Executive Summary

Developing a Process to Quantify and Facilitate Flow Regime Restoration Ecosystem Improvements

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CH2MHILL

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EXECUTIVE SUMMARY

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Introduction

This Executive Summary covers a series of related documents[1] developed under a study to address Great Lakes flow regime-based ecosystem improvements[2]. Together, this series of documents includes a watershed approach toward modeling and assessing environmental flows and developing stormwater best management practices (BMP) design standards, an accounting system to quantify ecosystem improvements based upon flow regime restoration, and processes and tools to facilitate these ecosystem improvement transactions. One key tool, private contracts, is common to a range of facilitated ecosystem improvement processes and an example contract is included. All of the documents and products of this research use the same underlying concept of the dependence of fish species in streams on flow duration curves to illustrate the application of the tools to advancing ecosystem restoration. However, each of the documents stands on its own merit in terms of providing a generalized tool and/or approaches that can be applied to a range of methods for defining and assessing environmental flows.

The need for restoration in the Great Lakes has been a key focus for policy makers, regulators, and stakeholders representing federal, state, First Nations, cities, environmental organizations, and other interested people who have been very active in Great Lakes management issues. Development of the flow regime restoration principles presented in this document occurred within the context of these ongoing efforts. A Presidential Executive Order in May 2004 started the Great Lakes Regional Collaboration (GLRC) (www.glrc.us), which developed a comprehensive restoration strategy focusing on eight issues, including several where flow regime played an important role. The Annex to the Great Lakes Compact addresses water supply management and conservation measures and takes a protective approach toward evaluating new and increased withdrawals of waters of the Great Lakes. Example conservation measures go beyond drinking water conservation to include watershed and stormwater management practices that better manage flows to achieve ecosystem improvement. Another important flow-related management effort includes fisheries restoration programs mandated for the U.S. Army Corps of Engineers

[1] Executive Summary, Chapter 1: Watershed Flow Regime Restoration Evaluation Process, Chapter 2: Developing Stormwater BMP Quality Gallon Metric, Chapter 3: BMP Evaluation Process, Chapter 4: Quality Gallon Accounting System Protocol, Chapter 5: Facilitating and Funding Stormwater Management for Ecosystem Improvement, Chapter 6: Ecosystem Improvement Transaction Example Contracts, Chapter 7: Study Evaluation, Chapter 8: Study Communication Summary

[2] The project team members (CH2M HILL in association with The Conservation Fund, Cook and Franke, Public Sector Consultants, and Stormtech) acknowledge the generous support from the Great Lakes Protection Fund as part of their Growing Water suite of research projects.

(USACE) whereby they are to explore methods to restore Great Lakes fisheries through flow management opportunities.

Each of these Great Lakes management efforts contains goals consistent with the flow regime restoration principles contained in this study. Better watershed flow management can provide the following:

- Improved water conservation as required in the Great Lakes Charter Annex
- Help in restoring fisheries as provided in the USACE program
- Improved in-stream water quality, which the U.S. Environmental Protection Agency (USEPA) and state environmental departments recognize as heavily dependent upon run-off
- Watershed restoration with resulting downstream benefits to the Great Lakes

The flow regime restoration approach provides principles and examples of how better water management can have multiple benefits to the Great Lakes themselves and achieve multiple objectives of various Great Lakes management programs. A key study finding is that, in the absence of significant funding or regulatory requirement for flow regime restoration or other restoration, appreciable progress towards restoration goals is unlikely.

The Importance of Flow Regime

Flows in our watersheds serve many purposes. Water flow provides habitat for aquatic communities, quenches our thirst, grows our crops, provides cooling water and process water for industry, and creates recreation opportunities. These benefits are naturally limited, but more services from water can be obtained with proper management that is based on understanding the relationships between flows and healthy streams capable of sustaining life, ecosystems, and economies.

Studies have shown that land-based flow changes affect the ecology of the receiving water bodies and their associated water-dependent natural resources (Doyle et al. 2005, Bunn and Arthington 2002). Consequently, resource changes result from flow alteration associated with land use changes such as development and agriculture, or surface and groundwater pumping. Decision makers have the ability to control the water flow within a watershed through purposeful management of these and other activities, and create higher beneficial uses than would otherwise occur.

This study acknowledges that, in addition to flow, water quality changes, invasive species, physical alterations, and other development-related factors in a watershed also have an important influence upon the aquatic community and other beneficial uses of water. The effects of these factors not withstanding, if healthy flows do not occur, then, even with no other impairments, beneficial uses will not be met. Nevertheless, control measures must be implemented to mitigate other impacts.

Developed without the benefit of stormwater BMP implementation, older, urbanized watersheds are areas where flows have obviously changed. Urbanized areas face many challenges to flow restoration, one of which is the lack of space to implement stormwater controls; however, small measures implemented broadly across watersheds have the potential to improve the beneficial uses provided by these waters. Because flows in urbanized watersheds have been most dramatically affected by development, they also offer strong potential for restoration. For that reason, this study focused upon flow restoration opportunities within two urbanized watersheds: the Rouge River near Detroit, Michigan, and the Menomonee River near Milwaukee, Wisconsin. The methodology and results are transferable to watersheds in other ecoregions.

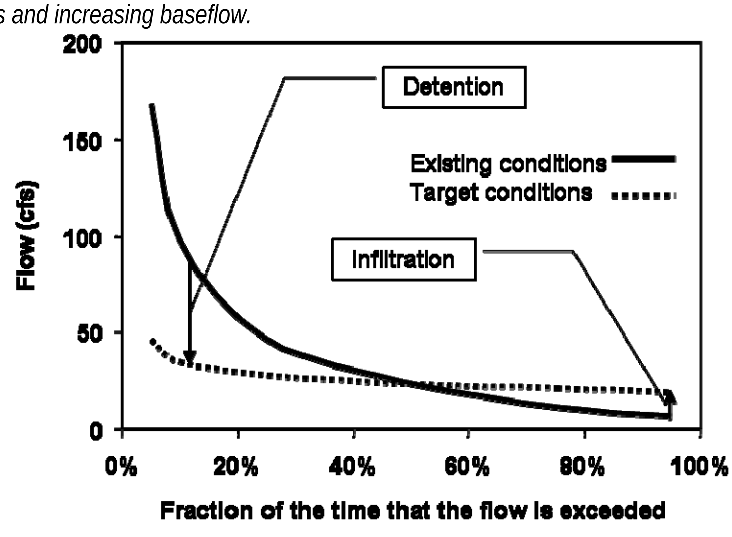
Flow Restoration Characterization Method

The flow measurement methodology chosen for this study uses a flow duration curve to derive desired reference flow conditions in a watershed. This methodology, developed by Wiley, et al., uses watershed characteristics, such as tributary area, watershed slope, land use, surficial geology, precipitation, and other factors to estimate a flow duration curve for a watershed.

Because fish species live within a spectrum of flow conditions, it is assumed that maintaining the overall reference flow duration curve will also be beneficial for them. The reference flow duration curve can then be used as an ecological target flow for the watershed. Given the point or points along the curve that coincide with critical conditions for fish presence, this would determine the design standards for stormwater BMPs.

A conceptual graphic depicting the existing and reference or target ecological flow condition is shown in Figure ES-1.

FIGURE ES-1
Existing and Reference or Target Ecological Flow Condition
Conceptual depiction of the effect of stormwater management BMPs in matching the ecological target flow duration curve by reducing peak flows and increasing baseflow.



For the purposes of this study, the flow duration curve of interest corresponds to the time at which flow increases would most significantly affect fish species. After consultation with fisheries biologists in the upper Midwest, the month of June was selected as a critical period for warm water species because they hatch during that time of year.

It has been shown that there is a correlation between higher flows and higher hatchling mortality (Bovee 1994). Consequently, when higher flows occur from increased urbanization, additional hatchling mortality is expected. The flow duration curve at a reference condition can provide the ecological target for stormwater design criteria to minimize hatchling mortality.

Restoration Metrics: "Gallons" and "Quality Gallons"

Measurement of BMP implementation through a metric can help track implementation progress. The effect that a BMP has on the flow regime is measured by the volume that is required to preserve or restore the flow regime. For the purposes of accounting for BMP design size, the volume unit of gallons is used in this study. Other units of volume such as cubic feet or acre-feet could be used, but are often not understood by the general public. Having a unit that the general public understands can be beneficial toward gaining acceptance of responsibility for their share of the solution, especially when dispersed stormwater BMPs (such as rain gardens) are used on private properties.

The "additional" benefits or impacts to the ecosystem beyond achieving flow restoration from a stormwater BMP are taken into account through a concept termed *Quality Gallons*. The environmental impacts of the BMPs, whether they are positive or negative, are taken into account by the use of multipliers that modify the BMP volume into a "quality"-based volume. As discussed in Chapter 1, the water stored or infiltrated by a BMP is a measure of the BMP's contribution to the flow restoration target. The stormwater BMP volume in gallons is then converted into a "quality" volume by the use of factors that account for the BMP environmental impacts. "Quality" factors include the following:

- **BMP type** quantifies the impact, either positive or negative, that a specific stormwater BMP has on different ecosystem functions, such as moderating temperature and reducing nutrient loadings.
- **BMP location** quantifies the benefit associated with constructing a stormwater BMP at a location that will have the greatest benefit on the receiving stream and downstream aquatic resources.
- **Watershed priority** quantifies the benefit achieved by locating a stormwater BMP in an area and for a purpose that is identified as a restoration priority by watershed stakeholders.

The number of BMP gallons or Quality Gallons needed in a subwatershed can be determined through watershed planning. As BMPs are implemented, the progress made toward the overall subwatershed goal can be tracked with these metrics. Chapters 2 and 3 demonstrate the methods of estimating ecosystem improvement targets in terms of Quality Gallons as well as computing contributions to the target due to implementation of various BMPs.

Quality Gallon Accounting System

The "Quality Gallon" (or any flow-based ecosystem improvement metric) is an important first step toward implementation. However, stakeholders were quick to point out that a systematic method of quantifying the gains from stormwater management, setting priorities, and ranking alternatives was essential for moving the concept of stormwater management for ecosystem improvement forward.

The function of the Quality Gallon Accounting System (QGAS) protocol described in Chapter 4 is to develop guidelines and performance standards for quantifying and verifying the flow regime-based ecosystem improvements resulting from implementing changes in water and land use management practices. The QGAS provides:

- The scientific foundation for linking the projects to the ecosystem improvement targets
- A consistent basis for measuring progress toward the target
- A common metric for comparing the relative contributions of different flow restoration projects within the sub-watershed
- A comparable basis for making project comparisons across watersheds.

A such, the accounting system can be implemented transaction by transaction through contractual arrangements between two or more parties, or it can provide the rules of exchange for a full scale market with a large number of buyers and sellers. The steps in designing the QGAS—including the example registry for reporting, verifying, and certifying ecosystem improvements—are generally applicable to a range in methods of defining and quantifying ecosystem improvements. These steps are carefully described and illustrated in Chapter 4 using the "Quality Gallon" metric.

Facilitation Methods

In the face of increasing pressure to reduce rather than increase taxes, finding cost-effective solutions and creative ways to implement projects are critical success factors for advancing stormwater management goals. Some communities are considering market-based trading approaches (that is, similar to air emissions trading and trading in pollutant load reductions) to fund stormwater management (City of Portland 2006).

Chapter 5 describes several alternative methods to fund and implement stormwater BMP retrofits measured in gallons and Quality Gallons of flow regime restoration. The alternative funding mechanisms vary from one time event funding sources, funding sources from incentives that could be offered to the redevelopment community, and market-based approaches. The facilitation discussion includes examples of successful institutional approaches for identifying BMP opportunities as well as practical considerations that, if in place, can improve the likelihood of BMP implementation.

Of all the various implementation methods described in Chapter 5, the Rouge River and Milwaukee Area watershed stakeholders identified flexible stormwater ordinances as an appropriate mechanism for their communities. Furthermore, they indicated that, stormwater ordinances covering new development and redevelopment are a promising near-term solution for making ecosystem improvement progress, and in the Milwaukee Area, for achieving water quality targets. Flexible ordinances to achieve ecosystem improvement were seen as a way to make the concept attractive to developers who could then more intensively develop one highly profitable location in return for restoring offsite locations that may have greater ecological value than market value as developed property.

Study structure and key lessons

To restore flow regime, watershed managers and decision makers will require better watershed management tools. This study examined several tools that could help fill the need. The approach and findings of this study have been divided into separate documents (chapters) to provide a quicker summary and better access to potential users.

Key lessons have been learned through the course of this study and have strong application towards flow regime restoration, stormwater BMP projects, and ecosystem management in the Great Lakes. The study structure and key lessons are summarized in Table ES-1.

Areas for Further Study

During the design standard development, some questions were raised where additional analysis and research could be useful. Additional analysis could be useful in the following areas:

- Rainfall associated with flow duration curve exceedence levels. Analysis of data indicated that the precipitation depth that controls infiltration and most significantly influences the 5 percent to 95 percent exceedence flows is difficult to predict and depends upon antecedent moisture conditions. Research to identify a simple method in determining an ecological design precipitation event would be beneficial.
- Release rate associated with flow duration curve exceedence levels. The release rate for a BMP associated with the flow duration curve restoration is difficult to determine. The data used to develop a target flow duration curve used a data set where the minimum catchment area was approximately 30 square kilometers. BMPs treat an area much smaller than this. The approaches used in this study use engineering judgment to choose a practical release rate based upon professional engineering experience. Additional research could help identify appropriate release rates and verify design storms for stormwater BMPs.
- Physical stream integrity and flow duration curve exceedence levels. The flow duration curves developed by the University of Michigan focused on stream biological conditions and did not incorporate any physical conditions of the stream. Consequently, flows that control the channel geometry, such as the bankfull flow, are not included in the flow duration curve. Additional analysis to associate the flow duration curve to such physical conditions may be beneficial. It may also be useful to extend the flow duration curve restoration concepts in this study to include the flows that directly affect the physical structure of the channel, in addition to flows that directly influence the biology of the stream. This is because, where the physical channel structure is changing, the resulting habitat and biological community will also be affected.

TABLE ES-1
Summary of Study Structure and Key Lessons Learned

Document	Content Summary	Key Lessons
Chapter 1: Watershed Flow Regime Restoration Evaluation Process	A method to analyze and measure flow regime health and select an ecologic target flow using a flow duration curve. "Gallon" flow regime restoration measurement metrics development. Case study results examining flow regime restoration using stormwater management BMPs within the Rouge River and Menomonee River watersheds.	Flow regime restoration targeting conditions in June when fish are just hatching is the most critical month for warm water fisheries in the upper Midwest study areas. The effects of urbanization upon the flow regime are not readily observable when the ground is frozen or saturated. Flow regime restoration is possible by controlling relatively small storm events (less than 1 year return period). Infiltration based BMPs are more effective at restoring the flow regime than detention based BMPs. For both the Rouge River and Menomonee River watersheds, BMPs were effective in improving the flow regime. Restoring to an undeveloped flow regime condition does not appear possible. Alternate flow duration curve targets may be needed where an undeveloped target is not achievable. Minimum watershed model data requirements depend upon the level of certainty needed on the potential for flow regime restoration Detailed flow regime restoration predictions using flow duration curves may not always be necessary for other watersheds when stormwater BMP practices intended to restore flow regime, applicable BMP design standards, and potential for results become generally known.. Consequently, as the flow regime restoration body of knowledge grows, the lessons are expected to be readily transferable to other watersheds. Methods exist to incorporate undeveloped land use conservation within a flow regime restoration program.
Chapter 2: Developing Stormwater BMP Quality Gallon Metric	Measures to quantify known restoration benefits that may be difficult to define using traditional benefit metrics such as habitat features. "Quality Gallon" metric development incorporating both positive and negative ecosystem impacts associated with stormwater BMP implementation.	The "Quality Gallon" metric can differentiate BMPs in their capability to account for watershed specific restoration needs in areas such as: habitat creation, water temperature, or other environmental services. Quality Gallons provide a metric for achieving multiple benefits from restoring flows at least cost. Quality Gallons provide a unit of exchange for facilitating transactions to achieve multiple environmental goals. It is beneficial to define "Quality Gallon" factors in a simple, uncomplicated manner.

TABLE ES-1
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Chapter 3: BMP Evaluation Process	Examples of how to analyze watersheds and evaluate individual restoration projects for expected benefits. The chapter includes examples from both the Rouge River and Menomonee River watersheds.	Example BMP analysis for flow regime restoration indicated infiltration based BMPs (for example, rain gardens) improve the flow regime. Urbanized areas require implementation of many BMPs such as rain gardens or porous pavement to restore the flow regime.
Chapter 4: Quality Gallon Accounting System Protocol	Includes processes that could be used to formalize a “Gallon” and “Quality Gallon” accounting system and project registry. Examples include: under what circumstances a project would be eligible, how to quantify the benefits provided by the project, and reporting procedures to document project benefits. Methods to verify and certify “Quality Gallons”.	The Quality Gallon system can define: 1) The scientific foundation for linking the projects to the ecosystem improvement targets 2) A consistent basis for measuring progress toward the target 3) A common metric for comparing the relative contributions of different flow restoration projects within the sub-watershed 4) A comparable basis for making project comparisons across watersheds
Chapter 5: Facilitating and Funding Stormwater Management for Ecosystem Improvement	Contains methods to facilitate ecosystem improvements through existing opportunities and potential future means. Examples include: supplemental environmental projects (SEPs), incentive zoning or flexible stormwater ordinances, superior environmental performance incentives, and stormwater trading. Includes a summary of common actions that can be taken to remove barriers to flow regime restoration projects.	Non-traditional sources for restoration implementation include: SEPs, zoning incentives, transfer of development rights, flexible stormwater ordinances, and regulatory incentives. Stakeholders supported flexible stormwater ordinances in exchange for additional BMP implementation. Actions to take to encourage BMP implementation include: A watershed plan that identifies BMPs and locations as well as expected proportional benefits of each BMP in achieving target flow regimes. Consistency in design standards and goals between the local stormwater ordinance requirements and the target flow regimes and watershed plan conclusions. Developer and regulator awareness of alternative stormwater BMPs contained in the watershed plan. Preliminary design/estimated costs and required property control for offsite BMPs.A developer will be concerned about cost and not how many gallons are created unless there is a regulatory requirement that needs to be met. The developer (or other) will have to pay to build the BMP and will want to know whether twice as many Quality Gallons are a bargain when comparing projects of the same cost. There will have to be an incentive for why a developer or other buyer would choose projects with higher Quality Gallons. If there is not a regulatory driver or environmental offset driver, there nonetheless could

TABLE ES-1
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Document	Content Summary	Key Lessons
		be an environmental stakeholder driver. Developers will want their projects approved and approval could be easier if they can demonstrate that their preferred projects provide comparatively higher ecosystem restoration benefits through the use of Quality Gallons.
Chapter 6: Ecosystem Improvement Transaction Example Contracts	Guidance for and examples of the legal, real estate, or maintenance agreements necessary to conduct an ecosystem improvement transaction measured in gallons or Quality Gallons. Includes examples from a variety of settings summarized in Chapter 5.	Requiring contracts or easements for residential property BMP implementation (for example rain gardens) may discourage property owners from implementing BMPs. Stakeholders believe monitoring requirements for stormwater BMPs should be no more stringent than current stormwater BMP monitoring associated with development requirements.
Chapter 7: Study Evaluation	User feedback topics such as: the flow regime restoration approach taken in this study, the use of “Gallons” or “Quality Gallons”, example ecosystem improvement contracts, and general study feedback.	There is support for managing and restoring flows as a pathway toward aquatic ecosystem restoration. Stakeholders view stormwater BMPs as multipurpose tools capable of ecosystem restoration in addition to traditional roles, such as flood control. Stakeholders are unsure if “Quality Gallons” provide the best means of capturing additional benefits from BMPs, but generally agree that such a metric is desirable and useful for advancing ecosystem improvement goals. Participants supported the idea of trading requirements with little benefit for greater flexibility to obtain demonstrable gains. They expressed the view conducting pilot studies that produce visible benefits is a logical project extension.
Chapter 8: Study Communication Summary	Providing management officials and potential users with expanded exposure to flow regime restoration project tools developed through this study.	In presenting the study findings in conference settings, the biggest interest has occurred from outside the Great Lakes.

- The flow duration curve regression equations developed by the University of Michigan can be expanded to other states or ecoregions. Developing applied methods to use a target flow duration curve for restoration and stormwater management design standard development could be very useful. In addition, identifying the percent exceedence flows that most directly impact various fish species (for example, cold water or warm water) life-cycles could be beneficial to targeting restoration and preservation criteria and the most critical time of the year to focus design standard development.
- Developing guidance that addresses the identification of an appropriate flow duration curve target (when a target representing limited urbanization in a watershed cannot be achieved), or research showing at which threshold aquatic species become less abundant would be very beneficial.

The participants in the Flow-Based Ecosystem Improvement Implementation Workshops identified pilot studies as the logical next step to demonstrate how ecosystem improvements could result from implementing flexible stormwater ordinances using the Quality Gallon Accounting System Protocol.

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