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DEGRADATION AND RECOVERY IN URBAN WATERSHEDS:

Executive Summary Narrative and Recommendations

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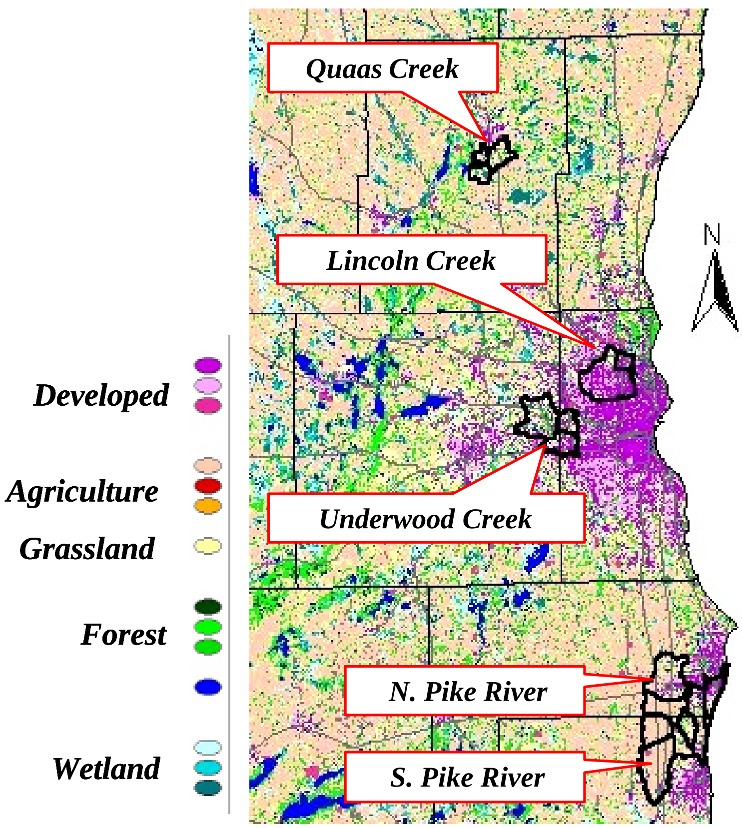
Introduction

The purpose of this project, funded by the Great Lakes Protection Fund, was to examine the effects of modifications in the physical structure of urban floodplains on flow-regime and aquatic biological communities. Flooding problems along Lincoln Creek (a highly urbanized watershed in the City of Milwaukee) and North Pike River (a rapidly urbanizing watershed in Racine County) in southeastern Wisconsin resulted in the implementation of two large-scale construction projects to change the stream channels and surrounding floodplains in attempts to reduce flooding risk.



In addition to channel modifications, both Projects incorporated the creation of large (20-30 acre) in-line floodplain complexes, wetlands and pond ecosystems. Newly constructed stream channels were meandered through these wetland basins, allowing for a physical reconnection of the floodplain with the stream.

Our research project was designed to measure the impacts of restoration activities on hydrology, nutrient dynamics, water quality, habitat, invertebrates, and fish by comparing changes within the two treatment streams (Lincoln and North Pike) with regional reference streams (Underwood Creek – urbanized, South Pike River – agricultural, and Quaas Creek – mixed land uses).

The project on Lincoln Creek, conducted by the Milwaukee Metropolitan Sewerage District (MMSD) was completed in June 2002 (Details and updates at http://www.mmsd.com/projects/watercourse1.cfm).

The initiation of the North Pike River project was delayed form its original plan and construction began in April 2002. Phase I and IIa were completed in December 2003 and water was diverted into the first wetland restoration section in January 2004. Although this delay has prevented us from being able to directly assess the direct ecological success of the project at this time, the added year of background data will provide greater statistical power for the eventual evaluation in the coming year.

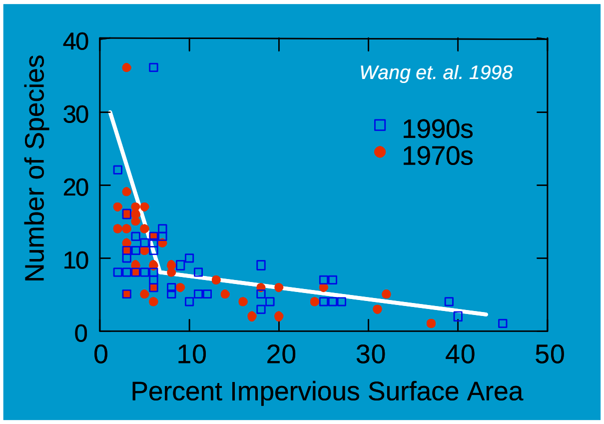
The overall goals of the monitoring portion of this project were to first attempt to identify the likely stressors that are most responsible for the declines in biotic integrity of urban streams and then to assess whether the floodplain restorations had any measurable impact on improving these stressors and eventually biotic integrity. A number of specific predictions were identified in the early stages of the research. These predictions included:

1. Summer and winter base-flow would improve within and below restored sections relative to upstream and reference streams
2. The effects of storm runoff and episodic thaw events would be reduced below restored sections. Peaks would be lower, duration longer, and total discharge from events would be lessened (due to the combined effects on infiltration and evapotranspiration).
3. Nutrient concentrations (Phosphorus and nitrogen) would decrease as water passes through the restored floodplain section, due in part to the increased biological activity in the more-natural restored stream reaches.
4. Fish and invertebrate habitat would improve as a direct result of changes in hydrology, stream bottom substrate, bank stabilization, sediment processing by meandering, and establishment of wetland vegetation.
5. Proximity effects: The positive influence of restoration sections on hydrology, water quality and stream habitat would dissipate further down stream. However, since multiple sections will be constructed, we can eventually test of additive effects downstream. i.e.: are multiple small restorations better versus fewer larger sections?

The purpose of this narrative is to provide an analysis of the major findings of our research and to provide an evaluation of the projects from the perspective their impacts on improving the ecological and biotic integrity of their respective aquatic ecosystems. Since we have been able to collect more post-construction data on Lincoln Creek, we will be able to draw more conclusions regarding that system and will emphasize how what we have learned from the Lincoln Creek project can be used to guide future designs and activities on the Pike River. To date, we have evidence to support predictions 1, 2, and 5. We believe that predictions 3 and 4 will be born out over time as the restorations have greater time to establish biotic complexity.

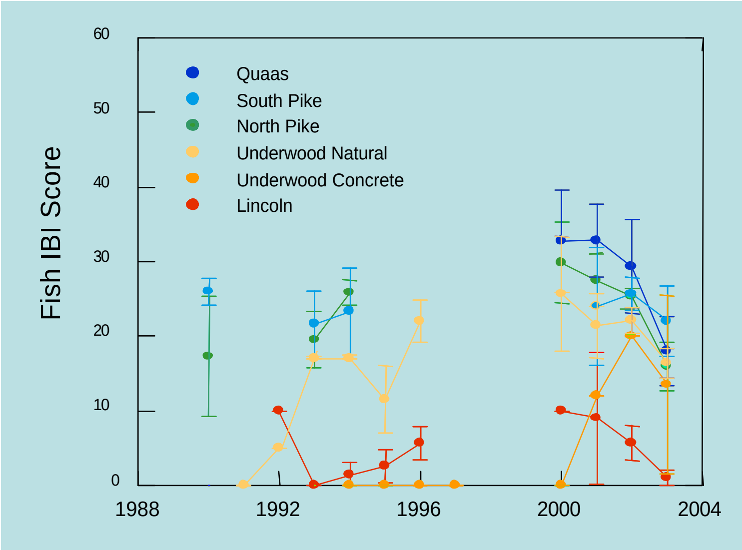
For those interested in more information, the field methods utilized and summaries of the data collected are presented in a series of interim reports that are available through links on our project website. These interim reports for Lincoln Creek and the Pike River are located at www.uwm.edu/~ehlinger and by following the links to monitoring data pages at www.uwm.edu/~ehlinger/ysi_data.htm. The monitoring work on these streams is continuing with funding provided by the Town of Mount Pleasant and the Milwaukee Metropolitan Sewerage District. Individuals interested in obtaining additional information about this project may contact Timothy Ehlinger at ehlinger@uwm.edu.

Patterns of Biotic Integrity in Urban Streams



The observation by Wang and Lyons (1998) that the loss of fish species is directly correlated with increased urbanization was one of the most direct motivations for undertaking this project. The basic pattern is very striking: Fish species numbers decline rapidly as the percentage of impervious surfaces rises above 10 percent for a given watershed.

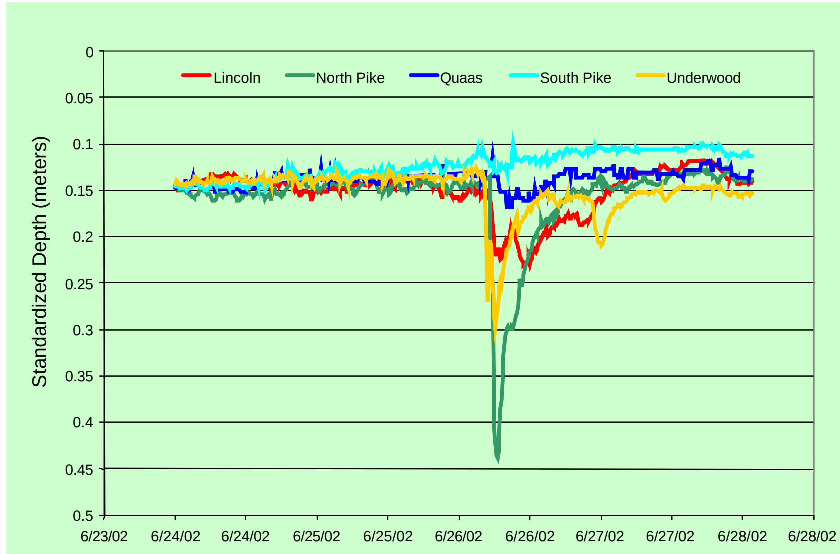
Although very significant, this pattern does not provide much insight into the likely mechanisms for how urbanization impacts biotic integrity. Conversely we need to answer to the question: What factors (other than impervious surfaces) can we mitigate in order to restore biotic integrity in urban watersheds? One of our objectives in this study was to try to identify the factors responsible, and to determine if the floodplain and flow modifications in the Lincoln and Pike Rivers served to ameliorate those stresses.



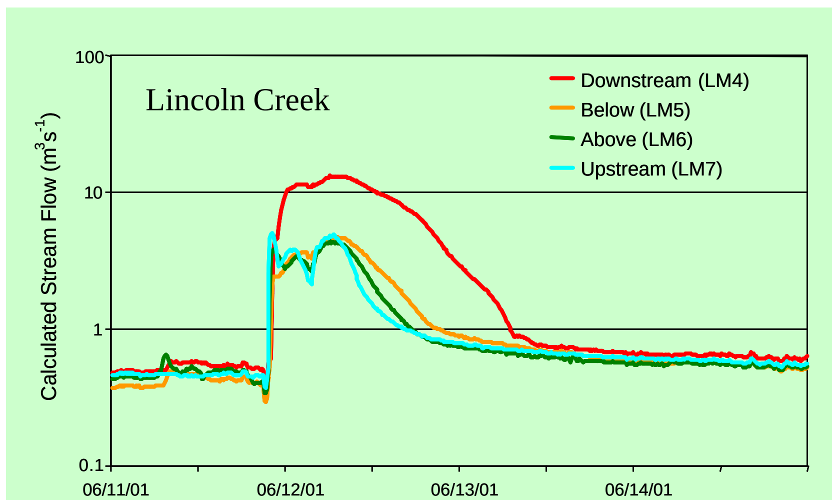
The basic pattern detected in our study streams confirms that there is a strong relationship between urbanization and declines in the Wisconsin fish Index of Biotic Integrity (IBI), with more developed watersheds exhibiting lower IBI than watersheds with less urbanization. Note that the basic pattern holds across most years, however there was a signficant overall drop in IBI in 2003 in all streams due to low rainfall resulting the lowest recorded flows in over 50 years for many streams in southeastern Wisconisn.

During the course of our study (2000-2003) we collected fish and habitat data for a total of 45 stations from among the 6 streams. It is interesting to note that there was no significant correlation between fish IBI for our urban streams and habitat quality (as measured by the Wisconsin Low Gradient habitat rating system). This suggests that habitat quality alone is not the responsible factor limiting fish communities. This is by no means a surprising result, but is important none-the-less in as much as it suggests that physical habitat modifications alone will not be sufficient to restore urban fish populations. It is necessary, therefore to examine the more detailed mechanisms of flow regime and water quality indicators as they relate to biotic integrity.

Storm and Base Flow Patterns



Flow patterns among the treatement and reference streams were measured by the use of depth recording YSI 6200 sondes. An example of the depth response in streams for a typical summer storm event are shown to the right. This figure indicates that the streams with the lowest amount of development (Quaas and South Pike exhibit very small "spikes" in flow during this storm. In contrast, the urbanized North Pike, Lincoln, and Underwood showed drastic and rapid increases in depth during the course of the storm.



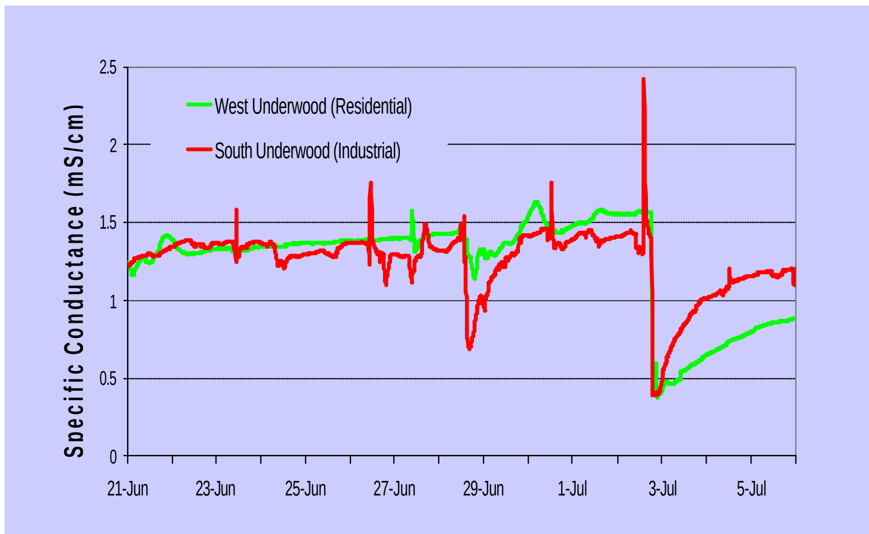
What is revealing about the depth response, is the fact that the depth of the "restored" Lincoln Creek does not rise as fast as the other urban streams, and similarly it drops slower than either N. Pike or Underwood. The reasons for this are due largely to the wetland/detention basin installed on the Havenwoods State Park. This basin has worked effectively to buffer the downstream reaches from the rapid peaks of flow and then release the water more slowly over time. This response is observed in the next figure, which shows calculated flow over time for recording stations setup above, within, and below the Lincoln Creek restoration basin.

Based upon these types of data, we can clearly state that the Lincoln Creek channel and floodplain modifications have had the intended effect on the flow patterns in the stream. They have reduced the sharp peaks and extended the flow release from the wetland areas.

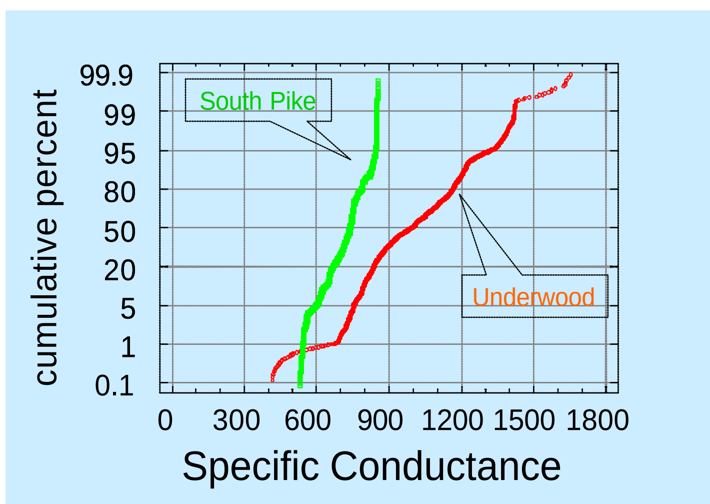
Because of extreme weather variations among years, additional monitoring data will be necessary before we can definitely state that the channel modificaitons have improved baseflow. During 2002 we measured higher baseflows whereas in 2003 they were lower. We hypothesize that the increased baseflow in Lincoln Creek is due to concrete removal and reconnection of the stream channel to groundwater inputs.

Water Quality Patterns

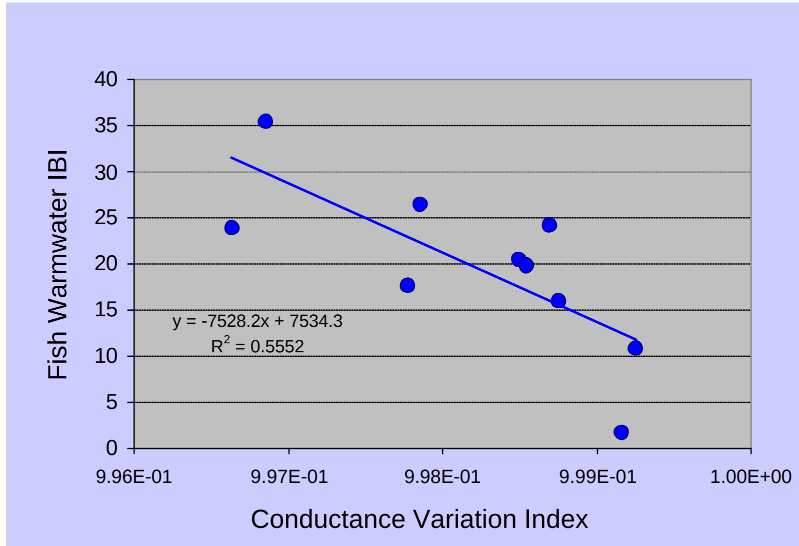
The data collected with the YSI sondes clearly show that the critical features of water quality are flow-dependent in urban watersheds. Specific conductance is the parameter that reveals the greatest amount of information regarding land use and flow regime. Specific Conductance serves as an indirect a measure of the amount of dissolved material in water. Baseline differences in conductance are often attributable to whether or not the source of the water is a glacial/limestone groundwater aquifer (i.e. hard water with higher conductance) compared surface water sources and rainfall (lower conductance). However, what is interesting in our data is the way that conductance changes in response to rainfall events are very indicative of the surrounding land use patterns.



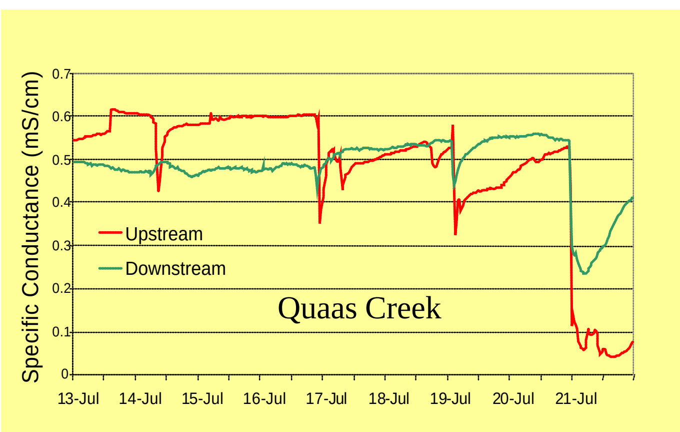
For example, a comparison of the temporal changes in conductance shows a distinct "spike" in conductance at the very start of each rainfall event followed by a strong decrease for an industrial branch of Underwood Creek between compared to a residential subwatershed. The initial increase is a signal produced by the flushing of material off of parking lots, roads and other impervious surfaces directly into the stream. The decline following the initial "flushing" is indicative of the large volume of low conductance rainwater running off of the "clean" surface into the stream. By comparison, the residential subwatershed has less impervious surface, and the spikes in conductance appear to be more buffered. This is likely do to the combination of higher infiltration rates (i.e. more lawn), and the presence of stormwater retention basins in the subwatershed slowing down the initial first flush runoff.

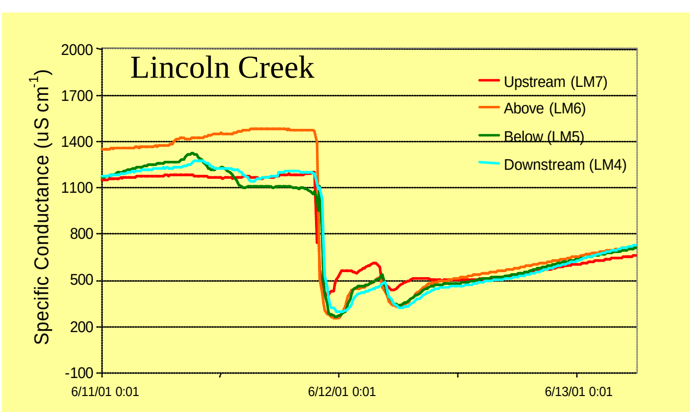


We analyzed the effects of conductance fluctuations on streams by using a cumulative probability distribution approach. In essence, we calculated the probability that specific conductance for a particular stream station was either at or below a given level. This is similar in concept to the practice of calculating "flow exceedance" curves for rivers in order to determine the 2, 10, and 100 year probability flows. An example of the cumulative distribution functions for the streams in our study demonstrates the general pattern that streams like South Pike that have low levels of impervious surface have low variability and a slope close to vertical. By comparison, streams like Underwood have higher variability (a greater slope away from vertical). We used a least squares regression to calculate the slopes of these probability relationships for the summer months (June-August 2002) for sondes that were placed near our fish sampling stations. Using this slope as an index of conductance variation, we compared this data with the average fish IBI for these stations. This analysis clearly indicates a very strong relationship between conductance variability and the biological integrity of the fish community.



We suggest that this relationship indicates a fundamental relationship between flow regime and water quality in urban watersheds. In particular, as more water is “intercepted” and shed by impervious surfaces before it can infiltrate into the soil, we will observe greater variation in conductance and declines in IBI. We propose to use this as a major component of our monitoring program for the foreseeable future.

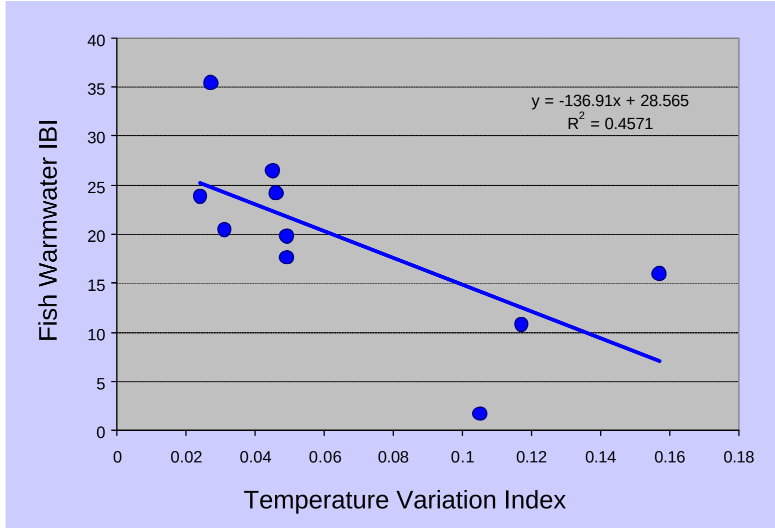




The potential value of using this index as a monitoring parameter for flow-regime restorations is illustrated by examining the function of well established and/or natural riparian wetlands in buffering conductance variation. For example, the figure on the right shows the impact of a natural wetland complex along Quaas Creek on the conductance fluctuations during a series of summer storms. This particular wetland is downstream of a new shopping center complex and it is apparent that the wetland is mitigating the spikes and dips in dissolved solids. By comparison, the new wetland complex in Lincoln Creek had much less of an impact on conductance during its first year in operation. We anticipate that this will improve as the vegetation in the wetland establishes and the biological complexity in the system increases. We expect to continue monitoring in this location for at least two additional years with funding provided by the MMSD.

Temperature, Algal Production & Dissolved Oxygen Patterns

Next to specific conductance, the most striking differences among streams were in the patterns of diurnal oxygen and temperature fluctuation. In particular, urban streams with reduced baseflow and low tree canopy cover exhibited extreme daily fluctuations in dissolved oxygen and stream temperature. These factors are related to declines in IBI in a way similar to those described for specific conductance in the previous section; IBI decreases in conjunction with increased variation in water temperature and DO.



Detailed analyses for the effects on dissolved oxygen for Lincoln Creek are presented in our interim report located at http://www.uwm.edu/~ehlinger/data/lincoln2003report082503.pdf. In June 2003, the Milwaukee Metropolitan Sewerage District provided funding for us to monitor the continuing recovery of Lincoln Creek. The implemented sampling program emphasized the restoration of ecological function, and, in particular, the role of the nuisance green algal filament *Cladophora* as a bottleneck inhibiting the establishment of a more complex/natural food web, better nutrient trapping, and greater aesthetic appeal of the stream to local residents. Specific activities included: 1) extension of the GLPF-funded project to determine whether the nuisance *Cladophora* problem is gradually improving as the stream matures (comparison to existing GLPF project data collected for 2000-2002), 2) testing the specific role of limestone substrate in stimulating *Cladophora* nuisance blooms by deploying alternate rock substrates, 3) performing small-scale *Cladophora* removal experiments to test for resulting desirable changes in the stream invertebrate and microperiphyton algal communities, 4) generating baseline data for Underwood Creek (another urban stream soon to undergo major restoration) which will facilitate developing an engineering plan that can prevent the occurrence of another nuisance *Cladophora* problem.

In addition, two new graduate students began thesis projects which will continue our investigations of the urban stream ecosystems. One will focus on questions relating to why *Cladophora* specifically has been so successful in the restored urban streams. The second student will study the interactions between heavy metal contaminants and the attached algal communities of streams. Attached algae can sequester and then release large quantities of heavy metals being transported through streams, and these algae can tolerate much higher levels of metals than aquatic vascular plants without suffering lethal effects. Our hope is that both these studies will encourage the consideration of periphyton attributes in future designs of practical stream restoration projects; selecting for substrate types and flow regimes that encourage development of a periphyton community that is esthetically pleasing, that provides an effective resource base for the stream consumers, and that also can serve to effectively mitigate heavy metal contamination- often an unavoidable attribute of urban stream ecosystems.

Community Outreach

Restoration efforts are short-lived without community support. Our research group has worked extensively with both the MMSD and the Town of Mt. Pleasant Stormwater Utility District in developing and implementing community-based stewardship programs for their respective watersheds. As part of a program sponsored by the Pike-Root Watershed Information Network, we contributed to the creation of a brochure explaining the design concepts and anticipated benefits of the Pike River project which was distributed within the Mt. Pleasant community.

We also worked with the Urban Open Space Foundation to design and hold a "Community Stewardship Day" for Lincoln Creek on June 1, 2002. This event was jointly sponsored with MMSD and the Havenwoods Environmental Center of the Wisconsin DNR. The day included tours of the watershed, canoeing, hands-on water quality monitoring, and sampling of fish and invertebrates. Over 200 persons attended the event, and key community contacts were identified who will serve as the core for the creation of a Lincoln Creek Community Stewardship Council.

We are also participants in two major efforts relating to freshwater policy formulation, implementation, and education in Wisconsin. First, the University of Wisconsin-Milwaukee, in partnership with numerous community organizations and agencies is holding a "Milwaukee Clean Water Forum" on October 5, 2002. This forum will involve community leaders and citizens in workshops and discussions to identify the problems facing the Milwaukee watershed and attempt engage them in finding solutions. We will be moderating sessions in this forum and making presentations. Second, the Wisconsin Academy of Arts and Sciences has undertaken an initiative called "Waters of Wisconsin" in an attempt to build a consensus position for the management of Wisconsin's water resources founded on a sound scientific, economic, social, and cultural footing. The WOW statewide symposium will be held on October 21, 2002 in Madison. Tim Ehlinger will be serving as moderator for the session on Aquatic Life and Biological Integrity.

As part of the first phase of the North Pike River Restoration project, the meandering stream and associated wetlands and uplands were planted with lives plants and seeds during the spring of 2003. The project was a combined effort including environmental consultants, University of Wisconsin-Milwaukee students and staff and community members from the town of Mount Pleasant. This collaboration provided a tremendous opportunity to bring together a diverse group of people who all had the same concern for the success of the North Pike River.

A volunteer work day in April 2003 on the Pike River drew over 30 volunteers who contributed 246 combined hours of service. Native seeds, rootstock and plant plugs were planted behind coconut fiber biologs, along the stream bank and in and around surrounding wetland areas within the flood plain. Biodegradable erosion matting was laid along the banks to stabilize the more easily erodable areas and in stream fish habitat was created with boulders left behind from the construction. The planting was a great success with an estimated 70% survival rate for the newly planted material. The project demonstrated the great pride that many people have about the Pike River restoration project and how the collaboration of people working together really can make a difference, and it is hoped that volunteer involvement will continue for planting efforts on downstream restoration sections.

General Conclusions

The work conducted under this project funded by the Great Lakes Protection fund has allowed for the establishment of a monitoring infrastructure which will allow for the continued evaluation of the benefits resulting from the major flow-regime modifications in the Pike River and Lincoln Creek watersheds. The involvement of the community in the monitoring work through collaborations with the Friends of Milwaukee's Rivers and the Pike-Root Watershed Information Network has raised public awareness of the value of these ecosystems. This in turn will provide additional impetus for the longer-term monitoring and management of these watersheds.

The research that has been concluded to date on the Lincoln Creek project has been able to answer several important questions. It is clear that the creation of the in-line wetland detention basis has had a positive impact on both flow-regime and habitat in the Lincoln Creek watershed. These modifications have significantly improved the flashiness in the stream to the point were water velocities during storm events do not cause major habitat destruction. At present however, variable water quality including temperature, oxygen, and conductance are serving to limit the reestablishment of biological integrity in the system.

Although we are continuing research to evaluate the causes of these fluctuations, we believe that they will improve to some extent "on their own" as vegetation and shading along the new channels develops. For example, greater canopy cover will serve both to reduce incident heating from solar inputs (reducing summer temperature fluctuations) and at the same time reducing the potential for *Cladophora* production (reducing oxygen fluctuations). To this end, we have recommended that the Pike River project increase the rate and amount of shrub plantings along new stream banks in order to facilitate a more rapid recovery along their project reaches. Clearly, there is a need to better balance the requirements of flood water conveyance (for which trees and shrubs along the banks creates problems for flow) with the ecological needs of the stream (where woody debris and shade create opportunities for biotic enhancement). It is hoped that the continued research in this project will contribute to helping define that balance.