPHA) and the mesohabitat model with multivariate criteria (MesoHABSIM). The following conclusions were drawn upon the results:

- Only MesoHABSIM passed the model validation test performed when using additional fish collections.

- Univariate habitat suitability criteria, as used in standard PHABSIM, are a major source of disagreements between the models.
- The second largest source of inaccuracy is an error introduced during the extrapolation of microhabitat observation (as in PHABSIM and HARPHA) from the site scale to the river scale.

Developing a sustainable management plan for the Pomperaug River watershed. Connecticut
Connecticut State Department of Environmental Protection
Pomperaug River Watershed Coalition

The Pomperaug River watershed is a rural, 90 square mile area in west central Connecticut (http://www.pomperaug.org/aboutthecoalition.html). The watershed includes the Pomperaug River and its tributaries, including the Nonnewaug River and the Weekeepeemee River, which meet to form the Pomperaug, and Transylvania Brook and Hesseky Brook. This river system runs over the Pomperaug Aquifer, a highly productive aquifer that yields millions of gallons of water a day.

The Pomperaug watershed has a relatively low level of human-induced alterations compared to other rivers in the region. It has high quality groundwater and surface waters, and more than half of the basin remains in forest cover. Because of relatively high ecological integrity, the Pomperaug serves as a model of a healthy river ecosystem and could be used as a reference river for other river systems in the region. However, rapid population growth in the region and higher per capita water use has caused an increase in water demand, putting considerable pressure on the Pomperaug aquifer. Thus, the growing water demand could jeopardize the quality of the Pomperaug ecosystem.

In order to protect the river, the Pomperaug needs a well-defined, long-term watershed management plan that will assure the sustainable use of the resource and mitigate existing deficits. The plan should address both ecological and water management goals and follow a well-balanced concept for resource use that will maintain the ecological integrity of the river. It prompts a comprehensive study carried out by multidisciplinary team of scientists representing environmental and engineering perspectives.

This pilot project (performed in collaboration with local USGS) covered the concept development and the first stage of the habitat component of the comprehensive study outlined above. A watershed-wide instream habitat survey was conducted in order to develop a quantitative instream habitat model. This model will provide a general overview of available fish habitat, which will be used for the concept development process. Just last month the Connecticut Senate allocated additional funding to continue the study.

Measuring River Ecosystem Health in Western Massachusetts
- The Mill River, Hatfield, MA
Massachusetts Executive Office of Environmental Affairs
Massachusetts Environmental Trust
(copy of the reports previously provided on CD)

Located on the western edge of the Connecticut River valley, the Mill River is a tributary of the Connecticut River. The watershed is widely recognized as one of the state's most significant environmental attributes due to its exceptional wildlife habitat. At present, the river and its tributaries are known to support the greatest diversity of freshwater mussels in Massachusetts, including the state's only viable population of Federally Endangered dwarf wedgemussels. It also contains one of the Commonwealth's largest blocks of un-fragmented forest, an exemplary floodplain forest community, and habitat for over 20 state-listed plants and animals (most found in or adjacent to the Mill River and its tributaries). Nine native mussel species, four of which are classified as rare and endangered (one federally endangered), have been found in the river. However, due to a growing demand on water withdrawals from both major tributaries of the Mill River (Roaring Brook and West Brook), the unique fauna within the ecosystem could be irreparably damaged if protective measures are not taken.

From a physical standpoint, the Mill River is characterized by a 44 mi^2 drainage area and an average channel width of 24.6 ft. The study area encompasses a 12.6 mi stretch of river upstream of the confluence of the Connecticut River. The main stem of the Mill River is a low gradient, warm-water stream that winds through fairly flat topography. It is strongly influenced by its interaction with groundwater flow through the surrounding wetlands, as well as cold upland tributary streams that drain the hilly topography to the west.
The study investigated the availability of suitable fish habitat and dwarf wedgemussel under low flow conditions. The primary tools used for this effort were the MesoHABSIM habitat simulation model and the target fish community developed specifically for the Mill River.

The main conclusions of the study were:

1. Although the Mill River has relatively high abundances of fish habitat, the river is still greatly affected by human activity.
2. Chronic low flows cause habitat alteration and high water temperatures
3. The sporadic water quality problems and thermal stresses act as "environmental bottlenecks"
4. The flow patterns in the Mill River are stable due to complex interactions with adjacent wetlands and subsurface flows
5. Large and stable habitat clusters are necessary for sustainable dwarf wedgemussel colonies
6. The largest colony of dwarf wedgemussels can be strongly affected by present and future water withdrawals

Long-Term Impact Analysis of the University of Connecticut's Fenton River Water Supply Wells on the Habitat of the Fenton River
Connecticut
University of Connecticut

As part of a satisfactory finding by the State of Connecticut's Office of Policy and Management (OPM) (part of the University of Connecticut's (UConn) Environmental Impact Evaluation for the North Campus Master Plan), it is required that UConn conduct a study to evaluate water withdrawals from the University's Fenton River water supply wells. The study will focus on the impact of the wells and their effect on the aquatic habitat of the Fenton River. UConn withdraws water using water supply wells placed in a stratified drift aquifer located along a one-mile section of the Fenton River. The four Fenton River wells are registered by CTDEP for a maximum withdrawal rate of 0.8443 million gallons per day, MGD (1.31 cubic feet per second, cfs) (CTDEP Letter, June 21, 1991). As part of the impact assessment of UConn's water use, the University study team will investigate the relationships between fish habitat and instream flow for a section of the Fenton River from Old Turnpike Road to Mansfield Hollow Lake.

The overall goal of the study is to develop relationships between instream flow and habitat in the Fenton River for selected fish species and life stages using a physical habitat model such as the Physical Habitat Simulation System (PHABSIM). The project is led by a team of scientists from the Environmental Research Institute at the University of Connecticut. The Instream Habitat Program at Cornell University is subcontracted to provide scientific and logistic support for specific tasks related to the first objective.

Fish habitat assessment on Stony Clove Creek, NY using MesoHABSIM
New York
Greene County Soil and Water Conservation District
New York City Department of Environmental Protection

The Stony Clove Creek, located in Greene and Ulster counties, flows through the central Catskill Mountain region of eastern New York. In the town of Phoenicia, the Stony Clove joins the Esopus River, eventually emptying into the Ashokan Reservoir, which supplyies New York City with nearly ten percent of its drinking water.
From a physical standpoint, the Stony Clove Creek faces river management problems due to historical hydrological alterations, impaired aquatic fauna and fisheries, and dramatic seasonal fluctuations in flow. The New York City Department of Environmental Protection (DEP), in partnership with the Greene County Soil and Water Conservation Districts, is restoring stream channel stability in priority sub-basins in order to improve water quality in city reservoirs. This study was therefore prompted by the need to develop a comprehensive, multi-objective Stream Management Plan.
To help accomplish this task, the Instream Habitat Program and the Greene County Soil and Water Conservation District conducted a detailed instream habitat study of the main stem of the Stony Clove. This project also served to demonstrate the applicability of a newly-developed instream habitat modeling technique (MesoHABSIM) in conjunction with the Target Fish Community approach in the integration of aquatic habitat management, flood protection and

water quality protection. Using fish habitat as an indicator of ecological health, this study investigates the availability of suitable fish habitat under low-flow conditions.
The main conclusion of this project was the dramatic deficit of brook trout habitat associated with a lack of woody debris and pool structure. It also showed the utility of MesoHABSIM for river restoration. It lead to Phase II of the project on the Westkill River with a purpose of evaluating individual measures of natural-channel-design approach to restoration.

Instream habitat evaluation of Santee River below Wilson Dam
South Carolina
Santee Cooper Power

The construction of the Santee Dam in 1942 resulted in the diversion of a majority of the natural stream flow from the 37-mile reach below the dam. This strongly modified the character of the Santee River, and consequently may have effected the species composition of downstream fauna. Presently, the Santee Dam is involved in a federal re-licensing process under the Federal Energy Regulatory Commission (FERC). The current license expires in 2006. FERC is required to evaluate and balance the competing interests of the project.
Following the recommendations of the US Fish and Wildlife Service (USFWS), South Carolina Department of Natural Resources (SCDNR), National Marine Fisheries Service (NMFS) and South Carolina Coastal Conservation League (SCCCL), Santee-Cooper Power is sponsoring a study to identify measures that will:

1. Enhance ecosystem integrity and function
2. Evaluate the existing fish community
3. Evaluate various flow scenarios that are consistent with variations characteristic of the natural flow regimen.
4. Evaluate the stream channel and its connection to its floodplain
5. Evaluate water quality, including optimal temperature and oxygen levels during summer months

The instream habitat evaluation study will develop a quantitative relationship between flow releases and fauna composition in the upper 37 mile reach of the Santee River. The goal is to evaluated flow increases for habitat enhancement, protection or mitigation in the study section. These recommendations will then be evaluated by the FERC along with the other competing interests of the overall project. Normandeau Associates in collaboration with Cornell University is conducting the the project.

Merrimack River Watershed Assessment Study
Massachusetts and New Hampshire
U.S. Army Corps of Engineers (New England District)

As a subcontractor to CDM, Normandeau Associates in helping the New England District of the US Army Corps of Engineers develop a watershed management plan for the Merrimack River. The Merrimack River watershed has a total drainage of 5,010 square miles with about three-quarters of the watershed in New Hampshire and one-quarter in Massachusetts. The water quality in the river is impaired and the river does not fully support beneficial uses such as aquatic habitat recreation, water supply, and hydropower.

The study is developing a watershed management plan that will guide investments to achieve conditions that support feasible beneficial uses. This will be accomplished by conducting a water resources and ecosystem restoration investigation of the Merrimack River. The study will be used to answer the questions:

- What are the existing and potential future feasible uses of the river?
- What are the pollutant sources that may impact these uses?
- What is the relative contribution of pollutants from various sources?
- What project(s) will provide the most significant return on investment?
- Which projects have the highest priority?

The study will be conducted in several phases. Phase I efforts will identify current and potential future uses of the river, assessing the existing water quality conditions, identifying and quantifying pollutant loads to the river, developing models to evaluate the effects of all existing pollutant loads including non-point sources, evaluating various CSO and non-CSO abatement strategies, and completing an initial inventory of potential ecosystem restoration projects in the watershed. Phase II efforts will be determined following the results of Phase I and undertaken based on availability of non-Federal and Federal funding. At this time it is anticipated that Phase II efforts may focus on in-stream flow issues, possible testing for nonstandard water quality parameters, more detailed analysis of abatement alternatives, and providing for preliminary assessment of ecosystem restoration projects identified in Phase I.

The study will include an inventory of current and potential future uses, determining existing water quality conditions (dry and wet weather), analyses of river water quality using models to evaluate benefits of alternative abatement strategies, determining relative contribution of pollution from varying sources, and evaluating the benefits of alternative abatement plans. Specifically the scope will include data and analysis needed to determine causes of water quality degradation in the Merrimack River and to assess the impact of CSO and other point and non-point contributions to the river.

Aziscohos Dam Minimum Flow Study
Magalloway River, Wilsons Mills, Maine
Central Maine Power Company

Normandeau Associates used computer modeling procedures of the Instream Flow Incremental Methodology (IFIM) to quantify the amount of habitat available for brook trout and landlocked Atlantic salmon over a range of alternative stream flows in the tailrace and bypass area for a proposed hydroelectric station. Normandeau developed habitat suitability curves for landlocked salmon in cooperation with the Maine Department of Inland Fisheries and Wildlife. In addition, Habitat Evaluation Procedures (HEP), developed by the Western Energy and Land Use Team, were used to determine the amount of habitat for the evaluation species in the bypass reach and in a compensation area. This was done to assist in the development of a plan to mitigate for losses in habitat associated with the project.

Hiram Project Instream Minimum Flow Study
Saco River, Baldwin and Hiram, Maine
Central Maine Power Company

Normandeau Associates performed an instream minimum flow study for Central Maine Power's (CMP) Hiram Hydroelectric Plant on the Saco River. This study, the first of its kind in Maine, utilized the Instream Flow Incremental Methodology (IFIM), developed by the Western Energy and Land Use Team of the U.S. Fish and Wildlife Service (USFWS). The primary purpose of the study was to predict the impacts that various low flows would have upon the spawning habitat for sea-run Atlantic salmon and habitat to support their fry and juveniles below the hydroelectric plant. Normandeau developed habitat suitability curves from literature and unpublished data. The IFIM was supported by the Physical Habitat Simulation System (PHABSIM) library, which includes the computer programs WSP, IFG-4, and HABTAT, plus linking and support programs. The IFIM demonstrated an acceptable minimum flow of approximately half the New England Regional Aquatic Base Flow, which was approved by the Federal Energy Regulatory Commission.

Farmington River IFIM
Farmington River, Connecticut
Connecticut Department of Environmental Protection

Normandeau Associates conducted an instream flow study on the West Branch and mainstem of the Farmington River in Connecticut (covering 81 miles). The study objectives were to determine the instream flow requirements needed to support fisheries habitat, recreational resources, and aesthetic qualities at a level sufficient to qualify the West Branch of the Farmington River for Federal designation as Wild and Scenic. Additionally, Normandeau identified the quantity, quality, and timing of diverse river uses in relation to existing flows. An alternatives analysis was conducted: 1) to determine the level of additional consumptive withdrawals from the river system that was compatible with Wild and Scenic River designation, and 2) to examine the effects of various flow regimes (including those associated with a one hundred year drought) on competing stream uses.

Instream flow needs for fisheries within the Connecticut section of the West Branch and mainstem of the Farmington River were assessed using the Instream Flow Incremental Methodology (IFIM). The effects of alternate flows on recreational opportunities and aesthetics were assessed based on: 1) a user survey of recreationists on the river during spring, summer, and fall, 2) a field evaluation of recreational conditions conducted by experts and local volunteers, and 3) an evaluation of how scenic conditions are affected by flows based on videotapes and panel review.

The alternative analysis required the development of a hydrologic model that integrated existing watershed yield, water storage of three major reservoirs, flow rights of a downstream riparian user, and flow requirements to sustain historic recreation and fisheries resources.

Johns River Dwarf Wedge Mussel Survey
Dalton, NH
New Hampshire DOT

Normandeau Associates was contracted by the New Hampshire DOT to search for dwarf wedge mussels (*Alasmidonta heterodon*), a Federally listed endangered species, in the Johns River near its confluence with the Connecticut River. This study was conducted to determine whether reconstruction of the bridge that crosses the Johns River would adversely affect a resident dwarf wedge mussel population. The entire substrate of the Johns River that would be affected by construction activities was systematically searched by a Normandeau diver.

Prior to conducting the search, a dwarf wedge mussel expert with the US Fish and Wildlife Service asked the diver to locate specimens from an area of the Connecticut River where a known population existed to verify the diver's ability to identify specimens in situ. The diver successfully located several specimens within a 15 minute search and satisfied the USFWS concerns.

Snowmaking Needs vs. Minimum Flow Requirements
Killington, Vermont; Mt. Snow, Vermont
Killington Ltd.

Diversion of water from small, headwater streams for snowmaking purposes has resulted in serious concerns by state and federal fisheries and wildlife officials regarding potential impacts to aquatic biota. Normandeau has been involved with three minimum flow studies for Killington, Ltd.

These efforts included evaluation of minimum flows required to sustain native coldwater fisheries in small headwater streams, negotiations with state fisheries and wildlife biologists, and presentation of expert testimony at Vermont Act 250 hearings. Winter minimum flows negotiated for two of these projects have yielded minimum flows substantially less than initial agency standards based on summer flow requirements. The third project, which is ongoing, involves the use of the U.S. Fish & Wildlife Service developed Instream Flow Incremental Methodology (IFIM) on Vermont's Ottauquechee River.

Peshtigo River Instream Flow Studies
Caldron Falls, Johnson Falls and Peshtigo Dam; Northeastern Wisconsin
Wisconsin Public Service Corporation

In response to a request from the Federal Energy Regulatory Commission for additional information regarding the effects of various flows on the Peshtigo River, Normandeau Associates conducted two instream flow studies.

An instream flow assessment for fisheries was conducted in the free-flowing sections of the river below three hydroelectric projects: the Caldron Falls Project, the Johnson Falls Project and the Peshtigo Project. Habitat conditions (depth, velocity, substrate and cover quality) were documented at representative transects at a series of five flows, including ones typically associated with project operations as well as run-of-river conditions. Rates of downramping associated with proposed project operations were also recorded at the study transects. Effects of project operations

were evaluated for spawning walleye and for the fry, juvenile, adult and spawning stages of white sucker and smallmouth bass.

A second study focussed on the effects of various flow regimes on whitewater boating below the Johnson Falls Project. Normandeau Associates designed and conducted a systematic field evaluation of whitewater boating conditions under a series of seven flows. A group of expert boaters, using criteria and data sheets developed by Normandeau, ran the river at the various flows and evaluated the boating conditions. Results were later tabulated and analyzed. The effects on fisheries of whitewater boating recreational flows were also evaluated.

A Geographic Information System for Aquatic Resource Characterization and Management in the Upper Ohio River Basin of Western Pennsylvania
Ohio River Valley Water Sanitation Commission (ORSANCO)

Normandeau Associates completed a 5-year, $1,000,000 effort to develop a geographic information system (GIS) for aquatic resources management in the Ohio River basin of western Pennsylvania. The study area covered approximately 110 miles of the Ohio, Allegheny, and Monongahela Rivers. The project was a joint venture of the Pennsylvania Department of Environmental Protection (PA DEP), the Pennsylvania Fish and Boat Commission (PFBC), and the Ohio River Valley Water Sanitation Commission (ORSANCO). The objectives of the project were 1) to create and apply a GIS in the characterization of aquatic habitat and use by fish and mollusks, and 2) to develop and implement GIS-based resource inventory and management applications.

ArcInfo and related software systems (products of Environmental Systems Research Institute, Inc.) were used to develop a sophisticated GIS application for the storage, retrieval, management and analysis of aquatic resources data. The GIS will be used to aid in the design of field studies to inventory physical habitat. Further analysis of the data acquired from these studies will be used to refine habitat characterizations and their representative coverages within the GIS.

Normandeau developed the basemap by photorevising existing 1:24,000 scale digital mapping using newly flown 1:8,400 scale true-color aerial photography. Coverages were developed for bathymetry (depth) and aquatic areas (large, relatively homogeneous sections defined on the basis of river morphology) where existing information was available and sufficient. Normandeau performed aerial and river-level videography in order to characterize near-shore cover and substrate conditions, which became another coverage within the GIS. Spatial analysis of this data, combined with extensive review of fisheries literature and previous field studies, resulted in the development of a preliminary habitat characterization system. Normandeau performed a detailed side-scan sonar survey of the study area to acquire substrate and bathymetric data in the off-shore areas. The digital sonar images were interpreted and incorporated into the GIS via on-screen digitization using image processing software. Spatial analysis of this information was used to refine habitat characterizations.

Supporting coverages in the GIS include features such as the lock and dam navigation system, water intake and discharge points, recreational sites, hydroelectric facilities, transportation routes,

industrial sites and municipal boundaries. Digitized photographic images of areas representing different habitat categories, environmentally sensitive areas, and other features were integrated into the GIS to provide a visual reference medium.

The Ohio River Basin GIS is designed to interface with existing natural resources and environmental regulatory data storage and retrieval systems, such as U.S. Environmental Protection Agency STORET, 1REACH, and NPDES files; U.S. Geological Survey gaging station records and water quality/biomonitoring networks; and natural resources databases maintained by PA DEP and PFBC.

Provisions have been made to conceptually link the Ohio River basin GIS with efforts by state and Federal environmental agencies to develop natural resource inventory and classification systems which are regional and national in scope. The GIS enables natural resources trustees to better comprehend the present status of natural resources in the basin, and the structure and function of a large navigation river ecosystem.

Modeling Instream Habitat and Water Temperature Regimes in Marsh Creek
Gettysburg, Pennsylvania
Eisenhower National Historic Site, National Park Service

Marsh Creek is one of only two permanent streams flowing through Eisenhower National Historic Site (EISE). The ecological integrity of these streams, and particularly Marsh Creek, has been an ongoing concern for many years due to increased human development and disturbance of the upper watershed. The largest and most direct threat to Marsh Creek was the recent issuance of a permit to Gettysburg Municipal Authority (GMA) to withdraw surface water just upstream from the EISE boundary and augment withdrawals with well water (a novel permit situation within Pennsylvania). Water withdrawal and augmentation could comprise a significant fraction of the total stream flow in Marsh Creek through EISE, altering available habitat quantity or water quality. The proximity of the GMA activity (adjacent and just upstream of EISE), coupled with the relatively short length of stream within the Park boundary, are of great concern because the activity may substantially degrade the ecological integrity of a unique Park resource.

To address the ecological concerns of the Park Service, Normandeau Associates has been providing instream flow modeling and water temperature monitoring of the stream. A detailed study map of instream habitat units was constructed using a GPS unit with sub-meter accuracy and then plotted using ArcView software which will also serve as a spatially explicit data library for project samples.

The fish community was sampled using a mesohabitat approach -- quadrat samples (3.05 m X 6.10 m) of habitat use taken by electrofishing. To capture spatial variability of important habitat features within mesohabitat units, microhabitat measurements were collected using 1 m^2 grid samples within quadrats. Within each grid, nine evenly-spaced substrate measurements were taken and at the center of each grid, mid-column water velocity, bottom water velocity, and

water depth were measured. Cover within the four corners of the grid also were identified and enumerated. This sampling regime provides a spatially explicit, hierarchical habitat sample.

Next, a physical habitat model of the stream was constructed using transect-based descriptions of channel shape in RHABSIM. Available habitat for habitat guilds as determined from the quadrat sampling described above will be modeled, based on a combination of empirical measurements and available habitat literature. Physical habitat results will be integrated with water temperature monitoring at four sites to determine how water withdrawal activities are impacting the ecological integrity of the stream. Results also will serve to identify sensitive ecological components in need of continued monitoring and any areas in need of mitigation.

Contoocook River Waste Load Allocation Study
Town of Jaffrey, NH

Dr. Ballestero performed this project that identified the relation between low flows and oxygen deficits in the Contoocook River due to effluent from the Jaffrey wastewater treatment plant and to recommend solution strategies to mitigate these deficits. The project included: construction of a stream gage and its calibration, stream gaging, river surveying, development of flow duration curves, computer hydraulic analyses (to delineate habitat) and calibration, sampling and monitoring of water quality (temperature, pH, BOD, dissolved oxygen, nitrogen species), computer simulation of dissolved oxygen and calibration, and development of mitigation strategies. The study included NHDES (water quality bureau) input throughout its performance.

Assessing Cocheco River Contaminated Sediment Management Alternatives from Multiple Stakeholder Perspectives: The planned dredging of the Cocheco River from Dover NH to Great Bay created an opportunity to study several novel contaminated sediment management technologies under development at the Center for Contaminated Sediments Research at the University of New Hampshire. This study identified several key stakeholders, including town officials, abutters, non-government organizations, and local business representatives. Preliminary interviews were conducted with each stakeholder to identify the key criteria that would be the basis for evaluating any option. Four areas were of primary concern: water quality, ecological habitat, human habitat, and economics. A follow-up questionnaire helped reinforce and quantify the responses logged in the initial interview, and results were reported to the technology developers. Verification interviews ensured that survey responses were interpreted correctly, and introduced the performance characteristics of each alternative to the stakeholders.

The technology experts rated the performance of each technological option with respect to the decision criteria identified. Because not all stakeholder criteria were amenable to quantitative scales, experts relied on semi-quantitative or qualitative scales such as “high, medium, or low” were appropriate. This precluded use of an optimization approach such as cost/benefit analysis, which requires that all performance measures be reducible to a single scale. Moreover, stakeholder expressed a strong opinion that all criteria were interconnected, suggesting that overperformance in a single area could not compensate for poor performance in others.

A multi-criteria decision analysis (MCDA) called *outranking* was employed to study the trade-offs available to contaminated sediment managers, identify potential conflicts between different

stakeholder groups, and assess the potential for compromise or consensus. This approach simply determines the dominance of one alternative in comparison to another, with outranking scores weighted to reflect the relative importance of each criterion to different stakeholders, generating a unique preference ordering for each stakeholder. The planned alternative, dewatering and disposal at a compromised riparian site, performed well with most stakeholder groups, which was consistent with the fact that consensus had been achieved prior to initiation of the study. However, the MCDA model correctly predicted the first, second, third and fourth choices made by the majority of stakeholders, and in every instance predicted the top two choices correctly, suggesting that the model is consistent with stakeholders' intuitive or heuristic reasoning processes, and may be informative in problems of greater complexity or size.

Feasibility of Main Stem Reservoir Developments - Powder River
Wyoming Water Development Commission

Dr. Ballestero was a principal investigator of this project. The project objective was the water resources development of the Powder River Basin in Wyoming. The Powder River extends from the Bighorn Mountains eastward to the state boundary with Nebraska and northward to the state line with Montana. The river is characterized by very clear water from the west, and salty, turbid water from the south and east. Development strategies had to consider the effect of both removing fresh water and sediment. Many of the results of this study are now being employed in the assessment of the present coal-bed methane strategies in the same watershed. Dr. Ballestero was in charge of all hydrology and hydraulics on the project, as well as public involvement (numerous public forums) and interactions with the Wyoming Water Development Commission.

Legal, Environmental, and Hydrological Consequences of Missouri River Diversions
States of Iowa, Missouri, and Nebraska, also the Kansas City Southern Railroad

Dr. Ballestero was the lead investigator on this project. A very large water withdrawal was proposed by a private interest and approved by the federal government. The diversion would take water from the Missouri River at the Oahe Dam in South Dakota and pump it to eastern Wyoming. The objection by the downstream states to this proposal brought the matter before the US Supreme Court. Dr. Ballestero developed and produced the majority of the technical information to support the successful opposition to this project by the downstream states. Dr. Ballestero: developed long term flow statistics for the river (including flow duration curves and 7Q10), identified critical stream reaches of habitat adversely affected by the withdrawals, reviewed system-wide reservoir operation strategies and how these strategies would be affected by the diversion, prepared the hydrology in the context of the governing water law, prepared legal briefs, and supplied depositions.

Expert System for Landfill Siting
New Hampshire DES (Waste Management Bureau)

Dr. Ballestero was the lead investigator on this project. Siting new landfills is one of the most controversial issues facing local populations. This project reviewed all federal, state, and local laws and built there quantitative requirements into a computer model. In addition, the computer included quantifiable and judgmental stakeholder factors in its algorithm. The computer model was an expert system: it could be queried by a user and given site specific information, from various sites, and then rank the sites from most acceptable to least acceptable.

The model was meant as a screening tool, such that many sites could be prioritized without the need for extensive field work at each. The prioritized list from the expert system could then be used to determine how many of the top sites would then undergo further, more detailed field investigation. The model was compared to a concurrent study performed by traditional means. Of note: of the top 10 sites (out of 72) selected by the consultants, the expert system agreed with 8.

Appendix B – Personnel Resumes

On the following pages are brief resumes of all project personnel.

THOMAS P. BALLESTERO

Associate Professor of Civil Engineering
University of New Hampshire
Hydrology and Water Resources
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e-mail: tom.ballestero@unh.edu
Web site: http://www.unh.edu/civil-engineering/faculty/Ballestero/index.html

EDUCATION

Pennsylvania State University: B.S. in Civil Engineering, 1975
(Environmental Engineering)
Pennsylvania State University: M.S. in Civil Engineering, 1977
(Hydrology and Hydraulics)
Colorado State University: Ph.D. in Civil Engineering, 1981
(Hydrology & Water Resources)

REGISTRATION

Professional Engineering License in New Hampshire, Colorado, and Wyoming
Registered Professional Hydrologist (AIH)
Certified Ground Water Professional (NGWA)
Licensed Professional Geologist, New Hampshire

TECHNICAL SOCIETIES

American Geophysical Union, Member
American Institute of Hydrology, Member and Secretary of State Chapter
American Society of Civil Engineers, Member
American Water Resources Association, Member
American Water Works Association, Member
National Ground Water Association, Member
Universities Council on Water Resources

EXPERIENCE SUMMARY

1989-present	Associate Professor of Civil Engineering, UNH
1993-1999	Chairman, Department of Civil Engineering, UNH
1986-1999	Director, New Hampshire Water Resources Research Center, UNH
1983-1988	Assistant Professor of Civil Engineering, UNH
1982-1983	Division Manager, Water Resources, Simons, Li and Associates, Inc.
1980-1981	Senior Hydrologist, Simons, Li and Associates, Inc.

EXPERIENCE NARRATIVE

At the University of New Hampshire, Dr. Ballestero teaches eight different courses in hydrology and water resources engineering. His research interests are broadly in the field of water resources computer simulation and field measurement of parameters. Current research projects upon which he is working include: comparison of stormwater treatment technologies; urbanization effects on runoff and water quality, simulation of historic salt water reductions to New Hampshire salt water marshes; groundwater flow into coastal and estuarine systems; stream restoration; and constructed wetlands from contaminated sediments.

Dr. Ballestero has been nationally and internationally involved in water resources projects including: groundwater development in both northeast Brazil and Colombia, riverbank stabilization in Argentina, the effects of port construction in Brazil, testimony before the U.S. Congress regarding ground water contamination, measurement and development of landfill gas in Bermuda, monitoring of groundwater contamination in Colombia and South Korea, assessment of environmental hazards in northern Russia, estuarine monitoring in Puerto Rico, and an advisory/review capacity on the Boston Harbor clean-up program.

Dr. Ballestero has performed numerous consulting projects in the last 20 years. In the areas of river mechanics and sediment transport, these projects include: analysis of the Foster Pond earthen dam failure (Windham, NH), Hudson River sediment transport characteristics (Halfmoon, NY), analysis of coastal erosion and breakwater failure (Humboldt Bay, CA), Winnipesauke River bank failure and channel scour (Laconia, NH), and Little River flooding and erosion (Hampton, NH).

Prior to his employment at UNH, Dr. Ballestero was employed by Simons, Li and Associates, Inc. The primary consulting efforts of this firm was sediment transport. Dr. Ballestero's position there was Senior Hydrologist and Division Manager of the Water Resources Engineering Division. His primary efforts in this position was the project management of water resources development proposals (ground water and surface water supplies), hydropower feasibility analyses, hydrologic analysis and simulation, evaluation of contaminant migration, water rights, and design and evaluation of water monitoring networks. At the time he left Colorado, western states were just beginning instream flow studies.

Selected PUBLICATIONS (* - refereed)

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* Ballestero, T. P. and Jason C. Clere, Modeling of Estuarine Sediment Transport on the Piscataqua River: Evaluation of In-Channel Disposal of Dredge Spoils, submitted to ASCE Journal of Hydraulics, in revision.

* Ballestero, T. P., J. P. Marrone and D. M. Trottier, 1993, "Effects of Transportation Structures and Ice on Salt Water Marsh Hydrology and Hydraulics", in Hydraulic Engineering `93, V. 1, Hsieh Wen Shen, S.T. Su, and Fang Wen eds., ASCE, New York, NY, pp. 150-155.

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Ballestero, Thomas P., October, 1988, Piscataqua River Dispersion Study in the Vicinity of the Proposed Dover WWTP Outfall, Final Report, submitted to City of Dover, Durham, NH.

Ballestero, Thomas P., October 1985, Final Report: Dead River Physical Model and Computer Simulations, for SEA, Inc., UNH, Durham, NH.

Ballestero, T. P., January, 1985, Assessment of Hydraulic Consequences Due to Remediation Measures for PCB Contamination in the Acushnet Harbor, MA, for Normandeau, Inc., Durham, NH.

Ballestero, T. P., May, 1984, Analysis and Design of Streambank Stabilization for the Rio Paraguay at Puerto Formosa, Argentina, for Raymond International, UNH, Durham, NH.

Saunders, M. P., L. Butikofer, F. J. Trelease, T. P. Ballestero, and B. A. Anderson, 1983, Water Resources Development of the Powder River Basin, Wyoming, Wyoming Water Development Commission.

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Simons, D.B., T. P. Ballestero, B. A. Anderson, R. M. Summer, and Y. H. Chen, 1983, Analysis of the Hydrologic, Legal, and Environmental Effects of Surface Water Diversions from the Missouri River Basin, Simons, Li and Associates, Inc., CO.

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"Chapter III: Hydrologic Analysis" in Engineering Analysis of Fluvial Systems by Simons, Li and Associates, Inc., SLA, 1982.

Simons, D.B., R. M. Li, W. T. Fullerton, M. P. Conner, and T. P. Ballestero, Cowlitz Falls Hydropower Sedimentation Study, Simons, Li and Associates, Inc., CO, 1982.

Simons, D. B., R. M. Li, W. T. Fullerton, M. J. Ballantine, and T. P. Ballestero, 1981, Design of GCC Intake Structure on the Colorado River Near Debeque, CO, Simons, Li and Associates, Inc., CO.

Simons, D. B., K. G. Eggert, and T. P. Ballestero, 1981, Design and Evaluation of Water Monitoring Networks, US EPA, Washington, D.C.

Simons, D. B., R. M. Li, R. K. Simons, W. T. Fullerton, T. P. Ballestero, and M. P. Conner, 1981, Hydrologic Analysis of the Rio Grande River Basin, New Mexico, US COE, Albuquerque, NM.

Ballestero, T. P., 1981, Feasibility Analysis of Small Scale Hydropower Development on Meadow Lake Creek, Gilmore, Idaho, U.S. DOE, Washington, D.C.

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Education:

1998 - Ph. D. Natural Resources Management and Water Engineering, University of Agricultural Sciences in Vienna, Austria.
Advisors: Univ. Prof. Dr. Mathias Jungwirth and ao.Univ. Prof. Dr. Stefan Schmutz.

1993 - M.S., Environmental and Water Engineering, University of Agricultural sciences in Vienna, Austria.
Advisors: Univ. Prof. Dr. Mathias Jungwirth and Univ. Prof. Dr. Siegfried Radler.

1988 - B.S., Environmental and Water Engineering, Department of Hydrobiology, Fisheries and Aquaculture, University of Agricultural Sciences, Vienna, Austria.

1984 - Arabic, University of "Al Fateh", Tripolis, Lybia.

1980 - Advanced Mathematics Program in "Klement Gottwald" High School, Warsaw, Poland.

Special training courses

1994 – Instream Flow Incremental Methodology (IFIM) - Stream Habitat Sampling Techniques" Colorado State University, Ft. Collins, CO.

1994 - "Using Computer-Based Physical Habitat Simulation (PHABSIM) System", Utah State University, Logan, UT.

Research expertise and interests

Habitat modeling: Quantitative modeling of running water ecosystem with focus on system scale physical habitat assessment and modeling, Instream Flow/Habitat Models.
River restoration: Assessment and maintenance of ecological integrity, comprehensive river management concepts, river restoration planning, construction and evaluation.
Fish ecology and fisheries management: Fish community structure, diversity and population dynamics.
Fish passage: Development of innovative technologies for diadromous and freshwater fishpassage (design, planning, construction and evaluation).
River Survey and Instrumentation: physical and biological survey designs
Development and application of flow meters and multiplex sensors, ADP, GPS, Aerial Photography.
Computer Aided Design (CAD), Digital Terrain Models (DTM), Geographical Information Systems (GIS), Acoustic Doppler Profiling (ADV), environmental statistics, computer programming.

Academic and professional appointments

2004-present. University of Massachusetts, Amherst, MA .
Research Associate Professor, Department of Natural Resources Conservation.

2000-2004. Cornell University, Ithaca, NY.
Research Associate IV. Department of Natural Resources. Director, Instream Habitat Program.

2000-present. University of Massachusetts, Amherst, MA .
Adjunct Assistant Professor in Aquatic Ecology and Engineering, Department of Natural Resources Conservation.

2003-present. University of Connecticut, Storrs, CT.
Adjunct Assistant Professor in Aquatic Ecology and Engineering, Department of Natural Resources Management and Engineering,

1999-2000 Cornell University, Ithaca, NY.
Post Doctoral Fellow, Aquatic Ecological Engineering, New York Cooperative Fish and Wildlife Research Unit

1998-1999 University of Agricultural Sciences, Vienna, Austria.
University Lecturer, Institute of Water Provision, River Ecology and Waste Management Department of Hydrobiology, Fisheries and Aquaculture,

1994-1998 University of Agricultural Sciences, Vienna, Austria.
Research Associate, Institute of Water Provision, River Ecology and Waste Management. Department of Hydrobiology, Fisheries and Aquaculture,

1988-1994 Research Assistant, Department of Hydrobiology, Fisheries and Aquaculture, University of Agricultural Sciences, Vienna, Austria.

Select relevant publications in peer-reviewed journals

Nestler, J., Parasiewicz P. & N. L. Poff (accepted for publication). First principles based attributes for describing a template to develop the reference river. *River Research and Application*

Parasiewicz P. (2003): Upscaling: Integrating habitat model into river management. *Canadian Water Resources Journal.* Special Issue: State-of-the-Art in Habitat Modelling and Conservation of Flows **28** (2) p. 283-300.

Jacobson, R. & Parasiewicz, P. (2002): Methods for Defining Instream Flow Standards: New developments in habitat modeling. In proceedings of Connecticut Instream Flow Conference. Berlin, CT 3/23/2001, p. 99 – 113. Yale University.

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Parasiewicz, P. (1996): Estimation of physical habitat characteristics using automation and geodesic-based sampling. *Regulated Rivers: Research & Management*, Vol. 12, 575-583.

DONALD W. KRETCHMER
Senior Limnologist
Certified Lake Manager

Mr. Kretchmer has over 20 years of experience as a limnologist, specializing in freshwater aquatic ecology and fisheries. His experience involves aquatic ecosystem restoration and management, nutrient and dissolved oxygen modeling in lakes and streams, bioenergetics modeling of fishes, environmental impact assessment, permitting, natural resource damage assessment, and limnological, groundwater, surface water and fisheries fieldwork supervision, data interpretation and reporting.

EDUCATION

M.S. 1986, Water Resources Management, University of Wisconsin-Madison
B.S. 1982, Natural Resources, Cornell University

PROFESSIONAL EMPLOYMENT HISTORY

1987-Present	Normandeau Associates, Inc.
1986-1987	Alliance Technologies Corp.
1985-1986	University of Wisconsin, Center for Limnology
1982,	New York State, Cornell
1983-1984	Biological Field Station
1983	New York State Resource Information Laboratory

AFFILIATIONS

North American Lake Management Society
Lake Wentworth Association
Lakes Region Conservation Roundtable
NHDES Stormwater Recharge Advisory Subcommittee (1999-2000)
NHBIA Instream Flow Committee (1999-2002)

SELECTED PROJECT EXPERIENCE

Tennessee Valley Authority (TN and 7 other states) (ongoing) - Prepared water quality section of EIS for Reservoir Operating Study. Alternatives for the future management of water quality, transportation, flood control and recreation throughout the entire TVA system were evaluated. Task Manager.

U.S. Army Corps of Engineers (MA,NH) (On-Going) - Water Resource Evaluation of the Lower Merrimack River. Evaluating storm water, CSO inputs, background water quality, time of travel and bathymetry of the system as a part of a larger effort to understand the dynamics of nutrients, bacteria, and toxic substances throughout an 80-mile reach of the river. Includes all major tributaries between Concord, NH and seacoast. Project Manager.

Yadkin, Inc (NC) (On-Going) – Yadkin Water Quality Study. Evaluating the limnology of a river and reservoir system (four impoundments) as a part of a relicensing effort. Issues include nutrient enrichment, temperature, dissolved oxygen dynamics and mitigation of dissolved oxygen problems. Study design and results presented to large stakeholder group. Project Manager.

Tapoco Reservoir Water Quality Study (NC, TN) (On-Going) - Evaluated limnology, fisheries, and wetlands of river reservoir system's four dams as a part of relicensing effort. Project Manager.

U.S. Army Corps of Engineers (1997-2001) - Snake River Productivity Study (WA); Documented limnology and primary productivity of Lower Snake River to support modeling of potential changes in primary and secondary productivity associated with removal of four hydropower dams. EIS evaluated anadromous fish movement throughout the system. Project Manager.

Manchester WaterWorks (NH) (1999) – Lake Massabesic Watershed Management Plan. Prepared a comprehensive watershed management plan for the water supply for the City of Manchester, NH. Project incorporated transportation, GIS, water quality data, ground data and planning information. Project Manager.

New England Power (NH, VT) (1998-1999) – Fifteen Mile Falls Water Quality Study. Evaluated dissolved oxygen and water quality at a series of three major hydropower projects on the Connecticut River. Project Manager.

New York State Department of Environmental Conservation (1995-Present) - Onondaga Lake Natural Resource Damage Assessment Plan (NY); Prepared a plan to compensate the citizens of the Syracuse area and New York State for injury to the natural resources and recreational potential of Onondaga Lake attributable to releases of hazardous and non-hazardous substances over nearly a century. Project Manager.

SPECIAL TRAINING

USSCS, Short Course on TR-20 and TR-55; Computational Methods for Hydrology, 1988.
Maine DEP, Short Course on Phosphorus Allocation Methodology for Lakes, 1989.
New England Interstate Water Pollution Control Commission, Lakes Modeling Short Course, 1989.
University of New Hampshire, Working at a Watershed Level, 2000.
Utah State University, Basins 3.0 Training Workshop, 2001.

SELECTED PRESENTATIONS

Kretchmer, D.W., J. King, D. Ford and P. Massirer. 1998. Predictions Regarding the Aquatic System in the Lower Snake River after Dam Removal and Stabilization. Presented at the 18th Annual Meeting of The North American Lake Management Society November 10-13, 1998.

Juul S. and D.W. Kretchmer. 2000. Lateral and Vertical Total Dissolved Gas Concentrations within the Priest Rapids, Washington Hydroelectric Project. Presented at the 20th Annual Meeting of the North American Lake Management Society. November 2000.

A. Hunter Brawley

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Litchfield, CT 06759
203-263-2217
hbrawley@pomperaug.org

PROFESSIONAL EXPERIENCE

Management / Non-profit Administration

Executive Director, The Pomperaug River Watershed Coalition, Southbury, CT
(July 2001 to May 2003).

Managed all activities of non-profit watershed management organization dedicated to conserving regional water resources, including research, outreach, budgets, grant writing, website development, fundraising, and volunteer relations.

Senior Project Manager, LabLite LLC, New Milford, CT
(January 2000 to June 2001).

Product development, testing, sales, and customer service for a software company that provides Laboratory Information Management Software (LIMS) to environmental and other laboratories.

Environmental Assessment

Research Coordinator, The National Audubon Society, Southbury, CT
(March 1998 to January 2000).

Designed and implemented all research on birds and other wildlife at the 625-acre wildlife sanctuary. Conducted natural resources inventory, created checklists of wildlife and plants, and established environmental education programs.

Environmental Analyst, Land-Tech Consultants, Inc., Southbury, CT
(November 1996 to February 1998).

As Project manager conducted environmental impact statements, wetland assessments, and wildlife surveys; prepared federal, state and local permit applications; designed pond and tidal wetland restoration projects; and conducted lake diagnostic studies.

Scientific Research / Field Studies

Wetland Ecologist, The Deep River Land Trust, Deep River, CT.
(July to October 1995).

Responsibilities: Worked in association with The Nature Conservancy Connecticut Chapter on a conservation project at two freshwater tidal marshes in the lower Connecticut River.

Research Assistant, The Nature Conservancy Connecticut Chapter, Weston, CT.
(May to July 1995).

Responsibilities: Assisted with research on the productivity and survivorship of Worm-eating Warblers at the 1700-acre Devil's Den Preserve in Weston, CT.

Master's Thesis Research, Connecticut College Department of Botany, New London, CT..
(September 1993 to May 1995).

Conducted two-year study investigating relationships between bird populations and environmental conditions in tidal wetlands of Connecticut.

Research Assistant, Virgin Islands National Park, St. John, V.I.
(January 1995).

Assisted with long-term study of wintering migratory landbirds on St. John, U.S. Virgin Islands.

Research Associate, Connecticut College Arboretum, New London, CT.
(September 1992 to January 1994).

Conducted a natural resources inventory of The Harriet C. Moore Foundation property in Westerly, RI., including producing lists of all plants and animals (flora and fauna), conducting a breeding bird census, and identifying and tagging over 100 ornamental trees. Developed a five-year plan for the management and use of this 35-acre public land preserve.

Principal Investigator, The Nature Conservancy Connecticut Chapter, Middleton, CT.
(June to November 1994).

Studied five marshes in the tidelands of the lower Connecticut River to assess the impacts of the spread of common reed *(Phragmites australis)* on bird populations. Designed project that included the systematic collection of data on bird use, vegetation sampling, and an analysis of physical site characteristics.

EDUCATION

Connecticut College, New London, CT. Master of Arts in Botany, 1995.
Connecticut College, New London, CT. Bachelor of Arts in American History, 1982.
The Loomis Chaffee School, Windsor, CT. Graduated 1978.

PUBLICATIONS

Warren, R.S., P. E. Fell, R. Rozsa, A. H. Brawley, A. C. Orsted, E. T. Olson, V. Swamy and W. A. Niering. 2002. Salt Marsh Restoration in Connecticut: 20 years of Science and Management. *Restoration Ecology* 10 (3) 497-513.

Brawley, A. H. 1998. A Vegetation Survey and Conservation Analysis of Vaughn's Neck Peninsula. Report to The Candlewood Lake Authority. The National Audubon Society. 11 p.

Brawley, A. H., R. S. Warren and R. A. Askins. 1998. Bird Use of Restoration and Reference Marshes Within the Barn Island Wildlife Management Area, Stonington, Connecticut, USA. *Environmental Management* 22(4): 625-633.

Marsicano, L. J. and A. H. Brawley. 1997. Land Use, Watersheds, and Aquatic Resources. *Connecticut Woodlands* 62(3): p. 21.

Niering, W. A., and A. H. Brawley. 1996. Functions and Values Assessment of Area A Downstream Wetlands and Watercourses. Naval Submarine Base New London, Groton, CT. Report to Brown & Root Environmental, The Environmental Protection Agency, and The United States Navy. 36 p.

Brawley, A.H. 1995. Pratt and Post Coves: A Vegetation Survey and Conservation Analysis. Report to the Deep River Land Trust, Deep River, CT. 62 p.

Brawley, A.H. 1995. Birds of Connecticut's Tidal Wetlands: Relating Patterns of Use to Environmental Conditions. Master's Thesis, Connecticut College, New London, CT. 87 p.

Brawley, A.H. 1994. Birds of the Connecticut River Estuary: Relating Patterns of Use to Environmental Conditions. Report to the Nature Conservancy Connecticut Chapter Conservation Biology Research Program, Middletown, CT. 23 p.

Brawley, A.H., G.D. Dreyer. 1994. Master Plan for the Future Management and Use of Moore Woods. Connecticut College Arboretum Publication. New London, CT. 65 p.

Niering, W.A., R.S. Warren and A.H. Brawley. 1994. A Preliminary Inventory of the Ostrom Enders Estate, Waterford, CT. Connecticut College Report, New London, CT. 32 p.

Brawley, A.H., G.D. Dreyer and W.A. Niering. 1993. Connecticut College Arboretum Phase One Report to the Harriet Chappell Moore Foundation. Connecticut College Arboretum Publication. New London, CT. 100 p.

LEE CARBONNEAU
Certified Wetland Scientist
Terrestrial and Wildlife Specialist

Ms. Carbonneau has twenty years of experience assessing terrestrial and wetland communities throughout the northeastern United States. She is involved in all aspects of wetland delineation, functional assessment, mitigation design, and wildlife inventory and habitat assessment. She is a manager of ecological support projects for hazardous waste site remediation, highway projects, and commercial and industrial developments.

EDUCATION

M.S. 1986, Wildlife Ecology, University of New Hampshire
B.S. 1981, Forest Biology, SUNY College of Environmental Science and Forestry, Magna cum laude

PROFESSIONAL EMPLOYMENT HISTORY

1989-Present	Normandeau Associates, Inc.
1986-1989	The Smart Associates
1985-1986	Self Employed, Environmental Consultant
1983-1985	Institute of Natural and Environmental Resources, University of New Hampshire
1982	EIP Northeast and The Nature Conservancy-Long Island Chapter
1981	The Nature Conservancy-Lower Hudson Chapter

PROFESSIONAL AFFILIATIONS

Professional Wetland Scientist #882 - Society of Wetland Scientists

Certified Wetland Scientist #123 – New Hampshire Association of Natural Resource Scientists

SELECTED PROJECT EXPERIENCE

Tennessee Valley Authority (TN and 7 other states) (ongoing) - Prepared managed areas and ecologically significant sites section of EIS for Reservoir Operating Study. Alternatives for the future management of water quality, transportation, flood control and recreation throughout the entire TVA system were evaluated. Task Manager.

Yadkin, Inc (NC) (On-Going) – Evaluating the effects of reservoir management on wetlands, rare, threatened and endangered species, and wildlife habitat as a part of a relicensing effort. Tasks include air photo interpretation, field surveys, impact assessment. Project Ecologist.

PSNH – Merrimack River (2003) – Evaluated potential bald eagle winter perching and roosting habitat and nesting habitat along the Merrimack River from Concord to Manchester NH for dam relicensing study. Project Ecologist.

Sanborn Head Associates (2001-2003) Blackburn & Union Privileges Superfund Site, Walpole, MA. Wetland delineation, habitat assessment, ecorisk support and restoration design along the Neponset River. Project Manager.

Industrial Site Ecological Risk Assessment Projects (3 Sites in CT) (2000-2001) – Ecological inventory, conceptual site model development, exposure pathway and potential receptor evaluation for sites along the Connecticut and Quinnipiac Rivers. Senior Project Ecologist.

Fayscott Site, Dexter, Maine (1998-2001) -Wildlife habitat inventory for evaluation of remediation alternatives at a former manufacturing on East Branch of the Sebasticook River. Addressed Significant and Essential Wildlife Habitats, fisheries, reptile and amphibian habitat. Cover type mapping, wetland delineation, bird surveys, habitat evaluations. Project Manager.

PECO Energy Site Redevelopment Project (1998-1999) – Endangered species investigations and wildlife habitat evaluation on the shores of the Delaware River. Botanist/Wildlife Biologist.

NHDOT/Manchester Airport Access (1997-1998) – Wintering bald eagle survey and habitat assessment on the Merrimack River for major highway EIS. Principal Wildlife Investigator.

Coakley Landfill Superfund Site (1992-2000) - Wetland remediation and mitigation design, permit equivalency, construction management and long-term monitoring for North Hampshon NH site. Project Manager.

Newington-Dover Highway Improvement (1990-1991) – Environmental assessment and ecological constraints mapping for highway renovation. Project Manager.

Groundwood Pulp and Light Weight Coated Paper Mill Siting Project (ME) (1989-1990) – Resource inventory and mapping on remote sites in northern Maine. Wetland Scientist and Wildlife Biologist.

Research Natural Area Establishment (1986) –Establishment of 5 RNAs in the White Mountain National Forest, NH. Principal Investigator.

SPECIAL TRAINING

Design and Implementation of Treatment Wetlands (Water Environment Federation), 1996

Wetland Evaluation Technique Version 2.0 Certification (U.S. Army Corps of Engineers Course), 1988

Personnel Protection and Safety Training for Hazardous Waste Site Activities (OSHA Course), 1989-Present

OSHA Hazardous Waste Site Supervisor Certification

NASDS SCUBA Certification, 1980

MATTHEW D. CHAN, Ph.D.
Senior Scientist

Dr. Chan's primary topic of research has been stream fish communities and their habitat requirements, particularly in relation to flow regimes. To date, his project experience includes stream/fish ecology, habitat assessments, regulated rivers/instream flow studies (IFIM/PHABSIM), fish ecomorphology (morphometrics), multivariate statistics, bioenergetics, and the use of surrogate species for determining habitat preferences of threatened and endangered fishes. His experience covers both southeastern and mid-Atlantic geographic regions, and includes small streams and large rivers. His current duties include performing instream flow studies and statistical analyses.

EDUCATION

Ph.D. 2001, Fisheries Science, Virginia Tech
M.S. 1995, Biology, University of Mississippi
B.A., 1992, Biology Major Computer Science Minor, Wittenburg University

PROFESSIONAL EMPLOYMENT HISTORY

2001-Present Normandeau Associates, Inc.
1996-2001 Virginia Tech
1995-1996 USCE Waterways Experiment Station
1992-1995 University of Mississippi
1988-1992` Wittenberg University

PROFESSIONAL AFFILIATIONS

Sigma Xi
American Fisheries Society
Virginia Tech Chapter of American Fisheries Society
American Society of Ichthyologists and Herpetologists
Virginia Tech Graduate Student Assembly

SELECTED PROJECT EXPERIENCE

Santee-Cooper Power (2002-2003) –
Investigate river habitat using Mesohabsim approach in 37 mi bypass reach, conduct hydrologic analysis using IHA and ROV methods for reach, and develop two-dimensional river models (R2D) of selected shoals to evaluate small-boat navigation capability and stream habitat. Principal Investigator.

Tennessee Valley Authority (2002-2003) – Preparation of a programmatic environmental impact statement for the TVA system. Section Leader for assessment of aquatic resources.

National Park Service (2002) – Investigation of fish and habitat relationships relative to water withdrawal from Marsh Creek, a stream flowing through the Dwight Eisenhower National Historic Site, Gettysburg, PA. Principal Investigator.

SSM Group, Inc. (2002) – Assessment of instream flow needs to protect aquatic biological resources in preparation of an integrated resource plan for water for Montgomery County, PA. Principal Investigator.

Virginia Tech (1997-2001) – Physical habitat study (PHABSIM) and water temperature measurements of North Fork Shenandoah River, VA. Constructed a physical habitat simulation model for helping decision makers allocate flow for aquatic fauna in a river valley with an expanding population and frequent droughts. Research Associate.

Virginia Tech (1999-2001) – Ecological studies of the Smith River, VA. Multiple studies on the effects of daily hydro-peaking operations on river fishes, specifically impacts on a naturalized brown trout population. Research Team Member.

Virginia Tech (1996-2001) - Watershed model of the upper Roanoke River, VA. Study impacts of urbanization on fish communities. Research Team Member.

SELECTED PRESENTATIONS AND PUBLICATIONS

Killgore, K. J., S. T. Maynord, M. D. Chan, and R. P. Morgan II. 2001. Evaluation of Propeller - Induced Mortality on Early Life Stages of Selected Fish Species. North American Journal of Fisheries Management. In press.

Chan, M. D., and E. D. Dibble. 1997. A laboratory examination of velocity and substrate preferences by age-0 Gulf sturgeon, *Acipenser oxyrinchus desotoi*. Transactions of the American Fisheries Society 126:330-333.

Killgore, K. J., and M. D. Chan. 1996. U.S. Army Corps of Engineers, Waterways Experiment Station. North American Sturgeon: Implications for the Corps of Engineers. EIRP Bulletin 96-1, 7 pp.

Chan, M. D. and D. J. Orth. 2001. Using complex hydraulic variables and fish morphology to predict habitat preference of river fishes. Northeast Fish and Wildlife Conference: Instream Flow Symposium.

Chan, M. D. and D. J. Orth. 2001. Prediction of stream fish microhabitat with complex hydraulic variables, an ecomorphological approach. Mid-year meeting of the Southern Division of American Fisheries Society.

Chan, M. D., D. C. H., D. J. Orth, and T. Newcomb. 2000. Water Quality in the North Fork Shenandoah River during the Drought of 1999: Implications for Minimum Instream Flow. Tri-State Fisheries Conference/ Virginia AFS Meeting and as Poster at Graduate Student Assembly Research Symposium.

E. TERRY EUSTON
Principal Biologist

E. Terry Euston is a senior fisheries biologist with 31 years of experience in designing, managing, and conducting environmental monitoring, impact, and fisheries management related studies for hydroelectric, fossil, and nuclear power stations on waterways in the Northeast, mid-Atlantic, upper Midwest, and Pacific Northwest regions. Mr. Euston has investigated abundance, distribution, species composition, sport harvest, feeding ecology, and seasonal movement of fishes in a variety of lotic and lentic ecosystems influenced by these operations. He is trained to conduct and analyze instream flow studies using IFIM. Mr. Euston is also trained to evaluate hydro turbine entrainment and mortality with specific training in the application of HI-Z Turb'n Tag technology.

EDUCATION

B.S., 1970, Fisheries Science, Cornell University

PROFESSIONAL EMPLOYMENT HISTORY

1977-Present Normandeau Associates
1972-1977 Ichthyological Associates, Inc.
1968-1970 New York State Department of Environmental Conservation

PROFESSIONAL AFFILIATIONS AND SPECIAL TRAINING

American Fisheries Society
Mid-Atlantic Chapter, AFS
IF200 Designing and negotiating studies using IFIM
IF305 Field techniques for stream habitat analysis

SELECTED PROJECT EXPERIENCE

New York Power Authority (2003-Present) - Sport fishing survey of Upper Niagara River for Niagara Power Project. Project Manager.

New York State DEC (2000-Present) – Sport fishing survey of Hudson River estuary. Project Manager.

Reliant Energy (1997-Present) - managed environmental studies, prepared APEA materials in support of alternative relicensing of Piney Generation Station, Clarion River, PA.

Allegheny Energy (2000-2001) – Relicensing Environmental Studies. Project Manager.

U.S. Army Corps of Engineers (1998-1999) - Preparation of Resident Fish Appendix, a supplement to the Lower Snake River Juvenile Salmon Feasibility Study EIS evaluating dam removal effects on endangered chinook salmon. Project Manager/Co-author.

U.S. Army Corps of Engineers (1997-1999) - Aerial and ground creel surveys of 170 miles of the Snake River in WA and ID to support economic valuation studies of sport fishing and general recreation in impounded and free- flowing river sections. Project Manager.

U.S. Army Corps of Engineers (1995, 1997) - Assessed juvenile chinook salmon and steelhead injury and mortality utilizing HI-Z Turb'N Tag technology during spill and sluiceway passage at dams on the Columbia and Snake Rivers. Field Coordinator.

New England Power (1994-1995) - Evaluated turbine passage and bypass survival of Atlantic salmon smolts with HI-Z Turb'N Tag technology at Wilder and Vernon Hydroelectric Stations, Connecticut River, Vermont and New Hampshire. Principal Investigator.

Allegheny Power Service (1993-1995) - Responsible for the design, conduct and reporting of post-relicensing studies on the cumulative effects of four hydro stations on American eel passage. Full entrainment netting and radio telemetry were used to acquire data. Project Manager.

Allegheny Power Service (1990-1994) - Responsible for the final design, conduct and preparation of Exhibit E for FERC relicensing of five hydro stations in Virginia and West Virginia including studies of peaking power effects on fish and water quality utilizing IFIM on a river reach heavily impacted by acid mine drainage. Proj. Mgr.

Carolina Power & Light (1992) - Instream flow studies utilizing IFIM for a 12-mile bypass reach of the Pigeon River below Walters Dam, North Carolina and Tennessee. Co-field Leader.

SELECTED PRESENTATIONS AND PUBLICATIONS

Euston, E.T., S. Haney, K. Hattala, A. Kahnle. 2003. Hudson River Creel Survey-Recreational use of Hudson River fisheries resources. Presented at Hudson River Environmental Society conference, Poughkeepsie, NY.

Euston, E.T., D.D. Royer, and C.L. Simons. 1998. American eels and hydroplants: clues to eel passage. Hydro Review 17(4):94-103.

Relationship of emigration of silver American eels (*Anguilla rostrata*) to environmental variables at a low-head hydro station. WATERPOWER '97, ASCE, Atlanta, GA.

Euston, E.T., C.E. Denoncourt, K.J. McGrath, and J.D. Gerlach. 1996. Results of 1995 sports fishing surveys on the St. Lawrence River in the vicinity of the St. Lawrence-FDR Power Project. Presented at International Conference on the St. Lawrence Ecosystem, Cornwall, Ontario, Canada.

Jeffrey John Fountain
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Ithaca, NY 14850-9729 Phone (607) 253-7303
E-mail jjf28@cornell.edu

Education

May 2003 Cornell University Ithaca, NY
B.S. Science of Earth Systems, concentration in Ecology
Graduated with honors – Distinction in research
GPA ~3.3

May 2000 Paul Smiths College Paul Smiths, NY
A.A.S. Ecology & Environmental Technology
Graduated with honors – Summa cum laude

Selected course work

Analysis of Biogeochemical Systems, Intro to Biogeochemistry, Wetlands Ecology & Management, Global Ecology & Management, Physics & Chemistry of the Earth, Evolution of the Earth System, Soil Ecology, Forest Soils, Environmental Biophysics, Environ. Microbiology, Environ. Chemistry, Stream Ecology, Field Ecology, Limnology, Oceanography, Intro. to GIS

Work experience

August 2003 to present Instream Habitat Program Ithaca, NY
GIS/Field technician
Conduct fish habitat assessment on streams, electrofishing by boat and grid techniques
GIS based watershed hydrological analysis/modeling and map creation with Arc/Info Workstation

May – August 2001 Adirondack Lakes Survey Corporation Ray Brook, NY
Database Manager/Research Asstistant/Field Technician
Analyzed & compiled research papers pertinent to Adirondack waters; implemented a database of such research which was incorporated into GIS application.

Summers '98, '99, '00 – Feb. '01 Adirondack Aquatic Institute Paul Smiths, NY
Field/Laboratory Technician
Performed laboratory water chemistry analysis/lake & stream water sampling/chemical & physical throughout Adirondack Park
Examined lakes for exotic species/carried out their removal & interacted with public to inform them to their identification
Performed phytoplankton/aquatic macrophytes sampling & identification
Created a database application which included over 12 years of water quality and hydrological data collected by Adirondack Aquatic Insititute—select waters incorporated into GIS based water quality database

1992-1996 Honorable Discharge - U.S. Army
Tracked Vehicle Mechanic

Independently maintained platoon of 8 armored vehicles; troubleshooting, diagnosing, electrical, hydraulic, powertrain and suspension systems
Accelerated in rank from E1 Private to E4 Specialist in 20 months; received 3 Army Achievement Medals, 1 Good Conduct Medal and several Certificates of Acheivement

Summary of qualifications
Certified in laboratory safety, proficient in scanning electron microscopy and light microscopy. Water quality analysis, fish netting & electrofishing/fish ID, stream aquatic invertebrate sampling and ID, field navigation, lake elemental budgets and modeling, lake sediments analysis with paleolimnological techniques, field GIS data collection with multiple GPS units. Computer programs include: MS Office suite, SigmaPlot, Arc/Info Workstation, MatLab, MathCAD, SigmaPlot.

Professional memberships
Member, American Association for the Advancement of Science
Member, American Geophysical Union

References
Susan Riha, Department of Earth and Atmospheric Sciences, Ithaca, NY (607) 255-0314
Louis Derry, Department of Earth and Atmospheric Sciences, Ithaca, NY (607) 255-9354
Karen Roy, Adirondack Lakes Survey Corporation, Ray Brook, NY (518) 897-1354
Michael DeAngelo, Adirondack Watershed Insititute, Paul Smiths, NY (518) 327-6270
Michael Martin, Cedar Eden Environmental, LLC, Saranac Lake, NY (518) 891-6916

MARK L. HUTCHINS
Water Resource Engineer

Mr. Hutchins has been involved with water resource issues for more than 30 years. His expertise focuses on surface waters - lakes, rivers, streams, estuaries - and includes most aspects of water quality and quantity. Project experience includes input/output modeling to predict lake trophic state, DO/BOD modeling in rivers and streams, waste discharge plume modeling in estuaries and assessment of water quality impacts from various types of commercial, industrial and residential development. Mr. Hutchins as particular expertise in hydroelectric licensing/relicensing efforts, having been involved with water quality and quality studies for more than a dozen hydroelectric projects. Mr. Hutchins has been involved with the ski industry for more than 15 years. Activities have included wastewater discharge permitting , water quality impact assessments, water supply studies for snowmaking and minimum flow issues. Most recently, Mr. Hutchins has managed broad-based environmental documentation efforts to comply with NEPA regulations (EISs/EAs) and state permitting requirements associated with the ski industry, most of which has been related to snowmaking/minimum streamflow issues.

EDUCATION

M.S. 1977, Engineering/Water Resources, University of Maine
B.S. 1968, Geological Sciences, University of Maine

PROFESSIONAL EMPLOYMENT HISTORY

2002-present	Hutchins Consulting Services, Normandeau Associates, Inc.
1997-2002	Sno.engineering, Inc., SE GROUP
1985-1997	Normandeau Associates, Inc.
1982-1985	Maine Department of Environmental Protection
1973-1982	University of Maine, Environmental Studies Center, Land and Water Resources Center

SELECTED PROJECT EXPERIENCE

Vermont Yankee, VT (2002-present) - Participating in the preparation of a 316a document that evaluates potential impacts to the Connecticut River from an increase thermal discharge resulting from a proposed power upgrade at Vermont Yankee. Principal Investigator.

Attitash/Bear Peak, NH (2000-present) - Representing Attitash/Bear Peak's interests in proposed minimum flow regulation before the NH Department of Environmental Services and Legislative Committee hearings. Prepared formal responses to proposed regulations and proposed alternative minimum flow regulations. Project Manager.

Wildcat, NH (3rd party contractor to the U.S. Forest Service) (1999-2001) - Coordinated environmental and archaeological work to support the preparation of an Environmental Assessment for a variety of proposed actions at Wildcat Ski Area. Project Manager.

Great Northern Paper Company, ME (1998-present) - Providing water quality consulting services to GNP relative to water quality modeling of the Penobscot River. Project Manager.

Killington Ltd., VT (1996-1999) - Hydrologic analyses and biological evaluation of Woodward Reservoir in support of proposed snowmaking withdrawals; Act 250 compliance. Project Manager.

Pease Development Authority, NH (subconsultant to Underwood Engineers) (1996-1997) - Plume modeling using CORMIX to support a new wastewater outfall design. Project Manager.

Waterville Valley, NH (subconsultant to Sno. Engineering, 3rd party contractor to the U.S. Forest Services) (1995-1998) - Waterville
Valley snowmaking ponds EIS. Project Manager.

Town of Dartmouth, MA (subconsultant to Woodard and Curran, Inc.) (1995-1996) - Paskamanset River minimum flows. Project Manager.

Sugarbush, VT (subconsultant to Sno.engineering, 3rd party contractor to the U.S. Forest Service) (1994-1995) - Sugarbush snowmaking EIS. Project Manager.

Public Service Company of New Hampshire, NH (1994-1997) - Merrimack Station thermal impact evaluation. Project Manager.

City of Saco, ME (subconsultant to DeLuca Hoffman) (1994-1996) - Municipal tidewater wastewater outfall evaluation. Project Manager.

City of Saco, ME (subconsultant to DeLuca Hoffman) (1992-1996) - Saco River wasteload allocation. Project Manager.

Connecticut Department of Environmental Protection, CT (1992-1993) - Farmington River minimum flow. Principal Investigator.

Killington, Ltd., VT (1992) - Ottauquechee River minimum flow. Principal Investigator.

New England Power Co., MA, VT, NH (1991-1992) - Preparation of NPDES permit applications for 15 hydroelectric stations. Project Manager.

Central Maine Power Co., ME (1990-1991) - Moxie Stream minimum flow. Principal Investigator.

JENNIFER M. JACOBS

Environmental Research Group
Department of Civil Engineering
University of New Hampshire
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EDUCATION

Cornell University, Ithaca, NY	Ph.D., Civil Engineering, August 1997
Tufts University, Medford, MA	M.S., Civil Engineering, May 1993
Brown University, Providence, RI	B.S., Electrical Engineering, May 1987

PROFESSIONAL EXPERIENCE

2003 – present *Assistant Professor***.** University of New Hampshire, Dept. of Civil Engineering

1997- 2003 *Assistant Professor***.** University of Florida, Dept. of Civil and Coastal Engineering

2000 - 2003 *Affiliate Faculty Member.* University of Florida, College of Natural Resources

1989 - 1993 *Environmental Consultant.* Eastern Research Group, Lexington, MA

1987 - 1989 *Consultant.* Boston Systems Group, Boston, MA

PROFESSIONAL SOCIETIES

- American Geophysical Union, 1993 to present
- American Society of Civil Engineering, 1992 to present
- American Society for Engineering Education, 1996 to present
- International Association of Hydrological Sciences, 2000 to present
- American Meteorological Society (AMS), 2002 to present

RELEVANT PROJECTS

- NASA, 2004-2006: "*Multi-Scale Remote Assessment of Land-Surface Hydrological Response to Natural and Anthropogenic Stressors: A Case Study in the Florida Everglades Protection Area*".
- NASA NIP Award, 2001-2004: *"Characterization and Simulation of Remotely Sensed Soil Moisture for Rainfall-Runoff Modeling"*.
- SERDP, 1999-2004: *"Ecological Indicators of Environmental Change"*.
- Florida Department of Transportation, 2002-2004: *"Seasonal Variability of Near Surface Soil Water and Groundwater Tables in Florida"*.
- Florida Space Grant Consortium, 2001-2002: *"Characterization and Simulation of Remotely Sensed Soil Moisture for Rainfall-Runoff Modeling – Undergraduate Scholar"*.
- Suwannee River Water Management District, 2001-2002*:"Minimum Flows and Levels for the Lower Suwannee River Implementation Methodology"*.
- USGS, 2001-2002*:" Flow Duration Curves to Advance Ecologically Sustainable Water Management"*

RELEVANT PUBLICATIONS AND TECHNICAL REPORTS

Satti, S.R. and J.M. Jacobs. GWRAPPS: A GIS-based Decision Support System for drought water requirement. to appear in *Agricultural Water Management,* 2004.

Jacobs, J.M. 2003. Review of *Ecohydrology: Darwinian Expression of Vegetation Form and Function*, P.S. Eagleson, Cambridge University Press, Cambridge, United Kingdom to appear in *EOS Transaction, American Geophysical Union.* 2003.

Bryant, M.L., Bhat, S., and J.M. Jacobs. Throughfall characterization of heterogeneous forest communities in the southeastern U.S., *Journal of Hydrology*. Accepted September 2003.

Ripo, G.R., J.M. Jacobs, and J.C. Good, An Algorithm To Integrate Ecological Indicators With Streamflow Withdrawals, Proceedings of the EWRI World Water and Environmental Resources Congress, Philadelphia, PA, June 2003.

Jacobs, J.M., G.R. Ripo, J.C. Good, and S.R. Satti*, Sustainable Watershed Ecohydrology And Optimized Water Management Using A Flow Duration Curve Framework, Supplement to European Geophysical Society/American Geophysical Union/EUG Joint Meeting, Nice, France, April 2003.

Satti, S.R. and J.M. Jacobs.GIS-based Water Resources and Agricultural Permitting and Planning System (GWRAPPS) - An ArcGIS Decision Support System for St. Johns River Water Management District (SJRWMD), 2002.

Tkaczyk, M*, J.W. Jawitz, J.M. Jacobs, S. Bhat*, P.S. Rao, and N. Haws, Rainfall/Runoff Analysis to Investigate the Effects of Soil Heterogeneity on Watershed Response Utilizing Topmodel, Supplement to AGU Spring Meeting, Washington, DC, May 2002.

Satti*, S.R and J.M. Jacobs. GWRAPPS: A GIS-based Decision Support System for Florida 1-in-10 Drought Water Requirements, Proceedings of the ASCE World Water and Environmental Resources Conference, Roanoke, Va, May 2002.

Jacobs, J.M. and G. Ripo. Minimum Flows and Levels for the Lower Suwannee River - Implementation and Methodology. University of Florida, *Final Report to SRWMD*, Gainesville, Florida, June 2001. 129 pages.

Good, J.C. and J.M. Jacobs. Ecologically Sustainable Watershed Management using Annualized Flow Duration Curves, Proceedings of the ASCE World Water and Environmental Resources Congress, Orlando, FL, May 2001.

Bhat, S., J.M. Jacobs, W. Graham, P.S. Rao, N. Haws*, W.F. DeBusk, J.W. Jawitz, Identification of Eco-Hydrologic Indicators of Ecological Impact: Phase I Results from Fort Benning, Georgia Watersheds, Supplement to AGU Spring Meeting, Boston, MA, May 2001.

Jacobs, J.M. and J.C. Good. Application of Annualized Flow Duration Curves to Minimum Water Flows and Levels, Supplement to AGU Spring Meeting, Boston, MA, May 2001.

Good J.C. and J.M. Jacobs, Use of Annualized Flow Duration Curves for Minimum Flows and Levels. Florida Section ASAE Annual Conference, Orlando Florida, Cocoa Beach, FL, May 2001.

Jacobs, J.M. and R.M. Vogel. Allocation of Water Withdrawals in a River Basin, Proceedings of the 25th Annual Conference on Water Resources Planning and Management, Chicago, IL, June 1998.

Jacobs, J.M. and R.M. Vogel. 1998. The optimal allocation of water withdrawals in a river basin, *Journal of Water Resources Planning and Management*, ASCE, 124(6), 357-363.

AL LARSON P.G.
Principal Geoscientist

Mr. Larson has 20 years of professional experience in environmental geology and hydrology. His experience includes numerous Environmental Impact Statements, Environmental Assessments and FERC Relicensing Studies. He has been responsible for the development and implementation of surface and ground water flow and quality monitoring networks, fluvial geomorphic assessments and hydrologic/hydraulic modeling and wetland restoration. His experience includes projects in the Pacific Northwest, Rocky Mountain, Central and New England Regions.

EDUCATION

M.S. 1983, Earth Science, University of New Hampshire
B.S. 1978, Geology, SUNY Cortland, NY
A.S. 1976, Geology, Orange County Community College, NY

PROFESSIONAL EMPLOYMENT HISTORY

1986-Present Normandeau Associates, Inc.
1985-1986 Wehran Engineering
1981-1985 Camp, Dresser and McKee

PROFESSIONAL AFFILIATIONS And REGISTRATIONS

American Geophysical Union
American Water Resource Association
Geological Society of America
National Ground Water Association
Professional Geologist, PA (PG-002373-G)
Professional Geologist, NH (#137)

SELECTED PROJECT EXPERIENCE

Ameren UE, MO (2001-Present). Member of Erosion Advisory Team for the Bagnell Dam FERC relicensing project. Reviewed historical studies of channel and bank erosion on the Osage River and recently completed Erosion Study Summary Report to be submitted with FERC relicensing documentation. Project Geomorphologist.

Tuckahoe Turf Farm, ME (2001-Present). Supervised hydrologic investigation of proposed turf farm and its impacts on wetland hydrology. Included installation of a network of piezometers and continuous water level monitoring. Project documented re-establishment of ground water flow system following elimination of subsurface drain system.

Portland General Electric, OR (2000-2001) – Performed an evaluation of sedimentation related to the operation of the Willamette Falls Hydroelectric Project. As part of the FERC relicensing process the accumulation of sediments in the Willamette River upstream of the dam was evaluated

based upon a review of existing environmental, geomorphic and hydrologic information. Project Geomorphologist.

FPL Energy Maine Hydro LLC, ME (2000-2001) – Assisted in fluvial geomorphic assessment of impacts associated with the operation of the Indian Pond (Harris Dam) Hydroelectric Project, including initial assessment of the impacts to aquatic habitat from hydroelectric peaking operations and white water boating flow releases. Assessment included preliminary geomorphic evaluation of the upper Kennebec River focusing on sediment transport and channel morphology. Project Geomorphologist.

Tapoco, Inc., TN and NC (2000-2001) – Performed an investigation of the impacts of the Tapoco Hydroelectric Project on the hydrologic regime of the Cheoah and Little Tennessee Rivers as part of a FERC relicensing study. This investigation involved the statistical analysis of stream flows and reservoir surface water elevation data. The objective of this analysis was to determine the range and duration of stream flows and the variability of reservoir surface elevations relative to their impacts on aquatic habitat. Project Hydrologist.

Maine Turnpike Authority, ME (1999). Performed hydrologic assessment of a former sand and gravel pit for a wetland creation design project. Installed a network of piezometers to evaluate depth to ground water and direction of ground water flow. Also investigated potential recharge and water quality impacts to a local municipal water supply well. Project Hydrologist.

Massachusetts Water Resource Authority, MA (1998) – Performed analysis of potential impacts of relief sewer on water resources in the Weymouth-Fore Drainage Basin as part of an Interbasin Transfer Permit Application. Evaluated impact of inflow/infiltration losses on surface and ground water resources. Project Hydrologist.

U.S. Army Corps of Engineers, WA (1997-1999) – Responsible for the development and design of a sediment quality database for the Lower Snake River. Interpreted sediment quality to evaluate potential impacts associated with the alternatives analysis in the Environmental Impact Statement for the Lower Snake River. Project Geologist.

SPECIAL TRAINING

Designing Stream Restoration Works, The Waterloo Stream Course, 2001.
Design of Surface and Ground Water Monitoring Networks, Colorado State University, 1981.
Wildland Hydrology, Research and Educational Center for River Studies:
- Fluvial Geomorphology for Engineers, 2000.
- River Morphology and Applications, 2001.
- River Assessment and Monitoring, 2001.

DENNIS W. MAGEE
Vice President/Group Leader

Mr. Magee has over 32 years of experience as an environmental consultant. He has been a principal investigator or program manager on several hundred projects occurring in offshore coastal, intertidal, freshwater wetland and terrestrial environments. Mr. Magee's primary areas of technical expertise are project scoping, management and permitting, vascular plant taxonomy, wetlands assessment and mitigation, and vegetation and wildlife investigations. Throughout his career, Mr. Magee's research interests have been focused on the vegetation and wetlands of the Northeast. This research has culminated in the publication of three reference works *Freshwater Wetlands*; *A Rapid Procedure for Assessing Wetland Functional Capacity*; and *Flora of the Northeast*.

EDUCATION

M.S. 1970, Forest Ecology & Botany, University of Massachusetts
B.S. 1968, Wildlife Biology & Zoology, University of Massachusetts

PROFESSIONAL EMPLOYMENT HISTORY

1978-Present Normandeau Associates, Inc.
1975-1978 Interdisciplinary Environmental Planning (now ENSR)
1971-1975 Jason M. Cortell and Associates

SELECTED PROFESSIONAL ACTIVITIES

National level

- committees to develop hydrogeomorphic procedure guidance for depressional and slope wetland functional capacity
- guidance for USEPA personnel to determine the effectiveness of requiring wetland creation or restoration to compensate for permitted wetland alteration
- co-presenter of a series of training workshops on the Hollands-Magee wetland assessment method to state and Federal agency staff.

State or regional level

- assisted in the development of MADEP policy for evaluating and replicating wildlife habitat under the MA Wetlands Protection Act
- technical advisor to Maine Chamber of Commerce and Industry in drafting new wetlands legislation for the State of Maine
- testified in support of an act to establish an official rare plant list in Maine before the Joint Committee on Energy and Natural Resources

SELECTED PROJECT EXPERIENCE

Tennessee Valley Authority (On-going) – EIS on impacts of current hydroelectric system operations and proposed alternative operations on natural resources. Project Manager.

Alcoa Power Generating, Inc. (2001) – Hydroelectric project relicensing, Tapoco River (TN). Riparian resources baseline characterization and impact assessment. Project Manager.

Mount Snow Ski Resort (1999) – Trail expansion and snowmaking ponds (EIS). Project Manager.

US ACOE, WES (1997) - Developed a rapid procedure for assessing wetland functional capacity based on hydrogeomorphic classification. Project Manager.

Wisconsin Valley Improvement Company (1996) - Hydroelectric Project Relicensing (WI); Project Manager.

Great Northern Paper Company (1993) - Hydroelectric project relicensing (ME). Natural resources baseline characterization and impact assessment; FERC Exhibit E. Project Manager.

Great Northern Paper Company (1986) - Big "A" Hydroelectric Development Project (ME); Assessment of existing natural resources and feasibility study. Project Manager.

PUBLICATIONS

Magee, D.W. and H.E. Ahles. 1999. Flora of the Northeast:A Manual of the Vascular Flora of New England and Adjacent New York. Univ. of Mass. Press. 1248 pp.

Magee, D.W. A Primer on Wetland Ecology, Chapter 3. In. Federal Wetlands Regulation. The American Bar Association. In production. 52 pp.

Magee, D.W. and G.G. Hollands. 1998. A Rapid Procedure for Assessing Wetland Functional Capacity Based on Hydrogeomorphic (HGM) Classification. The Association of State Wetland Managers. Berne, NY. 190 pp.

Magee, D.W. 1981. Freshwater Wetlands: A Guide to Common Indicator Plants of the Northeast. Univ. of Mass. Press. 245 pp.

Magee, D.W. 1996. The Hydrogeomorphic Approach: A Different Perspective. Society of Wetland Scientists Bulletin. Vol. 13, No. 2.

Taylor, W. and D.W. Magee. 1992. Should All Wetlands Be Subject to the Same Regulation? Natural Resources and Environment. American Bar Association. V. 7, No. 1, Summer.

DONALD P. MASON
Aquatic Ecologist

Mr. Mason has over 17 years' experience assessing the effects of habitat alteration on aquatic ecosystems. His specialties include evaluating the effects of hazardous substances, hydropower, and commercial development on fish and benthic macroinvertebrate com-munities. Mr. Mason has conducted and managed several studies using freshwater macroinvertebrates as pollution indicators, assessing the impacts of road and highway construction on aquatic communities and searching for rare, threatened, or endangered aquatic species.

EDUCATION

M.S. 1982, Entomology, University of New Hampshire
B.A. 1976, Biology, Plymouth State College

PROFESSIONAL EMPLOYMENT HISTORY

1985-Present	Normandeau Associates, Inc.
1983-1985	Battelle New England Marine Research Laboratory
1982-1983	Normandeau Associates, Inc.
1982	Charles T. Main, Inc.

PROFESSIONAL AFFILIATIONS AND SPECIAL TRAINING

North American Benthological Society
New England Association of Environmental Biologists
Freshwater Mollusk Conservation Society
Rapid Bioassessment Protocols (RBP)
Habitat Evaluation Procedures (HEP)

SELECTED PROJECT EXPERIENCE

Tri-Town Wildlife Surveys (2001-Present) - Survey for three species on the MA Natural Heritage and Endangered Species Program list in the west branch of French's Stream on the former South Weymouth Naval Air Station property (MA). Principal Investigator.

Pond Eddy Bridge (PA) Mussel Survey (2001-2002) - Conducted a mussel survey near the Pond Eddy Bridge, Delaware River. Project Manager.

Centredale Manor (RI) Restoration Project Superfund Site Human Health and Ecological Risk Assessment (2001) - Analyses of benthic macro-invertebrates, fish, emerging aquatic insects, ichthyoplankton, and soil earthworms community and bioaccumulation at a multi-unit apartment complex on the property of a former chemical manufacturer contaminated with dioxin and PCBs. Project Manager.

Elizabeth Mine (VT) Superfund Site Bioassessment (2000-2002) – habitat and benthic community

assessment along Copperas Brook, heavily contaminated with acid mine drainage and metals from an abandoned mine. Project Manager

Tenney Brook Tributary (VT) Expert Witness Testimony (2000-2001) - Testified before Vermont's Act 250 Board regarding habitat quality of an unnamed tributary that was proposed for relocation. Project Manager.

Natick SSCOM Tier II Ecological Risk Assessment (1998-2001) - Assessed benthic macroinvertebrate and fish communities near two stormwater outfalls suspected of discharging SVOCs, PAHs, and pesticides using a recently developed biomonitoring protocol designed for lentic environments (Hicks 1997). Project Manager.

Paulins Kill (NJ) River Dwarf Wedge Mussel Survey (1999) - Surveyed 8 miles of the river for Dwarf Wedge Mussels and characterized mussel habitat. Field Supervisor.

East Branch of Sebasticook River (ME) Habitat Inventory (1998) - Evaluated impacts to benthic macroinvertebrate and fishery habitats in areas where sediment levels of heavy metals and PCBs were elevated. Project Biologist.

City of Manchester (CT) (1994, 1996, 1998) - Assessment of the fish and benthic macroinvertebrate communities in the Hockanum River for discharge permit application for municipalSanitary Landfill and sewage treatment plant. Sr. Ecologist.

Dexter Corporation (CT) (1997) - Surveyed of streambed in Stony Brook (CT), near an aqueduct proposed for reconstruction, to look for Dwarf Wedge Mussel. Project Manager.

New Hampshire DOT (1997) – Diver survey in the Johns River (NH) at a bridge reconstruction site, to look for Dwarf Wedge Mussels. Project Manager.

Paradise Pond (MA) Dredging Mitigation Project (1997) - Mitigation for dredging impacts on a downstream population of Dwarf Wedge Mussel. Technical Director.

City of Brockton (MA) (1997) - Shoreline survey (Silver Lake) for two freshwater mussels included in the Massachusetts list of species of special concern. Project. Manager.

Maritimes & Northeast Pipeline (ME) (1997) - Conducted a freshwater mussel search and evaluated mussel habitats in several stream crossings. Project Biologist.

SE Technologies, Inc. (CT) (1997) – Assessment of benthic macroinvertebrate community using EPA's RBP II and endangered aquatic species search near a closed electroplating facility in Fivemile River (CT). Project Manager.

Deschutes River Natural Resource Damage Assessment (OR) (1996-1997) – Assessment of short and long term effects of a diesel spill on the benthic macroinvertebrate community with on-site approval by State, Federal, and Tribal trustees. Principal Investigator.

DOUGLAS A. NIEMAN
Senior Scientist
Certified Fisheries Professional

With 25 years experience at Normandeau, Mr. Nieman's duties include applied research and evaluation of aquatic populations, communities, and environmental variation in streams and rivers and instream flow-habitat needs of aquatic biota. He has formal training and experience in biostatistics and statistical ecology, including multivariate and multimetric data analysis. Mr. Nieman is trained in the U.S. Fish and Wildlife Service Instream Flow Incremental Methodology (IFIM) and has conducted IFIM studies in PA, NC, SC, TN, WV, MA, CT, NH, and ME. He has training in hydrology, fluvial geomorphology, and stream assessment using the Rosgen methodology. Mr. Nieman conducted research and formulated conceptual designs for a GIS for aquatic resource characterization of the Three Rivers in western PA, including use of side-scan sonar for characterizing benthic habitat.

EDUCATION

M.S. 1978, Zoology, Oklahoma State Univ.
B.S. 1976, Zoology, The University of Oklahoma

PROFESSIONAL EMPLOYMENT HISTORY

1979-Present	Normandeau Associates, Inc.
1978-1979	Oklahoma Department of Wildlife Conservation
1976-1978	Oklahoma Cooperative Fishery Research Unit, Oklahoma Fish and Game Council Fellow
1976	Oklahoma Department of Wildlife Conservation

PROFESSIONAL AFFILIATIONS

American Fisheries Society
Pennsylvania Academy of Science
Ecological Society of America
PA Registry of Biodiversity Inventory Specialists

SELECTED PROJECT EXPERIENCE

Public Service Company of New Hampshire (2002-Present) - Principal: flow and habitat management of three bypasses at hydroelectric projects on the Merrimack River, NH.

Santee-Cooper Project (2001-Present) – Co-investigator: hydrologic analyses (IHA), MesoHABSIM, R2D 2-dimensional modeling and floodplain inundation evaluations for the lower Santee River, SC.

Reliant Energy Company (1999-Present) – Principal: instream flow study on the Clarion River, PA to support FERC relicensing of a large hydroelectric facility.

PECO Energy Company (1979-Present) – Principal: multiyear, multidisciplinary monitoring program to evaluate effects of flow augmentation on water quality, stream habitat, and aquatic communities in a Piedmont warmwater stream in southeast PA.

Alcoa Generation, Inc. (2000-2001) – Principle: instream flow, stream habitat restoration, and habitat fragmentation evaluations for Cheoah-Little Tennessee River systems in NC as part of FERC relicensing of four hydroelectric projects

FPLE Maine Hydro, LLC. (1999-2000) – Principal: instream flow study on the Kennebec River, ME in support of FERC relicensing of a large mainstem hydroelectric facility.

U.S.A. Waste, Inc. (1998) – Co-investigator: technical guidance for stream habitat restoration to civil engineers designing a relocated channel at a northeast PA landfill.

Ohio River Valley Water Sanitation Commission (1989-1998) – Co-investigator: provided fisheries ecology expertise for a GIS of the Three Rivers area near Pittsburgh, PA. Duties: developed an aquatic habitat classification and described fish habitat-use patterns using multivariate analyses of habitat suitability information; aided development of information systems needed to acquire, store, and analyze natural resources inventory data.

Northeast Utilities Company (1997-1998) - Principal: instream flow study using IFIM/PHABSIM on the Housatonic River, CT.

Massachusetts Water Resources Authority (1996-1998) - Principal: IFIM/PHABSIM study on the Swift River below Quabbin Reservoir, MA.

Woodard and Curran Environmental Services (1995) - Principal: analysis of habitat suitability in relation to stream flow in the Paskamanset River, MA using PHABSIM.

Allegheny Power Service Corp. (1993) – Principal: instream flow study of the Cheat River, WV below Lake Lynn Hydro Station, which included application of dual-flow habitat modeling with PHABSIM.

Carolina Power & Light Company (1992) – Co-investigator: instream flow study of the Pigeon River bypass at a hydroelectric station in NC. Duties involved all phases of the project, including post-study negotiations with regulatory agencies to determine minimum flow recommendations as part of the FERC relicensing process.

SPECIAL TRAINING

IFIM Training Courses:

IF 200: Designing and Conducting Studies Using IFIM
IF 305: Field Techniques for Stream Habitat Analysis
IF 310 Using the Computer-Based Physical Habitat Simulation System

- Two Dimensional Hydraulic Simulation and Habitat Modeling with R2D Software. U.S. Fish and Wildlife Service National Conference and Training Center, Shephardstown, WV, March 2001
- Multivariate Ecological Data Analysis. U.S. Fish and Wildlife Service National Conference and Training Center, Shephardstown, WV, February 2000.
- Stream Restoration Construction Techniques, Brightwater, Inc. Ellicott City, MD, May 1999.
- Applied Fluvial Geomorphology using the Rosgen Stream Classification System, Brightwater, Inc. State College, PA, September 1998.
- Aquatic Habitat Assessment - Methods and Analysis, NY and PA Chapters of the American Fisheries Society, January 1996.
- AFS Continuing Education Courses:
    - Fishery Economics for the Non-economist. August 2002.
    - Introduction to GIS. August 2002.
    - Fluvial Geomorphology. August 2000.
    - Modeling Demystified. August 1998.
    - Microcomputer Applications in Fisheries Science. August 1997.

ROBERT M. ROSEEN, Ph.D.

Environmental Research Group
Department of Civil Engineering
University of New Hampshire
Durham, NH 03824

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fax: 603-862-3957
e-mail: robert.roseen@unh.edu

Formal Education

University of New Hampshire, Durham, NH, PhD Civil Engineering, Water Resources Engineering, May 2002.

Colorado School of Mines, Golden, CO, MS Environmental Science and Engineering, 1998.

Clark University, Worcester, MA, BA Environmental Science/Chemistry, 1994.

Professional Experience

2002-present Research Engineer II, University of New Hampshire, Department of Civil Engineering, Water Resources.

2001-Present Water Resources Engineer, The Bioengineering Group, Inc., Salem, MA

1998-2001 Graduate Research Assistant, University of New Hampshire, Department of Civil Engineering, Water Resources.

1997-1998 Environmental scientist and engineer, Waterstone Environmental Hydrology and Engineering, Boulder, CO.

Instream Flow, Dam Removal, Riparian Restoration, Hydrologic Monitoring, Modeling, and Channel Design

- Selected as UNH Team member for the NH Coastal Program "On-Call Engineering Team" for Dam Removal Feasibility Studies, Fall 2003. Dr. Roseen has been working with the New Hampshire Department of Environmental Services and the River Restoration Task Force to develop a collaborative monitoring and research endeavor between the state and UNH.
- Hydrology and hydraulic modeling analysis and report produced for proposed dam removal and associated restoration for the Mill River Dam, Stamford Connecticut. The impoundment is a head-of-the-tide dam with water quality degradation associated with low-velocity, high-residence time waters. Restoration impacts evaluated included sediment transport and impacts on flooding.
- Hydrology and hydraulic modeling analysis and report produced for current, proposed restoration, and historic conditions for the Popes Branch and Fort Dupont watersheds. The project is for the Army Corps of Engineers, Baltimore District, in partnership with the District of Columbia Department of Health, is developing a restoration plan for Pope Branch and the lower end of Anacostia Park.
- Hydrology and Hydraulics modeling analysis and report for the salt marsh restoration of Broad Meadows Marsh, Quincy, MA. This report entailed evaluating 100-year risk of tidal flooding, wave overtopping, designing flooding regime to optimize salt marsh revegetation and channel design for the Army Corps of Engineers, New England Division.

Project Management Skills

- Co-PI on a current 3-year research project titled the *Center for Stormwater Technology Evaluation Verification.* Responsibilities include coordinating the development of the research facility for the Environmental Research Group at the University of New Hampshire, permitting and contracting procedures, development of collaborative efforts with manufacturers, site design for 12 stormwater treatment devices, selection of treatment technologies, evaluation of site hydrology, and sampling and monitoring design. This project will fund research for 1 doctoral and 2 masters level engineering students.
- Coordinated a three-year study of groundwater discharge to the Great Bay Estuary. This study verified a new methodology using innovations in thermal infrared remote sensing, GIS, and field characterizations for determining total groundwater flow to the coastal waters.
- Led a 2-year cooperative effort for the research and publication of *Groundwater Potentiometric Surface For Bedrock Aquifer Of Area Immediately Surrounding Great Bay, Southeastern New Hampshire* between the USGS and UNH. This effort entailed massive reconnaissance and field efforts to assess, survey, and sample over 200 wells in 7 communities surrounding the Great Bay Estuary. Coordination of multiple survey teams, multiple sampling events, database management, and data reduction.

Relevant Publications and Technical Reports

Roseen, R. M., M. Collins, *Mill River Dam Removal Feasibility Study, Rippowam River, Stamford, Connecticut* , Principal author and water resources engineer.
Roseen, R. M., M. Silva, Summer 2002, *Hydrology and Hydraulics Investigation for Popes Branch Watersheds Restoration Project*, Maryland, Principal author and water resources engineer.
Roseen, R. M., K. Barrett, September 2001, *Hydrology and Hydraulics Investigation for Broad Meadows Restoration Project*, Quincy, Massachusetts, Principal author and water resources engineer.

Professional Licenses and Affiliations

Engineer-IN-Training, License #3768, New Hampshire, 1999
American Geophysical Union
American Society of Civil Engineers
Society of Wetland Scientists
Geological Society of America

Dr. Thomas P. Seager

Research Project Engineer, Environmental Research Group
244 Environmental Technology Building
University of New Hampshire
Durham NH 03824
Tom.Seager@unh.edu
(603) 862-4023

Education

Clarkson University	Civil and Environmental Engineering Principal advisor: Dr. Thomas L. Theis	Ph.D. 2001
Clarkson University	Civil and Environmental Engineering	M.S. 1994
Clarkson University	Civil and Environmental Engineering	B.S. 1987

Professional Appointments

Aug. 2002 – present	Research Project Engineer Environmental Research Group, UNH
Jan. 2002 – Jun. 2002	Visiting Assistant Research Professor Civil and Environmental Engineering, Clarkson University
1998-2001	Environmental Manufacturing Management Research Fellow Civil and Environmental Engineering, Clarkson University
1999-2001	Lucent Technologies/NSF Industrial Ecology Research Fellow Civil and Environmental Engineering, Clarkson University
1997-1998	Instructor and Teaching Assistant Civil and Environmental Engineering, Clarkson University
1996-1997	Adjunct Assistant Professor Civil Engineering, Union College
1993-1997	Tenure-track Instructor Civil Eng. & Construction Mgt. Tech., Hudson Valley CC
1991-1993	Teaching & Research Assistant Civil and Environmental Engineering, Clarkson University
1990-1992	Consulting construction engineer

Honors, Awards, and Professional Activities

Member, Int. Assoc. of Public Participation
Member, Society of Risk Analysis
UNH Climate Education Initiative Committee (Aug 2002-present)
Editorial Board, Founding Member, *Progress in Industrial Ecology* (Aug 2003-present)
Guest co-Editor, *Res., Cons., & Recycling*, Special Issue on Highway Materials (expected 2004)
Summer Symposium for Sustainability Organizing Committee (June 2001)
Founding Chair, International Student Committee on Industrial Ecology (June 2000 - June 2001)
George A. Gray Outstanding Civil Engineering Graduate Student Fellowship (1998)
Outstanding Graduate Student Teacher Award, Clarkson University (1991)
Gananoque99: Student Environmental Research Conference Organizing Committee Chair (1999)
Chi Epsilon Civil Engineering Honor Society, Clarkson University (1986)

Related Professional Experience and Certifications
Environmental Health and Safety Doctoral Resident, Eastman Kodak Corp. (summer 1999)
Engineer-in-Training (registered NY, 1987)
Surveyor-in-Training (registered MA, 1989)
Surveying Engineer (1987-1990) and Consulting Surveying Engineer (1990-1996)

Book Chapters
Seager TP. 2004. Introducing industrial ecology and the multiple dimensions of sustainability. In *Strategic Environmental Management* edited by B Bellandi. John Wiley & Sons: New York NY. In press.

Rogers SH, Seager TP, Gardner KH. 2004. Combining expert judgment and stakeholder values with PROMETHEE: A case study in contaminated sediments management. In *Comparative Risk Assessment and Environmental Decision-Making* edited by I Linkov. Kluwer Academic Press: Boston MA. In press.

Linkov I, Varghese A, Jamil S, Seager TP, Kiker G, Bridges T. 2004. Multi-criteria decision analysis: A framework for structuring remedial decisions at contaminated sites. In *Comparative Risk Assessment and Environmental Decision-Making* edited by I Linkov. Kluwer Academic Press: Boston MA. In press.

Journal Publications
Grimes HG, Seager TP, Theis TL, Powers SE. 2004. A game theory framework for cooperative management of the bottle lifecycle. *Env. Sci. & Tech.* Under review.

Seager TP, Theis TL. 2004. A taxonomy of metrics for testing the industrial ecology hypotheses and application to design of freezer insulation. *Journal of Cleaner Production*. In press.

Dalton JL, Gardner KH, Seager TP, Weimer ML, Spear JCM, Magee BJ. 2004. Properties of portland cement made from contaminated sediments. *Resources, Conservation, and Recycling.* In press.

Seager TP, Theis TL. 2002. Exergetic pollution potential: Estimating the revocability of chemical pollution. *Exergy, An International Journal*. 2:273-282.

Seager TP, Theis TL. 2002. A uniform definition and quantitative basis for industrial ecology. *Journal of Cleaner Production*. 10(3):225-235.

Seager TP, Theis TL. 2002. A thermodynamic basis for assessing GWP & ODP policy trade-offs. *Clean Technologies and Environmental Policy*. 4:217-226.

Selected Courses Taught

Graduate:
Env. Systems Analysis & Design

Baccalaureate:
Hydrology
Engineering Measurements
Environmental Eng. Senior Lab
Land Measurements

:

Associate
Concrete Construction
Civil Eng. Tech. Computer Applications
Site Development
Construction Surveying
Survey I (Civil Tech)
Site Surveying
Construction Management Seminar