FINAL REPORT – GLPF GRANT 758

Identifying and Valuing Restoration Opportunities and Resource Improvements at Watershed and Subwatershed Scales

Applied Ecological Services
Steve Apfelbaum
John Bell
Rio Roland

Habitat Solutions
Scudder Mackey

The Nature Conservancy
Michele DePhilip
Mary Khoury

Illinois Natural History Survey
Leon Hinz

November 2007

EXECUTIVE SUMMARY

The primary objective of this project was to develop, test, compare, validate and apply a suite of integrated GIS watershed and hydrologic assessment tools and metrics that link hydrologic impairments with restoration opportunities within four pilot watersheds within the Great Lakes basin. As part of these assessments, a new suite of metrics were developed that when integrated, can be used to measure and assess the relative value of hydrologic improvements resulting from different types (or classes) of hydrologic restoration projects. A list and summary description of the tools developed, tested, and applied in this project are provided in the Tool Description Summary that follows.

The project team developed a suite of landscape/watershed tools that can be used as screening (or scoping) tools to identify hydrologic impairments, and explicitly link those impairments to the landscape. The landscape/watershed tools (stream power, CN surface/wetland water retention, pathways) are especially useful for scenario testing, comparing different types and combinations of restorative actions, and/or hypothetical "what-if" analyses.

The In-stream tools were found to be much more effective testing time-dependent hypotheses using site-specific data. These in-stream tools are temporally scalable and can be tuned to characterize and test the fundamental characteristics of flow (magnitude, timing, frequency, duration, and rate of change) at local scales. Moreover, the fundamental characteristics of flow have been linked to ecological parameters, which makes these tools useful for ecological assessments.

We initially envisioned a non-dimensional Hydrologic Benefit Index that measures the degree to which specific restoration or improvement actions contribute positively to environmental flows. Because of fundamental spatial and temporal scale incompatibilities between the instream and landscape/watershed tools, it is not possible (or appropriate) to create a single integrated metric to assess the relative value of hydrologic improvements. Rather, the project team developed a suite of Hydrologic Benefit metrics based on both the landscape/ watershed tools and the in-stream assessment tools that can be applied individually or as a group over a range of spatial and temporal scales. These metrics were normalized by the difference in base case (presettlement) conditions and worse case (paved paradise) conditions so that between-watershed comparisons could be made. Moreover, the hydrologic benefits (or impacts) of different types or combinations of restorative actions can be compared using these tools and metrics. The metrics developed include: Percent Stream Power Change, Power Change Metric, Power Change Ratio, CN Change Metric; Diversion Ratio, Pathway Alteration Metric, and Potentially Restorable Wetlands.

Four pilot watersheds were selected for further analyses: the Shiawassee watershed in Michigan; the St. Joseph watershed in Michigan, Indiana, and Ohio; the Milwaukee watershed in Wisconsin; and the Paw Paw watershed in western Michigan. These watersheds represent regions with different hydrologic regimes, different landcover and land uses, and different water use/supply regimes. These tools were applied to these watersheds to test real-world applicability under different scenarios.

Results of these comparisons showed that change in stream power (discharge) from presettlement to current conditions varied greatly within and among the demonstration watersheds. In general, the greater the change in land cover from presettlement conditions, the greater the change in stream power. The highest percent change was in the Milwaukee watershed with an average percent change of 150%. The St. Joseph watershed had an average percent change of 122%, and the Paw Paw and Shiawassee watersheds had stream

power changes of 90 and 78%, respectively. Change in stream power generally was higher in downstream reaches than in headwater reaches. Power Change metric values were highest in the St. Joseph and Milwaukee watersheds with values of 22 and 21 respectively, and lowest in the Shiawassee and Paw Paw watersheds with values of 10.5 and 9, respectively. With respect to landcover, both the St. Joseph and Milwaukee watersheds are highly altered. Results show that changes from presettlement to agricultural landcover can be as hydrologically significant as changes from presettlement to urbanized landcover. Scenario testing within the Milwaukee and Shiawassee watersheds also showed that loss of wetlands reduces water retention and may significantly increase discharge and stream power at subwatershed and catchment scales.

The project team considered the potential effects of flow path changes (pathway analyses) that considered such factors as withdrawal location, the type withdrawal, the amount of water diverted, consumed, and/or returned, and the type of source and receiving waters. Due to data limitations, pathways analyses were performed on three of the four pilot watersheds. The proportion of return flow volumes ranged from 1.81% to 5.53% of the total volume of receiving waters. These volumes are relatively small and may not be detectable (or measurable) at watershed or subwatershed scales. In fact, none of the in-stream hydrologic assessment tools had the resolution or sensitivity to detect flow augmentation (or depletion) due to flow path diversions in these watersheds.

Instream analyses were completed using data from 17 USGS stream gages within the four demonstration watersheds where >20 years of continuous data were available. Both single and two-period (historical and recent) analyses were performed on eight of the gages with especially long periods of record. Results were comparable between the single and two-period analyses. Analysis of the gage data showed that low flows – both seasonal (summer/fall) flows and annual low flow events – have increased over time in all four watersheds. However, there were no consistent trends in changes to high flows (high flow events and spring flows) among watersheds or among sites within the same watershed. Conversion to developed and agricultural land cover and/or channel modifications could lead to increased low flows due to increased ‘efficiency’ of the stream network. These changes could also be caused by regional climatic patterns as well. In general, flashiness increased in all watersheds since the 1970s. These increases results are consistent with changes in land cover.

These tools and metrics have been applied by The Nature Conservancy to identify, guide, and evaluate on-the-ground restoration projects designed to restore hydrologic function to agricultural land and drainage channels in pilot catchments and subwatersheds in the Shiawassee and St. Joseph watersheds. These tools are also being applied in the St. Joseph watershed by The Nature Conservancy as part of the Joyce Foundation’s Maumee River restoration project. The Nature Conservancy and the Southwest Michigan Regional Planning Commission are also using these tools to assess potential hydrologic impacts of proposed development (build-out analyses and scenario testing) in the Paw Paw watershed as part of a larger U.S. EPA-supported Section 319 project. In the Milwaukee River watershed, staff at the University of Wisconsin - Milwaukee is coupling these tools will an innovative hydrologic assessment tool based on neural net analyses to identify and guide on-the-ground hydrologic and habitat restoration activities by MMSD and other local communities.

Project Tool Summary

Great Lakes Basinwide assessment tool

This tool was developed to identify watersheds that represent examples of the watershed types and landscapes within the Great Lakes, and where both hydrologic and landscape data are available to thoroughly evaluate, compare, and validate hydrologic and GIS landscape assessment models and tools. The project team developed a consistent and systematic method to screen Great Lakes watersheds using the following initial selection criteria: Imperviousness, Dam Storage Capacity, Canals/Ditches, Minor Road Intersections, Major Road Intersections, and Potential Restorable Wetlands (hydric soils without wetlands).

Watershed assessment tools

The project team reviewed several tools that assess landscape and instream alterations and selected the following tools to apply in the four demonstration watersheds. Not all tools reviewed here were applied to the pilot watershed. This list includes several tools developed by the project team.

- **Stream Power Tool** – (AES, Habitat Solutions) -The stream power tool calculates a surrogate for total stream power using a flow accumulation approach that integrates the hydrologic response of changing land cover and of landscape elements (e.g. soils, slope, and drainage network) on stream hydrology. Variation in stream power can be compared over differing time periods. 'What if' scenarios can also be tested to assess potential hydrologic responses to changes in land cover. This tool can also be used to identify areas of maximum hydrologic restoration potential.

- **Wetlands Water Retention/Storage Tool** – (AES, Habitat Solutions) – This tool is designed to identify and quantify potential hydrologic restoration opportunities associated with wetland restoration sites within watersheds and/or subwatersheds. This tool estimates the volume of water retained or stored by wetlands by integrating existing wetland, hydric soil, and non-urban land use coverages. Historical and/or what-if analyses can be performed to assess the potential hydrologic impact (or benefit) of wetland losses and/or restoration.

- **Water Use/Pathway Assessments** (Habitat Solutions) – Pathway assessments are designed to identify and assess the connections and pathways that water takes as it moves across, or through a watershed. These analyses are based on surface and groundwater datasets that include water supply, water storage, and water discharge within, and between, watersheds and subwatersheds. When combined with other tools, these assessments can be used to identify potential hydrologic restoration opportunities by restoring natural connections and modifying anthropogenic water use and discharge patterns at watershed and subwatershed scales.

- **Flow Duration Curve Regression models** (University of Michigan, Michigan DNR, EPA Star Grant collaborators in IL, MI, and WI) – Specific flow-exceedance frequencies along flow duration curves (e.g. Q05, Q10, Q25, Q50, Q75, Q90, and Q95) can be estimated with multiple linear regression models that use catchment characteristics (e.g., geology, land cover, drainage area, average annual precipitation) as predictive variables. When generated using regression models, flow exceedance frequencies can be predicted for any stream reach within a particular region provided that appropriate catchment characteristics can be obtained. These models predict several points along the flow duration curve and can be used to characterize flow patterns when appropriate stream flow data are not available. This tool can be used to summarize current flow conditions, establish reference conditions, or forecast potential flows under different landcover scenarios.

- **Assessment of Dams** – The team used the best available information on the location of dams to estimate the potential impact of dams on stream flows in each of the four demonstration watersheds. The team calculated the number of dams and dam density for subcatchments within each of the four demonstration watersheds.

- **Assessment of Channel Modification** – To estimate the degree channel modification within each watershed, the team identified stream reaches that were either coded as 'channelized' within the National Hydrologic Dataset (NHD) or appeared unnaturally straight on the digital raster graphic files (DRGs). The percent of total stream length that had been artificially straightened was calculated for several subcatchments within each of the four demonstration watersheds.

Hydrologic assessment tools

The project team also reviewed and applied several tools that calculate changes to hydrologic statistics. These tools require daily streamflow as input, obtained either from stream gages or simulated using a watershed hydrologic model.

- **Indicators of Hydrologic Alteration** (The Nature Conservancy) – The Indicators of Hydrologic Alteration (IHA) software summarizes long periods of daily hydrologic data into a manageable series of ecologically relevant hydrologic metrics. The software permits single period analysis, which is useful for assessing long-term trends, and two-period analysis, which is used to compare flow regimes for two discrete periods, ideally before and after a discrete change in land or water management.

- **Richards-Baker Flashiness Index** (Baker et al. 2004) – The R-B Index is used to quantify the frequency and rapidity of short-term changes in streamflow. Flashiness is an important characteristic of a stream's hydrologic regime. A variety of land and water management changes may lead to increased or decreased flashiness. This flashiness index is based on mean daily flows. The index is calculated by dividing the path length of flow oscillations for a time interval (i.e., the sum of the absolute values of day-to-day changes in mean daily flow) by total discharge during that time interval. This index has low interannual variability relative to most flow regime indicators and thus greater power to detect trends.

- **Baseflow Separation Algorithms and Baseflow Index Models** (USGS & Environment Canada) – Estimates of the baseflow component of streamflow were calculated for all stream gages within the US portion of the Great Lakes basin by Neff et al (2005). The baseflow index (BFI) values can be used to identify potential changes to the groundwater component of streamflow over time. Piggott and others (2002) also developed regression models to approximate the BFI by using the proportions of surficial-geology classes within the areas that are upstream of the gages. These models were developed using flows measured at gages in the Great Lakes basin (US and Canada) and corresponding catchment characteristics of these gages. These models were not applied to ungaged sites within the scope of this project.

ACKNOWLEDGEMENTS

The project team would like to acknowledge and thank the Great Lakes Protection Fund for their encouragement and support of this work. Onsite assistance was provided by members of the

Nature Conservancy's Michigan and Indiana chapters including Mr. Joseph Draper – St. Joseph watershed and Mr. Kenneth Algozin – Shiawassee watershed. Dr. Tim Ehlinger provided data and technical guidance for the Milwaukee River watershed. Additional assistance was provided by members of the advisory group during individual and small-group discussions. Members of the advisory group included: Ed Glatfelter; Laura Hewitt; Dr. Timothy Ehlinger (Professor, Great Lakes Water Institute, University of Wisconsin – Milwaukee); John Gulvas (Environmental Services, Consumers Energy); Michael Hahn (SEWRPC); and Dan O'Riordan (Great Lakes National Program Office - U.S. EPA). Mr. Jason Carlson of Applied Ecological Services provided GIS support, and assisted with development of the regional screening tool. Ms. Kate Barrett with the Wisconsin DNR provided access to data and reports for the Milwaukee River watershed, including updated wetland inventory maps and coverages. Special thanks to Shari Emerson with Applied Ecological Services who provided editing and formatting expertise essential to completion of the final project report. This work was supported by GLPF Grant #758 as one of a suite of projects funded under the Protection Fund's "Growing Water" initiative.

Primary Technical Team
- Rio Roland, Applied Ecological Services
- Dr. Scudder Mackey, Habitat Solutions
- Michele DePhilip, The Nature Conservancy
- Dr. Leon Hinz, Illinois Natural History Survey

Primary Management Team
- Dr. John Bell, Applied Ecological Services
- Mary Khoury, The Nature Conservancy
- Steve Apfelbaum, Applied Ecological Services
- Mark O'Leary, Applied Ecological Services

Technical Contributors
- Dr. Tim Ehlinger, UW-Milwaukee
- Joe Draper, The Nature Conservancy –Indiana
- Ken Algozin, The Nature Conservancy - Michigan
- Kate Barrett, Wisconsin DNR
- Jason Carlson, Applied Ecological Services

Programming Support
- Jia Ma, Applied Ecological Services

Administrative/Editing Support
- Shari Emerson, Applied Ecological Services