Determining Peak Flow Under Different Scenarios and Assessing Organism Passage Potential: Identifying and Prioritizing Undersized and Poorly Passable Culverts

WRI Update: 2015-2016

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Prepared November 11, 2016
The New York State Water Resources Institute (NYS WRI) and the New York State Department of Environmental Conservation (DEC) Hudson River Estuary Program (HREP) has undertaken a coordinated research effort on water resource infrastructure in New York State, with a focus on the Hudson and Mohawk River basins.

The primary objective of this multi-year program is to bring innovative research and analysis to watershed planning and management. In particular, WRI-HREP is working to address the related topics of water infrastructure, environmental water quality, and economic vitality, especially as they pertain to land use planning and management in the Hudson and Mohawk watersheds. The WRI-HREP program coordinates individual research efforts so as to fit within the context of, and be responsive to, New York State’s growing concerns about aging public infrastructure, economic constraints on public investment, and the recent requirement for State planning agencies to incorporate principals of “smart growth” as promulgated in the 2010 Smart Growth Public Infrastructure Policy Act.

In the following pages we report on progress made in year four (2015-2016). Projects are discussed within the following broad themes:

1) **Infrastructure Assessment** - Water-related infrastructure including water supply and wastewater treatment facilities, distribution networks, decentralized treatment installations, dams, constructed wetlands, “green” infrastructure, etc., and their current state and effectiveness at providing water and ecosystem services regionally at reasonable cost

2) **Economic Vitality** – Benefit/cost analyses of infrastructure development and regional economic vitality with respect to water infrastructure and its effect on private and public investment and industrial development

3) **Integrated Management & Planning** - Integration of scientific, economic, planning/governmental and/or social expertise to build comprehensive strategies for public asset and watershed management, including application of smart growth principles

4) **Source-Water Protection** - The economics and benefits of source watershed protection strategies and the use of ecological services to meet water supply and quality needs, as opposed to treatment at point of delivery

5) **Climate Change Resilience** – Assessing and managing risks of climate change on water infrastructure and communities and/or applying a climate resilience focus to any of the research themes provided above

Following this summary we also include:

- A link to the full versions of final reports, which are available at our website [http://wri.cals.cornell.edu/grants-funding](http://wri.cals.cornell.edu/grants-funding)
- Outreach efforts currently underway
- How we are adapting our efforts to support research and create effective outreach products
- A list of recently funded projects

**For a copy of previous summary reports,** please contact Brian Rahm (bgr4@cornell.edu), or go to [https://wri.cals.cornell.edu/grants-funding](https://wri.cals.cornell.edu/grants-funding)

Cover photos taken by WRI staff and Weiming Wu
Infrastructure Assessment - Water-related infrastructure including water supply and wastewater treatment facilities, distribution networks, decentralized treatment installations, dams, constructed wetlands, “green” infrastructure, etc., and their current state and effectiveness at providing water services regionally at reasonable cost

Cross-cutting impressions

Previous research suggested that further research is still needed on a variety of understudied stormwater and wastewater infrastructure systems, including ditches, culverts, on-site wastewater treatment systems and “green” infrastructure installations. While each of these systems can be effective under certain conditions, their design and management often lacks rigor, can be inconsistent, and/or is at odds with water and air quality goals. For green infrastructure to deliver on its promise of improved and cost-effective stormwater management, continued monitoring is necessary to generate a better understanding of robust technologies and their environmental benefits over a range of conditions. For “grey” infrastructure systems, such as engineered water treatment facilities and sewer distribution networks, application of regional and watershed systems analyses could help to improve efficiency of financing models, and improve environmental outcomes. Municipal asset management is also a critical need.

Current research focuses on assessments of emerging contaminants and their transport through wastewater conveyance and treatment systems. Results confirm that many micropollutants are not being removed during conventional treatment processes, and may pose understudied risk to receiving waters. Continuing efforts on ditch and culvert networks are expanding our knowledge of how these landscape features are impacting downstream surface water quality. There is now progress in attempts to mitigate negative impacts through management practices in ditches, as well culvert replacement and right-sizing. Still, landowner and stakeholder perceptions remain a challenge to implementing, or even experimenting with, new approaches and prioritization schemes. On-going assessment of septic systems is leading to better understanding of daily and seasonal fluctuations in performance and GHG emissions.

What researchers found

Cayuga Lake as seen from Ithaca College campus

Project Title: Emerging Pollutants: From College Campuses to Cayuga Lake
Susan Allen-Gil (Ithaca College)
We investigated the concentrations of over 200 chemicals in the Ithaca water system, including many emerging pollutants of concern. 24-hr composite samples were collected 4 times from 5 different locations (raw drinking water, treated drinking water, wastewater influent, wastewater effluent, and Cayuga Lake). We detected many compounds at all points in the water system in varying concentrations. Pharmaceutical and personal care compounds detected most frequently and in the highest concentrations include caffeine, nicotine, metformin, atrazine, and carbamazepine. Microplastics were also detected in lake samples. Based on the influent data, there was no clear difference in concentrations when college students were in town. Ecological investigations suggest that caffeine can alter fish swimming behavior, but only at higher concentrations than those observed in Cayuga Lake. Pilot studies also suggest that small microplastics
(5 µm diameter) may cause increased mortality in *Daphnia magna*. Key findings include:

- Fall Creek raw drinking water has detectable concentrations of many emerging pollutants, but most are removed by the treatment process.
- Emerging pollutants vary in the extent to which they are degraded or removed as biosolids by the wastewater treatment process.
- Caffeine, carbamazepine, and microplastics have the capacity to affect aquatic organisms, but not at the concentrations currently reported for Cayuga Lake.

(A roadside ditch during wet weather)

Project Title: **Coupling in-ditch studies and modeling to understand the landscape - wide nitrogen transport and denitrification (N2, N2O) potential of roadside ditch networks across catchments**

Rebecca Schneider & Roxanne Marino (Cornell University)

In this project, we evaluated the potential for roadside ditches to transport and transform nitrogen (N) across mixed use, agricultural landscapes by coupling site-specific field measurements and a GIS-based modeling tool. We compared dissolved (NO$_3$+NO$_2$) and gaseous N (N$_2$O) fluxes among three rural roadside ditches – two associated with active agricultural fields and one ditch draining a woodlot. Both ditches adjacent to ag fields were major conduits of dissolved nitrogen (with concentrations ranging from 10-40 mg/L and high flow rates), whereas the woodlot ditch was frequently dry and had nitrate concentrations of less than 0.1 mg/L. Nitrous oxide fluxes from the soils were present on all seven sampling dates (May – late Sept), with the highest levels in the two ag ditch sites; however, flux rates varied substantially through time and among sites. Currently, no simple and cost-effective tools exist to estimate the impacts of roadside ditches on the entire interconnected network of streams and ditches in a watershed. In order to begin scaling up our site-specific field data to whole watersheds, and to aid in identifying “hot spots” for greenhouse gas production and N transport or removal, we developed a GIS-based toolset (Ditch Tools) that incorporates the specific effects of a watershed roadside ditch network into the hydrologic landscape using publicly available GIS data sets. Key findings include:

- Roadside ditches are significant conduits of dissolved nitrogen moving from agricultural fields to adjacent streams, and can be seasonally high emitters of nitrous oxide.
- Based on our model, roadside ditches can significantly reduce water flow distance and travel time in mixed use, predominantly agricultural landscapes.
- Ditch Tools is being developed to provide a useful, cost effective tool for guiding larger-scale field studies of roadside ditch networks and best ditch management practices.

Project Title: **Assessment of the Effectiveness of Impervious Area Reduction and Green Infrastructure at Improving Water Quality and Reducing Flooding at the Watershed-Scale**

Katherine Meierdiercks (Sienna College)

This project builds on work examining the relationship between landscape characteristics and water quality and quantity using field monitoring and geospatial datasets from the Kromma Kill Watershed in Albany County, NY. Simple statistical analyses were used to examine the correlational relationships between watershed characteristics, such as drainage density and percent imperviousness, and water quality and quantity. Hypotheses were then developed and tested using a rainfall-runoff model: EPA’s SWMM. Following this, a Siena undergraduate student used the model to examine the impact of green roofs versus constructed wetlands on water quality and quantity in the Kromma Kill Watershed. Both projects highlight the complexity of urban landscapes and the processes that control water quality and quantity in watersheds. Results suggest that simply reducing the percentage of effective imperviousness through green infrastructure (GI) may...
not be the most effective solution for every management objective. Additionally, special attention must be paid to the type of GI utilized, as some practices are better suited for specific conditions. Key findings include:

- **One size does not “fit all”** - reducing the percentage of imperviousness is not effective in all watersheds
- Retention based GI (wetlands) is best suited for reducing peak flow in a **centralized manner**, and for **removing selected pollutants**
- Detention based GI (green roofs) is best suited for **decentralized approaches** for reducing surface runoff, and for generally reducing all pollutants

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Project Title: **Seasonal and diel variation in trace gas emissions from septic system leach fields**, Todd Walter (Cornell University)

Use of onsite septic systems to treat wastewater is projected to increase in upstate NY. Greenhouse gas (GHG) emissions from septic systems are a potential source of pollution that has been quantified by only two studies to date. Neither of these studies considered the temporal variation of trace gas emissions. Here, we seek to refine existing estimates by measuring GHG emissions in seasons other than summer and across a 24-hour period. Over the June to December sampling season, N₂O emissions were significantly greater from the leach field than the control lawn between June and mid-August; all other gas emissions were comparable to the control lawn emissions throughout the study. In the course of one 24-hour period in early August, leach field N₂O and CH₄ emissions varied significantly relative to the control. These results indicate that septic system GHG emission measurements must be considered in context of time of year and time of day, and scaled appropriately. Key findings include:

- **Methane and nitrous oxide** are the only GHGs with emissions from the leach field that are at any time of day or year **above background levels**
- When scaling GHGs, it is important to consider the context of the **time of year, time of day, and geographic location**
- We suggest methane and carbon dioxide emissions from the leach field are **negligible**, and previous estimates of nitrous oxide emissions from the leach field should be scaled down by ¼
User-friendly tools were developed to automate the evaluation of largest passable storm per culvert. In all evaluated counties, the majority of culverts were able to pass only the 25-year storm or smaller. With current climate change predictions, the model indicates that the number of culverts undersized for their drainage area will increase in each evaluated county by 2050.

Culvert assessment in the Hudson Valley

Project Title: **Identifying and prioritizing undersized and poorly passable culverts**, Todd Walter & Art DeGaetano (Cornell University)

Climate change models predict increased rainfall for New York State. To prevent that increased rainfall from leading to large increases in flooding of roadways and property, assessment and necessary improvements of stormwater infrastructure must be made. This study evaluates the maximum passable stormflows for individual culverts in counties and watersheds of interest in New York. Study findings are reported to stakeholders as supporting information to help prioritize culvert replacement. To better assess the vast quantity of culverts in the state, tools have been created in ArcMap and Python script to automate the calculation and evaluation processes. The evaluation effort, supported by field teams gathering culvert measurements throughout the Hudson Valley and Tompkins County, is ongoing. To date, culverts in nine New York counties have been evaluated. The evaluated culverts show a pattern of greater numbers of culverts being able to pass smaller storms than large ones and increasing numbers of culverts being able to pass smaller storms with future climate predictions. Key findings include:
Economic Vitality — Benefit/cost analyses of infrastructure development and regional economic vitality with respect to water infrastructure and its effect on private and public investment and industrial development

Cross-cutting impressions

Previous research suggested that industrial activity in some sectors, such as energy and fuel transportation, has been increasing. However, local and regional benefits resulting from this activity are overestimated, and the burden of cost associated with emergency preparedness and environmental risk falls disproportionately on local communities. Despite this, regional economic vitality is indeed linked to water resources and related infrastructure. Public infrastructure investment creates a foundation upon which commerce and private investment can thrive. Alternatively, poor public water infrastructure and regional coordination can be a barrier to economic growth, and can lead to or exacerbate environmental risks. Because the public often does not see such infrastructure, its value is underestimated. Private and industrial investment in water resource infrastructure is also essential. There is an opportunity to better use, market, and brand regional water resources to promote water-related businesses, and build on existing water technology industries.

Project Title: The Water Infrastructure and Finance Innovation Act of 2014: structure and effects, Richard Geddes (Cornell University)

Many U.S. municipalities are facing challenges due to aging water and wastewater infrastructure. Many systems require immediate repairs, upgrades and replacement, while available funding is limited. Readily available low-interest financing will assist those municipalities. The 5-year pilot Water Infrastructure Finance and Innovation Act (WIFIA) approved by the U.S. Congress in 2012 was a step in that direction. WIFIA focuses on supporting large-scale projects that may be under-served by existing State Revolving Funds (SRFs).

The authors examined the structure and implementation of WIFIA and its impact on existing financing mechanisms. The cost of debt service to four representative communities in New York was compared using WIFIA, SRFs and tax-exempt municipal bonds. Although WIFIA financing offers the lowest debt-service cost, savings from WIFIA depend on the spread between U.S. Treasury rates and borrowing rates of the SRF administrating agency. Key findings include:

- Loans secured through WIFIA result in lower debt service costs compared to SRF and tax-exempt municipal bonds
- Savings are subject to the spread between U.S. Treasury bonds and the SRF-administering agency’s credit rating
- Although WIFIA looks promising, its long-term viability will depend on the success of the 5-year pilot program, assuming it is implemented
Integrated Management & Planning - Integration of scientific, economic, planning/governmental and/or social expertise to build comprehensive strategies for public asset and watershed management, including application of smart growth principles

Cross-cutting impressions

Previous research suggested that effective management of water resource assets at the municipal level requires appropriate planning, financing, technology, management, maintenance and community buy-in. At the watershed and/or regional scale, water resource management presents a challenge; decision-makers face difficult tradeoffs because of various and competing stakeholder perspectives. Inter-municipal agreements are often critical tools for areas where multiple jurisdictions share important infrastructure. Recent state policies incorporating concepts of smart growth have started to get agencies and local decision-makers thinking about the sustainability of their community. These policies hold promise as a tool to mitigate water resource infrastructure challenges, and researchers are making stronger links between landscapes and human and ecological health in urbanized areas. But, smart growth needs to be combined with other management and engineering efforts. As a whole, New York is increasingly adopting a unique leadership position in smart growth policy, though the results of this policy require time to assess, and are dependent on local planning processes.

Current research continues to focus on how various stakeholders engage with each other on planning and development issues. Older municipalities with ageing infrastructure, combined sewer systems, and shifting urban tax bases are particularly challenged. Decision support tools are being advanced, but indicate that the best solutions involve cooperation between municipalities, a variety of financing options, and multi-year strategic planning efforts. For some locations, analyses suggest that infrastructure can serve to educate, and provide river access to, the public, and that this can be leveraged into support for more functional approaches elsewhere. Additional research has started to focus on planning and support for the removal of aquatic barriers, such as dams and culverts, in the Hudson River watershed. Removing these barriers has ecological and economic advantages and disadvantages, and initial studies are informing predictions of sediment and contaminant transport so that stakeholders can assess what’s right for them.

What researchers found

Riverfront Park in downtown Troy

Project Title: CSOs and landscapes as infrastructure in Troy, NY, Brian Davis (Cornell University)

This report describes the combined sewer overflow (CSO) infrastructure of Troy, NY as a landscape at four different scales. It is intended to allow for a more integrated understanding of the problem of combined sewer overflows in the Capital Region generally, and Troy specifically, as identified in the Long Term Control Plan (LTCP) of the NYS DEC. In particular, it includes the role of public space, hydrography, soil type, tidal change, topography, and forest cover alongside the plumbing of the city. By collecting, producing and analyzing spatial data we draw conclusions about the relations between water quality, land use, and public space. The study concludes that the waterfront and historic area (“River City”) should not be a primary strategic zone for green infrastructures that focus on stormwater detention, but should instead focus on social cohesion and identity, flood prevention, and
access to the river. The role of the steep “Forest City” running north-south could be protected as habitat and recreation space to preserve current infiltration and detention performance. The suburban and rural areas on the “High City” should in most cases be the areas targeted for detention and retention of stormwater because of their infiltration potential. Key outcomes include:

- **Green infrastructure** does not always have to be used to primarily detaining stormwater; in some cases it can be a tool **intentionally designed for increasing environmental literacy** and access to the river itself
- **New types of green infrastructure** need to be developed in order to address this
- Troy’s suburban zones above the bluff hold high infiltration potential and may be **prime places for integrating stormwater detention green infrastructures**

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Project Title: **Assessment of Sediments Impounded by the Burden Pond Dam on the Wynants Kill Creek of New York**, Weiming Wu (Clarkson University)

Burden Pond Dam is a small old dam located on the Wynants Kill Creek, a tributary of the Lower Hudson River in New York. For safety concerns and to connect the upstream and downstream aquatic habitats, removal of this dam is being considered as a management strategy. This project aimed to assess the quantity and quality of sediments within the Burden Pond Dam impoundment. Cross-sections were surveyed and sediment core and grab samples were collected in order to quantify deposited sediments and analyze their chemical composition. These data and results are useful for dam removal feasibility and impact studies and help managers predict potential hazards sediments may pose if reintroduced into the environment. Key findings include:

- Upper lake sediments consist of gravel and sand, while sand, silt and clay dominate sediment closer to the dam
- It is estimated that about **28.8 acre-feet of sediment will likely be eroded and transported downstream** if the dam is removed or failed
- PCBs and pesticides are not abundant in the lake sediments. However, the lake sediments are enriched with nitrogen and phosphorus, as well as metals including aluminum, potassium, magnesium, manganese, barium and iron
- Mercury concentration in lake sediments is **above the State’s Class C contamination threshold**
Source-Water Protection - The economics and benefits of source watershed protection strategies and the use of ecological services to meet water supply and quality needs, as opposed to treatment at point of delivery

Cross-cutting impressions

Previous research suggested an urgent need to characterize the economic and environmental costs and benefits of ecosystem services provided by source watershed protection, particularly in areas where grey infrastructure is aging and funding is limited. While the New York City watershed management program serves as an example of how source water protection can viably meet water supply quality goals without extensive water treatment, less is known about how municipalities with fewer resources can also leverage benefits from this approach. Water resources managers and planners will have to continue to explore and balance the costs and benefits of various development scenarios if we want our understanding of watershed protection to be robust.

What researchers found

Project Title: Target Screening for Micropollutants in the Hudson River Estuary during the 2015 Recreational Season, Damian Helbling (Cornell University)

Monitoring studies aimed at assessing water quality and environmental risk from micropollutants are challenging to implement due to the large number of potential analytes and the spatial and temporal variability at which micropollutants occur in surface water systems. We addressed these challenges by collecting samples during the 2015 recreational season from eight sites along the Hudson River Estuary from the confluence with the Mohawk River to the Tappan Zee Bridge. We used solid-phase extraction and high performance liquid chromatography mass spectrometry (HPLC-MS) to quantify the occurrence of 117 micropollutants in each sample. We selected a diverse set of micropollutants including pharmaceuticals, pesticides, and industrial chemicals. We confirmed the occurrence of 83 of the micropollutants in at least one of the collected samples. Eight micropollutants were quantified in every sample collected: atenolol (β-blocker), atenolol acid (metabolite of atenolol), venlafaxine (anti-depressant), caffeine (stimulant), paraxanthine (metabolite of caffeine), sucralose (artificial sweetener), methyl benzotriazole (an industrial chemical), and DEET (an insect repellent). These data represent the first comprehensive survey of micropollutants in the Hudson River Estuary and will be invaluable for developing future research projects aimed at assessing spatial and temporal variability of micropollutant occurrence and the consequent environmental risk. Key findings include:

- First comprehensive monitoring for micropollutants in the Hudson River Estuary
- The number and types of pesticides measured were spatially and temporally stable
- The number and types of pharmaceuticals measured were determined by proximity to wastewater treatment plant outfalls

The Hudson River near one of the micropollutant sampling locations
Climate Change Resilience – Assessing and managing risks of climate change on water infrastructure and communities and/or applying a climate resilience focus to any of the research themes provided above

What researchers found

Project Title: Design for climate-resilient Hudson River communities, Joshua Cerra (Cornell University)

This pilot project investigated planning and design implications of emerging municipal climate adaptation interests by developing alternative design strategies for a downtown waterfront location in Village of Catskill, New York. The project was developed in a senior urban design studio at Cornell University Department of Landscape Architecture. The project accessed a climate-adaptive design framework to identify projected climate change hazards, risks, and potential climate adaptation opportunities for downtown Catskill’s water systems, ecosystems, and built environment features. The project team reviewed planning and policy documentation, conducted contextual analysis and site reconnaissance and interviewed stakeholders prior to developing five alternative design concepts that addressed projected climate change risks in combination with the urban revitalization interests and needs of stakeholder interviewees. These concepts included provisions for green infrastructure, flood-adapted landscapes and structures, contributions to urban ecosystems, and other features. The alternative design concepts developed for Village of Catskill can serve as a case study for other Hudson Valley municipalities seeking to confront climate risks to their water systems, built environment, ecosystems and community as their municipality changes and grows.

Key findings include:

• Many Hudson waterfront communities are subject to climate change associated risks, but few climate adaptation precedents are scaled to the size of these municipalities
• This project identified the Catskill, NY downtown waterfront as a pilot site for an academic design studio investigation exploring projected climate change impacts and potential climate adaptation options
• During this design process, five alternative design concepts were generated to address goals for climate adaptation and urban renewal consistent with the interests of Catskill and its stakeholder entities

An alternative design concept drawing
Full versions of final reports are available at our website
http://wri.cals.cornell.edu/grants-funding

Outreach – How have we been communicating results of our work?
For a complete listing of outreach activities performed by WRI and HREP staff, please see our website at http://wri.cals.cornell.edu/news

2016-2017 – Funded projects for the next year
Funded projects fall within two administrative categories. Competitive research involves investigators from institutions across the state who responded to a formal request for proposals. These researchers will work largely independently, but can be contacted regarding opportunities for cooperation and outreach. Coordinated research involves Cornell faculty who have agreed to meet quarterly to facilitate discussion and synergy among individuals, as well as with staff from WRI, HREP and the Mohawk River Basin Program.

Competitive Projects

Project Title: Water Quality and Algal Community Dynamics in the Finger Lakes (Lisa Cleckner – Hobart & William Smith Colleges)

Project Title: Evaluating Septic System Inputs into Sodus Bay using Oblique Imagery, Optical Brighteners, and DNA-based tracers (Paul Richards – SUNY Brockport)

Project Title: Innovative water treatment by chitosan modified diatomaceous earth for small public water systems in rural areas (Xinchao Wei – SUNY Polytech)

Project Title: Mohawk River Water Quality: Risk Evaluation of Combined Sewer Overflow and Runoff Events (Carolyn Rodak – SUNY Polytech)

Project Title: Prediction of Sediment Remobilized by Removal of an Aged Dam in the Hudson River Watershed (Weiming Wu – Clarkson University)

For information on the HREP and MRBP Action Agendas please see:

Coordinated Projects

Project Title: Design for Climate-resilient Hudson River Communities (Josh Cerra - Cornell University; Landscape Architecture)

Project Title: Green Infrastructure Scenarios for communities in Troy (Brian Davis - Cornell University; Landscape Architecture)

Project Title: Assessing the effectiveness of green infrastructure (Todd Walter - Cornell University; Biological & Environmental Engineering)

Project Title: Tracking Molecular Transformations of Organic Matter in Water Treatment Processes (Ludmilla Aristilde - Cornell University; Biological & Environmental Engineering)

Project Title: Characterizing microplastics in surface water (Todd Walter - Cornell University; Biological & Environmental Engineering)

Project Title: Tributaries and sewage outfalls: Identifying the relative contribution of sources of micropollutants in the Hudson River Estuary (Damian Helbling - Cornell University; Civil & Environmental Engineering)

Project Title: Septic systems and surface water quality (Ruth Richardson - Cornell University; Civil & Environmental Engineering)

Project Title: Culvert assessment and modeling (Todd Walter - Cornell University; Biological & Environmental Engineering)

In addition to the projects listed above, WRI staff and interns, in cooperation with Hudson River Estuary Program and Mohawk River Basin Program staff will conduct research related to infrastructure effectiveness, economic vitality, integrated management, smart growth, and watershed protection. For more information on these efforts please contact Brian Rahm (bgr4@cornell.edu).