

Prospectus to Nominate the Connecticut River as a Hydrologic Observatory

<http://www.unh.edu/erg/connho/>

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I. Spatial Extent of Hydrologic Observatory

a. Scientific Rationale for Design

The Connecticut River basin possesses some characteristics that make it unique for studying hydrologic issues that transcend scale. The watershed was first dramatically altered through natural processes (glaciation) and then heavily impacted by human stresses (dams, deforestation, acid precipitation/deposition), only to exhibit recent decades of return to a more natural state (reforestation, land conservation, stream restoration, pollution abatement, and dam removal). The watershed is sufficiently north to be classified as a cold region. More specifically to hydrology, the watershed exhibits the spectrum of flooding problems: ice dams, convective storms, hurricanes, rain on melting snow, and low pressure systems. Due to its rich natural diversity and special qualities, in 1998 it was designated an American Heritage River. The entire watershed is a National Fish and Wildlife Refuge. The estuarine wetlands at the mouth of the Connecticut River are some of the least developed or disturbed large-river tidal marsh systems in the United States, and the most pristine in the Northeast. The Nature Conservancy awarded special recognition to the tidal wetlands by designating them as one of their "Last Great Places". The Northern Forest is a continuous tract of forested land covering 26 million acres from New York to Maine. This is a nationally significant natural resource and includes approximately one-sixth of the Connecticut River watershed.

The geologic setting of the Connecticut River offers both inter-basin geologic heterogeneity and large-scale homogeneity. Sub-basins along the eastern side of the Connecticut River are generally underlain by granites and other crystalline rocks which, for example, offer little buffering to the effects of acidified precipitation. These effects are well documented at the Hubbard Brook Long Term Ecological Research (LTER) site. In contrast, sub-basins along the western side of the Connecticut are underlain by calcareous-rich rocks and generally have been little impacted by acidified precipitation. Inter-basin studies on the differential effects of geology on watershed processes across the Connecticut River watershed are simplified by relatively small variations in precipitation, relief, climate and anthropogenic disturbances (e.g., urbanization and N deposition rate, Aber et al., 2003) across the watershed. This east-west symmetry of geologic heterogeneity is similar in Connecticut watersheds as small as a few hundred kilometers to those as large as 10,000 square kilometers. Land use, precipitation, and relief are similarly more or less homogeneous across this range of scales, greatly simplifying analyses of scaling of hydrologic processes across a large range of scales.

USGS stream monitoring began early in New England with numerous gages having records beginning in the 1910s. This lengthy record coincides with other changes in the New England landscape, primarily the shift away from agriculture and grazing (both cattle and sheep). The peak of land clearing occurred in the late 1800s and declined dramatically over the 20th

Century, with many parts of the region currently at their highest levels of forest cover in well over one hundred years. This reforestation provides a rare opportunity within the scientific community to evaluate hydrologic changes due to watershed amelioration.

Hydrologic shifts have occurred throughout the 20th Century in all the gaged, unregulated streams in the region (Magilligan and Nislow, 2001) and are best demonstrated by the gage record of the White River in east-central Vermont. Besides decreased peak flows over time, significant changes have occurred in low flow conditions due to land use change. Low flow minima have steadily risen over the period of record as shown by the changes in the 1-day minimum flow, although all low flow durations (3-day, 7-day, etc.) show the same increasing trend (Magilligan and Nislow, 2001). The increased low flow over time probably reflects the 20th century re-forestation and corresponds to the type of hydrologic changes that occur following land use change (Potter, 1991). Comparison of the mean annual hydrographs for the beginning (1912-1922) and end (1990-2000) of the record shows the different shapes of the recharge limb during the autumnal recharge, and also the different magnitudes of the snowmelt signal (Magilligan and Nislow, 2001). Baseflow begins earlier in the fall and also remains higher than in the beginning of the record through the fall and into the winter runoff, in part due to increases in soil infiltration. Because the Upper Connecticut River basin lacks other forms of disturbance, such as urbanization, it becomes a fantastic laboratory to analyze hydrologic response to climate and land use change at large watershed scales.

One of the salient characteristics of studying the Connecticut River is that it is an especially sensitive region to climate change, especially its response to extreme events such as floods. The Connecticut River basin possesses a continental humid climate with precipitation averaging ~ 900 mm/yr with a relatively even distribution throughout the year. The even precipitation pattern, however, does not manifest in an even flood distribution. New England possesses a mixed population flood regime with several flood-producing mechanisms present: rain (sometimes as hurricanes), rain-on-snow/frozen ground, and snowmelt (Magilligan and Graber, 1996). Large floods have ravaged New England throughout the early to mid-twentieth century with catastrophic floods occurring in 1927, 1936, 1938, 1954, 1955, 1969, and 1987 (Jahns, 1947; Patton, 1988). These different flood-producing mechanisms result in floods of varying seasonal timings (spring runoff events vs. fall hurricanes), intensities, and durations, with each flood-producing mechanism being sensitive to different elements of climate change. Global climate change models indicate that not only will the means of precipitation and temperature be affected, but that changes in variability may be even more pronounced. For New England, this may result in the greater occurrence of hurricane-induced floods, which for many parts of the Connecticut River basin have been the largest floods of record (1927, 1954, and 1955). Moreover, recent analyses of 20th century climate change indicate that New England rivers are already reflecting global warming with the timing of the spring flood occurring earlier in the latter part of the record (Hodgkins et al., 2003). Thus, the Connecticut River becomes a sensitive indicator to contemporary and future climate changes.

Numerous dams exist within the Connecticut River basin (over 1000), and their occurrence offers a unique opportunity to evaluate the effects of impoundment on watershed hydrologic, geomorphic, and ecological conditions. Because of the intensity and frequency of floods in the region, a series of flood-control dams were constructed in the 1950s and 1960s on some of the major tributaries of the Connecticut River. Conversely, most of the large dams on the mainstem Connecticut River are hydropower dams that were constructed in the early and middle part of the 20th century. These hydropower dams are operated by various public and

private utilities and contain a mixture of storage reservoirs and run-of-the river power generation facilities (Fallon-Lambert, 1998). As a result of the intensified construction of dams over the years, the region possesses one of the highest frequencies of dams per area in the United States (Graf, 1999) which provides a unique opportunity to evaluate the effects of impoundment on a watershed scale. Initial hydrologic analyses in the Connecticut River basin indicate that dams have profoundly influenced flow characteristics, and these hydrologic shifts resulted in significant habitat loss and dis-connectivity between floodplain surfaces and the modern hydrologic regime (Magilligan and Nislow, 2001; Nislow et al., 2002).

By the 1980's all basin states had enacted regulations for wastewater treatment in public systems as well as private (septic) systems. Since the 1990's, basin states have looked towards instream flow regulation, and in the new millennium, basin states are actively pursuing stream restoration and dam removal programs. In fact the 172-year-old McGoldrick Dam (on the Ashuelot River) was the first dam in the state of New Hampshire to be removed (July, 2001). Numerous dams in all Connecticut River watershed states are under varying stages of study for their removals. For over two decades, basin states have been actively cooperating between themselves and their federal counterparts on the restoration of the salmon fishery. All basin states have land trusts associated with the watershed.

There are NGOs at local through interstate levels specifically focused on the various aspects of watershed issues. This existing, publicly visible and supported watershed interest infrastructure underscores the ability to muster significant grass roots support for various research endeavors. A partial list of these NGOs includes: The Connecticut River Salmon Association, The Connecticut River Watershed Council, American Rivers, Clean Water Action, Clean Water Network, Chicopee River Watershed Council, Connecticut Riverfest (NH and VT) Connecticut River Salmon Association, Inc., Deerfield River Watershed Association, Farmington River Watershed Association, MA Watershed Coalition, Millers River Watershed Council, NH Coldwater Fisheries Coalition, NH Rivers Council, Rivers Alliance of Connecticut Riverfront Recapture, Inc. (Hartford, CT), River Network, Vermont Natural Resources Council, Vermont River Conservancy, Westfield River Watershed Association, and the White River Partnership.

Formal research consortia have also been focused on the Connecticut River watershed. These consortia include: the Connecticut River Airshed Watershed Consortium, Harvard Forest, and the nearby Hubbard Brook watershed.

b. Site Characteristics

The Connecticut River Watershed is a 28,000 square kilometer watershed that covers one third of the states of New Hampshire, Vermont, Massachusetts, and Connecticut. The >640-km long rivers' headwaters start on the Canadian border at the Fourth Connecticut Lake, and flows southward to discharge in Long Island sound. The lower 100 km of river are tidally influenced, indeed, the translation of the Native American name for the river is, "the long tidal river". The salt water portion of the estuary extends almost 32 km inland. The Connecticut River is responsible for 70 % of the freshwater inflow to Long Island Sound.

The Connecticut River is a sixth order stream that exhibits a dendritic pattern in an elongated scheme. This setting therefore affords many first and second order streams in almost parallel fashion, flowing west or east towards the central Connecticut River spine. There are 38 major tributaries to the mainstem Connecticut River, and 26 of these tributaries drain greater

than 250 square kilometers. There is in excess of 30,000 km of perennially flowing stream length in the watershed.

Land use in the watershed is dominated by forested regrowth (80%) followed by agriculture (12%), urban (3%), and the remainder being wetlands and water (5%). The urban areas include 390 towns, villages, and cities. The 2000 census identifies a population of approximately 2.3 million people. The watershed exhibits a broad range of population densities from extremely rural (< 30/sq. km) to urbanized (> 80/sq. km), with most of the urbanization occurring in the lower half of the watershed. Colonization in the watershed began in the 1600s and human influences on the river system include mining, combined sewer overflows, and waste load allocations for publicly-owned treatment works. In addition, a significant portion of the population living and working within the watershed has individual wells for ground water supply and septic systems for the disposal of wastewater.

The River drops 2,400 feet from its source to the sea. Geomorphically, the Connecticut River basin possesses high gradient streams to the low gradient estuary. In locations, active headcutting results in vertical instability whereas other tributaries are stable in bedrock valleys. Lateral instability is exhibited on the main stem and tributaries resulting in horizontal channel instability and the attendant issues of bank erosion and the legacy of past bank protection measures. Sediment transport also has resulted in reservoir sedimentation and river/estuarine shoaling. Much of the main stem and its tributaries exhibit well-established riparian zones however there are stretches where this zone is absent or constrained to a very thin border next to the river. In the 1800's, when much of the watershed was deforested, there was very little woody debris or shade from riparian vegetation: this had a dramatic effect on river geomorphology as well as habitat maintenance. As the watershed has reforested, there has been a dramatic shift in the types of habitat now sustained plant material availability to riverine and wetland habitats.

II. Existing Data Infrastructure

There are 68 active USGS stream gages in the watershed and another 13 gages within 100 km of the watershed. At Long Island Sound, the river discharges an average annual discharge of 450 m³/s yielding 0.016 cms/sq. km. Extreme flows here range from 27 m³/s to 8,000 m³/s. The USGS and state agencies also periodically monitor water levels in over 100 wells in the watershed. Many more wells are monitored in the basin by private and public entities (water supplies, contamination sites, bottling plants, industrial/commercial activities) who would be willing to share this rich database.

NOAA climate monitoring stations exist in 62 locations (<http://met-www.cit.cornell.edu/index.html>). Measured data includes atmospheric pressure, temperature, wind speed and direction, humidity, precipitation type and amount, cloud cover, and visibility. Much of this data is under the auspices of the Northeast Regional Climate Center which produces not only real time and historic information, but also derived productions such as solar radiation, evapotranspiration, and soil moisture. NOAA (through the NOS) also possesses a database of surface water level monitoring at 32 locations at the mouth of and in the Connecticut River estuary (http://www.co-ops.nos.noaa.gov/station_index.shtml?state=Connecticut&id1=846).

The USGS has been operating the Sleepers River watershed near St. Johnsbury, VT since 1991 (<http://nh.water.usgs.gov/CurrentProjects/sleepers/>); it is one of the five USGS WEBB sites (Water, Energy, and Biogeochemical Budgets). These are long-term sites for investigating

hydrologic and biogeochemical processes and trends. Prior to this USGS involvement, the Sleepers River watershed was a USDA ARS research watershed that was established in 1959: so there are some 40-plus years of hydrologic and meteorologic datasets. The Sleepers River watershed operates as a mini-HO, with the USGS conducting its own research while providing basic datasets and infrastructure to attract outside collaboration.

The Connecticut River basin has been the subject of two National Water Quality Assessment studies (NAWQA). The initial 5-year USGS NAWQA study of the Connecticut River basin began in 1991 and a second 5-year round is now ongoing. The NAWQA program aims to establish baseline conditions and long-term chemistry and biology for trends, with spatial sampling based on land use patterns. Among other results NAWQA has done a good job of identifying nitrate sources and relative importance of landscape types in Nitrogen delivery to streams.

Since 1907, environmental research has been conducted at the Harvard Forest (<http://harvardforest.fas.harvard.edu/>). Most of the data generated for these studies, including long term monitoring, is available at their web site. The USDA has four soil climate analysis network sites (SCAN <http://www.wcc.nrcs.usda.gov/scan/>) for the Connecticut River watershed.

Although not immediately in the Connecticut River watershed, the Hubbard Brook Ecosystem Study (<http://www.hubbardbrook.org/>) has been operating at the margin of the watershed since 1955.

III. Proposed Core Data

The core data set will include continuous collection of atmospheric, groundwater, vadose zone, and surface water measures in situ and using remote sensing products.

Streamflow will be based on the real time and other present USGS products. Some gages that were discontinued due to lack of funding will be considered for upgrade and re-starting. Up to one dozen other locations will be constructed. In addition, a network of five or six dozen staff gages will be installed that will be read manually by citizen monitors. Long term, periodic concurrent flows will result in rating curves for all of these staff gages.

Precipitation will be based on the existing NOAA network and other research installations (Hubbard Brook, Sleepers River, etc.).

Micrometeorological data include standard meteorological data and surface energy fluxes of water and sensible heat. Soil Moisture Using TDR is also data available at met stations to be included as core data.

Groundwater levels will be based on the current network of USGS and state environmental agency wells. In addition, existing wells that can be added to the network by simply adding a pressure transducer will be included. It is expected that three to four dozen more wells can be added to the USGS network.

Submerged Coastal Discharge will be reported as thermal infrared images taken twice per year (February and August). The images will be made as videos, and individual images cropped and digitized from the video.

Water Quality (instream and groundwater) will include presently available USGS data and that from state and local environmental agencies. This aspect alone is important because the data is presently being generated, but due to the diverse generation venues, it is not synthesized on the watershed-wide basis.

Remote Sensing Products as part of the core data will include: AVIRIS for multispectral characterization of land use, NEXRAD rainfall, LIDAR based topography and land cover characterization, GOES based solar and longwave radiation, AMSR and Hydros Soil Water and Snow Products, and MODIS Vegetation Products. The intent is to digitize these data streams and save it on an hourly time step, or as frequently as it is generated.

IV. Example Science Questions

- **What temporal and spatial scales best describe water-cycle variability as well as mass and energy fluxes from other multiple time scales?**

The existing ground-based and remote sensing data stream is effective for delineating and studying climate at various temporal scales: short term (weather), seasonal to inter-annual, and long term (climate change). This then will result in an effective data base for the characterization of global climate change (GCM) scale surface and energy fluxes. As one sensitive measure of climate change, a very recent USGS study (<http://ams.allenpress.com/amsonline/?request=get-abstract&issn=15200442&volume=017&issue=13&page=2626>) delineates the decrease in the ratio of snow to total precipitation over the past 50 years throughout New England. Similar such trends have been noted in biological responses to climate change, for example overwintering of bird populations that formerly migrated south.

Due to the lack of large, regional-scale overburden aquifers, the region is dependant on the localized characteristics of bedrock for water supplies. Although pioneering work on fractured rock hydrogeology was performed by the USGS at the Mirror Lake site, bedrock hydrogeology at small and large scales are poorly understood. This includes the role of regional ground water flow in stream flow hydrology and chemistry. The Connecticut River watershed possesses sufficient breadth to study bedrock hydrogeology across spatial scales. An important element missing at the present is knowledge of the mechanisms responsible for bedrock recharge and how water resources and land development effects the hydrology and water quality of the bedrock groundwater. This information is extremely useful to resource managers and regulatory agencies who are faced with proposals for water resources development and are constrained by state water laws being based on the equitable use doctrine. Complicating water resources development is the regional dedication to instream flow and the fact that in order to address instream flow, existing water uses and proposed water uses may not possess 100% reliability on free flowing water supplies as they had in the past. The Connecticut River watershed is a superb laboratory for synthesis and comparison between ET measurement from eddy flux tower sites (Fluxnet), process-based models and satellite-based models. Because of its large extent of contiguous forested land cover in the upper reaches, the Connecticut River provides an opportunity to study fluxes in cold weather region that is topography more complex than previous study regions (e.g., Little Washita River in Oklahoma). The best approach to scale from the local footprint to the regional/watershed scale and to disaggregate satellite-based measurements and to characterize the value of such measures in water cycle dynamics is still an open question to the communities at large. Numerous approaches are available to estimate evapotranspiration (ET) over large areas using a combination of remote sensing observations and ancillary surface and atmospheric data, often in combination with land surface models. Although ET data from the flux tower sites are not perfect, they can provide continuous measurements of moisture fluxes in terrestrial ecosystems. As forest communities are

considerable sinks of CO₂, the Connecticut River land surface-atmosphere work activity would naturally tie together CO₂ and energy fluxes. At a small scale, the Harvard Forest, can provide considerable insight to those fluxes over time and guide spatial considerations. The Harvard Forest, located in the central eastern portion of the Connecticut River watershed has monitored atmospheric fluxes in deciduous forested sites since 1989. One of the oldest and most intensively studied forests in North America; biomes found within the Harvard forest are representative of many communities found in the Connecticut River watershed including Eastern deciduous forest, hardwood-white-pine-hemlock forest, spruce swamp forest, and conifer plantations.

Because of its northern location, the Connecticut River watershed experiences winters severe enough to annually provide for the study of the impact of snow and ice on hydrology and hydraulics. In addition, there is an ample body of literature on acid snow and the water quality, and subsequent ecologic, impacts of spring snow melt. Although the blanket of snow and acid deposition can be fairly uniform, the resulting runoff, recharge, and resulting water chemistries can vary markedly between neighboring watersheds. This would include the application and validation of remote sensing technology to characterize spatiotemporal variability of the water cycle

Again, due to its northerly location, there is a dramatic difference in temperature between ground water and surface water in late summer and late winter. This makes all waterline areas (both coastal and freshwater) well suited to remote sensing of submerged ground water discharges. Ground water discharge to coastal environments is poorly understood and quantified. In other nearby New England coasts, the submerged ground water discharge is on the order of the flow from rivers, yet nutrient concentrations in the ground water are higher nutrient loads (Roseen, et. al., 2001).

The watershed is approaching four centuries of settlement and dramatic human influences. The long term impacts of land use change, wastewater treatment, environmental protection laws, road de-icing salts, and the shift from an agricultural to an urban-based society on water quantity and quality have all resulted in dramatic responses and the watershed integrates all of these influences. In a vein similar to urban “heat islands” and the effect of urbanization on microclimatology, the radical transformation of the Connecticut River watershed and the existing monitoring network can be studied to determine if such watershed wide human influences generate a climatic response.

- **How does stormwater management practice (typically occurring at the scale of the development) affect watershed hydrology and water quality?**

With Phase II of the Clean Water Act in full swing, stormwater management has entered a new era for the United States. There are numerous Phase II, and a few Phase I, entities within the Connecticut River watershed. By-and-large, stormwater management is enforced at the local level within this region and therefore stormwater management subscribes to site by site approval rather than regional watershed planning. Given the variability of communities and development pressures across the Connecticut River watershed, there are numerous locations of neighboring subwatersheds where the effects of differing stormwater controls can be compared. Additionally, the large-scale effects of such small-scale signals are in need of research attention: by prolonging hydrographs and reduced water quality in the outflows from the stormwater systems, we may be creating large scale consequences, for example geomorphic response, stress on aquatic communities, etc.

- **How can local and regional planning benefit from a hydrologic observatory?**

It has already been stated that anthropogenic influences have resulted in watershed response. Region-wide, at the state and local levels, the political mindset is to return the watershed to a “natural” state. For example, is it possible to re-create the flows and variability from pre-human influence? Can a reasonable or achievable facsimile of these flows result through stream and bank restoration and dam removal? What are the consequences to society if we attempt to do so? Planners and regulators often ask or ponder these questions, for example in the desire to meet instream flows. Given the dramatic forest re-growth of the Connecticut River watershed, it can be argued that the system is now more closer to pre-human influence than any time in the past 100 years. A hydrologic observatory on the Connecticut River can generate data and research that will be useful to planners for the purposes of decision-making: what is achievable versus what is desirable but not achievable, and at what price?

Along these lines, a hydrologic observatory will afford increased real-time monitoring and remote sensing which can be used to assist policy and management, for example flood warnings, recreational opportunities, water quality concerns, etc.

- **What is the legacy of watershed-wide dam construction and what are the realistic improvements to be expected of dam removal?**

In particular, because of the array of dams and dam types in the region, it is possible to evaluate the multiple effects of dams on changes in water and sediment discharge regimes. Generalizing the hydro-geomorphic effects of impoundment has remained elusive for the hydro-geomorphic community because of the array of dam types, varying regional climates, and differing initial conditions, with most of our current knowledge depending on the amalgam of case studies conducted worldwide. On-going research is evaluating the hydro-geomorphic impacts of impoundments within the Connecticut River basin to capture watershed scale impacts. General agreement exists within the aquatic community that particular nodes or zones within the riparian environment strongly record disturbance and become critical bio-indicators of ecological integrity. These aquatic "hotspots" commonly occur at terrestrial-aquatic interfaces and are nodes or patches that exhibit high reaction rates relative to surrounding areas. Disturbance at these hotspots may have tremendous ripple effects throughout the ecosystem. The channel bed represents one of these critical terrestrial-aquatic interfaces, and the accelerated sedimentation (i.e. embeddedness) due to impoundment has significant repercussions throughout community food webs.

There is a dramatic effect of multiple dams on sediment transport and ecology. The Connecticut River has the advantage of having both managed and unmanaged watersheds (such as White and Black rivers) to study these effects at the subwatershed level as well as scaling these effects up to the watershed.

The small-scale through large-scale issues involved with dam construction can be brought to a simple question: what are the impacts of control structures on river ecohydrology? For example, how do we characterize vegetation regimes and response to hydrology? In singular case studies of the consequences of dam construction, the impact of control structures on stream ecology (biota, sediment, channel structure, etc.) have been documented and predictable. On a watershed-scale basis, these distinctions may blur. Given the hundreds of dams in this watershed, how do we rank or compare the impact of individual structures in the big picture? The necessity of answering this question is to answer the contrary question: what do we get by removing an individual dam? This seems to be fertile territory for optimization research that

include the use of multi-criteria decision making in order to weigh public opinion and surrogate worth to make decisions on dam removal.

- **What are the long term geomorphic responses to natural and anthropogenic stresses and how do these stresses manifest themselves through stream morphology and attendant ecosystem characteristics?**

Until about 12,000 years ago the entire watershed was covered with upwards of one mile of ice (the exact depth estimates vary and obviously thin towards the coast, but visually the concept of a mile-thick mantle of ice is exciting). This ice sheet carved off the overlying rock and sediment across New England, dumping vast amounts of till in the Long Island Sound (e.g. Fire Island) and across the coasts of MA and CA (e.g. Cape Cod). Then, the ice melted and suddenly the lithosphere was free from the overburden of the ice. There has been a continuous process of rebound -- Isostatic Uplift -- of the crust across the region and the Connecticut River may provide a unique opportunity to study this. Specifically, mapping in and dating (using cosmogenic radionuclides) bedrock strath terraces along the long profile of the River would enable us to quantify the rates that the Connecticut has been incising the landscape since glacial recession. Similarly, mapping lake sediments in more detail than has been done would help lead to a differential uplift history of the region by plotting sediment elevation against distance upstream in the Connecticut River.

The climatic history has important ramifications with regard to the Carbon cycle and understanding the weathering history of a landscape. Research at the Hubbard Brook LTER is rudimentary as far as understanding long-term weathering rates of a landscape and the Connecticut headwaters would offer the opportunity to exploit the initiation of the unweathered state, i.e. we know that the bedrock was "reset" to an unweathered state when the glaciers receded. Weathering recorded IN THE ROCK can therefore be used to determine weathering rates.

All of these aspects of land surface change can be put in an exciting perspective because of the second aspect of the Connecticut that is truly unique. That is, the land-use history and the long-record of human impacts on the environment. The Harvard Forest as well as the Hubbard Brook Watershed offer good baseline studies to tie into when using this aspect of the Connecticut watershed. Importantly, the long history of the watershed also has a long history of documentation. So, both the glacial history and the human impact history make the Connecticut a superb site. The effect of deforestation (and loss of woody debris to stream) then reforestation (with re-supply of woody debris and channel cover) postures the entire watershed as a large-scale experiment on signal and response.

The Connecticut River has been identified by The Nature Conservancy (TNC) as a watershed at risk. TNC is committed to facilitating interactions between many stakeholders throughout the watershed, with the aim of documenting the many stresses on the river ecosystem, and formulating action plans for their remediation.

Among the many strategies for the Connecticut River identified by TNC and collaborators at preliminary meetings are plans to install new long-term observatories, (and, at the very least, access data from existing facilities) for monitoring discharge of water and sediment at selected locations along the river. The aim is to provide information for hydrologic and sediment transport models that, when coupled with recommendations from ecosystem specialists, can be used to aid in the management of flow regimes along the river.

This CUAHSI bid for support for a long-term hydrologic observatory on the Connecticut River watershed can be linked to this ambitious and worthwhile program. TNC has enjoyed success in this regard in other watersheds, to significant public acclaim. Participation in this next effort, in the service of scientific observatories, can contribute to the TNC program's technical and political success. Collaboration with TNC will undoubtedly enhance an ability to recruit students, many 'best-and-the-brightest' of whom especially desire to join environmentally-constructive research efforts.

- **What is the role of regional atmospheric Nitrogen sources on Nitrogen cycling throughout the watershed?**

Seitzinger, et al (2002) demonstrate the Nitrogen removal is inversely proportional to stream order and that Nitrogen fluxes can be reliably modeled on large-scale systems. The USGS NAWQA Nitrogen work could be expanded using Nitrogen isotopes, both for interpretation of ambient Nitrogen source and fate as well as by added isotopic tracer injections at smaller scales (e.g. contrasting landscape types at the Sleepers River watershed). Forest Service expertise, and their success with AVARIS for estimating foliar N, is related potential research.

The diversity of flowing water settings across the watershed provides for spectacular nested experiments on the hyporheic zone genesis throughout a watershed and the fate and transport of Nitrogen in this particular setting.

- **What role do riparian characteristics have on water quality?**

Riparian zones are credited with buffering surface water systems from land use activities. These effects include stream temperature moderation, removal of sediment and nutrients, and nutrient cycling. The study of the variety of riparian zones in the Connecticut River watershed affords analysis at various spatial scales in order to address the impact of riparian zones, and their loss, on water quality. This is especially imperative as towns are presently grappling with how to protect riparian zones and what minimum sizes to require. The Connecticut River watershed is at the northern terminus of the east coast urbanization zone that extends from Atlanta to Boston. This zone continues to expand and therefore the Connecticut River watershed will continue to undergo strong development pressure. The preservation of the riparian zone in the face of such pressure has never been more important.

- **How do Mercury cycling processes vary over the watershed scale?**

Another excellent science driver is the mercury issue. Tracking mercury and methylmercury in water and the food web (including humans, if consumption can be isolated) can be a major research endeavor. The Connecticut River watershed possesses a diverse landscape with a major mercury deposition gradient. The landscape mosaic, with wetlands and reservoirs (major MeHg generators), offers great research potential. The effect of urban landscapes and the effect of disturbance on mercury release have generally been understudied. Presently, Connecticut River Airshed Watershed Consortium as well as the NOAA AIRMAP program are specifically studying and collecting data on New England climate change and air quality. These programs are natural collaborators for the Connecticut River hydrologic observatory.