DELAWARE RIVER AND CATSKILL REGION HYDROLOGIC OBSERVATORY

A Prospectus by the Cornell University Hydrologic Sciences Working Group [1]

We review here the nationally unique opportunities for hydrology based research in the *Delaware River and Catskill Mountain (DelCat) Region* (Figure 1). It encompasses all of the Delaware river Basin and the New York City Catskills watersheds. This prospectus is an account of a forthcoming effort designed to elicit support and participation. With this prospectus and CUAHSI hydrologic observatory materials, we begin now contacting prospective participants and partners from a wide range of universities, research institutes, agencies, and organizations. After greatly expanding the user and research community for the DelCat observatory, we will design the facility to serve a large user base interested in studies on a wide range of basic and applied hydrologic science topics and issues. Therefore, this prospectus is a tool to define and justify a hydrologic observatory opportunity, and to forecast the nature of what the hydrologic sciences can achieve in the DelCat Region.

Figure 1. The Delaware River Basin and Catskill Mountain watersheds of the New York City water supply: the DelCat Study Region. Major outside water diversions shown.

1.0 The Observatory

1.1 Study Area

The Delaware River basin has been a key water resource region prior to the founding of our country. This mountain-river-estuary hydrologic system together with other watersheds in the Catskills has supported the population and economic growth of major metropolitan areas of the early United States by providing water supply, land and forests, transportation, power generation, fisheries, recreation, and pollution elimination. These facts hold today and water has always been critical for these ecosystem services. Today the region meets the water demand of 17.5 million people[2], and provides the water and waterways for the world's largest fresh water port, two prominent vacation regions, a historic agricultural area, the second largest US petrochemical center, major electric power generation, and one of the world's greatest concentrations of heavy industry. About one in four Americans live within an easy drive of the region. Meeting intense human demands within the limits imposed by the hydrologic cycle has resulted in a blend of extremes: vast water use infrastructure and the

highest level of water protection in the US. The DelCat Region includes extensive natural reserves (e.g., Catskill Mountain Reserve) with the longest undammed eastern US river (75% of its length in the National Wild and Scenic River System[3]).

The DelCat region includes two overlapping areas: the landscape draining to the Delaware Bay (24,474 km^2) and watersheds contributing to the New York City water supply system (green area on basin map). The New York City waters supply areas add about 1,700 km^2 of land draining into the Mohawk and Hudson Rivers. Including these Catskill Mountain watersheds allows full use of the New York City water monitoring and use data. A south-north precipitation gradient (1 – 1.3 m/yr) spans the study area with a reverse average annual temperature gradient is 13°C to 7°C. The average annual discharge of the Delaware River is 330 m^3/s at the head of tide near Trenton NJ. Total water use is about equal to the total average annual discharge with 4% in-basin consumption and 12% exported out of the basin. Despite the modest size of the study area, it includes 10 different hydrologic landscape units (Figure 2). All parts of the basin are humid hydrologic landscape regions with the northern portion of the study area almost exclusively with permeable soils and impermeable bedrock and the middle basin largely the reverse: impermeable soils and permeable bedrock. The lower basin is a rich mix of plains with permeable and impermeable soils and bedrock.

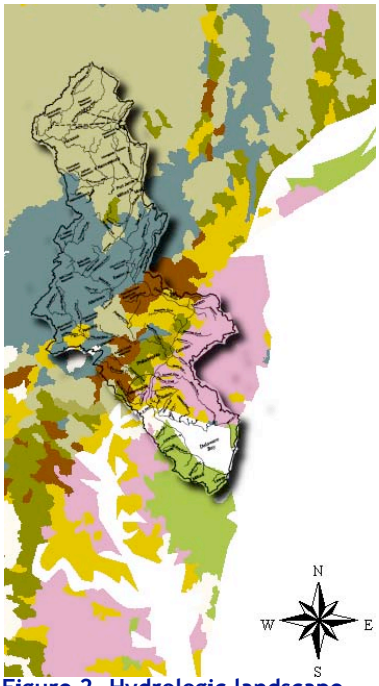

Figure 2. Hydrologic landscape regions[4] with the DelCat study region. [color codes at web site]

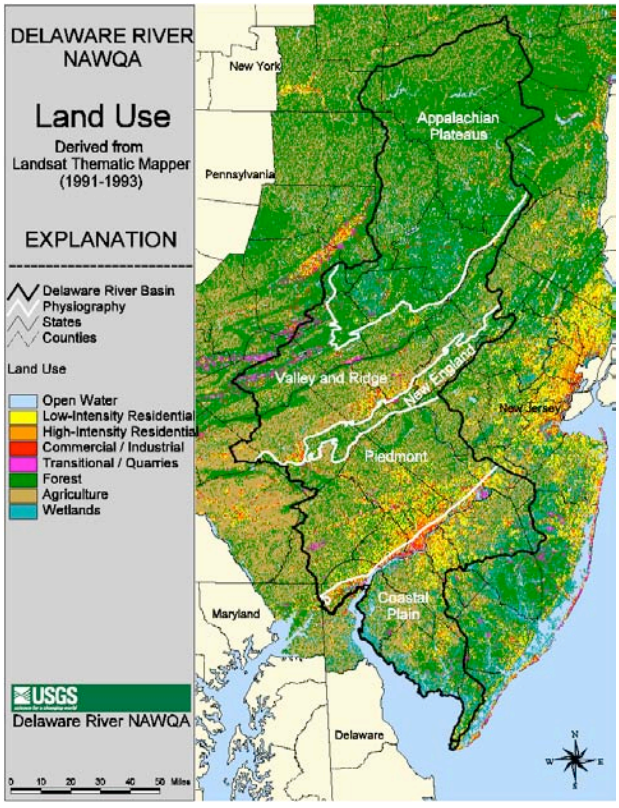

Figure 3. Delaware River basin land cover.

The primary land cover in the DelCat region is forest (61%) followed by agriculture (23%) and residential-urban (9%, Figure 3). The region includes many wetlands, natural lakes, and reservoirs. Most people (80% of ~7 million) live in the southern 40% of the region: Piedmont uplands and Coastal Plain. The northern portion is the heavily forested (85%) Catskill Mountains much of which is protected by the 1,200 km^2 Catskill Forest Preserve. This area is sparsely populated and the source of water for New York City (green in Figure 1) and many surrounding cities. Within the Preserve, some watersheds are virtually undisturbed (original forests) such as the upper Neversink River providing valuable control settings for potential paired-watershed studies. Although agriculture is an important land use in the Valley and Ridge, Piedmont, and Coastal Plain physiographic provinces, there remains some intact watersheds and land units of considerable size (Figure 3) and government protection. Unlike many other basins, agriculture is a minor water user (<1% withdrawals, <4% Consumption[2]).

1.2 Six Key Assets for a DelCat Region Hydrologic Observatory

UNIQUE HYDROLOGY – The study region has hydrologic properties and patterns unlike the standard cases and knowledge used in hydrologic design. Especially noteworthy are saturation excess overland flow and rapid subsurface flow, or interflow. The field of hydrology, especially engineering hydrology, is strongly influenced by a legacy of scientific theories based on data from the arid western US[5] where storm flow is largely attributed to periods when rain intensity exceeds soil infiltration capacity and annual streamflows are dominated by seasonal processes (e.g., snow melt). The DelCat area is humid and mean monthly precipitation is steady through the year and rain intensity rarely exceeds soil infiltration capacity on the vegetated areas. The DelCat covers half of the USGS hydrologic landscapes[4], providing opportunities to investigate the different hydrological settings representative of the Northeast and Mid-Atlantic regions.

NATURAL SETTINGS AND HUMAN DOMINATION – The region includes a range of watersheds that range from pristine to completely altered. The mainstem of the Delaware River is the largest undammed river in the eastern US[2]. Water from the Delaware River basin is fully obligated because river flows are carefully managed to meet essential human needs (New York, Trenton, Philadelphia, central New Jersey and others). This human dominated hydrologic system is under increasing water demand that can only be met by better water management, and the system is especially vulnerable to extreme hydrologic events that will stress current water regulating institutions and arrangements.

DIVERSITY OF WATER QUALITIES – Water quality varies greatly in the study area and it is managed in very diversified ways. The City of New York is protecting (Catskill Forest Preserve with $1.5 Billion watersheds management program[6,7]) much of the Catskill Mountains for the highest possible water quality to maintain its minimal treatment of the city water supply. This case is likely the most rigorous water quality management effort anywhere. In contrast, the Schuylkill River in Pennsylvania has widespread (30% of waters) and serious water quality impairment[8,9] due to agricultural practices, storm water runoff, sewage overflows, PCBs, and abandoned mine drainage.

CLIMATIC TRANSITIONS – The study region spans completely forested mountain to major urban areas with sharply differing air quality. The Delaware River basin also spans mountain and highland interior areas with coastal microclimates. Atlantic coast storm tracks often bring moisture-laden air into the eastern portion of the region with drier conditions left on western ridge and mountain slopes. The opposite pattern occurs with precipitation events moving in the prevailing west to east direction.

LONG AND INTENSE HISTORY OF HYDROLOGIC MONITORING – The study region has possibly the most extensive and intense hydrologic and climatic data collection of any eastern US river basin largely due to the critical importance of basin water to major population centers. New York, Philadelphia, and other cities were among the earliest centers of US population and their needs contributed to some hydrologic monitoring records being among the longest available anywhere. A look at the scope of data in time and space is provided below.

NATIONAL ENVIRONMENTAL ISSUES – Some of the most debated and studied issues of US environmental management have an active role in the DelCat Region: river flows for fisheries, acid rain impact on forests, nonpoint source pollution, urbanization, forest fragmentation, groundwater contaminants and radon, freshwater flow to estuaries, estuarine nitrogen loading, endangered species recovery, and water supply safety. Reference conditions remain abundant in the Catskill Forest Reserve, Delaware River National Recreation Area, and other sites.

1.3 Monitoring and Data Resources

Delaware River Basin and Catskill Region monitoring and study programs with data and measurement resources. This summary is a condensed first inventory of readily accessible programs. With the release of this prospectus, the DelCat Hydrologic Observatory Team will seek cooperation of the agencies and offices listed here. More information on these programs is at: http://environment.cornell.edu/Initiatives/HydrologicObservatories/DelawareRiver/

Program and components	Representative parameters	Spatial scope	Temporal scope
USGS, National Atmospheric Deposition Program [NADP/NTN/MDN], http://nadp.sws.uiuc.edu/			
National Trends Network	Precipitation, wet deposition measurements, monitoring	Mercer County NJ Ulster County NY Lancaster County PA Pike County PA	1981, 2002, to repeat
Mercury Deposition Network	Mercury deposition	Lancaster County PA Pike County PA	2000, 2000, to repeat
USGS National Stream Water-Quality Monitoring Network, http://water.usgs.gov/pubs/dds/wqn96cd/			
Delaware & Schuylkill Rivers	Water chemistry, atmosphere, human activity, trends	2 basin sites	1970s, continuing
USGS, National Water Quality Assessment [NAWQA] Program, http://nj.usgs.gov/nawqa/delr/			
Land use, nonpoint	Nutrients, pathogens	Fixed sites by land use	1999-2001, to repeat
Sediments, water, biota	Contaminants, ecological status	Fixed sites by land use	1999-2001, to repeat
Surface, groundwater	PCBs, trace-radio elem'ts, toxics	Fixed sites by land use	1999-2001, to repeat
Water supply, recreation	Pathogens, pesticides	Fixed sites by land use	1999-2001, to repeat
Habitat, alterations	Fish, benthos, organism health	Fixed sites by land use	1999-2001, to repeat
Streamflow, withdrawals	Water quality, biotic integrity	Fixed sites by land use	1999-2001, to repeat
US EPA Clean Air Status and Trends Network [CASTNet], http://www.epa.gov/castnet/			
Nitrogen	Deposition: wet, dry, compounds	NY, NJ sites	1998, 1999-2001, ...
Sulfur	Deposition: wet, dry, compounds	NY, NJ sites	1998, 1999-2001, ...
NOAA NWS Middle Atlantic River Forecast Center [MARFC], http://www.erh.noaa.gov/er/marfc/			
River stage, flooding	Flows, water temp., snow cover	Select major tributaries	1969, continuing
US Forest Service, http://www.fs.fed.us/foresthealth/, http://www.fs.fed.us/ne/fia/index.html			
Forest Health Prg [FHP]	Invasives, pesticides, status	Basinwide	1998, continuing
Inventory-Analysis [FIA]	Forest condition, assessment	Basinwide	1970s, now routine
US Army Corps of Engineers, Philadelphia District, http://www.nap.usace.army.mil/cenap-dp/projects/drb_projects.htm			
Comprehensive Study	Birds, water, dredged material, Land uses, flood management	Lower basin, bay	2002, ongoing

Program and components	Representative parameters	Spatial scope	Temporal scope
New York City Watershed Protection Program, http://www.ci.nyc.ny.us/html/dep/watershed/home.html			
Water Supply Quality	Many physicochemical, microbes	ca. 100 sites	1930s, routine
	Cryptosporidiosis, giardiasis	ca. 100 sites	1992, repeating
Agricultural Lands	Farming practices	Catskill area	1992, routine
Forestry Lands	Harvest levels, practices	Catskill area	1997, repeating
Stream Management	Channel status, stability	Catskill area	1996, repeating
Wetlands Assessment	Functional analyses, mapping	Catskill area	1996, repeating
Delaware River Basin Collaborative Environmental Monitoring & Research Initiative [CEMRI - USFS, USGS & NPS], http://www.fs.fed.us/ne/global/research/drb/summary.html			
Forest Status	Calcium depletion	Intensive study basins	[synthesis of efforts]
	Biomass, production	Intensive study basins	"
	Health, invasive species	Intensive study basins	"
Land Cover	Habitat fragmentation	Basin, Intensive studies	"
	Land uses, health status	Basin	"
Habitat	Hydrology, water quality	Intensive study basins	"
Geographic Info System	ecoregions, geology, soils	Basin	"
	physiographic provinces	Basin	"
	Infra-Red Photos, DEM	Basin	"
Delaware River Basin Commission, http://www.state.nj.us/drbc/			
Scenic Rivers Monitoring	Aquatic biota, water chemistry	Main river, quality tribs	1984, continuing
Lower River Monitoring	Physic chemistry, biology	Lower main river	1998, continuing
	Microbes, flows, channel form		
	Macro invertebrates, habitat		
Estuary Vessel Survey	Microbes, radioactivity, metals	Tidal and bay	1960s, continuing
	Algae, carbon, oxygen, tissue		
	Toxics, and others		
Philadelphia Water Department, http://www.phillywater.org/wqr/wqr2002/wqr2002.pdf			
River source monitoring	More than 100 parameters	Freshwater tidal reach	Many long term records
Schuylkill sources	Water quality, land use, impacts	52 monitoring sites	Many long term records
EPA National Estuary Program, Delaware Estuary Program, [DELEP], http://www.delep.org/			
Habitat, Living Resources	Wetlands, GIS, habitats	Estuary	1998 start
Toxics	Chemistry, PCB, others	Estuary	Ongoing
Monitoring	Fish advisories, tissues	Estuary	1997, Ongoing
	Sediment chemistry, microbes		
Indicators	Agriculture, fisheries, water, etc.	Estuary	1970s, continuing
Water Quality	Common water parameters	Estuary	Ongoing
Water Use	Withdrawals, consumption	Piedmont and lower basin	1992, continuing

2.0 Research Opportunities

2.1 Hydrologic Extremes

The DelCat provides a backdrop to investigate hydrologic extremes spatially and temporally. The region is marked by substantial spatial and temporal variability in climate. Average annual precipitation and snowfall increase by more than 40% and 100%, respectively, over a distance of only 30 km in the heart of the basin. This marked climate variation is related to the DelCat Region topography and, more importantly, to the interaction between the defining topographic features and prevailing storm tracks. Precipitation from storm systems moving northward along the East Coast is enhanced as moisture-laden air is advected up the eastern slopes of the Catskills, while areas on the western slopes often see a decrease in precipitation during such scenarios. Similarly precipitation from storms approaching from the west is enhanced on westward facing slopes. Integrating the substantial existing observation network with new core data targeted high-resolution meteorological and hydrological monitoring networks will quantify the influence of these spatial variations on key hydrological parameters.
The area has also seen a substantial increase in precipitation over time. Annual precipitation across New York State increased by approximately 15 cm over the last 100 years; nearly 20% more water input. More importantly, this gain has resulted from a sharp increase in extreme rainfall events. Nationally, high-intensity events are significantly increasing the annual total precipitation[10]. This increase in especially pronounced (>15% increase in extreme precipitation events) in the Northeastern U.S. during spring[11] which potentially translates to a significant increase in high streamflow events seasonally and annually. Additionally, recent years have seen some of the longest periods of consecutive rainless periods and these extremes are especially important in the DelCat Region because of the full extent to which its water resources already used.

2.2 Sustainability of Water Resources

There are no large Eastern river systems with as intensive human water demands as in the DelCat Region. The hydrological system is fully utilized with water use essentially equaling discharge from the system during years with average or below rainfall. For most uses water returns to the stream, but in this region a large volume of water (14% of basin total) is diverted from the headwaters to New York and surrounding communities. Interestingly, and perhaps unique to North American rivers, the largest demands are at the top and bottom of the system contributing to prominent socio-political conflict. Originally in 1931 and amended in 1954, the US Supreme Court established water allotments to New York to insure sufficient water for downstream users and ecosystems. The DelCat Region provides a glimpse into future inevitable water sustainability issues that other basins in humid regions will ultimately experience as populations continue to rise. The DelCat Region and the communities that depend on its water will become the leaders for the Eastern US, pioneering innovations in water conservation including ways to effectively engage a society that is not accustomed to water shortages. Of particular interest is the sensitivity of the systems sustainability to climate change. Recent studies suggest that changes in regional and national precipitation[10] and evapotranspiration[12] patterns will significantly alter the large-scale hydrological cycle and exasperate water sustainability issues. To assess these types of issues will require long-term measures of the primary hydrological fluxes and storages extending the already impressive discharge records in the DelCat Region.

2.3 Hydrologic and Biogeochemical Cycles

The sources, transport, storage, and fate of common elements in the environment (carbon, oxygen, hydrogen), major nutrients (phosphorus and nitrogen) and life supporting elements (sulfur, calcium, iron, silicon, and others) dominate biogeochemical research. Water is central to biogeochemical processes and element cycles normally include terrestrial, soil, waterway, atmospheric paths. Much of the research currently linking hydrology and biogeochemical cycles conducted at intensively studied sites can be well executed in the DelCat Region because of the availability of varied field sites ranging from pristine forests to industrialized salt marshes. Biogeochemical hotspots[13,14], or sites of elevated reaction rates, are often at the terrestrial-water interface and key hydrologic points. An emerging research topic, hotspots would be expected across the DelCat Region because of the complex natural and human waterways, water bodies, and land uses. Especially valuable for future research would be the long protected main river valley where land-water interfaces may be most influenced by altered river flows rather than site-specific riparian degradation. The role of human activities and land uses on biogeochemical cycles, another national research priority[13,15], can be well addressed in our study region at any scale from local to across multi-physiographic zones. The emerging importance of restoring biogeochemical cycles in human dominated areas and common stoichiometric ratios are highly relevant to the DelCat Region because of the patchwork of hydrologic and physiographic landscape units with diversified human activities. In an ongoing effort to maintain water supply quality, New York is essentially conducting a regional scale experiment on the extent that state-of-the-art mitigative measures such as source controls, nutrient sinks, and upland to streamside retention practices reduce runoff nutrient concentrations. The intensive effort to monitor and protect water quality and quantity throughout the basin makes the DelCat Region especially valuable for scaling up biogeochemistry-hydrologic studies in scale and strategically siting more traditional intensive site studies of elemental and water cycles.

2.4 Hydrology and Ecosystem Functions

Research on biogeochemical cycles is fundamental to understanding the relation between hydrology and ecosystem function. Here though, we comment on the unique assets of the DelCat Region for supporting research relating hydrology to species, communities, and biotic patterns at the landscape scale. Land cover, climate, and habitat features commonly explain the distribution of species and communities. Human impacts on the flora and fauna of a region are well understood at the local scale, but consequences of large scale dynamics in climate, hydrology, and human land activities on biotic patterns within ecosystems remain weakly recognized. The DelCat Region presents well documented and rapidly changing patterns in human activity over a heterogeneous landscape with complex climate making varied hydrologic patterns expected. Water and biotic conditions have been the target of great societal debate relative to environmental management across our study region. In the north, decades of study and contention have pitted the management of New York City water supply operations with river fisheries advocates[16] because reservoir management determines river volumes and temperatures that limit trout biomass and distributions. Flow alteration is a major human impact on aquatic systems because streamflow is acts as a master variable shaping the lotic environment for all aquatic life[17]. Floodplains of large rivers have attracted much scientific interest recently because of uncertainty about organic matter flux and its influence on riparian plant and animal communities[18]. With the extensive and protected floodplain of the main Delaware River, scientists have a grand opportunity to clarify this issue under human altered river flows. In the south, water quality has limited fisheries and habitat in the lower Delaware

River and estuary. Once the most productive estuary for some prominent Atlantic Coast fisheries (e.g., American shad and Atlantic sturgeon[19]), water quality degradation in the Philadelphia area acted as almost a complete block to migrations and a limiting factor on much of the habitat. Today, improved water quality has allowed recovery of these river migrating species and the length and extent of habitat protection along the main Delaware River affords researchers an exceptional opportunity to relate aquatic species migrations to hydrologic conditions in the absence of river dams. Overall, the DelCat Region affords broad opportunities to study how water cycle alteration relates to the biotic ecosystem patterns from forested headwater watersheds to an industrialized estuary.

2.5 Chemical and Biological Contaminants

There are copious research opportunities related to pollution and understanding the impacts of various contaminant types and sources on ecosystems with both human and natural dimensions. Chemical and biological contaminants have been a substantial research focus because New York and Philadelphia rely on clean water from the region and many human activities within the region, especially coal mining and agriculture, pose inherent risks to water quality[20]. Additionally, like much of the Northeastern US, the DelCat Region is susceptible to the deposition of pollutants that originate far downwind (Ohio, Michigan, etc.), and there has been substantial research focusing on acid rain, nitrogen, sulfur, and other contaminants that enter the area via atmospheric deposition[21]. Biological contaminants, like pathogens, also constitute good research opportunities as evidenced by substantial work in the region on *Crytosporidium parvum* persistence, lifecycle, and hydrological transport[22]. Of particular interest is linking watershed responses to contaminants with specific hydrological processes. Current nonpoint source pollution models are generally little more than complicated approaches to creating regressions between land use and pollutant output, with little defensible process-based science to support the results. Such models are valuable for estimating how reductions in contaminant sources may result in reductions in watershed yields, but they provide virtually no insight into designing spatially distributed water quality protection management practices[23]. A full understanding is needed of the temporal and spatial relationships among hydrological flowpaths, contaminant sources, and biogeochemical processes.

2.6 Example DelCat Region Science Advancements

Several hundred scientific journal articles have been published on the DelCat Region addressing research topics across the full spectrum of hydrologic sciences: hydrology, meteorology, forest ecology, aquatic-ecology, biogeochemistry, geology, and various perspectives on pollution. Interest in the region has increased substantially in the past decade; approximately 75% of the scientific journal articles were published between 1990 and 2004. The following is a brief, woefully incomplete, summary of some relevant DelCat Region research that demonstrates the breadth of recent scientific advancements.

The region's unique hydrology is well studied, especially in the Catskills[24]. It is well established that storm runoff in the rural parts of the region, and much of the northeast in general, is a combination of rapid, shallow subsurface flow, a.k.a. interflow[25] and overland flow generated from parts of the landscape where the soil saturates to the surface, so called saturation excess overland flow [26]. Saturation excess is being increasingly recognized throughout the DelCat region and much of the US as an important process in need of more detailed measurement and modeling. Currently the common water quality models and

nonpoint source control practices assume the traditional storm runoff mechanism, infiltration excess, which occurs when the rainfall intensity exceeds the soil infiltration capacity (Hortonian overland flow concept[5]). Now the DelCat region has attracted researchers trying to bridge current hydrological science with water quality protection[27].

The DelCat Region has played a central role in understanding human impacts on biogeochemical and ecological systems especially with respect to ecosystem effects of acid rain[28], nitrogen (N) deposition[21], N loss[29] and forest N-saturation[30]. Many of these research topics have the extra-regional or air-shed dimensions which are well measured and monitored in the region. Phosphorus associated with agricultural runoff has also received extensive investigation because of its potentially negative impacts on the New York City water supply[31]. The existence of base-line data on these important issues provides an excellent foundation for continued long-term research, especially with respect to developing water quality protection strategies over a wide range of scales from a residential lawn to the nation's power plant emissions.

Coastal nutrient inputs from rivers and watersheds has caused rapid and substantial degradation of estuaries[32,33] and the recognition of a pressing national research need[34]. The tidal Delaware River and estuary has had a long history of pollution induced ecosystem stress[35,36] but the river and upper bay has recovered considerably with improving water quality in the last two decades. Ecological improvements have been clear[37,38] including the potential for endangered species recovery[39]. While much more effort will be expended to improve this river and estuarine system[40], the Delaware River has provided researchers and environmental managers a clear example of ecosystem scale response to stress and recovery.

3.0 Capabilities to be Provided by a DelCat Observatory

CONNECTING LAND, WATER, AND ATMOSPHERE – Novel data sets will be required to move beyond earlier studies and presently prevailing paradigms. These data sets will become available by continuous monitoring at the stations of the existing NOAA network, which is currently being upgraded substantially with Doppler radar systems and other ground-based sounders. In addition, short-term (up to one month) intensive and focused experimental campaigns will be organized, in conjunction with NASA and other Federal Agencies (NOAA, USGS, USDA-Forest Service); the objective of these campaigns will be to calibrate the parameterizations needed (i) for the upscaling of the routine measurements by the regular station network, (ii) for the optimal interpretation of satellite-based observations over the area, and (iii) to allow the development of appropriate mesoscale modeling strategies required in hydrologic forecasting related to flash floods and droughts, and in the monitoring of broader climate evolution over the northeastern US.

PROCESSES LINKING RUNOFF QUALITY AND QUANTITY – Advanced understanding and forecasting of runoff quantity and quality from landscape units now requires field based, spatially distributed studies. All water accounting components need to be measured and modeled in highly instrumented study watersheds. We would employ at various scales spatially distributed sets of piezometers, water and physicochemical monitors, and moisture sensors to collect data on runoff, interflow, evapotranspiration, and constituent chemistry intensively and extensively including runoff producing areas. Our instrumented watersheds would be deployed across the DelCat Region by hydrologic landscape units and soil types so as to develop process based predictive capability for detailed hydrographs and chemographs in varied settings.

THE RIVER CONTINUUM: PHYSICAL AND BIOTIC GRADIENTS ACROSS THE REGION – Natural stream channels are thought of as highly organized products of climate, geology, and land cover setting. From headwaters to a large river, there is a linear progression in changing channel properties that are highly correlated with drainage area. Nevertheless, stream channels are dynamic and self-adjusting because they are the product of erosion, sediment deposition, and hydraulic processes. Stream channels are also regarded as habitat templates on which the biota conform in present time through colonization, population persistence, and local extinction. Ecologists have added energy dynamics (solar, organic inputs) to the organization of stream ecosystems and that introduced non-linear factors in the headwater to large river continuum. We want to study channel-habitat patterns across the stream size gradient in different environmental settings using a series of fixed hydraulic-ecological monitoring stations (flow, chemistry, sediments, channel form, migratory species, organism drift, biomass production, community composition) along the stream size gradient from headwaters to Delaware Bay. We would cover an intact headwater to main river gradient using the Beaver Kill River – East Branch Delaware – Delaware River. To add human alteration to the series, we would add the Leigh and Schuykill Rivers as further headwater to large river gradients. Data obtained from this observatory component would go beyond quantifying and modeling regional hydrologic-ecologic patterns to understand how human activities disrupt some of the most classic principles of hydrology and fluvial geomorphology.

BLANKETING THE REGIONAL LANDSCAPE – With recent advances in remote sensing technology and applications, we can now observe the DelCat Region on a regular, high definition, and multiparameter basis. Advanced remote sensing capability would provide more data, unique data, and comprehensive spatial coverage to understand basic hydrologic and environmental processes thus providing a new infrastructure in which to conduct multidisciplinary research. Satellite sensors, airborne surveys, fixed beam sensors, internet data relays and other technologies can yield real time information on land form, channel dynamics, water and organism movements, atmospheric conditions and constituents, water quality, vegetation status, and details of land uses through time. Aside from sensor technology, vastly expanded capabilities are now at hand in data access, visualization, spatial data integration, and data management. Our expectation is to build remote sensing capabilities into a hydrologic observatory to integrate the hydrologic and environmental systems and the respective research communities.

FOLLOWING THE WATER TO PEOPLE AND POLICIES – Water resource planners have traditionally sought to meet inceasing human water demand by developing new water sources. Today much more attention is being devoted to improved water use efficiency, distribution, equity, and sustainability: sometimes called "soft path" strategies[41]. Vast data are available on water use and consumption in the DelCat Region. We want to harness this information with associated measures of human activity such as energy production, population changes, economic activities, weather, agricultural production, and others. A regional scale integrated database of daily or weekly water uses and human activities will be used to understand and model the hydrologic-human water system for simulating practices and policies promoting water sustainability in this fully appropriated hydrologic region.

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– Go to the web site below for references and further information
– Interested in participating on this effort? Email Mark.Bain@Cornell.edu
– A listing of all team members and participants is at the web site