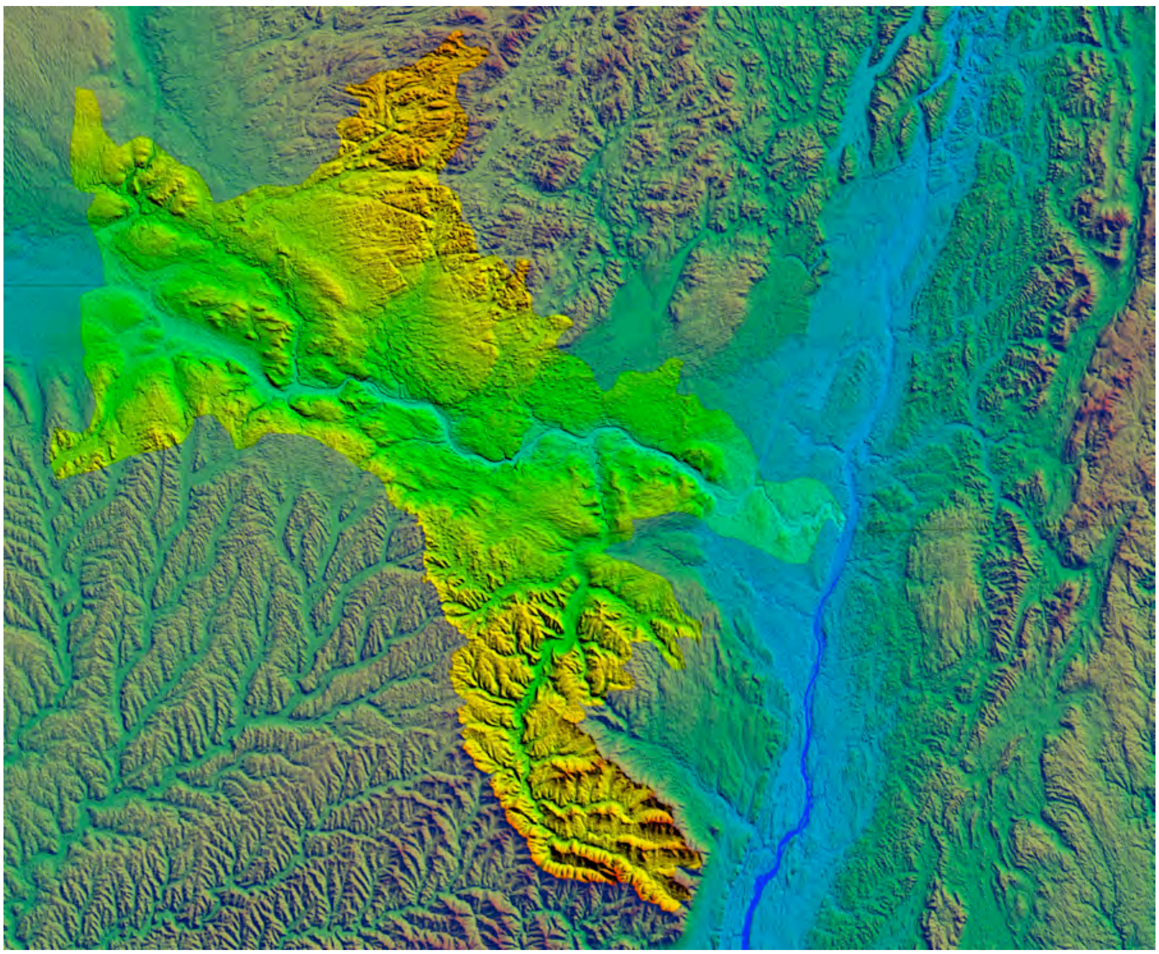
Mohawk Watershed Symposium

March 27, 2009

Olin Center, Union College

Schenectady, New York



Program and Abstracts

Preface

The Mohawk Watershed is a unique and distinctive drainage basin that has major tributaries that empty the Adirondacks to the north and the Catskill Mountains to the south. The main trunk of the river occupies a natural topographic gap in the Appalachian mountain chain, which provides a unique and distinctive link between Atlantic and the interior of the continent. This aspect of the geography of the river played a crucial role in the westward expansion by early settlers and eventually was the primary reason the Erie Canal was positioned, in part, along the spine of this key waterway.

As cities and commerce grew along the river, so did pressure on the waterways, the flow of the river, and the ecosystems that thrive in the watershed. In the past decade we have seen some important advances and setbacks in the watershed. An aging infrastructure, much of which is over 50 years old, is starting to show signs of decay and is in need of repair. The 1996 mid-winter flood was the worst in decades and the ice jams that resulted caused considerable damage in the lower parts of the basin. Likewise the 2006 flood that resulted from and incredible series of early summer rains provided residents in the upper part of the drainage a reminder of the power of water and the serious nature of regional flooding In 2005 the Gilboa Dam on the upper reaches of the Schoharie River was diagnosed with conditions related to its advanced age, and there was soon a swarm of activity related to fixing this dam and mitigating consequences of its potential failure.. Some recent activity on the West Canada Creek has highlighted the delicate balance between riparian rights, and water use for consumption or canal use.

Are watershed dynamics changing right in front of us? One key question surrounds the changes we might expect given a dynamic and changing climate that so far appears to be delivering more water to the system, but is also making it much more variable in nature. How do we plan for this? And how do we manage all of the complex needs in a watershed? The first thing we need to do is to understand the system. These are some of the central questions that have framed this conference. As a first step, we are attempting to bring together interested parties to first explore some of the crucial scientific and engineering issues within the basin. From this, we hope that conference participants will have a better appreciation of the complexity and unique qualities of this watershed.

John I. Garver   Jaclyn Cockburn

Mohawk Watershed Symposium - 2009
27 March 1009, Olin Center, Union College, Schenectady NY

- FINAL PROGRAM -

Friday 27 March 2009

Oral session (Olin Auditorium) - Registration and Badges required

8:30	*8:50*	**Registration, Coffee. Olin Foyer**
8:50	*9:00*	**Introductory remarks** *John I. Garver, Geology Department, Union College*
9:00	*9:20*	**Watershed yield of Hg to Onondaga Lake and some lessons for the Mohawk (Invited)** *Betsy Henry, Senior Managing Scientist, Exponent; Gary Bigham, Exponent*
9:20	*9:37*	**Gilboa Dam and Schoharie Reservoir** *Howard Bartholomew, Dam Concerned Citizens, Inc.; Michael Quinn, Director, CHA Companies, Inc*
9:37	*9:54*	**Patterns of Scour and Methods of Remediation of Impacted Infrastructure Facilities** *Ashraf Ghaly, Ph.D., P.E., Union College*
9:54	*10:11*	**Recent Flood Studies in the Mohawk Watershed** *Ricardo Lopez-Torrijos, Watershed Geographic Information Technologies, NYS Department of Environmental Conservation*
10:11	*10:28*	**June 2006 Flood in Mohawk River basin** *Thomas P Suro, US Geological Survey*
10:28	*10:45*	**The West Canada Riverkeepers** *Kathleen Kellogg, Executive Director, West Canada Riverkeepers*
10:45	*11:15*	***COFFEE and POSTERS***
11:15	*11:35*	**Using Dual Isotope Tracers to Learn about the Sources and Transformations of Nitrate during Transport in the Mohawk River basin (Invited)** *Douglas A. Burns, U.S. Geological Survey, Troy, NY, Elizabeth W. Boyer, Pennsylvania State Univ., State College, PA, Emily M. Elliott, Univ. of Pittsburgh, Pittsburgh, PA, Carol Kendall, U.S. Geological Survey, Menlo Park, CA*
11:35	*11:52*	**A historical perspective of Ice Jams on the lower Mohawk River** *John Garver, Jaclyn M.H. Cockburn, Geology Department, Union College*
11:52	*12:09*	**Wetlands, sub-catchments and invasive plants in the Adirondack Park portion of the Mohawk River watershed** *Mark Rooks, New York State Adirondack Park Agency*
12:09	*12:26*	**Organizing for action in the Mohawk River Basin** *Frederick E. Miller, Mohawk Valley Heritage Corridor Commission*
12:26	*12:43*	**Establishing a Gradient of Environmental Condition in the Mohawk River Basin for use in Prioritizing Environmental Management Decisions** *Karen M. Stainbrook, Watershed Assessment Associates; Alexander J. Smith, NYS Department of Environmental Conservation Stream Biomonitoring Unit; Robert W. Bode, Mohawk River Research Center, Inc.; Gary R. Wall, Mohawk River Research Center, Inc.; J. Kelly Nolan, Watershed Assessment Associates*
12:43	*13:53*	**- LUNCH - (on your own)**
13:53	*14:13*	**River Assessing Nutrient Runoff in the Little Chazy River, northeastern New York (Invited)** *David A. Franzi, Center for Earth and Env. Sci., SUNY Plattsburgh; Robert D. Fuller, Center for Earth and Env. Sci., SUNY Plattsburgh; Steven Kramer, William H. Miner Agricultural Research Inst. Jeffrey Jones, Center for Earth and Env. Sci., SUNY Plattsburgh*
14:13	*14:29*	**GIS Model of Aquatic Habitat Suitability for the Central Mohawk River Basin** *John B. Davis, Univ. at Albany/SUNY, Department of Biological Sciences; George Robinson, Univ. at Albany/SUNY, Department of Biological Sciences*
14:29	*14:45*	**The New York State Canal System** *Carmella R. Mantello, New York State Canal Corporation*

14:45	*15:01*	**A Hydrostratigraphic Model of glacial deposits in the eastern Mohawk Lowlands** *Robert J. Dineen, Geigertown, PA*
15:01	*15:17*	**The Environmental Study Team - youth development through local environmental field research** *John M. McKeeby, Schoharie River Center; Caitlin McKinley, Duanesburg High School; Ariana Schrader-Rank, Schalmont High School*
15:17	*15:47*	**COFFEE and POSTERS**
15:47	*16:03*	**Responsible Planning for future ground water use from the Great Flats Aquifer** *Thomas M. Johnson, Hydrogeologist, Alpha Geoscience*
16:03	*16:19*	**Lower Mohawk River Fisheries** *Norm McBride, Region 4 Fisheries Office, NYS Department of Environmental Conservation*
16:19	*16:34*	**Current trends and future possibilities: monitoring for the future and how watershed dynamics may be affected by global climate change** *Jaclyn M.H. Cockburn, John Garver, Amanda Kern, Geology Department, Union College*
16:34	*16:50*	**The NYSDEC Mohawk River Basin Program: an ecosystem based approach to managing the resources of the Mohawk River and its watershed (invited)** *Anne Reynolds, Paul Bray, Alexander Smith, NYS Department of Environmental Conservation*
16:50	*17:00*	**Discussion and Concluding remarks** *Cockburn, J.M.H.*

Poster session (all day)

F1 **A GIS Study of the Mohawk River Watershed Using Digital Elevation Models**
Ashraf Ghaly, Ph.D., P.E., Union College

F2 **Failure of the Bowman Creek landslide, Schoharie Creek**
Amanda Bucci, J.I. Garver, Environmental Science and Policy, Union College

F3 **A GIS Study of Flow Pattern and Flooding in the Mohawk River Basin**
Isaiah Buchanan, Samuel Rothblum, Environmental Science and Policy, Union College

F4 **USGS stream and water monitoring**

F5 **Dam Concerned Citizens**

F6 **Schenectady County Environmental Advisory Council (SCEAC)**

All speakers will be have available poster space.

Symposium Reception (Old Chapel) 5:30 PM to 6:30 PM

Old Chapel (on campus, walking distance to Olin Center)

Symposium Banquet (Old Chapel) 6:30 PM to 8:30 PM

Keynote talk: "Bums and Drums along the Mohawk"
R.H. Boyle

DAM CONCERNED CITIZENS

Ralph Arrandale, President
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PO Box 310
Middleburgh, NY 12122

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The Dam Concerned Citizens, Inc. is a citizen advocacy group that is primarily focused on the safety of the Gilboa Dam and the Schoharie Reservoir it impounds. The DCC, Inc. was formed, unofficially in December 2005, the first official meeting having been held on March 14, 2006, and shortly thereafter incorporated as a not-for-profit corporation under Section 402 of the Laws of the State of New York. Article III of our by-laws states: "The purposes for which the Corporation is organized is to improve the safety, protection and welfare of Schoharie Valley residents from the threat of flood by causing speedy and thorough repairs to be made, and flood mitigation capability to be added to the Gilboa Dam; inform people about dam issues and flood hazard response; and provide the public a voice in dam and flood issues".

The corporation recognizes a widespread dam safety problem and seeks to accomplish the following goals not only locally at the Gilboa Dam, but worldwide: (1) use of the highest design, construction, operation, maintenance and inspection standards on dams; (2) independent oversight of the design, construction, operation and maintenance of dams by qualified dam engineers, at no cost to local governments or residents; (3) dam owners' indemnification of downstream residents and local governments for financial costs and losses attributable to dams; and (4) increased media awareness and improved quality of media reporting on dam and flood issues.

In addition to the foregoing corporate purposes and except as otherwise provided herein, the Corporation shall have all the general powers set forth in Section 202 of the Not-for-Profit Corporation Law, together with the power to solicit and receive grants, bequests and contributions for corporate purposes. Special thanks are due to Lester Hendrix of Schoharie, NY, for his website which dealt with issues of dam safety and for his hard work in helping to create DCC, Inc.

Issues currently being pursued by DCC, Inc., as well as the ones already mentioned, include:

1. **A continuous, sub-surface release of reservoir water into the Schoharie Creek below the Gilboa Dam at a rate of 50-75 cfs**. Such a "conservation release" would help to restore the biosphere below the dam to some semblance of its pre-dam condition and should not impede the ability of the reservoir to fulfill its purpose of providing drinking water for NYC.

2. **Continuous maintenance, upkeep and operations of the 4 large siphons placed on the Gilboa Dam in 2006**. These siphons are capable of discharging approximately 900 cfs at peak efficiency. This approximates the Shandaken Tunnel's maximum output. Until the low level outlet works are installed, there exists no viable sub-surface or low level outlet in the Gilboa Dam, the siphons are a useful, temporary tool to lower reservoir levels by discharging water up and over the Gilboa Dam

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into the Schoharie Creek. During the state of emergency at the Gilboa Dam from October 2005-December, 2006, water was discharged in excess of Ashoken Reservoir needs through the Shandaken Tunnel, simply to keep the Schoharie Reservoir levels low enough to avoid the risk of a sliding failure. This caused high water problems on the Esopus Creek but was deemed an acceptable practice as the risk of dam failure at Gilboa was unacceptable. DCC Inc. does not wish to impose any further burden on the Esopus watershed and therefore supports the continued presence of the siphons at the Gilboa Dam.

3. **Continuous monitoring of the 80 post-tensioned anchors on the masonry portion of the Gilboa Dam, via "sentinel anchors" placed adjacent to the Gilboa Dam**. These anchoring devices exert downward pressure on the spillway, which is a gravity dam, helping to increase its overall factor of safety. DCC, Inc. would like to see a sentinel anchor installed on the Gilboa Dam spillway so that actual measurements, of tension exerted on the submerged bed rock, could be observed.

4. **The creation of a position of "public inspector" for the renovation work to be done on the Gilboa Dam commencing in the fall of 2010**. This inspector would report to the public of any deficiencies, difficulties, or problems encountered in the rebuilding of the Gilboa Dam. There will be many agencies and entities represented by inspectors at the dam work site. However, none of them report directly to the public. In light of past difficulties at the Gilboa Dam, the public is entitled to know the unfiltered and unvarnished truth about the Dam as work continues.

5. **The construction of a additional "Crest Wall" on top of a portion of the existing spillway of the Gilboa Dam**. Based upon the success of the 220' long 5.5' deep Notch placed in the Gilboa Dam in 2006, used to lower reservoir levels, void creation for high water events and flood attenuation, DCC, Inc. firmly believes an additional flood attenuating device in the form of a "Crest Wall" should surmount the existing spillway. More details on this "Crest Wall" can be obtained by going to the DCC, Inc. website at www.dccinc.org.

The Gilboa Dam and Schoharie Reservoir

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In 1926 the New York City Board of Water Supply began moving water from the Schoharie Reservoir, via the 18-mile-long Shandaken Tunnel beneath Balsam Mt. to the Esopus Creek and the Ashokan Reservoir(1). This landmark feat of civil engineering diverted much of the flow from what is now becoming the most productive tributary of the Mohawk River.

There have been both positive and negative consequences as a result of this human induced "stream piracy". One great benefit resulting from the sequestering of flows up to 900 cfs from the 314 mi^2 catchment of the Schoharie Reservoir has been the great augmentation of the 257 mi^2 contribution of the Esopus Creek above the Ashokan Reservoir(2). The Schoharie Reservoir supplies on average 16% of the drinking water requirements of New York City(3). While the Schoharie Reservoir makes a substantial contribution to NY City's drinking water needs, it is the smallest in both surface area and volume of the six West-of-Hudson-Reservoirs owned and operated by the New York City Department of Environmental Protection. Because of its small size relative to its catchment basin, the Schoharie Reservoir has the ability to fill rapidly. Two of the highest peaks of the Catskills, Hunter Mountain, el. 4,040' and Westkill Mountain, 3,880', and the "cloud raking" and rain making potential of the southeast slope of the Catskill Mts., both in close proximity to the Hudson River, lie within the upstream drainage basin of the Schoharie Reservoir(4).

The Gilboa Dam and Schoharie Reservoir

A major negative effect of the Gilboa Dam and the Schoharie Reservoir it impounds is that during the summer and early autumn months the Schoharie Creek is in effect forced to start itself all over again 35 miles from its headwaters, north of the Gilboa Dam. This effect of the Gilboa Dam is not confined to only the summer and autumn months as stream flow data demonstrates that it can take place any month of the year. All that is necessary for this severing of Schoharie Creek flow to take place, is to have the Reservoir elevation to be below crest level, 1130' or "notch" level of 1124.5' above sea level and to have the amount of water diverted from the Schoharie Creek drainage via the Shandaken Tunnel greater than the amount that is entering the Schoharie Reservoir.

For several months of each year, a very unusual set of circumstances occurs where the 886 mi^2 drainage basin of the entire Schoharie Creek at Burtonsville, NY, (USGS gauge #01351500) has less stream volume than the 232 mi^2 drainage basin of the Schoharie Creek at Prattsville, NY (USGS gauge # 0135000). The Gilboa Dam, when it is not spilling at elevation of 1124.5' actually diminishes the Schoharie Creek's effective catchment at Burtonsville, NY to 649 mi^2. Even at that figure, the Burtonsville catchment is more nearly triple that of 237 sq. mile water catchment basin of the Schoharie Creek at Prattsville, NY; such is the highly productive nature of the Schoharie Creek headwaters. The 314 mi^2 figure for the Schoharie Reservoir

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includes the drainage north of Prattsville, NY and south of USGS gauge station at Gilboa NY (USGS gauge #01350101).

There are very few rivers in the world that decrease in size and volume as they flow away from their source towards their destination. This unnatural condition is enhanced due to the direction of flow of the Schoharie Creek from S.E. to N.W., over its 85-mile course to the Mohawk River, at Fort Hunter, NY. During this flow, the Schoharie Creek is subjected to more or less daily strong solar influence, ie. east to west stream flow travels with the sun. Also, the Schoharie Creek drops precipitously in its first few miles from it's source at Acra, NY, quickly changing from a mountain brook to a frequently placid, valley stream[(5)]. The Schoharie Creek drainage predates the last ice age and is today a greatly "under fit" stream corridor[(6)].

The Schoharie Reservoir is small, relative to its catchment basin and both fills and spills rapidly in times of sudden snow melt or major storms, or a catastrophic combination of both factors. It is during the "major events" that one can witness the true magnitude of the Schoharie's mighty drainage. The tragic collapse of the bridge over the Schoharie Creek on the NYS Thruway, April 5, 1987 and the enormous snow melt induced flood of January 18 & 19, 1996 bears witness to the extreme flash flood potential of the Schoharie Creek.(7) With these factors in mind, what measures can be taken to remedy some of the negative impacts of the Schoharie Reservoir on those residing downstream of the Gilboa Dam?

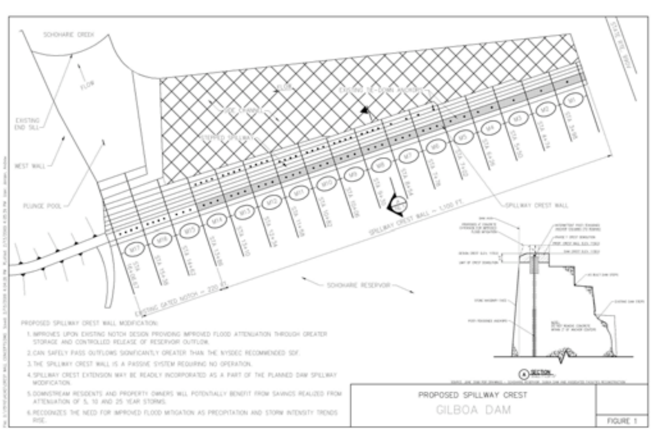
Several things can be done to improve the lot of those residing downstream of the Gilboa Dam, while having no detrimental impact on either the quantity or quality of water provided NYC by the Schoharie Reservoir:

1) At the present time, due to the unequal relationship between the size of the Schoharie Reservoir (1142 acres) and it's catchment 314 sq. mi., its ability to assist in flood mitigation is somewhat compromised. Upon completion of dam reconstruction work (2015), the new, sub-surface, low level outlet release works will provide a means for preemptively drawing down the water levels of the Schoharie Reservoir in anticipation of a flood. These works will have the capacity to reduce the volume of the Reservoir by 90% (21 billion gal.-2 billion gal.) in 14 days, assuming there is no refilling. This is a federally mandated guide line for the minimum rate of low level outlets. Had such a mechanism been in place, spring 1987, the Reservoir could have been lowered to accommodate the run-off from the 40" snow pack of that winter. Instead, the melt water filled the Reservoir, a major north east storm struck on Sat., April 4th, filling the Reservoir to its second highest elevation of record, 1135.69". This huge volume of water as measured at the Gilboa Dam caused the collapse of a portion of a bridge crossing the Schoharie Creek on the NYS Thruway, Sun., 4/5/87, and the loss of 10 lives[(8)]. The impact of this tragedy attracted attention world wide on issues of bridge safety and inspection regimes.

Ironically, there was little focus on what could have been done, 50 miles upstream of the thruway bridge at the Gilboa Dam, to prevent this disaster. It is possible that the bridge failure could have been averted had adequate release works been in place and in operation in a timely manner to create a void/storage in the Reservoir. The operation of low level release works are a proactive response to a perceived threat of future flooding posed by heavy snow pack. But, it takes time to draw a reservoir down and a low level outlet works is <u>not</u> a "quick response" flood mitigation tool.

2) A Crest Wall is another means of flood mitigation, involving attenuating the spill, thus reducing per second volume by the lengthening of spill time. It is passive, always in place and operational; it is economical; and most importantly, it works. This means of reducing the flood impact for areas north of the Gilboa Dam in portions of Schoharie, Montgomery, and Schenectady counties is the simple addition of a Crest Wall to the masonry spillway of the Dam. Until 2006, the 1324'

spillway of the Dam had no opening. Whenever the Reservoir filled to spillway crest elevation of 1130’, the waters spilled over and across the entire width. In response to the Gilboa Dam crisis of Oct. 2005 a 220’l x 5.5’d notch was cut in the western side of the spillway. This, in effect, lowered the Reservoir to elevation 1124.5’ and created a void/storage capacity of 2 billion gallons before the Dam could be “topped”. All the time the Reservoir would be filling to elevation 1130’, the notch would be spilling water up to a limit of 8600 cfs. During the time it takes to fill the Reservoir form 1124.5’-1130’ storms often pass through. The utility of the notch in attenuating discharge, and the four siphons, an emergency stop-gap measure put in place until a low level outlet is constructed, was demonstrated in the disastrous flooding late June, 2006. Based upon the success of the notch, it is proposed that an additional 4’ high crest wall be added to a portion of the existing 1324’ spillway at the Gilboa Dam. This addition would allow up to 20,000 cfs to spill before it “tops”; this attenuation time is assuming the Reservoir is at an elevation of 1124.5’. If the Reservoir were lower due to preemptive use of the low level outlet, attenuation would be lengthened. Preemptive releases pose less threat of causing Reservoir short fall due to increased rates or precipitation now occurring. Crest wall construction and low level outlet operation offers real potential relief in terms of life and property of those down stream of the Gilboa Dam.

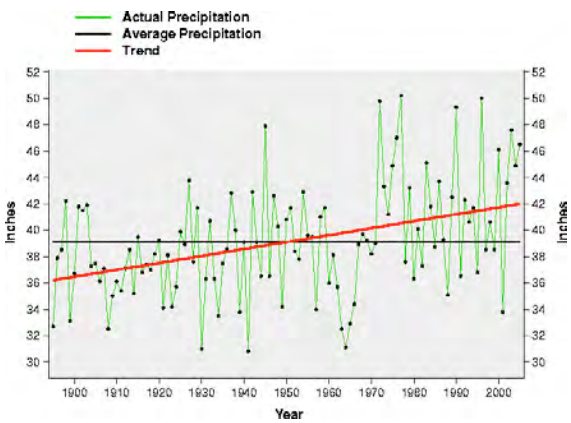


3) Implement a continuous release of water from the Schoharie Reservoir north of the Gilboa Dam in times of non-spillage over the 1124.5’ elevation notch. This water need not come from the coldest part of the stratified column of water in the Schoharie Reservoir. The trout of the Esopus Creek have come to depend on that thermal layer. It has been estimated, by local professional fisheries biologists, that a flow between 50-75 cfs would greatly enhance the ability of the Schoharie Creek to reestablish itself below the Gilboa Dam, in times of non-spillage. This enhanced flow would provide waters for recreation in the Forever Wild section of the Schoharie Creek adjacent to Stryker Rd, from the 990V Bridge northward to Nickerson’s Camp Ground. Further downstream these waters will benefit Mine Kill State Park, the Blenheim-Gilboa Pumped Storage Project, owned and operated by the Power Authority State of New York (PASNY), anglers and other water sports. The Schoharie Creek is an important source of water for agricultural irrigation and increased flow will benefit farm business, while being returned through the soil and transpiration to both the water table and atmosphere.

4) In wintertime, continuous releases from the Schoharie Reservoir will help to create sufficient flow in the Schoharie Creek downstream of the Gilboa Dam to help prevent the formation of thick ice, which in times of spring run-off often leads to ice jams. The salutary effects of releases from Gilboa Dam in helping to prevent ice formation has been amply demonstrated by the functioning of the four siphons used as temporary draw down mechanisms, since 2006. In times of reservoir elevations of less than 1124.5’, the Schoharie Creek north of the Gilboa Dam has little current. This, coupled with low temperatures, is a sure recipe for thick ice formation in the slow moving eddies of the Schoharie Creek. With enhanced flow from

the siphons since 2006, pack ice has been incised by increased current in winter time, and the threat of ice jamming has thus been greatly reduced.

5) Whatever void is created by non-spillage release of water from the Schoharie Reservoir, via a continuous release regime will assist in the creation of a storage void to help accommodate "frozen assets," i.e. water from melting of snow pack in times of thawing. The NYCDEP has committed to a void draw down equivalent equal to 50% of the estimated water content in the Schoharie Watershed Snowpack.



It is a fair question to ask where the water will come from to provide for a continuous subsurface release in times of non-spillage. In 1970, the average precipitation total was 36"; it is now 42"[9]. As of January, 2009, 47.79" has fallen at Albany, NY[10]. This condition and trend is even more pronounced in the Schoharie Watershed. For whatever reason, it is beyond argument that the twenty-first century is a wetter time than when the Schoharie System, as the NYC Board of Water Supply called it, was designed. An additional source of 50-75 cfs Conservation Release Water is made available by the NYCDEP compliance with the State Pollution Discharge Elimination System (SPDES) Permit. Schoharie Reservoir Release Regulations (6NYCRR Part 670) states that from June through October each year, NYCDEP is to send through the Shandaken tunnel to the Esopus Creek, only enough water to create a maximum flow of 300 million gallons per day when combined with stream flow upstream of the Allaben Portal.

NYCDEP is also obligated to send enough water through the Tunnel to maintain a minimum flow of 160 million gallons per day in the Esopus Creek. Thus, the Shandaken Tunnel discharge under most conditions prevailing from the months of May-October is limited to less than 50% of its carrying or design capacity. The excess water that can not be discharged under normal operating circumstances can and should be used to meet the Conservation Release Requirements of the Schoharie Creek north of the Gilboa Dam.

In the eight decades since the completion of the Gilboa Dam/Schoharie Reservoir system, methods of weather prognostication have greatly improved. Though the engineering, the thought and design as manifested at Gilboa are superb, it is hoped that the twenty-first century is a more enlightened age in terms of a more reasonable approach concerning matters such as the conservation release being advocated in this paper. The citizens living downstream of the Gilboa Dam are asking not for the release of the coldest water, rather just any water at all. The sight of crayfish, Dobson Fly larvae, and May Fly larvae fortunate enough to be mobile (*Isonychia bicolor*, etc.) all scurrying for cover when the Schoharie Creek at North Blenheim, NY, drops 2 feet in a matter of minutes, is heart breaking. Such precipitous drops occur when the so-called recreational releases take place via the Shandaken Tunnel starting each spring around Memorial Day. These releases of up to 900 cfs at Allaben and downstream on the Esopus Creek are intended to benefit tubers, kayakers and tourism along Rt. 28 in the Esopus Valley. The citizens of the Schoharie valley aren't asking for an end to recreational releases of Schoharie Reservoir water into the Esopus, rather, they are asking for a continuous release of reasonable quantities of life sustaining water into the Schoharie Creek north (downstream) of the Gilboa Dam. NYCDEP refers to water that leaves the Schoharie System northward over the dam or through the notch or siphons as "waste water". For those of Native American ancestry, this term is especially galling. It is not "waste water" that the Schoharie Creek north of the Gilboa Dam needs, but the vital life giving force of water released at a reasonable and sustainable rate of flow. Surely, with the sophisticated technology of today and a more enlightened attitude on the part of the NYCDEP, the time for Conservation Releases is at hand.

Footnotes

1. Merriman, Thaddes, Board of Water Supply Annual Report, 1923, p. 93. plate 6.
2. Galusha, Diane, "Liquid Assets", p. 265.
3. Galusha, Diane, "Liquid Assets", p. 264.
4. Evers, Alf, "The Catskills", front piece.
5. Austin, Francis M., "Catskill Rivers", p. 210.
6. Fluhr and Terenzio, Engineering Geology of NYC Water Supply System, p. 34.
7. Daily Gazette-April, 1, 2007, p. 1.
8. Daily Gazette-April, 1, 2007, p. 10.
9. Precipitation graph-National Weather Service.
10. Daily Gazette-Jan. 1, 2007, 2008. & 2009, Annual Weather summaries.

References

1. Board of Water Supply, City of New York-Annual Reports 1917-1927, Thaddes Merriman, Chief Engineer.
2. Evers, Alf, "The Catskills", Doubleday, Garden City, NY, 1972.
3. Francis, Austin, M., "Catskill Rivers", Nick Lyons, 1983, NY, NY.
4. Galusha, Diane, "Liquid Assets, A History of the New York City's Water Supply", Purple Mountain Press, Fleischmanns, NY, 1999.
5. National Weather Service, Albany, NY, 2005. courtesy, Dr. Robert Titus.
6. New York State Geological Survey, "Engineering" Geology of New York City Water Supply System", Thomas W. Fluhr, p.e. and Vincent G. Terenzio, p.e., Oct. 1984.
7. "The Daily Gazette", Schenectady, NY, Annual Weather Summaries-2006, 2007, 2008.

THE TEMPORAL PACE OF LANDSLIDE MOVEMENT DETERMINED FROM GROWTH ASYMMETRY IN *TSUGA CANADENSIS*, BOWMAN CREEK, MOHAWK RIVER WATERSHED, NY

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Landsliding in New York State is a widespread problem, and there are a number of historic events in Schenectady County and in the Mohawk drainage basin. This study investigates the timing of slumping at Bowman Creek, which is a small tributary that empties into Schoharie Creek at Burtonsville. We are interested in this slumping because this process is potentially one of the main ways that large volumes of sediment is mobilized in the watershed. The lowermost part of the slope failed during a torrential rainfall event in July 2008. In fact, this high-volume rainfall event cause tremendous damage to the infrastructure in Bowman Creek and Chaughtanooga Creek (Wolf Hollow), and these two areas are of particular concern to the County.

The Bowman Creek slide (N 42.80306, W -74.25895) is incised at its base by Bowman Creek, which is a small brook that flows west into Schoharie Creek near Burtonsville, New York. The slump on Bowman Creek is ~27 meters high, over 53 meters horizontal along the base. It is entirely on private property. For this study, *Tsuga canandensis* (Eastern Hemlock) was cored, as they are abundant and have extremely good, long annual records, and they produce clear distinct annual rings. Other trees on the hillslope are *Fagus grandifolia* (American Beech), *Acer saccharum* (Sugar Maple), and *Betula alleghaniensis* (Yellow Birch), and *Tsuga canadensis* (Eastern Hemlock). *Pinus strobus* (White Pine) also occurs on the slopes of Bowman Creek, but not directly on the slump.

Dendrogeomorphology is the study of tree rings as they relate to the geomorphic processes of the substrate that the tree is growing on (Stoffel and Bollschweiler, 2008). This method is helpful for assessing mass movement on landslides and slumps. Stress in a tree can be distinguished in the growth of tree rings in a tree core by the size and color of the rings because trees respond to the tilting and root disturbances. Conifers that grow on a slope add more growth to the downslope side of the tree to compensate and force straightening (Bollschweiler and Stoffel 2008). Eccentric growth of the trunk occurs after mass movement and tilting, and growth adjustment results in an easily detectable change within the rings. Reaction wood is easily distinguishable from normal annual rings, because it is darker than uninterrupted tree growth because the cell walls are thicker and the wood is rich in lignin. The rings on the opposite side correspond with the reaction wood by growing smaller (very tightly), and they may even be lighter in color.

Methods. Tilted *Tsuga candenensis* were cored on the crown, body, and toe of the slump. Cores were taken with an 18" increment borer. Upon extraction, cores were slid into a plastic sleeve in the field, and then mounted in a grooved plywood board with wood glue. They were sanded progressively with 60, 100, 150, and 220 grit, and finished with a linen cloth. Individual cores were scanned on a 17" flatbed high-resolution scanner (Epson Expression 10000 XL). The cores were generally scanned at 600 DPI (or greater), with an adjacent metric ruler. The resulting images were cropped in Adobe Photoshop, and then imported into Adobe Illustrator.

In Illustrator, cores were enlarged and individual annual years were measured, and the length was determined and calibrated against the millimeter ruler. For all the trees with successful downslope and corresponding upslope data, three plots were made showing the annual growth ring width, the ring width ratio, and the ring difference throughout time. Here we only show plots of upslope and downslope ring plots. When these two diverge, the tree has grown eccentrically.

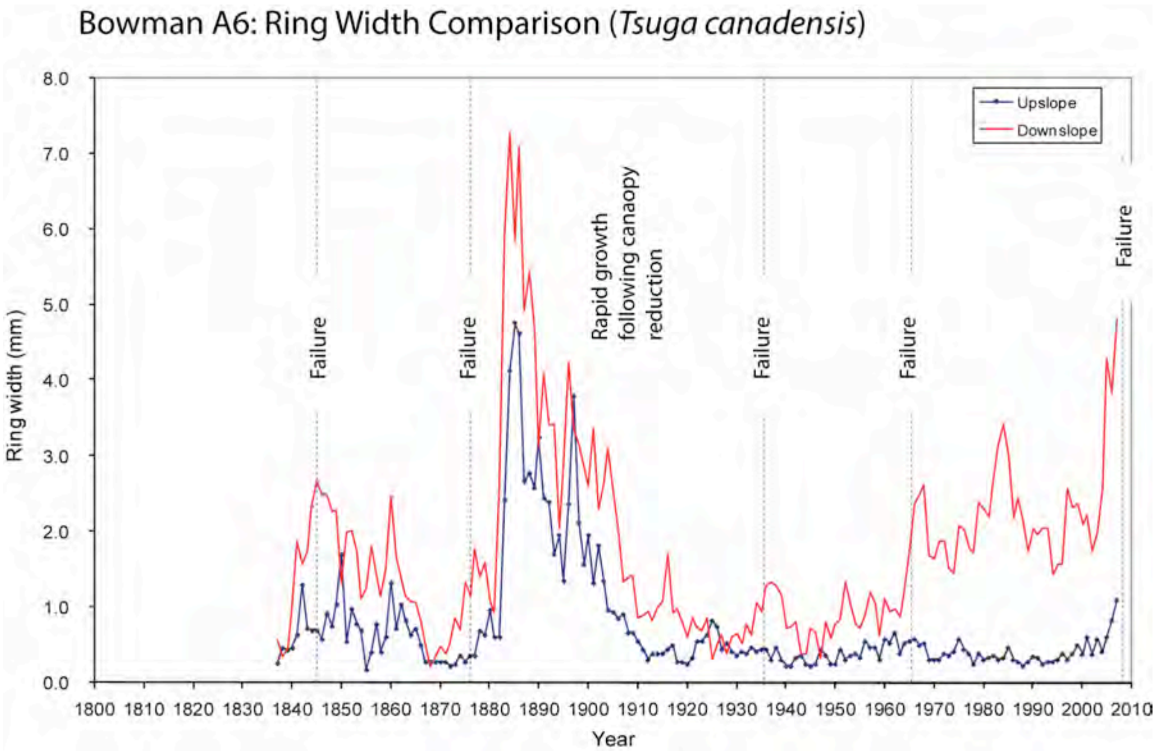

Figure 1: Plot showing tree rings in sample A6, a slice from a Tsuga canadensis that was felled as a result of the 2008 slip event. Red (upper) is the ring width plot of the downslope side and blue (lower) is the plot of the upslope side of the tree.

Results. Eccentric growth of tilted trees on the Bowman slide are related to ground movement that is likely both creep as well as sharp dislocations related to slip events.

Tree-ring records from the Bowman slump indicate that the movement history of this hillslope is complex. Tilted trees across the entire slump all show movement with reaction wood on the downslope side of the tree throughout their growth history.

All tilted trees studied show eccentric growth in their rings between 1970 and 1990. This result is a clear indication that there was mobilization over the entire slump at some point during this entire 20-year interval. For brevity, we show the record of a single tree (A6), but our conclusions are based on 11 complete records that are discussed in detail in Bucci, 2009 (see also condensed summary from the upper slope in Figure 2).

Tree A6 from the lower part of the Bowman Creek slip is one of the best records from the study as it shows an excellent record of progressive, decades-long movement on the slump (see Fig. 1). One of the most impressive aspects of this record is that some of the most eccentric growth and most prominent reaction wood is during a three year period of 2005-07. The slip and failure of this block occurred in July 2008 (and the toppling of the tree). Therefore reaction wood and the largest eccentric growth of this tree for three years *before* the ground actually failed in an event and killed the tree. One possible explanation is that ground motion occurred for several years, and that trees begin to react to internal ground movement before an actual slip occurs. One implication is that rapid eccentric growth of trees on a slope may be used to predict future failure.

If there is progressive movement in the form of rapid creep, the results from trees on the upper part of the slump are interesting and worthy of note. The three successful cores from tilted trees at the top of the slump all showed rapid growth on the ring width comparison graphs from the past five years (see Fig. 2). Like tree A6, this result is important because there have not been any obvious slip events with ground breakage on the upper part of the slump in the past decade. The tree rings would suggest that slip on the upper part is imminent if the same pattern occurs as is seen in A6. Note that the summer of 2008 event only affected the bottom block in the slump (A). It is quite possible that the tree ring records (C) show that there is current ground movement (rapid creep) and this rapid ring growth may be a predictor that there is internal ground deformation, and that that uppermost part of slump could fail at any time.

Implications and conclusions

This active slow-moving slump shows a record of 175 yr of deformation and tree tilting and as such it is ideally suited to reveal subtle clues as to the relationship between ground movement and precipitation. There are clearly periods of ring asymmetry that is inferred to relate to enhanced slip and this study serves as a starting point for developing a regional evaluation of the historic significance of landslides.

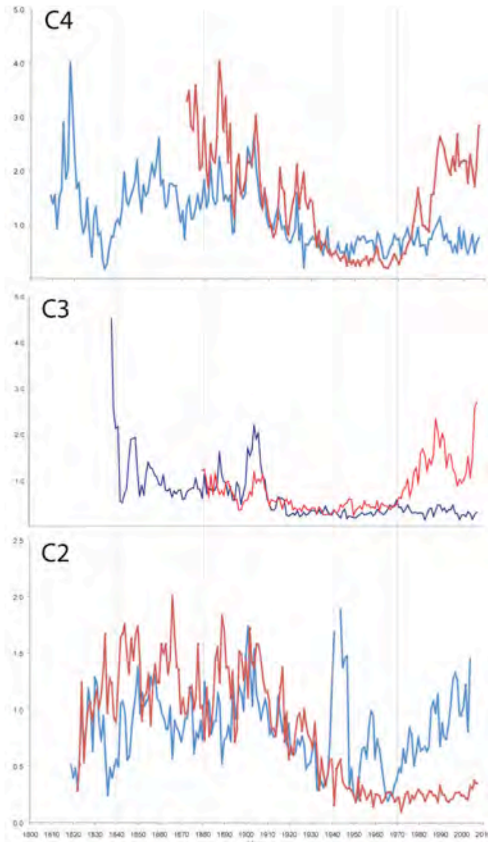

Figure 2: Ring-width asymmetry for the three trees on the upper part of the slump. All three show a pronounced asymmetry in the last few years, but this trend started in c. 1970.

Eccentric growth indicates that this landslide is actively moving. Slip in 2008 is part of that current phase of movement, and the highly eccentric growth of A6 suggest ground motion and slip started 3 yr before failure in 2008. Therefore, one likely possibility is that deformation and ground motion in this instance first occurred as accelerated creep, and that motion precedes failure. If this model is correct, slip on upper of the slope (C) is imminent because all trees successfully evaluated on that part of the hillslope show rapid and wildly eccentric growth in the past few years.

Movement at the base is complex and trees show a number of different responses to movement over time, which is likely related to differences in the size and complexity of slide blocks. Tree growth and eccentricity patterns on the upper part of the slope is much more simple in comparison. This pattern likely reflects the fact that the upper block responds to only a single separation point or slip surface.

Rapid and dramatic growth from c. 1880 to 1910 is inferred to be release from suppression growth that likely responded to the formation of a canopy gap. Maximum growth occurred 1880-82. If this gap was formed by trees felled in a slip event, similar to what happened in 2008, then our best estimate of the timing of that slip is 1873-1880 based on ring asymmetry in A2 and A6. There are several alternate hypothesis as to how a canopy gap could have formed, logging is foremost among them.

We suspect that trees respond to disturbance rapidly, but then growth is followed by a long period of recovery that appears to last for more than a decade. Eccentric growth can precede slip (A6), and that growth is eccentric for some time after slip in the recovery phase. As such, assignment of slip or significant ground movement from asymmetry requires the evaluation and synthesis of many individual trees. In doing this, we recognize the following key periods of slip:

• 2005-P appears to be a period of enhanced instability. This is obviously manifested by the small volume slip in 2008, but wildly eccentric growth of trees on the upper part of the slope suggest instability that is the most dramatic that many of these trees have experienced in over 175 yr.
• 1970-76 tilting and slip was pervasive and acted progressively upslope over 6 yr. this period corresponds to a well-known extremely wet period in this area. Much of the slope appears to have been mobilized in this interval, and this is similar in timing to movement of comparable features in the Plotterkill Preserve (c. 15 km east).
• 1942-1946 appears to be a single, short-lived event that is also recognized in the Plotterkill Preserve (Bucci and Garver, 2009).
• 1873-1880 may have been when a slip occurred that caused a canopy gap recorded in rapid growth from c. 1880 to 1910.
• 1828-1833 may have been a time of instability on the slope. A single tree (B4) shows eccentric growth and reaction wood. As we would expect, old events are more difficult to decipher because the record is less robust.

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USING DUAL ISOTOPE TRACERS TO LEARN ABOUT THE SOURCES AND TRANSFORMATIONS OF NITRATE DURING TRANSPORT IN THE MOHAWK RIVER BASIN

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The effects of human activities on the nitrogen (N) cycle at regional and global scales is the focus of much research and concern because humans have more than doubled N fluxes, storage, and the rates of many N cycling processes. This human-induced acceleration of the N cycle is linked to myriad environmental concerns including soil acidification, tropospheric ozone, acute ground-water and stream-water pollution, and estuarine eutrophication (Galloway et al., 2003). At the regional scale, much work has focused on the controls of nitrate (NO_3^-) concentrations and fluxes in riverine environments that range in scale from small streams to large rivers (Boyer et al., 2002; Smith et al., 2005). Major uncertainties remain in our understanding of how N from various sources moves through landscapes to rivers and the extent to which N cycling processes alter these sources during transport (Schlesinger et al., 2006). The transport of NO_3^- is of concern in the Mohawk River watershed, because as part of the Hudson River watershed, N loads are transported to estuarine settings such as the Long Island Sound, where eutrophication has been identified as an issue of concern by state and federal environmental regulators.

One approach to learning about the sources and processes that affect the movement of N through the environment is to measure various isotopes of the element or its associated elements. In the case of N, the ratio of the stable isotope ^{15}N to the more common stable isotope ^{14}N can be used to trace sources and transformations through watersheds. In recent years, methods have been developed to measure both $^{15}N/^{14}N$ (reported as $d^{15}N$ relative to a standard) as well as the isotope ratio $^{18}O/^{16}O$ (reported as $d^{18}O$ relative to a standard). This dual isotope method has allowed investigators to better gain insight into the sources and movement of NO_3^- in watershed studies. In multi-land use watersheds such as the Mohawk River, a variety of sources such as fertilizer, human and animal waste, and atmospheric deposition can contribute to river NO_3^- loads. In this study, we measured NO_3^- concentrations as well as $d^{15}N$ and $d^{18}O$ of NO_3^- in the Mohawk River and in five additional streams (either within or near the Mohawk watershed) in differing land uses to learn about the sources and transport of N in the watershed.

Samples were collected monthly from each stream at a range of flow conditions for 15 months during 2004-05 and analyzed for NO_3^- concentrations, $d^{15}N_{NO3}$, and $d^{18}O_{NO3}$. Samples from two streams draining forested watersheds indicated that NO_3^- derived from nitrification was dominant at baseflow. A watershed dominated by suburban land use, but with all waste water discharged outside the watershed had three $d^{18}O_{NO3}$ values > +25‰ indicating a large direct contribution of atmospheric NO_3^- transported to the stream during some, but not all high flow periods. Two watersheds with large proportions of agricultural land use had many samples with $d^{15}N_{NO3}$ > +9‰ suggesting a waste source consistent with direct application of manure to fields associated with regional dairy farming practices. These data showed a linear seasonal pattern with a $d^{18}O_{NO3}$: $d^{15}N_{NO3}$ close to 1:2, consistent with seasonally-varying denitrification that peaked in late summer to early fall with the warmest

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temperatures and lowest streamflow of the year. The large range of d $^{15}N_{NO3}$ values (~10‰) indicates that NO_3^- supply was likely not limiting the rate of denitrification, potentially consistent with ground water and/or in-stream denitrification. Mixing of two or more distinct sources may also have affected the seasonal isotope patterns observed in these two agricultural streams. At a larger basin scale in the Mohawk River watershed that represented the average proportions of land uses in this study, none of the source and process patterns observed in the small streams were evident. These results emphasize that observations at small to medium size watersheds of a few to a few hundred km^2 may be necessary to adequately quantify the relative roles of various NO_3^- transport and process patterns that contribute to streamflow in large basins.

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CURRENT TRENDS AND FUTURE POSSIBILITIES: MONITORING FOR THE FUTURE AND HOW WATERSHED DYNAMICS MAY BE AFFECTED BY GLOBAL CLIMATE CHANGE

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It is predicted that mean annual temperature and mean annual precipitation will increase as a result of global climate change (NECIA, 2006). This change will have profound implications for northeastern watersheds and in particular the Mohawk. We suspect that there are several key changes that need to be considered for possible active monitoring systems and baseline studies. Climate-change scenarios would predict the following large scale, basin-wide changes: 1) **Variability in discharge**. A change in the precipitation patterns, which might mean that Atlantic tracking storms become a more significant factor, especially in the southern tributaries in the basin; 2) **Increase in Precipitation.** A change in overall precipitation across the entire basin; 3) **Temperature increase.** Increase in mean annual temperatures and an overall decrease in the overall freezing season. This has particularly important implications for the overall snowpack in the basin, and the dates and duration of the formation of ice on rivers and lakes in the watershed.

In this study, we evaluate the overall framework of global climate change in the Northeast as presented by NECIA (2006) and consider the impacts on the Mohawk Watershed. We then take the next step and ask what this might mean for active monitoring and basin-wide surveys that should be initiated now to better understand these changes.

Expected Climate Change Impacts for the Northeast. It is not our intent to entirely review the literature on climate change and its predicted impacts. It is vital to note that the impacts will be felt in the northeast and that water resources are likely to be the most severely impacted (Figure 1, 2). Weather observations made at the Albany International Airport and compiled by the National Climate Data Center (NCDC) under the National Oceanic and Atmospheric Administration (NOAA) indicate that the observations and predictions applicable to the Northeast are relevant for our area as well (Figure 3, 4, 5).

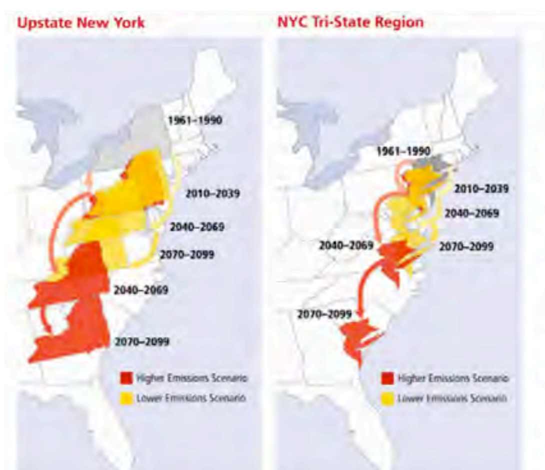

Figure 1: Estimated climate 'migrations' for Upstate New York and New York City, based on average summer heat index under lower- and higher-emissions scenarios projected by GCMs (NECIA, 2006).

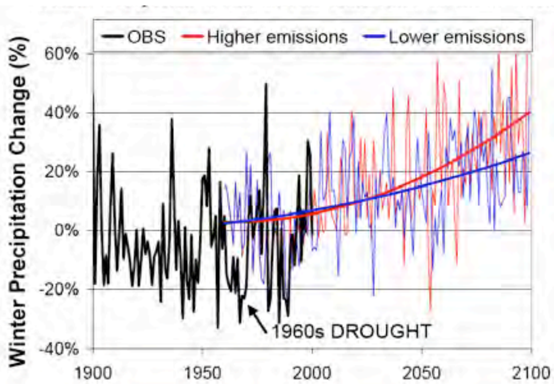

Figure 2: Observed and projected changes in winter precipitation. Predicted values are based on two different emissions scenarios (NECIA, 2006).

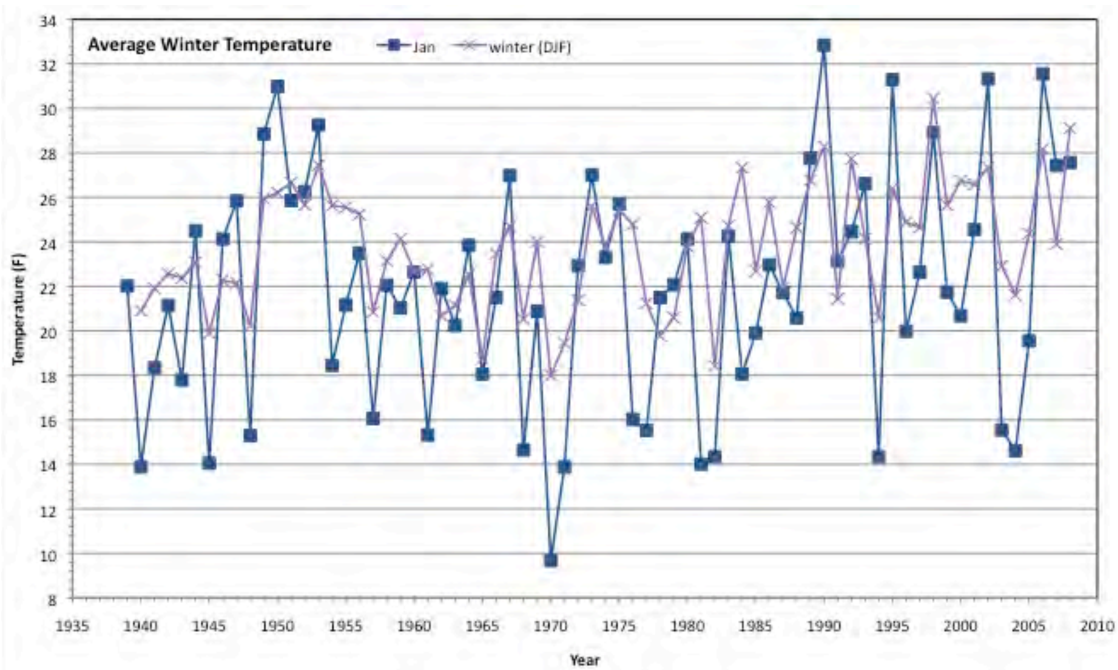

Figure 3: Winter temperatures recorded at Albany Airport through the 20th century. Both January average and Winter (December, January, February) averages were determined from daily observations.

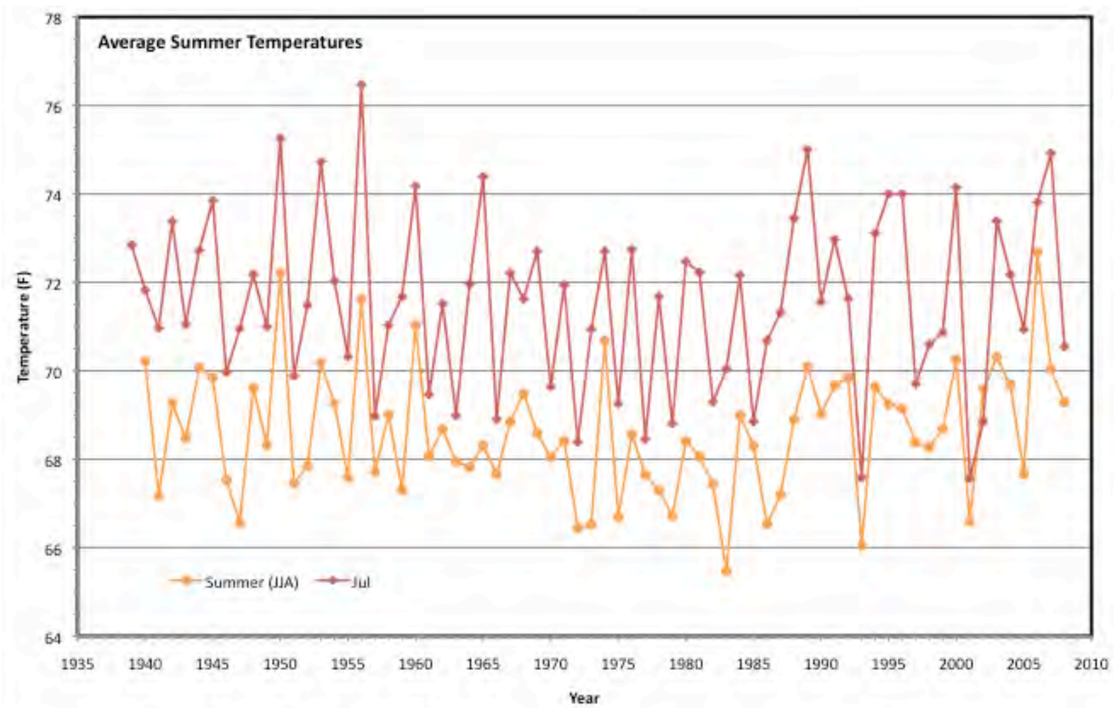

Figure 4: Summer temperatures recorded at Albany Airport through the 20th century. Both July average and Summer (June, July, August) averages were determined from daily observations.

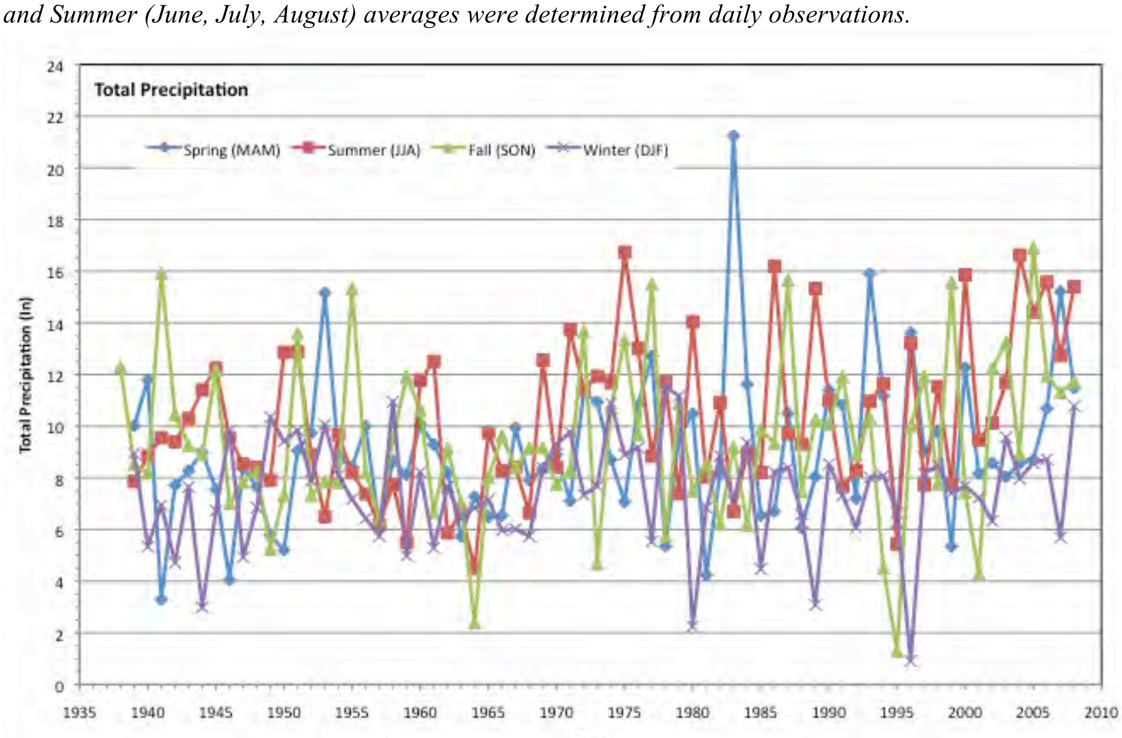

Figure 5: Total precipitation for each season, as observed at the Albany International Airport. The drought through the 1960s is clearly observed; the trends in recent decades suggest increased precipitation outside of the winter season.

Discharge and Flooding. We might anticipate an increase in the frequency and severity of rapid, high-discharge events that tend to be localized and therefore affect small tributaries. An example of such an event is the July 2008 outburst that was characterized by extremely high local rainfall that was very heterogeneous in its intensity. This event caused an extremely flashy discharge that resulted in considerable runoff in Chuctanunda Creek and Bowman Creek in Schenectady County.

Spring break up is likely shift to earlier in the year but the mean ice-out date, or the mean break up date might be imperceptibly different because historical variation has been high (Johnston and Garver, 2001).

The overall increase in discharge and frequency and severity of flooding appears to have already affected the basin in part because precipitation is high as determined from the historic records (Burns et al., 2001; Kern, 2008). Discharge data seem to suggest that the change in flood frequency and flood severity is more dramatic in the southern tributaries (i.e., Schoharie Creek, Figure 6; Kern, 2008).

Ice jamming and ice-jam flooding is a function of total ice thickness, rapidity of melt/thaw, and the rate of rise of discharge. We might expect earlier ice-out dates that have already been recognized in New England (Hodgkins et al., 2005). We might also see an increase in the number of mid-winter break up events, as we saw in January 1996, the most dramatic and damaging in recent history (Lederer and Garver, 2001). However, if winters are, on average, warmer, the decrease in the overall thickness of the ice pack may serve to lessen the severity of ice jam events.

One important change we can anticipate is the total number of low-flow events that occur annually or that might be related to prolonged drought. To a certain extent low flow and drought conditions are the most dramatic shocks and stresses to aquatic ecosystems. A key aspect of this is dramatic rise in water temperatures that reduce dissolved oxygen, and lethal combination for many aquatic organisms. This just occurred on the West Canada Creek (2007), as the relatively low amount of precipitation in that summer stressed the ecosystem and as a result fishing on this highly productive river was closed. While this event is a bit complicated because of a variety of demands on water from that river and the Hinckley reservoir, the lesson from this event is clear. During this low flow, restrictions were put in place, the aquatic ecosystem was stressed in what was otherwise a year of exceptionally high average flow on that river.

Water Temperature in the rivers and streams might change as well, which would have a dramatic impact on aquatic ecosystems. This change might be especially profound for fauna that have a life cycle timed to water temperature. Those organisms that take their reproductive clues from water temperature may shift dates for spawning, larval growth, and emergence. Note that if this effect is significant, there will likely be a widening gap between those organisms timed to daylight compared to those timed to water temperature, which is the case for some birds, and some fish. If this shift is dramatic, there might be important implications for fish and game management.

Sediment mobility. Higher average discharge and more variable discharge will have important implications for sediment mobility in the watershed. Highly variable discharge will likely increase bank erosion and mobilize sediment and debris in small tributaries. Highly saturated conditions cause increase in slope instability, and an increase in slumps and landslides may increase sediment supply in a non-linear way. A greater than average sediment load will obviously affect canals and the main trunk of the Mohawk that has a number of anthropogenic sediment traps (dams and locks). The increase in sediment supply may result in increased turbidity, and this would have additional consequences for aquatic ecosystems.

Monitoring Focus. The goal of this presentation is to outline the major processes likely to exhibit the impacts of climate change in the Mohawk Watershed. In all these cases, water resources may become limited. Understanding the additional consequences (e.g., aquatic ecosystem impact, navigability) will not be possible until the immediate physical processes are understood. The limited number of gaging stations along the lower reaches of the Mohawk and its smaller tributaries will certainly hinder our efforts at understanding the ongoing changes.

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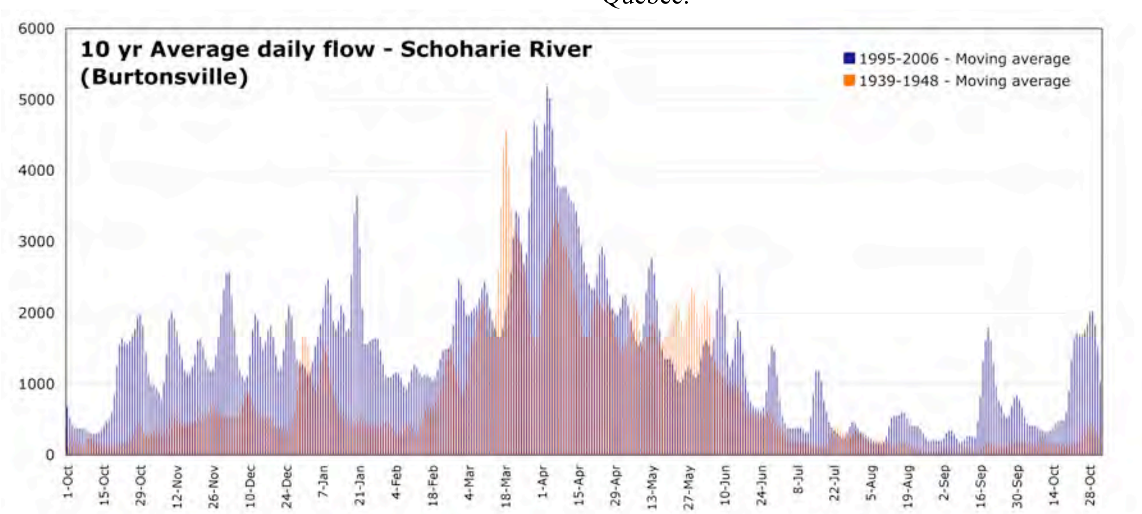

Figure 6: Daily discharge on the Schoharie Creek as measured at Burtonsville. This shows a comparison of two different decades. The blue is from 1995 to 2006, and the Red is from 1939-1948. Both lines are a 3-point moving average. This plot shows the difference in seasonal patterns, which appear especially different in the winter and the autumn.

GIS MODEL OF AQUATIC HABITAT SUITABILITY FOR THE CENTRAL MOHAWK RIVER BASIN

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Many of the processes that determine the physical features of watershed also determine their biological features, including habitat for aquatic organisms. With current digital information and mapping software, it is now possible to model the suitability of freshwater ecosystems for rare species (which typically have narrow habitat requirements), and to use the results for land use planning and watershed restoration studies. In this investigation, we examined stream habitats in 18 sub-watersheds centered on Montgomery County, as part of a broader NY State wildlife conservation initiative.

Previous work found that five parameters (stream size, habitat quality, water quality, stream gradient, and riparian forest cover) were sufficient to predict aquatic biodiversity in stream ecosystems of western NY State (Meixler 1999). Other work, which used sub-watersheds as the unit of analysis rather than stream segments, found that key metrics of ecological integrity were land cover, roads, dams, the total richness of rare species, and water quality (Howard, 2006).

Building on these earlier efforts, we have developed a geographic information systems (GIS) model of habitat suitability for streams in the central portion of the Mohawk River Basin. The model predicts the suitability of a stream reach for ten species of conservation interest, including freshwater mussels, dragonflies, and damselflies. The velocity and size of stream reaches that are known to have populations of these aquatic organisms were used to define the range of reaches that are also expected to have the same species in the study area. Streams were also evaluated for a number of water quality parameters: the NYS water quality classification of the stream; the presence of point sources of pollutant discharge; the percent of natural land cover within 30 meters of the stream; and impairments of the stream flow caused by dams or road crossings. The parameters were individually scored and added, and the total was rescaled to a maximum of 100. Stream reaches with higher scores represent more natural, less-impaired habitat. From the set of suitable stream reaches selected by velocity and size, the highest-scoring reaches were selected based on the sum of the stream quality parameters.

Geomorphic Parameters

The United States Geologic Survey's National Hydrography Dataset Plus combines hydrographic features with modeled attributes such as mean annual flow (cubic feet/sec), maximum velocity (ft/sec) and slope (cm/cm) ("NHD Plus User Guide" 2009). These data provide a way of estimating the range of geomorphic attributes that may be preferred

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by an aquatic species. In order to identify preferred stream habitats for aquatic species in the study area, NY Natural Heritage Program Element Occurrences for these species were intersected with NHDPlus stream reaches in the eastern portion of the state. Flow, velocity, and cumulative drainage area for each occurrence were extracted and statistics were calculated for each species. The results indicate that the mean annual stream velocity (attribute "MAVELU") and cumulative drainage area ("CUMDRAINAG") have small enough variances that they naturally divide the stream reaches into discrete habitat classes (Figure 1). Habitat suitability classes were defined for each species from the mean value and standard error. "Optimal" habitats are streams with mean annual velocity and cumulative drainage area within one standard error of the species mean. "Marginal" habitat is defined as the range between one and two standard errors of the species mean, for both attributes.

Habitat Quality Parameters

The 2001 National Land Cover Dataset (NLCD) was used to estimate the fraction of natural land within 30 meters of streams in the study area. In our definition, natural land excludes developed classes and cultivated crops. Flow impairment of stream segments was determined from two parameters, the number of stream crossings by roads, and the number of dams, weighted for the dam height. The combined flow impairment score is the average of the road intersection score and dam score. Water quality was estimated using the New York State water quality classification for each stream segment, and the presence of point pollution sources recorded in the US Environmental Protection Agency Region 2 facilities database. The water quality score for each stream segment is zero for streams with point pollution sources; otherwise it is a geometrically weighted value that we assigned to the water quality class, with class AA having the highest value. The three parameters for quality were added, and rescaled so the maximum value in the study area is equal to 100.

Results

The model provides planners and land managers with simple analytical tools. Streams that are found to be potential habitat for an aquatic species may be targeted for biological surveys, to determine whether the species are actually present. Approximately 47 percent of stream segments in the study area are predicted to be at least marginal habitat for one or more species of freshwater mollusk, damselfly, or dragonfly (Table I). We emphasize that these results are based on distributions of sensitive aquatic species. As indicators of habitat quality, they can be useful for locating high-value stream segments and watersheds. Streams can be further prioritized according to their habitat quality score (Figure 2). Streams that are potential habitat, and which also have high scores, may require heightened managment of adjacent land uses. Conversely, streams that are potential habitat but which have low scores present opportunities for restoration.

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A HYDROSTRATIGRAPHIC MODEL OF GLACIAL DEPOSITS IN THE EASTERN MOHAWK LOWLANDS

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Groundwater resources in the eastern Mohawk Lowlands include several unconsolidated aquifers. The Broadalbin Interlobate Moraine forms a surface water and groundwater divide in the graben between the City of Amsterdam and the Sacandaga Reservoir. A narrow, buried valley links the Sacandaga and Amsterdam-Mohawk groundwater systems near the City of Gloversville. Holocene Mohawk River alluvium and Pleistocene Glacial Lake Iroquois outflow deposits are the source of potable water for the City of Schenectady. Pleistocene deposits also contain several aquifers in a complex of glacial advance and retreat sediments. Evidence for a minimum of three glacial advance and retreat sequences is recorded in the reach of the Mohawk between Schenectady and the Noses fault scarp and in the Schoharie Valley. The glacial deposits form stacked sequences of aquifers and aquicludes. The simplified hydrostratigraphic model consists of glacial advance and retreat deposits. The sequence consists of basal fine-grained, coarsening-upward, proglacial lake deposits, overlain by compact till, overlain in turn by fining-upward proglacial lake deposits or alluvium deposited by free-flowing eastward drainage. The coarser-grained deposits are aquifers and the finer-grained or compact deposits are confining beds. This model is modified by the underlying bedrock topography. The west-dipping half-grabens in the Mohawk Lowlands acted as sediment traps, with thin glacial deposits along the upper dipslope and thick deposits on the lower dipslopes.

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ASSESSING NUTRIENT RUNOFF IN THE LITTLE CHAZY RIVER, NORTHEASTERN NEW YORK: A SYNOPTIC WATER SAMPLING STRATEGY IN NESTED SUBWATERSHEDS

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Lake Champlain, in northeastern New York and Vermont, is an oligotrophic to mesotrophic water body with low to moderate levels of phosphorus and nitrogen, the primary nutrients for primary productivity and principal determinants for associated water quality issues. Major sources of nutrients in Lake Champlain include point sources such as municipal sewage treatment plants in the cities of Plattsburgh and Burlington, and non-point sources including agricultural inputs. Extensive dairy operations in the Lake Champlain basin produce large quantities of manure, which is applied back to soils and can potentially become a major source of nutrients to nearby surface waters. Agricultural best management practices, including winter storage of manure in holding lagoons, have been applied extensively over the last twenty years. In spite of these efforts, water quality concerns persist at the mouths of some tributaries (New York State Department of Environmental Conservation, pers. comm., 2009). In this study we examine nutrient runoff to Lake Champlain from the Little Chazy River and its relationship to the hydrogeology, land cover and land-use practices in the watershed.

The Little Chazy River watershed (basin area = 145 km^2) is typical of rural, medium-sized watersheds in the region, demonstrating a broad range of watershed issues and concerns reflected throughout the Champlain lowland. The Little Chazy River originates in upland forests in the northeastern foothills of the Adirondack Mountains and flows eastward through the Champlain lowland to its mouth at Lake Champlain. It has two principal tributaries, Farrell Brook (basin area = 24 km^2) and Tracy Brook (basin area = 25 km^2). The headwater region is a predominantly forested area of moderate relief (<400m) that is underlain by thin glacial soils (generally <3m thick), Cambrian clastic sedimentary rocks and high-grade Mesoproterozoic metamorphic rocks. This region includes a large area of exposed sandstone bedrock, or sandstone pavement, known locally as Altona Flat Rock. Mainstream gradient in the headwater region commonly exceeds 10 m/km. The river descends steeply through the dense headwater woodlands to the Champlain lowland and flows through a patchwork of forested and agricultural lands before emptying into Lake Champlain. The Champlain lowland is underlain by thick glacial, glacial-lacustrine, and glacial-marine sediments, and lower Paleozoic sedimentary rocks. Local relief in the lowland is generally less than 100 m and the mainstream channel gradient averages approximately 1 m/km.

Methods

SUNY Plattsburgh and Miner Institute (SUNY/Miner) currently operate and maintain stream-gaging stations at as many as 17 locations in the Little Chazy River watershed (Fig. 1). The stations operate during ice-free periods only and records vary in length or continuity depending upon data needs and

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available resources. Records for the U.S. Geological Survey (USGS) gaging station near the river mouth east of Chazy were obtained from the USGS, Water Resources Division office in Troy, New York. All SUNY/Miner stations are equipped with Tru-Trac WT-HR water height (stage) dataloggers. Rating curves for each station are calibrated using the midsection method for determining discharge (USGS, 1977). Stream discharge was used to estimate nutrient loads from different portions of the watershed.

We adopted a high-resolution synoptic water-sampling strategy to determine the spatial and downstream distribution of nutrient concentrations in streams within the Little Chazy River watershed (Fig. 1). Synoptic sampling involves the collection of closely spaced water samples in a short time period (generally less than four hours) to provide a snapshot of nutrient concentrations and loadings throughout the watershed. Sample spacing along the mainstream, tributaries and other inflows varied with accessibility and land use. Channel distance between samples varies from more than 5 km in forested upland regions to a few hundred meters in villages or agricultural lands where anthropogenic inputs such as ditches and drains are more common. We collected 12 synoptic sample suites at approximately four-week intervals in 2008 from approximately 64 sites on the mainstream, tributaries and agricultural ditches and tile drains. The sample suites were broadly distributed across three discharge ranges: Q = < $1m^3$/sec (n=4), 1.0 – 10 m^3/sec (n = 7) and greater than 10 m^3/sec (n=1).

Water samples were collected in acid-washed 500 ml polyethylene bottles within a period of 4 hours to minimize temporal variations in nutrient concentrations. Samples were transported in coolers back to the lab and immediately split into two fractions; one which was filtered through a 0.47 mm membrane filter to remove particulates and the other left unfiltered. Filtered subsamples were analyzed for nitrate using a Dionex Ion Chromatograph with conductimetric detection and for soluble-reactive phosphorus (primarily phosphate) colorimetrically using a UV-Vis spectrophotometer with the ascorbic acid method (APHA, 1998). Unfiltered subsamples for Total Kjeldahl nitrogen were digested on a block digester using sulfuric acid with a copper sulfate catalyst (APHA, 1998), followed by analysis for ammonium using the salicylate-nitroprusside-hypochlorite procedure on a flow injection analyzer (APHA, 1998) modified for a Bran-Luebbe (Technicon) autoanalyzer. For total phosphorus, unfiltered water samples are digested using potassium persulfate in sulfuric acid on a block digester (APHA, 1998), followed by analysis for soluble-reactive phosphorus.

Results and Discussion

Stream discharge in the Little Chazy River is spatially heterogeneous and seasonally variable. Effluent conditions predominate in the upper and middle portions of the watershed, except for a local influent reach at the site of a former hydroelectric dam on Altona Flat Rock. The greatest proportion of stream flow during baseflow conditions is generated where the river descends from the uplands at Altona Flat Rock to the Champlain lowland near the village of West Chazy. Much of the increase can be attributed to several high-discharge springs that occur in this part of the watershed. The Little Chazy River becomes influent again as it crosses the Champlain Lowland. The influent reach occurs in an area of complex geological structure. The effect of water loss in this reach is most pronounced during low-magnitude baseflows and its size varies with baseflow magnitude. At low flow, nearly all of the stream flow is generated in the upper reaches of the watershed. As stream flow increases following runoff events, a greater proportion of baseflow is generated in lowland agricultural regions.

Nitrate concentrations in headwater forests were typically low (< 1 mg/L NO_3^-), and increased substantially upon entering lowland agricultural regions. Occasional abrupt increases in nitrate concentrations within the agricultural areas may be attributed to high concentrations in agricultural ditches or tiles, but this trend was not consistent due to the low discharges measured in many of these tributaries. Nitrate concentrations generally leveled off at 2-3 mg/L in the agricultural area between West Chazy and Chazy and actually decreased in a small, narrow impoundment immediately upstream from the village of Chazy. Nitrate decrease in the impoundment is most likely due to sequestration in algae, aquatic macrophytes and sediments, particularly during the growing season. Nutrient concentrations increased substantially in the 7 km-long reach between the village of Chazy and Lake Champlain, where the river traverses a low-relief, intensively managed agricultural area developed on deep glacial-marine soils. Nitrate concentrations increased markedly during high-magnitude runoff events and retention in the Chazy impoundment decreased as flushing occurred. Consequently, the downstream increase in nitrate concentrations was more uniform during events.

Downstream changes in phosphorus (total phosphorus and soluble-reactive phosphorus) concentrations generally mirror those observed in nitrate concentrations but exhibited substantially more variability, possibly due to measurement errors associated with relatively low phosphorus concentrations (10-100 mg/L).

The highest nutrient loads occurred during high-magnitude storm runoff events due to moderately elevated concentrations combined with high discharge. During these periods, bank-full and over-bank conditions in some reaches and overland stormflow probably contributed to contamination of surface waters due to erosion of surface applied manure in flood plains. During low-flow conditions, tile-drain systems provide much of the agricultural loading and macropore flow may exacerbate nutrient loss to surface waters.

Acknowledgements
We gratefully acknowledge the contributions from all of the many students who participated in research in the Little Chazy River watershed over the past two decades, especially Ethan Sullivan, Brian Huber, Derek Smith, Sean Keenan and Kevin Kieper, who were directly involved in the current study. Special thanks to the Office of Sponsored Programs and the Lake Champlain Research Institute at SUNY Plattsburgh. This study was funded by the New York State Department of Environmental Conservation and The Nature Conservancy.

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A HISTORICAL PERSPECTIVE OF ICE JAMS ON THE LOWER MOHAWK RIVER

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Ice jams are an annual occurrence on the Mohawk River. As a northern temperate river, ice jams are expected, but it is clear from the occurrence and relative frequency of ice jams, that the Mohawk is particularly vulnerable to ice jams and the hazards associated with them. Here we briefly review the history of significant ice jams, we highlight research on reconstructing ice jams, and then we propose an active monitoring system that could be used by emergency personnel to better respond to active jams during breakup.

Ice jams occur when the frozen river breaks up during events that result in rapid increase in discharge. Ice out and ice jams always occur on the rising limb of the hydrograph, when the floodwaters are building. When flow starts to rise it is not uncommon for unimpeded ice runs to develop, but invariably the ice gets blocked or impeded along the way by constrictions in the river, especially where the flood plain is reduced in size.

In a survey of the past ice jamming episodes, we have come to the conclusion that any restriction or narrowing of the flood plain and constriction of the channel is a possible jam point (Johnston and Garver, 2001). An important point worth keeping in mind is that deep sections of rivers move more slowly than shallow ones, and therefore surface flow and therefore ice movement is reduced. So, a transition from a shallow to deep channel may generate a point where ice can backs may occur up, regardless of floodplain geometry.

The lower part of the Mohawk River has chronic ice jam problems and the historic record indicates that the section between the Stockade and the Rexford Knolls is the most jam-prone in the entire watershed (Figure 1). As such the empirical evidence of ice jam locations are relatively well known to local emergency management authorities. However, there is a general lack of information as to the significance of individual jam points, and how often jams occur in different areas. In addition, many jam sites are inferred based on little or no data.

Commonly, ice jams will build to sufficient thickness to dam the river and this can result in spectacularly rapid rates of water rise behind the dam. In March 1964, the USGS Cohoes Monitoring Station recorded the greatest hourly flow ever recorded on the Mohawk River when discharge peaked at 143 k cfs (1000 cubic feet per second), although the mean discharge for the day was only about half this level. In comparison to other floods on the Mohawk River this was not a big event, but the ice jam that formed resulted in very high water levels for a short time: the high discharge was due to an ice jam that formed and subsequently burst forming an ice-jam-release wave that surged downstream (Jesek, 1999). News reports from this event suggest that the elevation of the backed up water was about 25 feet, although as far as we know this is unverified.

History. One of the worst ice jams in Schenectady history occurred on 13 February 1886 when a spectacular ice gorge formed and lodged in and around the islands near Schenectady. In this event, one-foot-diameter trees on the flood plain were reportedly snapped in half, and when the water receded, the remaining ice was piled 30 to 40 feet high (see Scheller et al., 2002).

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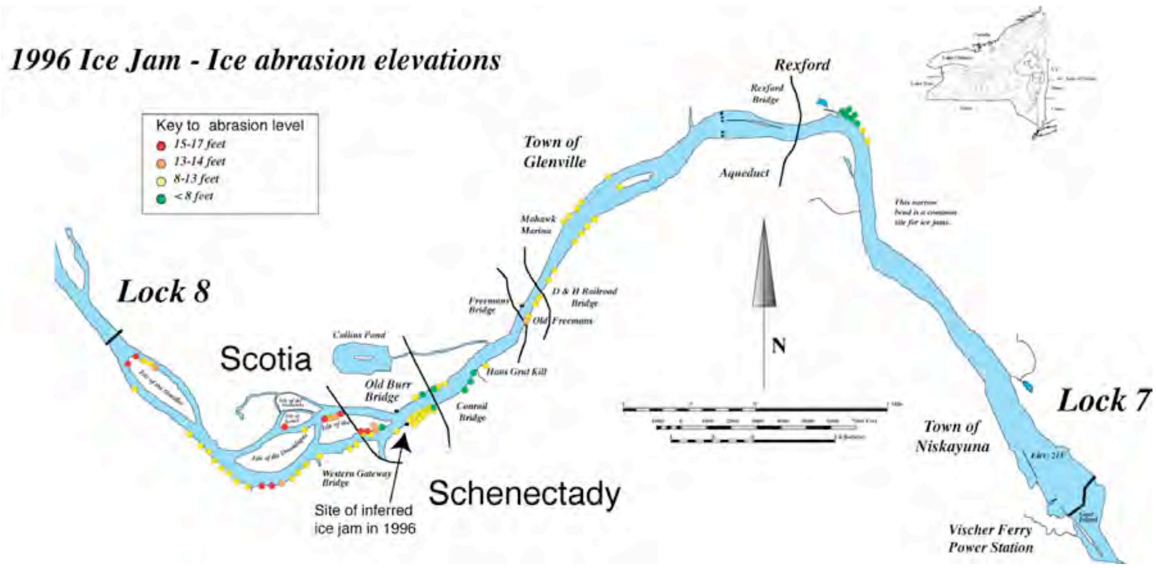

Figure 1: Map showing the elevation of measured ice scars on bank-lining trees along the Mohawk River in the Schenectady area. Scars on trees indicate the elevation of a slow-moving jam that caused damage along the riverbanks. The highest levels of tree scarring occur upstream from the Rexford Bridge and upstream of the Burr Bridge abutments. This area has chronic ice jams (from Lederer and Garver, 2000).

During this event, ice jammed at the Scotia Bridge, which linked downtown Schenectady with the Village of Scotia. Our analysis of the historic records indicates that this is a chronic jam point (same as the Burr Bridge abutments at the end of Washington St.).

The January 1996 flood is the worst recent flood and it is fairly well documented. This mid-winter thaw event (19-20 January 1996) resulted in the breakup of the Mohawk River and significant flooding, especially on the Schoharie Creek. As recorded at the USGS station at Cohoes, the event resulted in a mean discharge for the day on the Mohawk of 92 k cfs with a peak discharge of 132 k cfs resulting in extensive flooding of the Stockade area in Schenectady. Elevation of ice scars on trees lining the river banks (Figure 2) allow reconstruction of ice elevations and from these data (Smith and Reynolds, 1983), jam points may be inferred (Lederer and Garver, 2001). In the 1996 event, the highest ice-scar elevations occur between Lock 8 and the Stockade area in Schenectady, and almost no abrasion occurs below the Rexford Bridge. Two possible jam points are inferred from the data based on abrupt downstream elevation changes of the highest ice damage on bank-lining trees. One sharp elevation increase occurs between the Freeman's Bridge and the D&H railroad bridge where ice scar elevation increases from ~224 feet to ~226 feet (Figure 1).

Another sharp elevation drop occurs upstream of the still-standing abutments of the old Burr Bridge (a.k.a. "Scotia Bridge" after reconstruction) where maximum ice-scar elevations increases from ~226 feet to ~230 feet. We infer that the ice dam at the old Burr Bridge broke shortly before flood crest based on the maximum elevation of ice scaring just downstream in the Schenectady Stockade (228.4 feet), which falls just short of height of the river at crest (229.5 feet). Both jam points occur where abutments and berms (i.e. those associated with bridges) have dramatically restricted the flood plain thereby causing a severe restriction in flow.

Figure 2: The tree-lined park in Schenectady's Stockade still bears ice scars from the 1996 ice jam. Here the scar is about 14-15 feet above river level. Photo taken in the Summer of 2000, five growing seasons after the event, so it is well on its way to healing itself (Photo: J.R. Lederer).

The 15 March 2007 flooding in the Stockade was entirely related to ice jamming downstream from the city of Schenectady (Figure 3). During this event, discharge in the Schenectady reach of the Mohawk River never surpassed 45 to 50 k cfs, which makes this an insignificant event with respect to expected high water. However, the formation of the ice jam and the resulting backup of water was entirely responsible for the inundation that occurred in the Stockade. This reinforces earlier findings that the key component in these events is the evolution of stage elevation, which is not directly related to discharge. Back up of water behind the 15 March 2007 ice jam resulted in a ~13 feet elevation change. Breakage of the ice dam at about 6:45 PM resulted in a downstream rush of water referred to as an ice jam release wave that was recorded at the USGS station at Cohoes. Peak discharge at Cohoes occurred at 8:00 PM and then total discharge was 51.6 k cfs. It is possible that that was an ice jam release wave, but the measurements are too coarse (every 15 minutes) to determine this with certainty.

Figure 3: Flooding in the Stockade that resulted from the 2007 Ice jam on the lower Mohawk River. Picture taken in the late afternoon (~18:00) at nearly peak stage elevation. Peak discharge during this event was c. 50k cfs, but ice jamming resulted in back up of water that caused flooding (Photo: J.I. Garver).

The 2009 Ice Jam was, by historical standards, an insignificant event. The ice out event that occurred between 8 Mar and 10 March 2009 resulted in bank full conditions, and an ice jam occurred, but there was not significant flooding during this event. During this event, we collected data on the elevation of the river using two strategically placed pressure transducers during ice out which provides unique insight into how ice movement progresses (Figure 4).

Following a relatively cold winter with heavy precipitation, a moderate thaw accompanied by moderate rainfall increased runoff and subsequent breakup of river ice. At about 10:40 AM 8 March the water level rose rapidly in the Stockade of Schenectady. At about noon the R.A.C.E.S notes indicated that the ice had jammed and stopped in place. The toe of the ice jam was situated between the Stockade and the Freeman's Bridge (in, essentially, Schenectady). The ice floe that was jammed in place extended from the toe to a point slightly upstream from Lock 8, so it was about 4-4.5 miles long (~7 km).

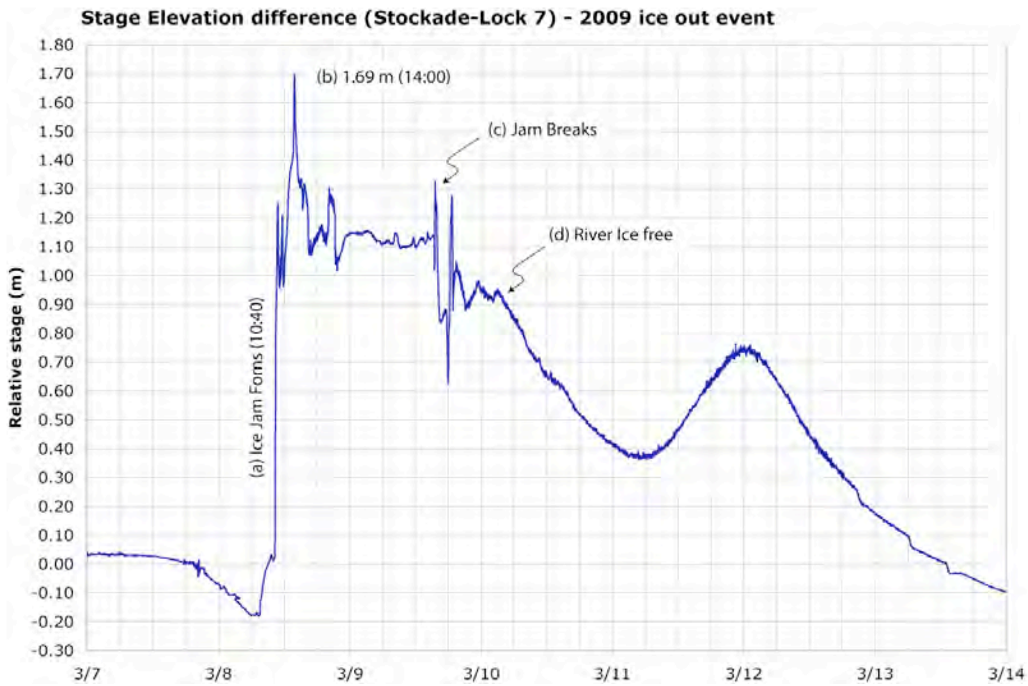

Figure 4: Difference in river elevation between the Stockade and Lock 7 measured by pressure transducers at 300 s intervals for the March 2009 ice out event. In this graph in situ measurements were made as a ~7 km ice jam lodged and then worked through the narrow channel in Schenectady. This plot shows the differential between the Stockade where water backs up due to ice jamming. High values in this plot indicate that the Stockade water level is higher than downstream sections of the river, and this backup is inferred to be cause by ice damming. The effect of a surge from breakup appears minor in this event (i.e. Jasek, 1999). (All times Daylight Savings time).

Downstream the peak flow at the Cohoes gage was recorded at 13:00 of that same afternoon (8 March) when 27.4 k cfs was recorded (all times are Daylight Savings Time). Historically, this is relatively low flow for an ice out event. At the highest point the differential between the Stockade and the Lock 7 occurred at 2:00 PM (14:00) when the difference was recorded as being 1.69 m. This means that a 1.69 m rise occurred in 200 minutes (3.3 hr) or a rise of about 0.5 m per hour during this interval. The jam stayed in place with little apparent movement, until the next afternoon, 9 March, when the ice floe became dislodged and worked its way downstream at about 16:20. Ice continued to pass through the system through that evening and the river was ice-free soon after.

Ice Jamming in Schenectady. Our analysis of the historical records suggests that the Rexford knolls, a bedrock-incised part of the Mohawk channel, is a distinct and chronic jam point for ice floes. This is because it is narrow, confined and there is no floodplain that allows the water and ice to spread out. Our research shows that over the several hundred years, it is typical for ice jams to form on the Mohawk between the Old Burr Bridge abutments and the Rexford Knolls - the most common jam points on this entire stretch of the Mohawk (between Schenectady and Lock 7).

As such, these ice jams pose a unique and serious hazard for the city of Schenectady (and to a lesser extent Scotia). We'd note that this part of the river channel is unique because it lacks a floodplain and because it is bedrock-bound.

This part of the Mohawk is relatively young having captured the main flow from the Paleo-

Mohawk at about 10 Ka (see Wall, 1995; Toney et al., 2003). Prior to this time, it is inferred that the Mohawk flowed north up the Alplaus channel and through what is now an abandoned channel occupied by Ballston Lake and adjacent lowlands in the paleo-channel. Although this is ancient history in the evolution of a river, it is relevant here because it provides a framework as to why this part of the Mohawk River has such a special hazard.

Since capture and readjustment of the course of the Mohawk, the river has had to rapidly incise into the bedrock high that now forms the Rexford Knolls. Even since settlement, this stretch of the river has been treacherous, and today we see that large ice floes have trouble getting through this narrow incised part of the channel. This is a natural feature, and the reduction in the effective width of the floodplain by abutments and berms – the Burr/Scotia Bridge being a major one – has exacerbated the hazard.

We suggest that the best mitigation strategy for this situation is a real-time monitoring network of pressure transducers that can provide fast reliable data on the condition of the ice movement through this key reach of the river (Robichaud and Hicks, 2001; White et al., 2007). These data could provide emergency personnel insight into ice dynamics (i.e. Figure 4) and a predictive tool that they have not enjoyed in the past.

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A GIS STUDY OF THE MOHAWK RIVER WATERSHED USING DIGITAL ELEVATION MODELS

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The Mohawk River and its tributaries have a watershed pattern that is worthy of studying. It runs mostly eastward with eleven dams along its path and major creeks. The river's Schoharie Creek has three major dams (Gilboa Dam, Blenheim Gilboa Upper Dam, and Blenheim Bilboa Lower Dam, Schoharie County). In addition, many smaller dams can be found in the Mohawk River's tributaries. Figure 1 shows the multitudes of dams in the area of the river's watershed with the ones on the river's main path and on its Schoharie Creek highlighted. Figure 2 shows a hillshade layer generated from a digital Elevation Model (DEM) [NED Shaded Relief, 1 arc second] with streams and water bodies layer superimposed on top.

Most of the dams on the Mohawk River and within its watershed are classified as high (H) hazard, and only a few are classified as slight (S) hazard or low (L) hazard (Figure 3). The Mohawk River has two major pour points. Based on the contour lines generated by the DEM shown in Figure 4, the Schoharie Creek pours into the Mohawk River, and the maximum discharge is measured at the pour point near Cohoes where the Mohawk confluences with the Hudson River.

Delineation of watersheds can be done at different spatial scales. A large watershed may cover an entire stream system with smaller watersheds for each tributary. Delineation of watersheds can also be area-based or point-based. An area-based method divides a study area into a series of watersheds, one for each stream section. A point-based method derives a watershed for each select point. Select points may be an outlet, a gauge station, or a dam. Figure 5 shows area-based delineation of the Mohawk River watershed. Point-based delineation will also be presented for major outlets and dams along the Mohawk.

Figure 6 shows a DEM-based, raster-generated TIN of the Mohawk River watershed. This mode of presenting the terrain helps in the delineation process of the watershed since the first step in developing a watershed is to produce a filled DEM. A filled DEM or elevation raster is void of depressions. A depression is a cell or cells in an elevation raster that is/are surrounded by higher elevation values, and thus representing an area of internal drainage. Using this procedure illustrates how watershed delineation varies with the selection of different pour points. Figures showing these different possibilities will all be presented.

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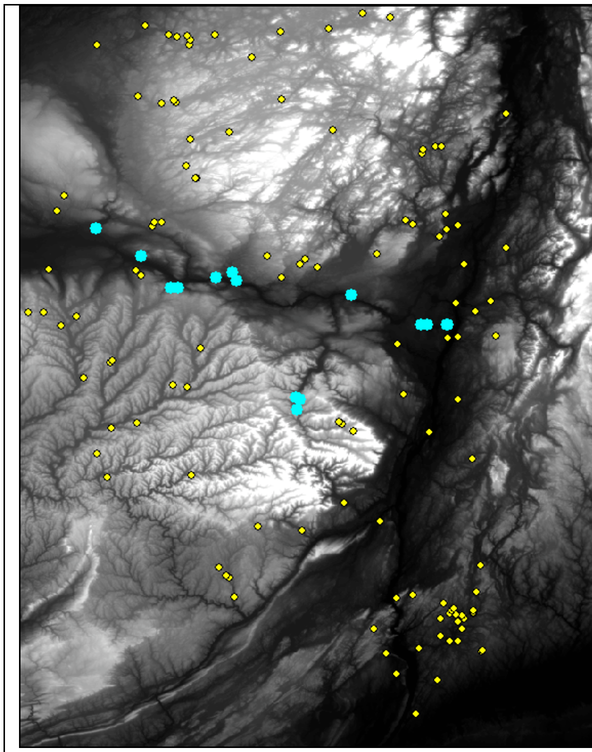

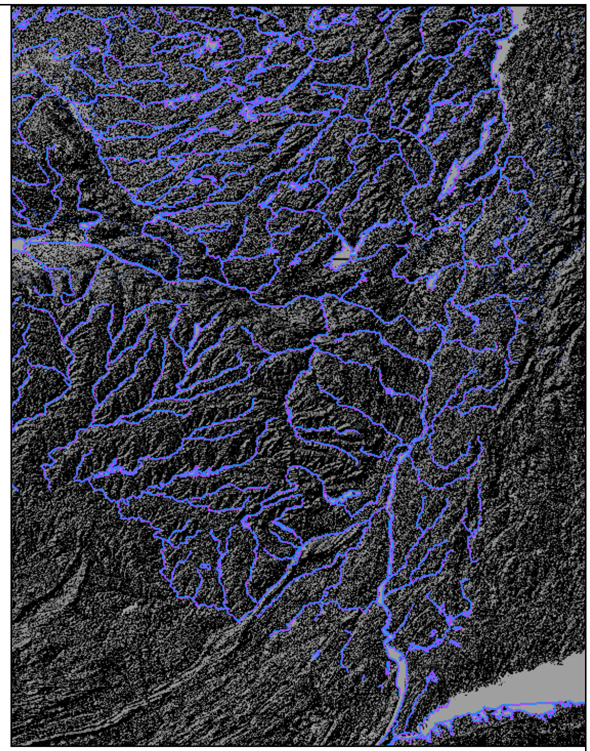

Fig. 1. Major dams on the Mohawk River and its creeks.	Fig. 2. Streams and water bodies in the Mohawk River watershed.

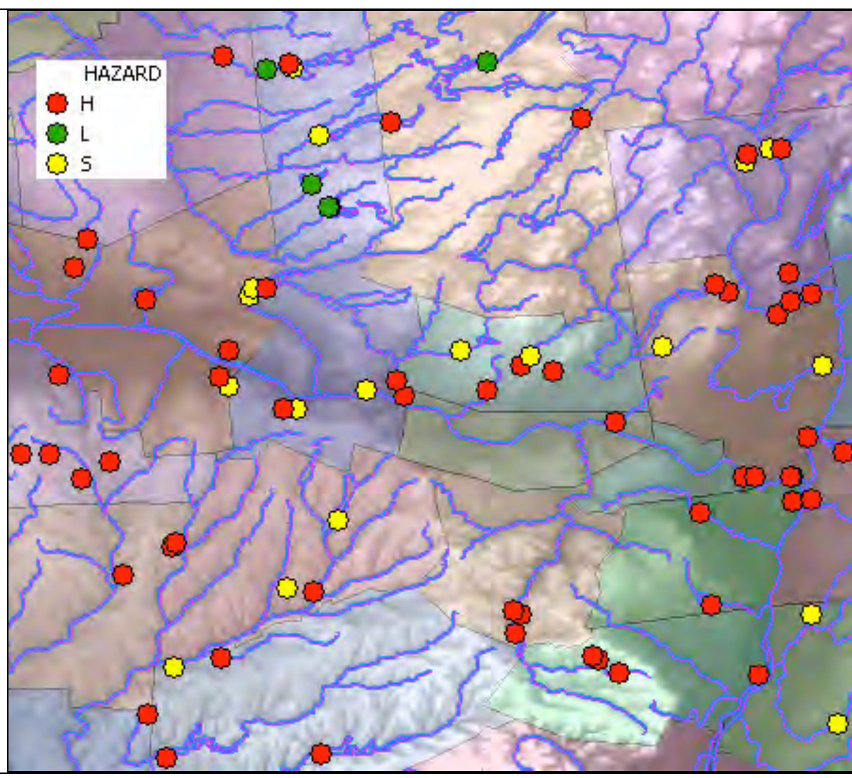

Fig. 3. High, Low, and Slight hazard dams.

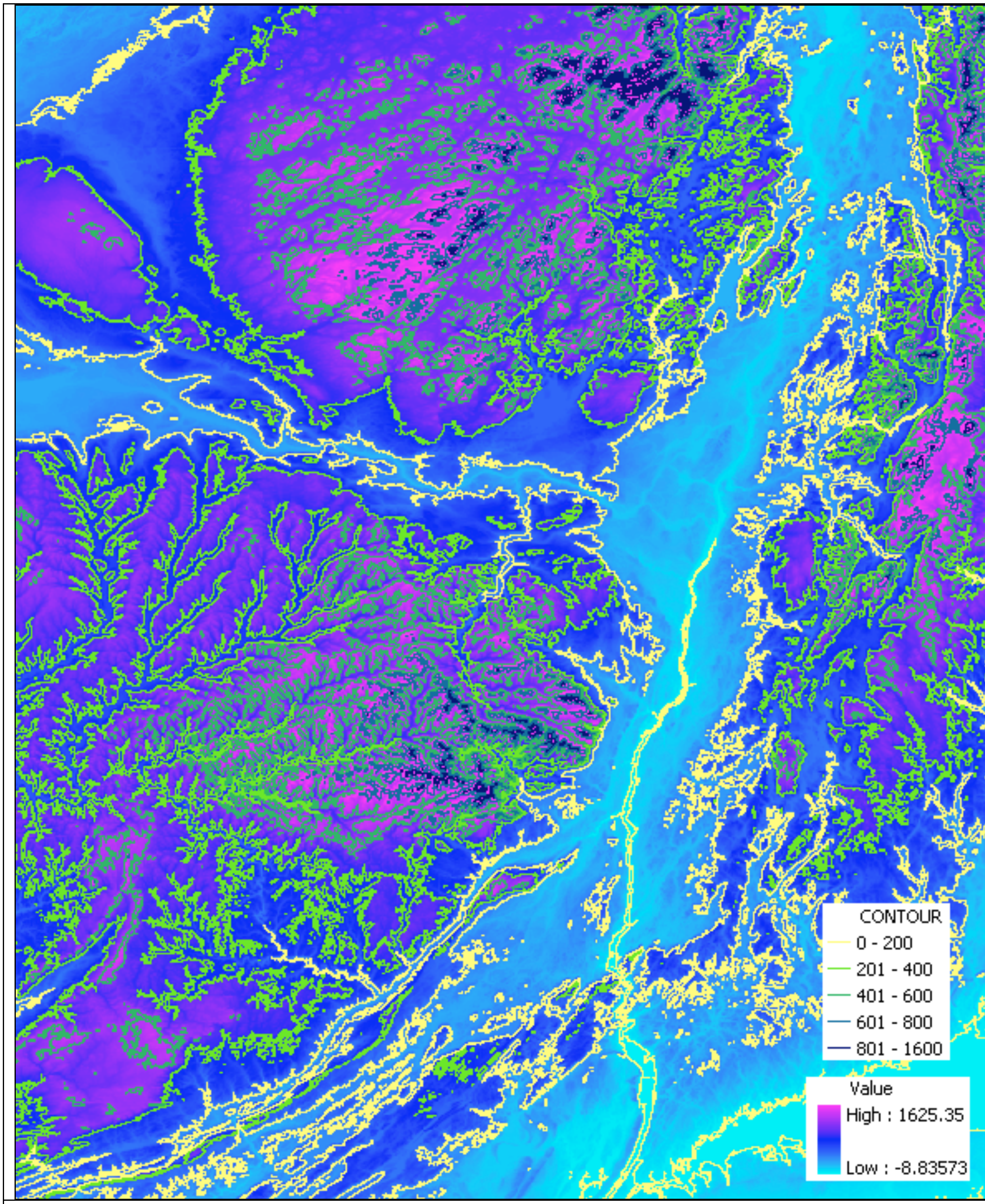

Fig. 4. Contour map of the terrain around the Mohawk River's (elevations are in feet).

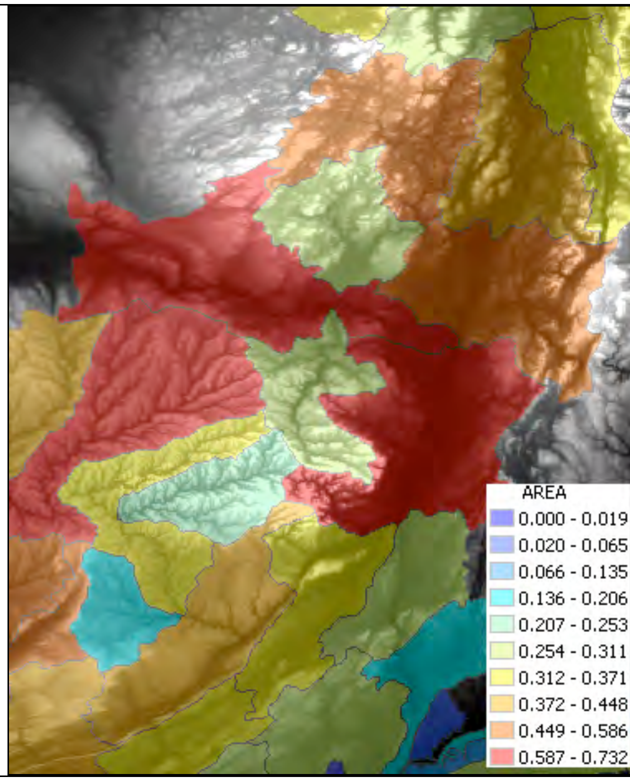

Fig. 5. Mohawk River's hydrologic units (watershed) proportioned by area (hundreds of square miles).

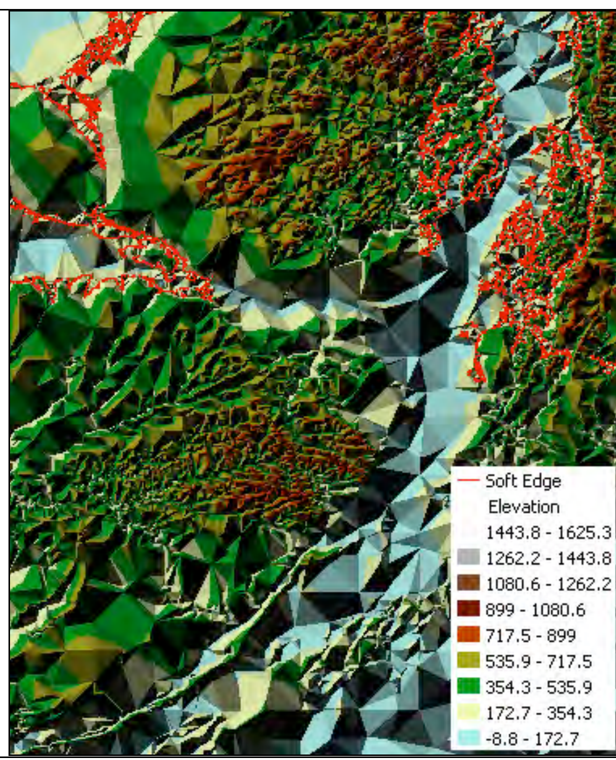

Fig. 6. A DEM-based, raster-generated TIN of the Mohawk River watershed.

Patterns of Scour and Methods of Remediation of Impacted Infrastructure Facilities

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The Mohawk River's waters usually freeze during winter time due mainly to lower temperatures and lesser discharge. Annual events of ice jams due to the melting of ice have resulted in significant damage to infrastructure along the river. Some of the reported ice jams had disastrous consequences that required considerable amount of funds toward the reparation effort. Ice jams are not the only source of problems for the Mohawk River. An accelerated rate of discharge may also cause irreversible damage to the foundations of piers and abutments of bridges and other infrastructure along the banks of the river. The scoured soils become another problems for structures such as dams where they are deposited and result in a build up of additional pressure on the upstream face of the dam. All these problems are interconnected and require preventive measures to ensure that scour does not occur in the first place.

Scour is mainly affected by the type and gradation of soil, site physical and geometrical conditions, flow rate, and to a lesser extent by many other factors such as orientation of infrastructure with respect to the direction of flow. With the variability and complexity of the problem under consideration, it is extremely difficult to predict scour depth or the time line it takes to reach a dangerous level. Simulating scour in a laboratory environment oversimplify the problem and ignores many field complexities. The US Federal Highway Administration (FHWA) in cooperation with many State Transportation Agencies have been collecting field data on scour at bridges at 79 sites located in 17 States, one of which is the State of New York. This data has been compiled to identify and isolate pier scour, contraction scour, and abutment scour. In 1995, the national database contained 493 local pier scour measurements, 18 contraction scour measurements, and 12 abutment scour measurements.

There have been 17 damaged or destroyed bridges due to scour in the NYS and New England states between 1985 and 1995. The April 1987 failure of the two spans of the New York State Thruway Bridge over the Schoharie Creek, Amsterdam, NY is widely attributed to the scour effect on the midspan pier supporting the bridge. Further investigations confirmed that the piers were not adequately protected against scour for long-term service conditions. The failure of that bridge occurred after 30 years of service and was not preceded by any measurable symptoms. Five vehicles fell into the flooded river, killing ten people. Immediately after this accident, many states initiated extensive inspection programs of their inventory of bridges to ensure their safety. The FHWA issued more guidelines related to scour inspection to help states assure the public that infrastructure facilities were safe. According to FHWA, the following are the three major types of scour:

1. *Degradation scour:* long-term changes in streambed elevation due to natural or human-induced causes, which can affect the reach of the river near the bridge.
2. *Contraction scour:* removal of material from the bed and banks across all or most of the channel width, resulting from the contraction of the flow area.
3. *Local scour:* removal of bed material from around piers, abutments, spurs, and embankments. Local scour is caused by the acceleration of flow and by vortices resulting

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from flow around an obstruction.

There has been many experimental, field, and numerical studies on the scour effect on bridge piers and abutments. There has also been extensive modeling of the scour phenomenon done using computational methods. This presentation will attempt to summarize the causes, patterns, and remediation methods of scour as related to infrastructure facilities. It will show that predicting scour pattern and depth with reasonable accuracy is possible, though difficult. It will also demonstrate that effective remediation and rehabilitation methods of deteriorating infrastructure can help lengthen the life of otherwise failing structures.

Reference

http://seamless.fhwa.gov
(report FHWA-03052.pdf)

Watershed Yield of Mercury to Onondaga Lake: Lessons for the Mohawk Watershed

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Onondaga Lake is located in the Oswego River drainage basin in Onondaga County adjacent to the City of Syracuse in central New York. Two major creeks, Onondaga Creek and Ninemile Creek, and the Metropolitan Syracuse Wastewater Treatment Plant (Metro) supply most of the water to the 1,200 hectare lake with several minor tributaries supplying the remainder. Percent contribution to mean daily flows in 1992 were as follows: Onondaga Creek 32.5, Ninemile Creek 30.9, Metro 18.0, Ley Creek 8.3, Bloody Brook 5.6, Harbor Brook 2.0, Sawmill Creek 1.5, Tributary 5A 0.7, and East Flume 0.5 (TAMS 2002). Onondaga Lake is a culturally eutrophic lake and is on the National Priorities List (NPL) due to industrial contamination. Two major remedial programs are underway at the lake: upgrades to Metro to bring the lake into compliance with surface water quality standards for ammonia, phosphorus, and oxygen, and remediation of contaminated sediment by Honeywell under the direction of New York State Department of Environmental Conservation (NYSDEC). Additional work is being undertaken by both Metro and Honeywell to address upland sources of contamination (Metro – nitrogen and phosphorus, Honeywell – hazardous chemicals) to the lake.

From 1992 to 2001, Onondaga Lake was the subject of a comprehensive remedial investigation to ascertain the nature and extent of contamination. Mercury was a major focus of the investigation due to elevated mercury concentrations in Onondaga Lake fish and the historical presence of two mercury cell chlor-alkali plants near the lake. Tributary loading of total mercury and methylmercury to the lake was determined based on water sampling and flow rate measurements in the tributaries from April through November of 1992. With the exception of Bloody Brook and Sawmill Creek for which only limited mercury data were collected, loading calculations were determined using the FLUX model (Walker 1987) for May 25 to September 21, 1992, the period for which substantial data on all mercury sources, sinks, and cycling processes were available (TAMS 2002). For a simple estimate of annual load, the calculated loads were extrapolated to an annual basis and the results are shown in Table 1. Tributary 5a and the East Flume were not included because they constituted only 1.2 percent of mean daily flow in 1992. This approach may overestimate loads because it emphasizes data from periods of the year when more flow is recorded. It may also underestimate loads because it does not include data from spring runoff when substantial mercury loading has been observed in other systems.

Calculation of specific yield is based on the annual load and the area of the drainage basin for each tributary. As shown in Table 1, Ninemile Creek clearly has a higher specific yield for total mercury than the other tributaries. Ninemile Creek is the receiving water body for historical discharge from one of the mercury cell chlor-alkali facilities, the LCP Bridge Street site, which has recently undergone remediation. Ninemile Creek itself is scheduled to undergo remediation within five years to remove and contain contaminated sediment. Harbor Brook has the second highest specific yield for total mercury. The

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lower reaches of Harbor Brook receive mercury-contaminated groundwater from the second mercury cell chlor-alkali facility (i.e., the Willis Avenue plant). This facility has been remediated and plans are underway to collect and treat contaminated groundwater and remediate Harbor Brook.

When considering specific yields, it must be noted that atmospheric deposition is generally the primary source of mercury to watersheds in the absence of point sources or mineral contributions. In comparison to specific yield values reported in the literature, Ninemile Creek and Harbor Brook are clearly outliers with respect to total mercury while Onondaga Creek and Ley Creek are within the range reported for urban rivers. The methylmercury specific yields from all four tributaries, however, are less than those reported for some pristine systems, particularly boreal forest wetlands. This finding is consistent with numerous studies that have shown little relationship between total mercury and methylmercury concentrations in water or sediment, primarily because the formation of methylmercury is a natural process subject to several site-specific factors (e.g., concentrations of dissolved oxygen, carbon, and sulfate). It also suggests that tributary loading of methylmercury to Onondaga Lake is not as important as in-lake sources of methylmercury with respect to bioaccumulation into fish tissue, a hypothesis that is supported by studies of methylmercury production and bioaccumulation within the lake.

Mercury data in fish tissue from the Mohawk River drainage basin (collected by NYSDEC) reflects a similar situation. Mercury concentrations in fish tissue within the rivers and creeks of the drainage basin are rarely elevated above levels of concern and no fish consumption advisories have been issued with respect to mercury. However, NYS Department of Health has issued fish consumption advisories based on mercury for Schoharie Reservoir, Pine Lake, Canada Lake, and Ferris Lake in the Mohawk River drainage basin, highlighting the importance of methylmercury production and bioaccumulation processes within lakes and reservoirs.

A watershed perspective on mercury transport can help to identify the potential for point source contamination as well as highlight the ubiquitous presence of mercury in water bodies due to atmospheric deposition. It also emphasizes the importance of watershed land use and in-lake or in-reservoir processes for methylmercury production and bioaccumulation.

TAMS. 2002. Onondaga Lake Remedial Investigation Report, Syracuse, New York. Prepared for New York State Department of Environmental Conservation, Albany, NY.

Walker, WW. 1987. Empirical methods for predicting eutrophication in impoundments. Report 4: Phase III: Applications Manual. Technical Report E-91-9. US Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS.

Table 1. Specific Yield of Total Mercury and Methylmercury from Onondaga Lake Tributary Drainage Basins

Tributary	Area of Drainage Basin (ha)	Annual Total Mercury Load (g)	Total Mercury (ug/m^2-yr)	Annual Methylmercury Load (g)	Methylmercury (ug/m^2-yr)
Ninemile Creek	29,800	3890	13.1	149	0.50
Onondaga Creek	28,500	1060	3.7	64	0.22
Ley Creek	7,740	258	3.3	3	0.03
Harbor Brook	2,930	248	8.5	8	0.27
Metro	NA	1870	NA	129	NA

Note – Annual loads calculated by extrapolating from May-September 1992 loads provided in TAMS (2002). NA is not applicable.

West Canada Creek Riverkeepers

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The West Canada Creek Riverkeepers is a citizen advocacy group focused on the Riparian rights on the West Canada Creek, a major tributary of the Mohawk River. The group that was to ultimately form the West Canada Creek Riverkeepers started meeting in the summer of 2007 with the aim of preserving and protecting the River. This first meeting occurred just before the water crisis of 2007 in which low late summer precipitation, and steady drawdown of the Hinckley Reservoir resulted in a limitation on water use. This event lead to NY State Department of Health having to intervene to ensure an adequate supply of drinking water for the Utica area. During the Water crisis of 2007 the Hinckley Working Group was formed and the Riverkeepers attended every meeting and spoke during the citizens comment period. During this crisis, the group was confronted with issues related to low water and the effect of low water throughout the watershed. As a result of this event, the group started learning about riparian rights, bills in Albany, and the principal players with interests in the water. The group quickly discovered that no one was listening to the citizens and formed the West Canada Creek Rivekeepers Inc. in the autumn of 2007. Formation of the group was driven by the recognition that there was a need for citizen advocates and because it was clear that there will be more threats to the River. The aim of the group is to be advocates for the West Canada Creek, by promoting education, and ultimately being keepers of this resource. The Riverkeepers consists of landowners, sportsman, business owners, artists, scientists, and historians who are all concerned with protecting this precious resource. In January 2009, the West Canada Creek Rivekeepers intervened in the lawsuit between the Mohawk Valley Water Authority and the NY State Canal Corp. This motion was filed to protect the riparian rights of those affected by the River. This case is currently in the NY Supreme Court.

Photo of the low water in the Hinckley Reservoir in 2007. Here a boat is high and dry near the confluence of Black Creek. Photo: Rob Thrasher.

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Responsible planning for future ground water use from the Great Flats Aquifer : Two Case Studies: The GEP Energy Project and the SI Green Fuels Boiler Project

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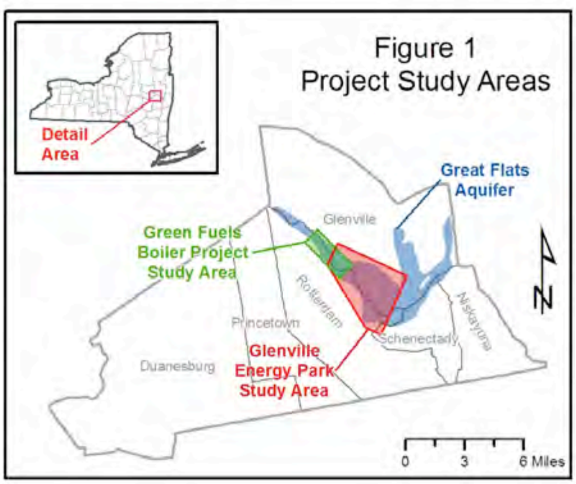
Introduction

The Great Flats Aquifer is a sole source water supply for the City of Schenectady, the Towns of Glenville and Rotterdam, the Village of Scotia, and the Hamlet of Rotterdam Junction. The Town of Glenville also serves neighboring water districts in the Towns of Clifton Park, Charlton and Ballston. Careful consideration should be given to the potential impacts from proposed projects on the availability and quality of ground water to adequately preserve and protect this resource. Two projects within the last 8 years provide examples of comprehensive hydrogeologic studies to evaluate potential impacts to the aquifer.

The Glenville Energy Park (GEP) project proposed withdrawing an average of 2.4 million gallons per day (MGD) of water with a peak of 4.0 million gallons per day from the City of Schenectady municipal well field on Rice Road in the Town of Rotterdam. The Green Fuels Boiler project by Schenectady International (SI) proposed withdrawing and additional 0.22 MGD from existing production wells owned by SI. The areas of study for these projects are shown in Figure 1.



The results of the hydrogeologic studies for each project are presented in reports submitted with project applications to the New York State Department of Environmental Conservation (NYSDEC). The report for the GEP project is dated December 2001 and titled *"Hydrogeology of the Great Flats Aquifer in the Vicinity of the Glenville Energy Park Site"*. Two reports were prepared for the Green Fuels Boiler Project. The first report is dated April 5, 2006 and titled *"Hydrogeologic Evaluation for the Green Fuels Boiler Project at Rotterdam, NY"*. The second report is dated June 9, 2006 and titled *"Supplemental Hydrogeologic Evaluation for the Green Fuels Boiler Project at Rotterdam, NY"*.

The objectives and the scope of work for both of these projects were similar. The objectives generally were to evaluate whether the withdrawal of additional water from the Great Flats Aquifer for the projects would adversely affect ground water availability and quality, particularly at residential wells or at the municipal well fields. The work scope of both projects generally included compiling available geologic and hydrogeologic data, characterizing and evaluating of the existing aquifer geologic and hydrogeologic conditions, and predicting of the potential affects

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of increased ground water withdrawal for the proposed projects. A qualitative hydrogeologic model was used to evaluate the potential affects associated with the GEP project. A quantitative computer ground water flow model was used to simulate various pumping scenarios and evaluate the potential affects of the Green Fuels Boiler Project.

GEP Hydrogeologic Study

The purpose of the evaluation was to determine the potential affects of withdrawing additional ground water (2.4 MGD average and 4.0 MGD peak) from the Schenectady municipal well field. The City of Schenectady well field has a permitted capacity of 35 million gallons per day and has been pumping at an average rate of approximately 12.7 MGD.

The geologic evaluation identified five primary geologic units including, in ascending order, bedrock, glacial till, outwash sand and gravel, glaciolacustrine sand, silt and clay, and alluvial sand and silt. The Great Flats Aquifer, from which municipalities obtain water, consists of outwash sand and gravel that filled the Mohawk River Valley as the glaciers receded.

The aquifer primarily receives recharge from precipitation directly to the valley surface and from runoff onto the ground surface from the upland adjacent to the Mohawk River Valley. Additional recharge is derived from the bedrock and glacial till below the aquifer. The primary discharge zone for the aquifer is the Mohawk River. However, the aquifer is recharged by the river where flow is induced from the river to the aquifer by pumping at the Glenville, Schenectady, and Rotterdam well fields. This recharge to groundwater by the river is a reversal of the normal relationship between the Mohawk River and the aquifer. The ability of the Mohawk River to sustain the Schenectady, Rotterdam, and Glenville well fields limits the susceptibility of those systems to drought conditions.

The water level in the Mohawk River is controlled by canal locks that are used for navigational purposes. The water level in portions of the aquifer adjacent to the river is dependent on the river level, which varies between navigational and non-navigational seasons. The cones of drawdown at the Schenectady, Rotterdam and Glenville well fields during the navigation season are shown in Figure 2. The cones of drawdown at these well fields are smaller during the navigational season than during the non-navigational season because of the higher head in the Mohawk River. Portions of the aquifer that are not located adjacent to the Mohawk River, such as where the Scotia well field is located, are not affected by river levels and exhibit normal seasonal cycles.

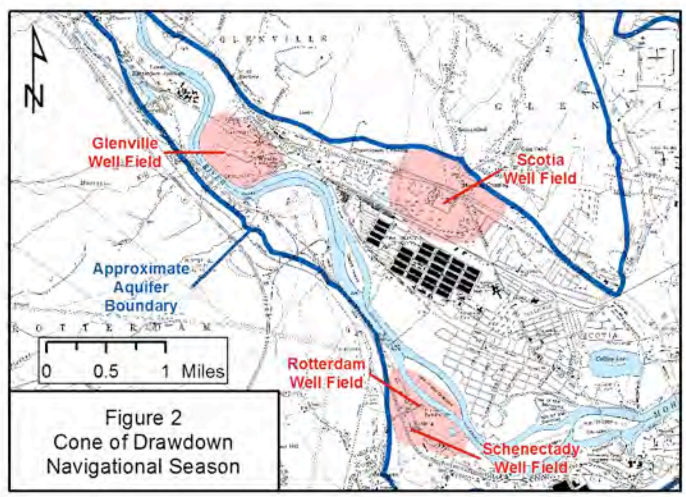

Figure 2
Cone of Drawdown
Navigational Season

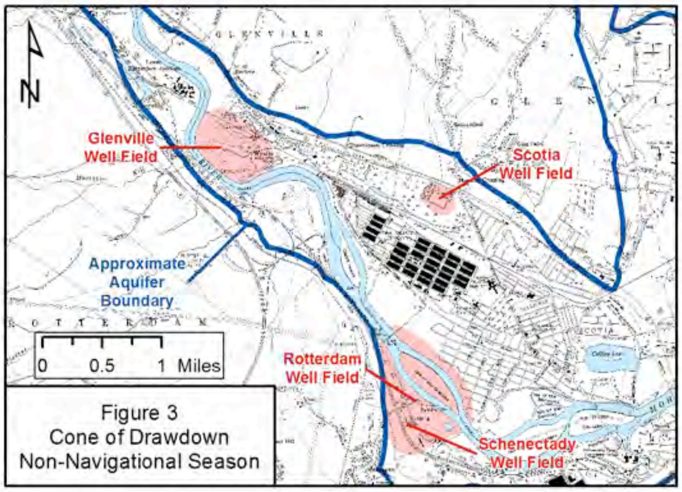

Figure 3
Cone of Drawdown
Non-Navigational Season

The susceptibility of the Schenectady, Rotterdam, and Glenville well fields to summer drought conditions is limited due to their proximity to the Mohawk River; however, they are susceptible to brief periods of dry, cold weather in late January and early February (i.e., non-navigation season). During such conditions of reduced contribution by the Mohawk River, the well fields will remove greater volumes of water from storage in the aquifer resulting in an expansion of the cone of drawdown at each well field. Figure 3 shows the expanded cones of drawdown during the non-navigation season. Pumping test results indicate that the water supplied by the Mohawk River to the Schenectady/ Rotterdam well field limits the cone of drawdown north of the well field, except during periods of severe climatic conditions and very high pumping rates. The short-term variations in the well field pumping rate have very little effect on the cone of drawdown because of the very high aquifer transmissivity and the hydraulic connection between the well field and the Mohawk River.

Comparison of the groundwater contour maps prepared during the study for the navigational and non-navigational seasons show that there is little seasonal change in groundwater levels or groundwater flow directions, except near Lock 8. Damming of water at Lock 8 during the navigational season results in a 14.5 foot difference in surface water elevation from the upstream to the downstream side of the lock, which is open during the non-navigational season. This condition creates seasonal changes in the groundwater gradient and the groundwater flow direction in the area north of the lock.

The results of the hydrogeologic evaluation for the proposed GEP project showed that the proposed additional pumping of 2.4 million gallons per day (4.0 million gallons per day maximum) at the Schenectady well field could be implemented without adverse impacts. The hydrogeologic evaluation showed that the increased pumping rate would not affect the groundwater flow direction or the groundwater quality of private well users, or adversely affect other municipal well fields.

Green Fuels Boiler Hydrogeologic Study

The Green Fuels Boiler hydrogeologic study was conducted as part of an environmental impact assessment to permit an alternative fuels boiler at the Schenectady International (SI) facility in Rotterdam, New York. Figure 4 shows the location of production wells within the Green Fuels Boiler study area.

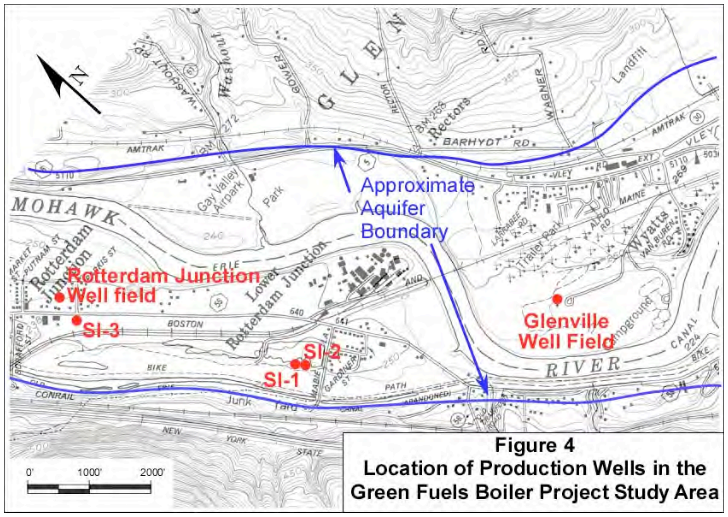

Figure 4
Location of Production Wells in the Green Fuels Boiler Project Study Area

Two of the primary objectives of the hydrogeologic study were to determine whether the Great Flats Aquifer has sufficient capacity to produce 0.22 MGD to the project and to assess the effects of additional pumping for the project at existing private or municipal pumping wells. The secondary objectives of the assessment included defining the extent of the hydrogeologic units, identifying recharge and discharge areas, defining ground water flow paths, and predicting changes in the ground water flow patterns and ground water gradients from the proposed increased pumping.

Considerable knowledge of the geologic and hydrogeologic setting in the Mohawk River valley was gained from the comprehensive evaluation of the Great Flats Aquifer as part of the GEP energy plant siting study. The results of that study were directly applicable to the hydrogeologic evaluation for the Green Fuels Boiler project.

The extensive information developed from the previous research and investigations of the Great Flats Aquifer and site area included geologic and hydrogeologic data from published reports, consulting reports to the municipalities that rely on the aquifer, well field data collected by the municipalities, subsurface data collected by others within the study area, and the results of the GEP energy plant siting study. Additional geologic, hydrogeologic and SI plant data were provided by SI. The available information was used to assess data that pertain to municipal well field production rates, historical pumping rates at the SI pumping wells, geologic logs and records for wells throughout the study area, and reports describing the hydrogeology of the Great Flats Aquifer and related geologic units. Geologic maps and cross sections were prepared to characterize the aquifer and to provide a basis for developing a computer ground water flow model to simulate existing and anticipated pumping scenarios.

The geologic and hydrogeologic maps prepared from the available information, the relevant pumping data, and the aquifer properties obtained from the existing reports were used to develop an analytical computer ground water flow model to evaluate various hydrologic and pumping conditions. The results of the ground water flow model are consistent with known hydrologic conditions, ground water flow patterns, and water levels during the navigation and non-navigation seasons.

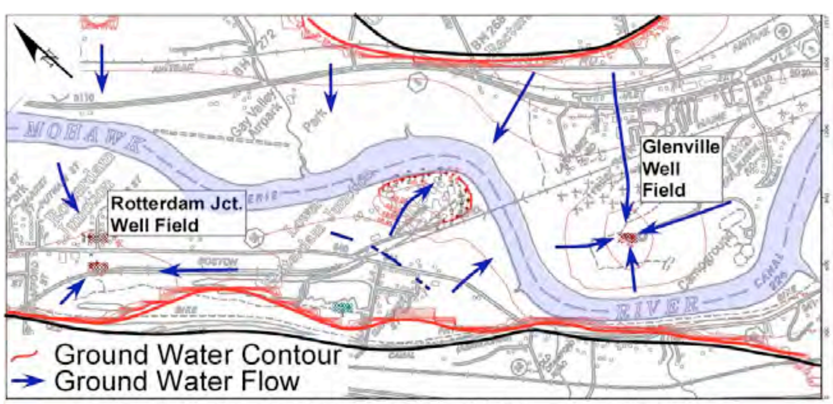

Figure 5: Computer Simulated Ground Water Flow
Non-Navigation Season

Figures 5 and 6 show typical computer model simulations for ground water pumping conditions at various wells under both navigational and non-navigational conditions.

The model simulation results show the ground water elevations, gradients and flow paths in the study area for currently existing conditions. The modeling simulations were used to predict changes in these conditions due to increased pumping for the boiler project. The simulations of existing conditions show that ground water elevations, gradients and flow paths normally vary as the level of the Mohawk River changes from the navigation to the non-navigation seasons. Simulations of projected conditions indicate that the impact of additional pumping would be minimal regardless of which existing SI pumping well was used. The aquifer readily produces sufficient water to support the proposed increased pumping rate without adversely affecting other pumping wells in the study area.

The hydrogeologic evaluation demonstrated that the Great Flats aquifer would support the proposed additional pumping for the green fuel boiler project without adversely impacting other pumping wells. The results of this hydrogeologic evaluation indicated that changes in local drawdown and ground water flow patterns by the proposed pumping would be minimal.

Conclusions

The Great Flats Aquifer is an essential and valuable resource for continued growth and development of the communities that rely on it for a source of clean, readily available water. Studies have shown that the aquifer can easily support withdrawal of quantities of water far in excess of those currently being pumped because of the hydraulic connection with the Mohawk River. However, not all portions of the aquifer benefit from this hydraulic connection. Studies should be performed on a case by case basis to identify the specific geologic and hydrogeologic conditions at proposed project sites or proposed wells to ensure that adequate water is available and sustainable.

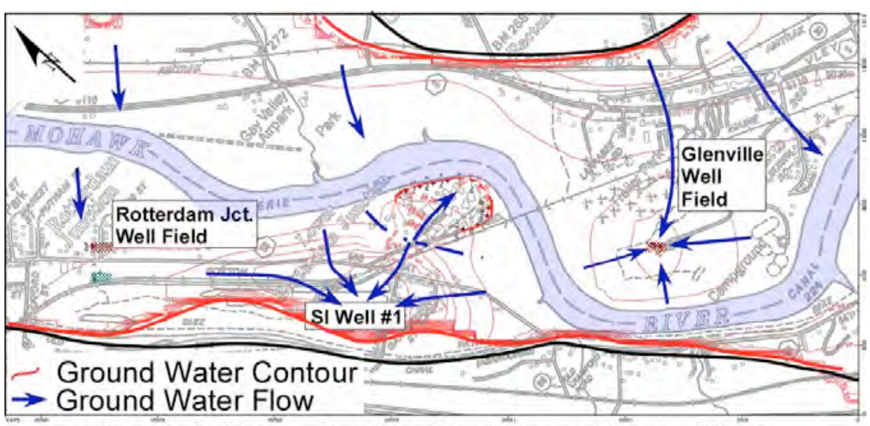

Figure 6: Computer Simulated Ground Water Flow; Navigation Season

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RECENT FLOOD STUDIES IN THE MOHAWK WATERSHED

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The Flood Insurance Study (FIS) and the Hazard Mitigation Technical Assistance Program (HMTAP) are the two Federal Emergency Management Agency (FEMA) managed programs that develop hydrology, hydraulic and flood hazard area determination studies in the Nation. In New York State they are carried out with co-sponsorship and in coordination with the State Floodplain Mapping Program, managed by the Department of Environmental Conservation (DEC). Although their primary purposes are flood insurance rate determination, floodplain management and emergency response planning, the studies provide valuable information for other purposes, hydrologic and otherwise. These include the H&H studies themselves, updates to the studied area topographic and hydrographic data, and the field collection of stream channel and near bank environment information. This abstract provides details about the existing and on-going HMTAP and FIS projects in the Mohawk Watershed, databases available and data distribution mechanism. It ends by pointing out some of the gaps in the studies, databases and data distribution mechanism, with some ideas on further work necessary to complete our knowledge and management capabilities of the landscape from a water resources point of view.

Terrain elevation data

In coordination between the FEMA and DEC floodplan mapping programs, several surface elevation data collection have been carried out in the watershed:

- Schoharie1998 and Greene1998: bare ground LiDAR was collected along the Schoharie Creek main stem and its main tributaries.
- FEMA DR1650 Mohawk2007: a 2-mile wide corridor centered on the Mohawk River with a few additions of LiDAR multiple return data were collected, and the point cloud was classified for bare ground. LAS format.
- CD2008 and Oneida2008: Area-wide multiple return LiDAR was collected in Albany, Schenectady and Oneida counties. As an example of the data characteristics some details about this data collection follow.

CD2008 collection

- In the spring of 2008, The Sanborn Map Company, Inc. acquired 451 square miles of terrestrial LiDAR data in Capital District, NY. An Optech ALTM 2050 Airborne LiDAR sensor was used for the collection. The LiDAR data associated with this metadata file is in LAS binary format, version 1.1.
- Accuracy: The data meets the FEMA specifications for a normal distribution and the overall RMSE of 0.097 meters (9.7 cm Table 3) is less than the National Standard for Spatial Data Accuracy (NSSDA) figure of 18.5 cm for 2 foot contour mapping. Individually, all of the ground cover categories also meet this standard. [As] expected the brush, high grass, and forested cover types have higher RMSE values as the vegetation removal algorithm used by the LiDAR vendor is not 100% efficient at removing points in which the vegetation intercepts the laser...

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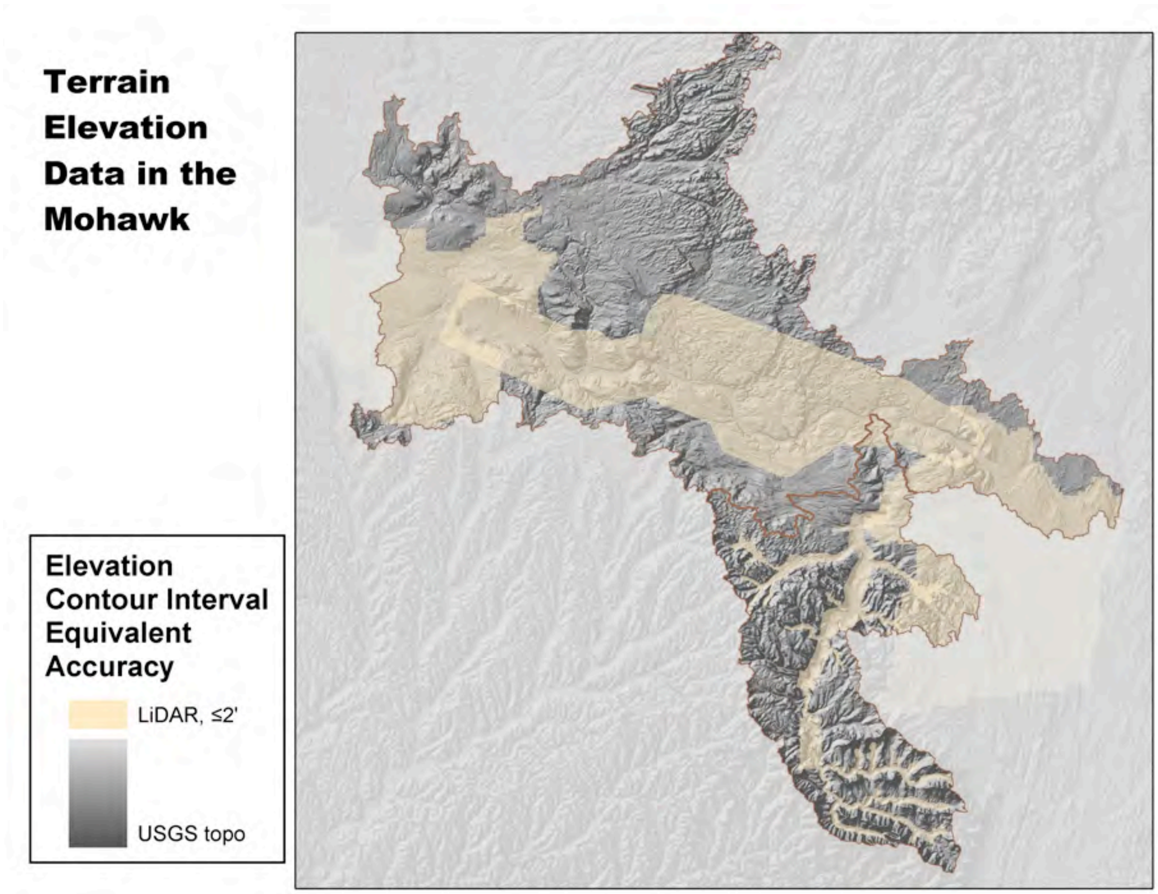

Figure 1 Terrain elevation data in the Mohwak Watershed.

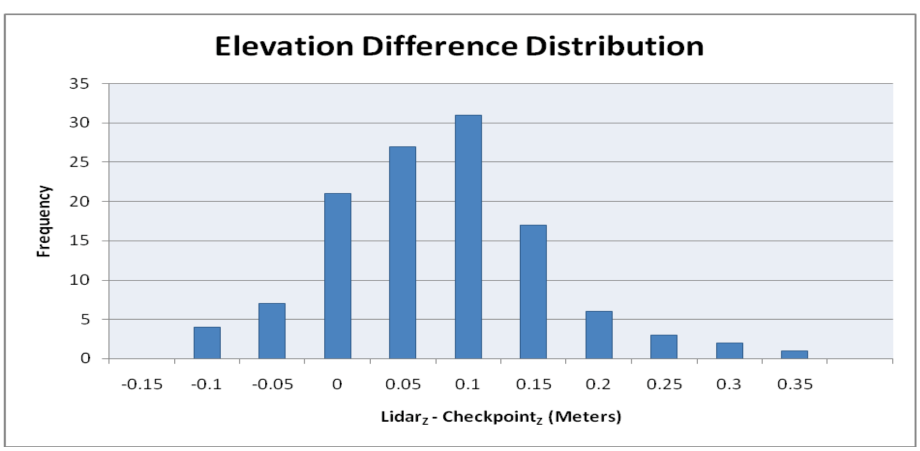

Figure 2 Capital District LiDAR collection area: Frequency Histogram for checkpoints, all cover types.

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Table 1 Summary of Error Residual Statistics for All the Checkpoints

Cover Type	RMSE (m)	Average Elevation Difference (m)	Standard Deviation (m)	Maximum Elevation Difference Value (m)	Minimum Elevation Difference Value (m)	Number of Checkpoints Used in Analysis
All 5 Cover Types	0.09735	0.05198	0.08264	0.30759	-0.12283	123

Point Density: ~ 2.7 points/m2 and ~ 0.6 ground points/m2, i.e. an average ground point spacing of ~1.3 m.

Bare Ground Classification assessment: …many occurrences of bridges and overpasses left in the ground classification. There were also… holes in the ground averaging around 7m in depth…. There were some spots where at least one building point was classified as ground.

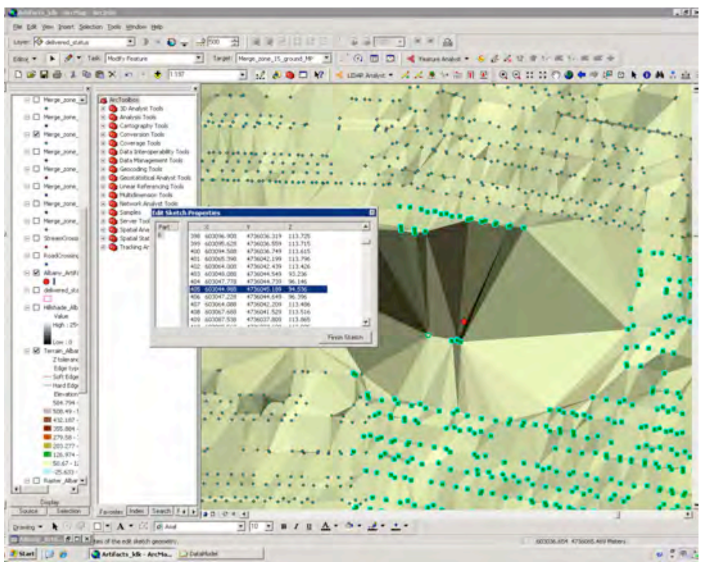

Figure 3 Example of a "Divot" artifact. The elevation of the points in the depression area are about 10m lower than the surrounding points.

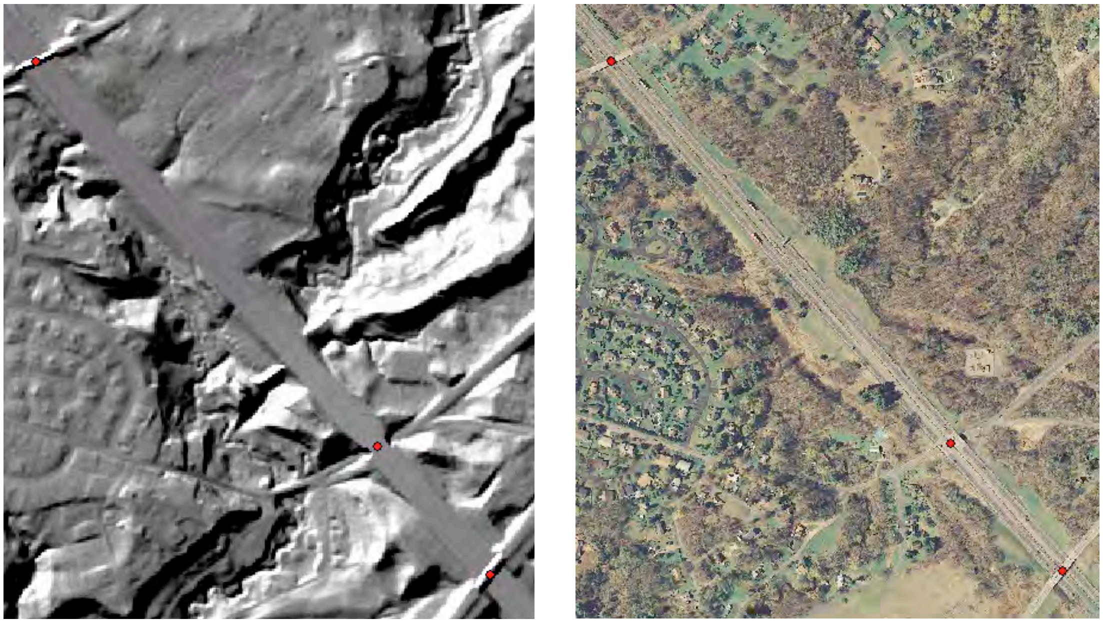

Figure 4 shows an example of elevated highways (overpasses) that were classified as ground.

Mohawk Watershed H&H Studies

Hydrologic and Hydraulic studies sponsored by FEMA and the NYS Floodplain Mapping Program seek to determine areas exposed to flood hazards in flood events of a set recurrence interval, the 100-year recurrence interval (1% yearly probability) flood being the most common. To arrive at these results the study uses stream flow determinations, terrain topography information and hydraulic models to arrive at the expected water surface elevation for such floods, using again the topography information to map the areas exposed to the flood hazard. To manage the available budget different stream segments are studied to different levels of detail: stream reaches along which the flood hazard level is higher get a more detailed study. Many stream reaches were studied in the 1970's and 80's, using mostly approximate methods (run off curve and USGS topo maps) or the HEC1 model. In the late 90's and this decade some of the previously studied stream segments have been re-studied, and a few never studied streams have received and approximate or detailed study. The level of detail in these more recent studies can be gleaned from the State Flood Mapping Program Planning Category Definitions memo, 12/15/05:

- Detailed (D)- …The level of effort includes orthophoto, LIDAR and stream breakline collection, survey of the channel and hydraulic obstructions (use of as-builts and DOT hydraulic studies, where appropriate and available), nomination of flowrates, and the development of HEC-RAS hydraulic models. Final maps will show the extent of the SFHAs, BFEs and floodways.
- Approximate (A)- …the anticipated level of development does not warrant the collection of field survey… The level of effort includes orthophoto, use of best available topography at the time of the scoping which may include LIDAR and stream breakline collection where available, use of as-builts and DOT studies (where appropriate and available), nomination of flowrates, and the development of HECRAS hydraulic models…

The following table and figure provides and overview of the studies carried out, or in the process of being finished, in the watershed.

Table 2 Recent and On-Going Detailed H&H Studies of the Mohawk River and Major Tribs

Flood Source	Study length (mi)	Downstream study limit	Upstream study limit
Mohawk main stem (Det., FW)	70.0	Montgomery/Schenectady County Border	Western border, City of Utica
Schoharie Creek	n/a	Several segments. Further downstream is Schoharie County border	4 mi S of Rt 30, S border of Middleburgh (T)
W Canada Creek (Det., FW)	2.4	Confluence w/Mohawk	County Hwy. 94 Bridge, Herkimer (T)
E Canada Creek (Det., FW)	9	Confluence w/Mohawk	Northern border, Dolgeville (V)
Fulmer Creek		Confluence w/Mohawk	Southern border, Mohawk (V)
Moyer Creek		Confluence w/Mohawk	Southern border, Frankfort (V)
Steele Creek		Confluence w/Mohawk	Southern border, Ilion (V)

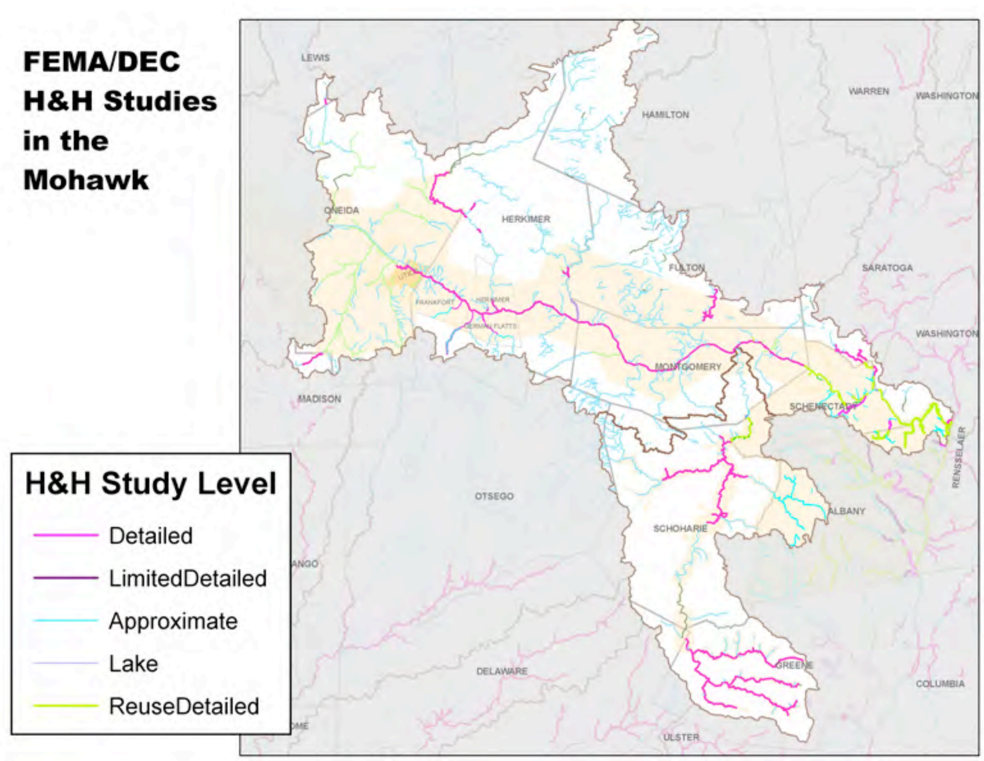

Figure 5 Recent and On-Going Detailed H&H Studies of the Mohawk River and Major Tribs

As an example of H&H study characteristics some details about the Mohawk River study follow.

Mohawk River HMTAP study

Detailed Data Collection: The contractor shall collect necessary data to perform the hydrologic and hydraulic analyses.

- Historical flood information, including high water mark reports published by the USGS and data collected or maintained by local communities;
- High Water Marks collected by FEMA and USGS from the June/July 2006 flooding event;
- Historic weather data for hydrologic modeling;
- New stream rating curves (as necessary);
- Previous hydrologic and hydraulic information including Flood Insurance Studies;
- Dam operation records;
- Dam damage assessments performed under FEMA as part of the DR NY 1650 response;
- Design plans and/or survey data for any existing structures (i.e. bridges, culverts, dams, levees) along the waterway or affecting flows;
- Stream cross section information based on surveyed information;
- Vertical datum conversion factors;
- Base Map Information (GIS data, aerial imagery) from Federal, State, and/or local sources; and
- Land use / Mannings "n" data.

Hydrologic Analyses: For the targeted watershed, the contractor shall develop revised discharges for the 10%, 2%, 1%, and 0.2% annual chance events and summarize them in a Summary of Discharges table. The contractor shall utilize available gage data after consultation with the USGS. The contractor shall perform all hydrologic analyses in accordance with Appendix C: Guidance for Riverine Flooding Analyses of FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners*.

Hydraulic Analyses: For all but the Mohawk River, along the identified stream reaches, the contractor shall develop a revised HEC-RAS hydraulic model, Floodway Data Tables (where applicable) and flood profiles for the 10%, 2%, 1%, 0.2% annual chance events. The Mohawk-Erie Canal is to be analyzed using MIKE 11, which can include some two dimensional (2-D) aspects in a 'loop network' without the detail of a true 2-D model. This one dimensional-plus (1D+) model would allow for the river/canal exchange of flow and incorporate some of the split flow occurring in the areas of islands without the extensive effort for calibration, verification, and general modeling required of a 2-D model.

Where applicable, the newly delineated floodplain and floodway boundaries must tie in to existing floodplain and floodway boundaries to within 0.5 feet vertically and smooth transition horizontally. Newly delineated flood profiles must tie in to existing flood profiles within 0.5 feet.

Major flood protection systems exist along the Mohawk River in Montgomery County and in the Village of Herkimer in Herkimer County. The contractor shall perform detailed surveys of the toe and top of all levees, dikes and dams comprising these systems so that a preliminary determination regarding the viability of the systems can be made. The flood recovery mapping produced for these areas shall reflect the results of this preliminary determination.

Study Deliverables:

1. Hydrologic input and output for the 10%, 2%, 1%, and 0.2% annual chance events.
2. Hydraulic input and output for HEC-RAS modeling, including the flood profiles for the 10%, 2%, 1%, and 0.2% annual chance events. Profile sheets and floodway data tables for the studied reaches will be submitted. The data shall be in hard copy and electronic format. In addition, the submitted data will include:
   a. A geo-referenced stream channel network;
   b. A geo-referenced line data set showing the locations of cross sections used for the computation of water surface profiles;
   c. A geo-referenced line data set showing preliminary floodway, 1%, and 0.2% floodplain boundaries, where calculated;
   d. All geospatial data sets utilized for parameter calculation in final format

(e.g. a spatial file of n-value polygons); and

e. Database tables summarizing key data.

3. A narrative description of the methodologies used to develop the hydrology and hydraulic information. This information will be provided in Technical Support Data Notebook (TSDN) format.
4. For the communities identified in Section IV, GIS-based workmaps showing the 1% and 0.2% floodplain boundaries and the floodway, cross-section locations, and base flood elevations, provided in digital and hard copy format.

Data Distribution

When the HMTAP/FIS projects have been completed, passed review and legally delivered to the affected communities, all data developed for these studies can be requested from FEMA via its *Map Service Center* web page at msc.fema.gov. It can also be requested by contacting NYSDEC Floodplain Management group, www.dec.ny.gov/lands/24267.html. Although the mechanisms for serving the data are improving and web page usability is being continuously improved, there are not publicly available web pages with a detailed listing of study components available for a particular stream segment and the tools to specify unambiguously the desired data request. This situation will have to await until the hydrologic and natural resource management community adopts an integrated water resources data model. The groundwork for this developments has already being laid through the work of David Maidment and his collaborators at the University of Texas Center for Research in Water Resources: the ArcHydro data model and the Flood Study Geodatabase data model. NYSDEC has collaborated with this with the development of a Terrain Elevation data model integrate to FSG. At this point there is no funding available for the implementation and deployment of the data models, hence the FEMA web page or direct contact with their or DEC's offices is the most reliable way to obtain the data.

Please direct further questions to:
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LOWER MOHAWK RIVER FISHERIES

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Overview

The 257 km Mohawk River is the second longest river in New York State with the lower 47 km located within the Capital District (Albany-Schenectady-Troy) area, the state's fourth largest metropolitan area. The river is also part of the New York State Barge Canal system. The magnitude of the resource, its close proximity to large numbers of people, and environmental assessment needs relating to commercial development necessitated updating fisheries information on the lower 122 km of river from Five Mile Dam, located 7.1 km upstream of Lock 16, downstream to the Hudson River. In 1979, the New York State Department of Environmental Conservation (NYSDEC) Region 4 Fisheries Office began a study of the lower Mohawk River to better understand its fisheries potential and management needs. A number of studies, primarily on the Crescent Dam to Lock 16 reach, were completed that culminated in the development of a fisheries management plan for the lower Mohawk River in 1994. Highlights of these fish studies are summarized.

River Description

Completion of the Erie Barge Canal in 1918 resulted in the canalization or obliteration of the succession of riffles, pool, and still waters that characterized the natural Mohawk River. Approximately 135 km of the 257 km free flowing river was changed to a series of permanent and seasonal impoundments. The 122 km lower Mohawk River contains five permanent dams, nine movable dams, nine locks, and five operational hydropower facilities. Another five locks and two guard gates are located within the 3.7 km landcut canal joining the Mohawk and Hudson Rivers that bypasses the 29.4 m high Cohoes Falls. All but 10.3 km of the lower river is canalized with 113 km containing a 61 m wide by 4.3 m foot deep shipping channel.

The Mohawk River can be classified into three channel basin types based on shape and use: natural river, river canal, and power pool. In the lower Mohawk River, the natural river section comprises a total of 10.3 km and is found in three reaches: Five Mile Dam to Lock 16, the Diversion Dam to Cohoes Falls, and at the mouth above the flooded branch sections to the New York State Dam. The river canal section extends 76.3 km from Lock 8 to Lock 16. The dams at Locks 8-15 are movable and only in place during the May through November navigation season and removed during the winter. These seasonal impoundments range in size from 74 to 248 ha. When these dams are removed, the river becomes free flowing throughout this reach. The 36.2 km power pool section extends from Lock 8 downstream to the Diversion Dam, Cohoes Falls to the New York State Dam, and the flooded stream sections at the mouth. These impoundments are permanent and range in size from 37 to 771 ha.

Effects of Erie and Barge Canal Construction

Completion of the Erie Canal in 1825 and the Erie Barge Canal in 1918 created a bypass around the Cohoes Falls that resulted in a direct waterway link between the Hudson River and Great Lakes. This bypass allowed fish to move east or west through the canal system to establish populations in other

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watersheds or within the Mohawk River. Fish moving west through the canal system include sea lamprey, alewife, and white perch. Fish moving eastward include smallmouth bass and gizzard shad. This movement through the canal system is still occurring. Freshwater drum, moving eastward, were first documented in 1990 at Lock 7 and are now present throughout the river.

Riverwide Fish Surveys
Fish populations throughout the lower Mohawk River were sampled with trap nets, electrofishing, and gill nets primarily in June between 1979 and 1983. Seining and trawling efforts occurred August through October in 1982 and 1983. Fifty-six fish species were recorded compared to 48 during the 1934 surveys. Six species collected in 1934 were not collected during the 1979-83 surveys but 12 additional species were collected during the later survey. During the June sampling, blueback herring were the most abundant fish collected followed by smallmouth bass, white sucker, yellow perch, brown bullhead, and rock bass. Numerically, game species represented 12.1% of the total fish collected compared to 25.4% for panfish, and 62.6% for all other fish species. The most numerous species collected by seine were young-of-year blueback herring, emerald shiner, spottail shiner, and bluntnose minnow.

Differences in Fish Community Structure by Channel Basin Type
The June, 1979-83, sampling data indicated major differences in fish communities in the four permanent power pool impoundments and the eight seasonal river canal impoundments. Comparisons of the relative percentage of the three fish categories-game fish, panfish, and other fishes-show that the lower Mohawk River fish community changes from panfish dominance in the power pool impoundments to game species dominance in the river canal impoundments. Excluding the anadromous blueback herring, game and panfish in the power pool impoundments represented 9.4% and 65.2% of the fishes collected compared to 36.3% and 23.8% in the river canal impoundments.

Angler Use
The lower Mohawk River supports a popular, warmwater fishery. In 1982 on the Crescent Dam to Lock 16 reach, the estimated total fishing pressure was 115,245 trips or 389,033 hours which is equivalent to 45.9 trips/ha or 154.9 h/ha. Shore and boat anglers made an estimated 59,622 and 55,623 trips, respectively. No other large (> 405 ha) warmwater system in New York at the time was known to support fishing pressure exceeding the 154.9 h/ha recorded from the lower Mohawk River.

Angler Catch and Harvest
Shore and boat anglers each caught (creeled plus release) about 0.9 fish/h in 1982 on the lower Mohawk River; however shore anglers creeled 0.29 fish/h compared to the 0.15 fish/h for boat anglers. Smallmouth bass, the dominant species caught by both shore and boat anglers were caught at a rate of 0.36 and 0.73 fish/h, respectively. For shore anglers, smallmouth bass comprised 41% of the total catch followed by rock bass (17%), yellow perch (9%), crappie (6%), and suckers (5%). For boat anglers, smallmouth bass comprised 78% of the total catch followed by rock bass (8%), walleye (3%), fallfish (3%), bullhead (3%), and yellow perch (1%). Anglers removed an estimated 77,626 fish weighing an estimated 25,930 kg from the Crescent Dam to Lock 16 reach during the May through September fishing season in 1982 for a per hectare yield of 30.9 fish and 10.3 kg. The per hectare harvest of 9.6 smallmouth bass weighing 4.3 kg was the highest recorded for a New York water with a 30.5 cm size limit.

Changes in Smallmouth Bass Abundance, Size Structure, and Fishery
Smallmouth bass were the dominant game fish in the lower Mohawk River and the second most abundant species collected during the 1979-83 riverwide surveys. Electrofishing catch rates ranged from 17.3 fish/h in the

Crescent impoundment to 155.1 fish/h in the Lock 10 Pool and averaged 70.7 fish/h for the entire lower river. Except for the Lock 15 Pool, smallmouth bass catch rates were highest in the seasonal impoundments. The electrofishing catch rates were very high and indicative of a dense population. By comparison, spring electrofishing catch rates in eight New York lakes from 1978 to 1980 averaged 8.9smallmouth bass/h with individual collections ranging up to 43.2 smallmouth bass/h.

The quality of the smallmouth bass fishery was assessed through the 1982-86 angler diary program. During this five year program on the Crescent Dam to Lock 16 reach, cooperators averaged 1.10 smallmouth bass/h and 0.51 legal (≥ 30.5 cm) bass/h. These catch rates were high and indicative of a very high quality fishery. In the St. Lawrence River, long recognized as one of the premier smallmouth bass fisheries in New York, diary cooperators from 1978 to 1980 recorded catch rates only half as high as those recorded in the lower Mohawk River. St. Lawrence cooperator catch rates averaged 0.60 fish and 0.32 legal fish/h, respectively.

In a similar 1996-97 diary cooperator study, smallmouth bass catch rates averaged 0.48 fish and 0.31 legal fish/h. Although these catch rates are still indicative of a good bass fishery, it represented a decline of 57% in the overall catch rate and a 40% decline in the legal catch rate from the very high 1982-86 cooperator catch rates. The diary data suggested a decline in smallmouth bass abundance, which was verified in a 1998 electrofishing survey of the Lock 8 Pool. This survey also revealed a change in the size structure of the bass population with fewer smaller bass and more larger bass present.

Smallmouth bass studies were conducted in the Locks 8, 10, and 14 Pools from 1985 through 1988 and these studies were repeated in 1999 and 2001 to verify the changes in bass abundance and size structure observed during the diary study and 1998 electrofishing study. In the 1985-88 studies, the electrofishing catch rate in the Lock 8, 10, and 14 Pools averaged 44, 69, and 35 fish/h compared to the average of 15, 9, and 8 fish/h recorded during the 1999 and 2001 studies, respectively. The RSD16 of smallmouth bass in the Lock 8, 10, and 14 Pool averaged 3%, 1%, and 0% in the early study and 29%, 40%, and 26% in the later study, respectively. The same three pools were electrofished in 2006 and the results were similar to those recorded in 1999 and 2001. The data suggests that the reduction in smallmouth bass abundance and the increase in larger fish occurring throughout the lower river in the eight seasonal impoundments are permanent. The reasons for this shift in abundance and size structure are not known but may be related to the establishment of zebra mussels in 1991. It is also not known whether a similar shift has occurred to the bass populations in the permanent impoundments downstream of Lock 8.

Contaminants in Fish

Contrary to popular opinion, all lower Mohawk River fish are safe to eat except for those fish caught at the mouth. The mouth is limited to catch and release fishing only because of elevated PCB levels in Hudson River fishes. This catch and release regulation applies to the Hudson River between the Troy Dam and Hudson Falls and includes all tributaries to the first impassible barrier which in the Mohawk River is the New York State Dam between Cohoes and Waterford. Currently, there are no health advisories on fish consumption from the lower Mohawk River. Historically, PCBs were a problem in the Mohawk River downstream of Lock 7 that resulted in an eat none health advisory for white perch and a one meal per month advisory for smallmouth bass in this 12 mile reach. However, these advisories were lifted in April, 1994, due to declining PCB levels which have fallen even further since then. White perch PCB levels in 1983, 1987, 1992, and 2006 were 7.3, 3.4, 1.3, and 0.5 ppm, respectively. Smallmouth bass PCB levels in 1983, 1987, 1992, and 2005 were 2.5, 2.1, 0.8, and 0.2 ppm, respectively. The US Food and

Drug Administration (USFDA) tolerance level for PCBs is 2.0 ppm. In the 2005 fish collections below Lock 7 and between Locks 8-9, mercury concentrations were consistently below the USFDA action level of 1.0 ppm. The three p,p'-DDT related compounds were frequently detected but their total concentrations were generally well below 0.1 ppm and well below concentrations considered harmful to human health or the environment. Several compounds were not detected in any sample. Non-detectable compounds include mirex, photomirex, trans-chlordane, heptachlor, heptachlor epoxide, aldrin, and lindane.

Summary

The lower Mohawk River supports an abundant and diverse warmwater fishery of high quality. It is a dynamic system whose fish community is still undergoing change. The smallmouth bass fishery has shifted from one dominated by fish in the 10-13 inch size range to one now dominated by fish 14 inches and larger. Freshwater drum, first collected in 1990, are now present throughout the river and locally abundant in some areas. Blueback herring abundance is declining throughout the river. Northern pike, once very rare, now provide trophy fishing opportunity throughout the river.

The river's close proximity to large numbers of people makes it an important recreational asset provided the public has access to the river and water quality remains good. Public and fee boat launch sites are located throughout the lower Mohawk River between Crescent Dam and Lock 16. Only the Lock 9 and 11 Pools have no boat launch sites. Shore fishing is most popular at the locks.

The lower Mohawk River fisheries management plan, completed in 1994, summarizes the historical background and the fishery. Fisheries issues were identified and included the following: hydropower development, stream flow fluctuation, stream diversion, zebra mussels, fishing ban, law enforcement, commercial fisheries, and fishing tournaments. Nineteen management strategies were developed including 31 specific recommendations for implementation. This management plan should be updated.

The Environmental Study Team :
YOUTH DEVELOPMENT THROUGH LOCAL ENVIRONMENTAL FIELD RESEARCH

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The Schoharie River Center (SRC) is a not-for-profit organization dedicated to educational and cultural programming about the Schoharie Creek and the communities near the Schoharie River Valley and the Mohawk River Valley. Formed in 1999, it is a community based organization that sponsors and operates two Environmental Study Team programs, one in Burtonsville, NY and another in Schenectady, NY. The Schoharie River Center, located in Burtonsville, NY is also active in a variety of community, historical and cultural programs and activities. The Environmental Study Team (EST) is an award winning Youth Development Program where middle and high school age youth work with ecologists and aquatic biologists to study, monitor and improve the water quality of local streams, rivers and lakes.

The Environmental Study Team has been studying, monitoring, and documenting the water quality of the Schoharie Creek and other streams and lakes since 2002. In 2007 the program was awarded a national Environmental Excellence Award from the Conservation Matters program sponsored by Sea World – Busch Gardens –Fuji Films. The SRC EST program was started in 2002 and meets in Burtonsville, NY. This program serves students from the Duanesburg, Schalmont, Schoharie and Amsterdam school districts, as well as several area private schools. Meetings are generally every other Sunday from noon to 4pm.

In 2008 a second program was started in Schenectady, NY and is co-sponsored by Watershed Assessment Associates. Its home is at the Watershed Assessment Associates building at 28 Yates Street in downtown Schenectady. This branch of EST serves students throughout the Schenectady area and meets twice a week. EST members learn how to conduct chemical tests to determine water quality, identify macro invertebrates found in the waters, prepare written scientific reports of their findings, learn photography and videography skills, prepare slide shows, as well as make presentations to the public.

The EST program is open to any interested youth ages 13 - 18. Parents are also welcome to participate. For more information about the EST program contact John McKeeby at schoharierivercenter@juno.com, or J. Kelly Nolan at jkn@rwaa.us.

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THE NYSDEC MOHAWK RIVER BASIN PROGRAM: AN ECOSYSTEM BASED APPROACH TO MANAGING THE RESOURCES OF THE MOHAWK RIVER AND ITS WATERSHED

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The Mohawk River has long been a driving force in shaping the natural environment and the life of communities throughout the Mohawk River Valley. For centuries people have flocked to the valley to capitalize on its fertile flood plain soils, its historic fisheries, and as an accessible means of transportation. For approximately 100 years, starting in the late 19th century, the environmental quality of the river and many of its tributaries declined due to the overwhelming pressures people brought with them. Manufacturing and transportation built dams, factories, roads, and rails throughout the basin and adjacent to the river. Major centers of population grew. Before the era of environmental regulation many unknowingly contributed to reducing the quality of the river they relied so much upon for progress. Basic regulations put in place since the 1970's especially the enactment of the Clean Water Act, have helped relieve these pressures and reverse the degradation of the river. Today the river and many of its tributaries are better than they once were. However, the gains made need to be substantially protected and managed. Legacy problems that have never been resolved must be addressed such as PCB contamination, sediment build-up in streams and erosion of stream banks, and occasional sewage pollution.

As a new initiative of the NYS Department of Environmental Conservation the Mohawk River Basin Program seeks to assist in the management of the environmental resources of the River and its watershed. This means working with others to help manage the river and valley for a sustainable future, involving the voices of all stakeholders, and partnering with established programs and organizations throughout the basin. The Mohawk River Valley is an excellent area for advancing State goals for ecosystem-based management of environmental resources, smart growth, and sustainable economic development including heritage development. The Mohawk River program will strive to make management decisions based on an understanding of the whole ecosystem. It is time for a new approach. Complex issues cannot be resolved using information from only once sector of available information. Therefore, the Mohawk River program will enlist the support and assistance of stakeholder and other organizations to help inform decision making processes related to the environmental quality of the Mohawk River Valley. Management practices in the Mohawk River Valley need to be designed to be adaptive and responsive to change, to promote coordination and cooperation among sectors; to balance competing uses; and to inspire compromise (NYS 2007). We hope that all parties interested in the Mohawk River Valley will come together to assist us in these goals.

Key Partnerships in the Basin

There are three significant programs already in existence within the Mohawk River watershed with which important collaborations have already begun to form. These organizations are closely oriented to the human uses of the river and its valley. They are the Mohawk Valley Heritage Corridor

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Commission (Heritage Corridor Commission), the National Parks Service Erie Canalway National Heritage Corridor (Erie Canalway), and the Army Corps of Engineers (Army Corps). A Mohawk River Program can add an important fourth leg to the stool to provide a focus on the natural environment. Fostering relationships with these organizations is vital to ensuring the completion of Mohawk River Program goals and objectives, specifically in areas where it does not have the expertise. Ultimately, a healthy environment, a rich cultural heritage and a vital economy go hand in hand. Here is what is already happening:

The Heritage Corridor Commission a non-profit 501(C)(3) organization established by the New York State Legislature in 1997; its mission is to preserve, promote, and celebrate the natural, cultural, and historic treasures of the Mohawk River Valley. Through a series of partnerships with local and state governments, civic groups, and private industry the Heritage Corridor Commission has worked diligently since 1997 to revitalize river valley communities, and develop a heritage tourism industry (MVHCC 2006). Their important work and established reputation in the community makes them a natural choice for partnership in fostering heritage development in the communities within the Mohawk River Valley.

In addition, in 2000 Congress adopted the Erie Canalway National Heritage Corridor Act, which designated the navigable waters of the Mohawk River Valley and many other canal areas throughout NYS as Heritage Areas (NPS 2005). This designation recognizes the significant heritage of the Mohawk Valley associated with Native Americans, European settlement and other epochs of American history including the building of the Erie Canal at the State and National level. One of the major elements of the Erie Canalway is its Preservation and Management Plan for the corridor. The plan offers guidance on implementing policies that protect and preserve the historic, natural, cultural, and recreational resources in the corridor (NPS 2005).

Both the Heritage Corridor Commission and the Erie Canalway are dynamic examples of emerging area-wide programs, which recognize major themes of our heritage and advance the intersecting goals of conservation, recreation, education and sustainable developments. Under New York State law, heritage areas are defined as an amalgam of natural and cultural resources. Both state and national heritage programs are compatible with the mission of a Mohawk River Basin Program.

In June of 2006 a major flooding event occurred throughout the Mohawk River Valley. This event shifted the focus of organizations like the Heritage Corridor Commission and the Erie Canalway away from cultural and heritage programs to the condition of the natural state of the river. In response to the devastating flooding, the Federal Government requested the Army Corps conduct a study of the Mohawk River and the flood (Army Corps 2008). The study was meant to develop recommendations to reduce the frequency and severity of flooding in the watershed and determine if a feasibility study would be warranted. This project is ongoing and the Army Corps is currently seeking a partner to cooperate in carrying out the feasibility study. This creates a significant opportunity for partnership between the DEC and the Army Corps. Working with other DEC Staff, which may be involved in such a partnership, and Army Corps staff, the Mohawk River Program will have the opportunity to contribute as well. By bringing its ecosystem based management strategy to managing environmental problems, the Mohawk River Program can help to shape a new, more sustainable and environmentally sound framework for flood management.

Mission of the Mohawk River Basin Program

The mission of the Mohawk River Basin Program will be to act as coordinator of basin-wide activities related to conserving, preserving, and restoring the environmental quality of the Mohawk River and its watershed, while helping to manage the resource for a sustainable future. Vital to the success of the program is the involvement of stakeholders and the creation of partnerships with established programs and organizations throughout the basin.

Action Agenda

The following is a list of measurable goals the Mohawk River Basin Program will strive to achieve. We seek input from as many people as possible who share a passion for the conservation of the Mohawk River. This list of goals is a template by which the Mohawk River program will direct its actions. Each goal has specific actions associated with them and a time frame by which to complete them. These actions should be considered steps, which lead to the fulfillment of this list of Action Agenda Goals. The proposed actions for each goal are described on the pages that follow.

Goals

1. **Understand and manage the natural systems of the Mohawk River watershed** while communicating to the public about their value to human communities and natural processes so that people can fish, hunt, bird, and enjoy the unique character of the valley and its living ecosystem.

2. **Protect and improve water quality in the Mohawk River watershed** so that communities are protected, drinking water supplies are conserved and natural processes are sustained.

3. **Reduce flood frequency and severity in the Mohawk River** so that river valley communities and their cultural heritage are protected.

4. **Preserve the historical, cultural, and recreational resources throughout the watershed that define the Mohawk River valley**, creating vital, healthy places to live, work and visit, connecting the river, the landscape and the people that live in the watershed.