Flow-Based Surrogate TMDLs, A Case Study in Ohio

Lower Grand River TMDL

January 2012

This fact sheet describes the characteristics of a good surrogate total maximum daily load (TMDL) and the factors that should be considered when selecting a surrogate for storm water-related impairments to aquatic life uses (ALUs). The fact sheet is based on lessons learned from the lower Grand River TMDL which was the first TMDL to use a flow-based surrogate approach in the State of Ohio.

Paine Creek, a tributary to the Grand River

Background

Many waterbodies appear on state Clean Water Act (CWA) §303(d) lists for ALU and stream biota impairments due to multiple stressors. An example of this case is a waterbody that is impaired by storm water discharges in urban areas. Impacts from storm water discharges may increase loadings of a variety of pollutants where hydrologic changes are important factors in their transport. Altered flow regimes (e.g., peak flows higher than pre-development and base flows lower than pre-development) also affect the habitat conditions of aquatic life. These multiple stressors, along with the lack of information indicating that any specific pollutant is causing or contributing to an exceedance of a particular water quality criterion, make it difficult to identify which pollutant is the most suitable for TMDL analyses. Therefore, using a surrogate measure, such as storm water runoff or impervious cover, which integrates the effects of multiple stressors and represents pollutant loadings, may at times be the appropriate approach for calculating the TMDL loading capacity and restoring waterbodies affected by urban storm water.

A surrogate correlates to a measure of biological response in the waterbody that can be linked to those pollutants and stressors, as well as to a state's water quality standards. This is consistent with the TMDL regulations that specify that TMDLs can be expressed in terms of mass per time, toxicity or other appropriate measure (40 C.F.R. §130.2(i)).

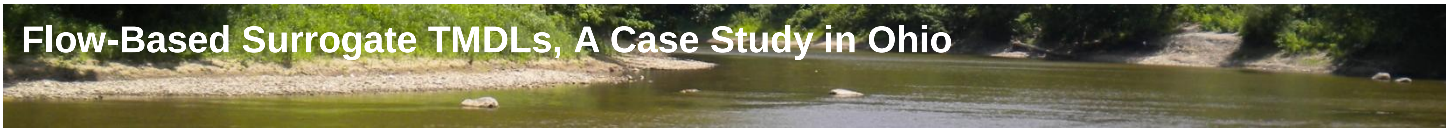
Using a Surrogate Approach

What is a Surrogate TMDL?

- A surrogate TMDL uses a target other than the pollutant-of-concern or a single pollutant that is a listed cause of impairment.
- The surrogate TMDL must be based upon a target that addresses the cause and/or source of impairment and will result in attainment of designated uses.
- Surrogates are not always water quality parameters, such as concentrations of a particular pollutant, or even a response variable like dissolved oxygen. Instead they can be a measurable watershed or waterbody condition that represents a stressor linked to water quality impairments. For example, the watershed's percent impervious cover (IC) has been used as a surrogate in several storm water-related TMDLs. IC represents a characteristic of the watershed that ultimately drives the amount, timing and potentially the quality of storm water entering a waterbody.

Why Surrogate TMDLs?

- Surrogate TMDLs have been pursued when use of a pollutant alone would have been insufficient to address the cause of impairment. They have also been pursued when the impairment is based on biological indices with no numeric pollutant criteria to use as the TMDL target.
- When the listed cause of impairment is general in nature, and a surrogate measure can be linked to multiple stressors, a surrogate measure can strengthen the specificity of the TMDL and focus more attention on the root cause of the water quality impairments (e.g., increased imperviousness) instead of a symptom (e.g., elevated pollutant loadings).
- Surrogate measures can often be better understood by the public, scientists, managers and regulators, and more directly tied to implementation than a pollutant load reduction.



Considerations for Selecting the Surrogate Approach

To determine if the surrogate approach is appropriate for a project, one should determine what assessment and indicators were used to determine that a water was impaired. listing . If Aquatic Life Uses are impaired as determined by poor biological condition or degraded habitat, a surrogate approach may be warranted. A stressor identification method can be employed to determine the likely cause, or causes, of the observed impairment. If the stressor analysis identifies a specific pollutant of concern, the TMDL can be developed for that parameter. However, if the analysis suggests that the ALU impairment is likely due to the synergistic effects of multiple pollutants and other storm water-related conditions, a surrogate TMDL may be appropriate.

Determining a Surrogate Parameter

The following considerations should be evaluated when determining if the surrogate parameter is right for a project:

- Demonstrates scientific linkage to the water quality criteria
- Demonstrates linkage to the water quality impairment
- Considers "critical conditions" relevant for addressing the impairment
- Target selection supported by data
- Measureable (for tracking progress and guiding implementation)
- Understandable by the public and implementation partners

Support for Surrogate TMDLs

Support for development of surrogate TMDLs has been growing, and has been articulated in several previous documents:

- *Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program* (U.S. EPA 1998).
- 2009 report Urban Stormwater Management in the United States, the National Research Council. "A more straightforward way to regulate stormwater contributions to waterbody impairment would be to use flow or a surrogate, like impervious cover, as a measure of stormwater loading ... Efforts to reduce stormwater flow will automatically achieve reductions in pollutant loading…".
- It is also important to note that development of surrogate TMDLs is consistent with regulations that specify that TMDLs can be expressed in terms of mass per time, toxicity or other appropriate measure (40 C.F.R. §130.2(i)).

Examples of U.S. EPA Approved Surrogate TMDLs

Two TMDLs developed in New England States pioneered the use of surrogate TMDLs:

- Eagleville Brook (CT) TMDL, which used impervious cover as a surrogate. For more details on how the Eagleville Brook TMDL was developed, please review the approved TMDL report available online at: http://www.ct.gov/dep/lib/dep/water/tmdl/tmdl_final/eaglevillefinal.pdf. The report includes as Appendix 2 the paper documenting the statewide linkage analysis to identify the percent impervious cover target.
- Potash Brook (VT) TMDL, which used storm water runoff volume as a surrogate. To access the final approved Potash Brook TMDL and important supporting analyses, visit Vermont DEC's Stormwater TMDLs web page: http://www.anr.state.vt.us/dec//waterq/stormwater/htm/sw_TMDLs.htm.

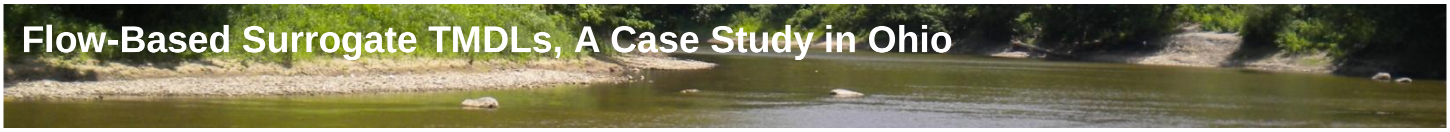
These TMDLs are consistent with existing regulations and provide meaningful numeric targets that assist in implementation efforts such as best management practices or numeric effluent limits into National Pollutant Discharge Elimination System storm water permits.

Development of a Surrogate Flow Regime TMDL for the Lower Grand River

The following discussion summarizes some of the key steps used to develop a surrogate (flow regime) TMDL for the lower Grand River in northeast Ohio.

The lower Grand River watershed is located in northeast Ohio and drains to Lake Erie near Painesville, Ohio. This 287 square mile watershed area is home to more than 110,000 people and encompasses all or part of seven municipalities in Lake, Ashtabula and Geauga counties. The watershed is primarily forested and agricultural with 16 percent being developed. The developed area is concentrated in the western portion of the watershed, while the eastern portion is primarily rural.

The geology in the area dictates that flow in the Grand River is fed primarily by rainfall and snow melt, with very little base flow. Consequently, discharge becomes quite small in the summer, so the river is sustained by the many coldwater tributaries that continually discharge ground water into the river. Those coldwater tributaries and other sources of base flow are essential to the overall health of the Grand River.



Lower Grand River watershed within the State of Ohio

A flow regime TMDL was developed for three impaired streams in the lower Grand River watershed including Red Creek, Kellogg Creek, and a portion of Big Creek. All three streams are impaired for ALU. Potential causes of impairment were identified in two previous documents and as part of the 303(d) listing process and include flow alteration, pollutants associated with urban storm water, and direct habitat alteration. The pollutants associated with urban storm water are further defined in the TMDL as typically including polyaromatic hydrocarbons (PAHs), metals, and lawn chemicals.

Example of small headwater stream in lower Grand River watershed

Stressor Identification and Linkage Analysis

Available data were evaluated and a weight-of-evidence approach was taken to identify the most likely stressors for each biological impairment. The following candidate stressors were identified:

- Flow alteration and imperviousness
- Habitat alteration
- Metals
- Organic enrichment and low dissolved oxygen
- Siltation and sedimentation
- Temperature

Available data obtained from Ohio EPA and other entities were evaluated with the objective of determining if the stressors from the candidate list represent the causes of impairment. The evaluation found that some candidate stressors are likely causes of impairment while other candidate stressors are not.

Qualitative Habitat Evaluation Index (QHEI) and total suspended solids (TSS) data were evaluated to determine the effects of habitat alteration and siltation and sedimentation. QHEI scores were good to excellent at sites with impaired aquatic life. TSS was not detected in over one-half of the samples and was below the target for reference conditions (i.e., least impaired) in most of the remaining samples. Thus, neither dataset was representative of the impairments.

Similar to TSS, metals concentrations were typically not detected or were below targets for reference conditions. Limited temperature and dissolved oxygen data did not correlate with the organic enrichment and low dissolved oxygen impairments.

Biological indices data were compared with impervious cover data to evaluate the impacts of urban/suburban runoff and storm sewers. The evaluations showed that aquatic community health (as measured by biological indices) decreased as impervious cover increased. Thus, flow alteration and imperviousness were determined to be the stressors impairing aquatic life. The three streams impaired by altered flow regimes are located in the western portion of the watershed where watershed imperviousness ranges from 13.1 to 14.7 percent. Imperviousness in the lower Grand River watershed is presented in the following figure.

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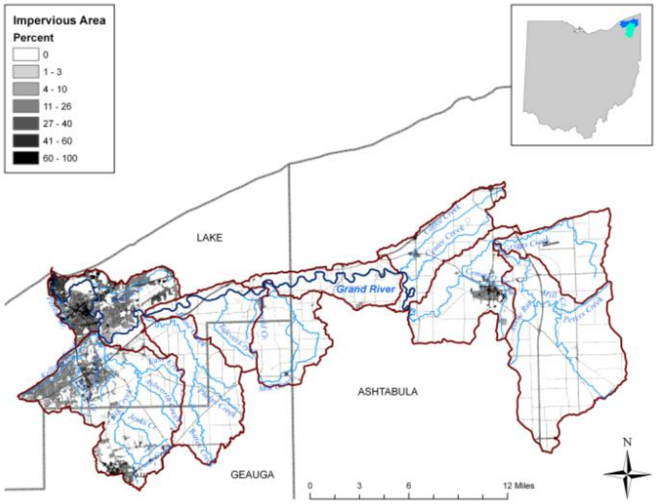
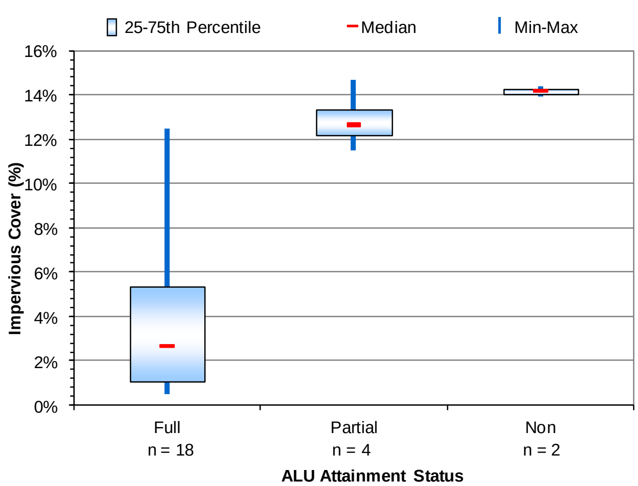


Imperviousness in the lower Grand River watershed

The impacts of urbanization are the cumulative effect of multiple stressors in the watershed and stream environment resulting from urban development. The literature indicates that impacts on aquatic life have been documented in cases with as little as 5 percent urban development and 10 percent impervious cover. For a general review of the impacts of urbanization and references to additional resources, see the CADDIS Urbanization Module and *The Importance of Imperviousness* (Schueler 1994).

Urbanization also directly affects habitat, riparian buffers, water temperatures, and runoff pollutants. For example, habitat is altered by channelization and dredging. Clearing riparian vegetation eliminates habitat (e.g., rootwads) and reduces shade. As components of the ecosystem are disturbed and altered, the aquatic species must respond, which in turn affects aquatic communities.



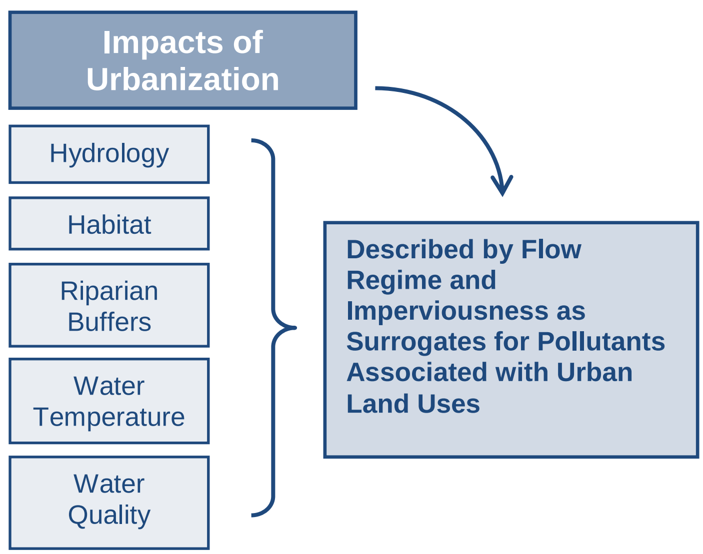
Biological attainment and levels of impervious cover at the assessment sites on western tributaries in the lower Grand River watershed

Determine Appropriate Surrogates

The effects of urbanization must be evaluated within the specific watershed because factors affecting aquatic life are impaired on a small/local scale. Possible surrogates, including imperviousness, peak flow, volume, flashiness, and flow regime were evaluated to determine which surrogate most closely matched the causes of impairment.

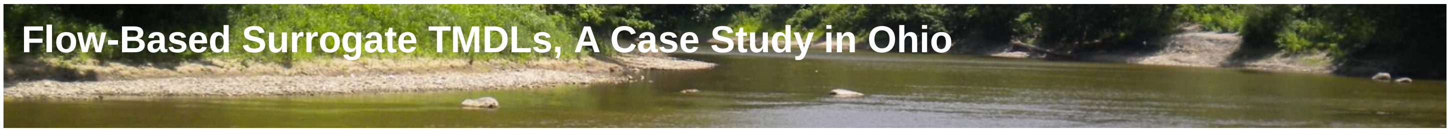
The health of aquatic communities is affected by hydrology, habitat, riparian buffers, water temperature, and water quality. Each of those factors is altered by urbanization. A linkage analysis showed that aquatic community response, driven by disturbance of each of those five factors, is impaired as urbanization (i.e., flow alteration and imperviousness) increases.

Peak flow, runoff volume, and flashiness were also considered as surrogates. However, these factors would not be good surrogates for this watershed because they do not account for the low flow critical conditions. Base flow in the lower Grand River watershed needs to be protected and TMDL analyses for these three factors would not directly lead to preserving natural base flows. Therefore, flow regime was selected as the surrogate because it addresses the full spectrum of flow conditions and describes the impact of urbanization.



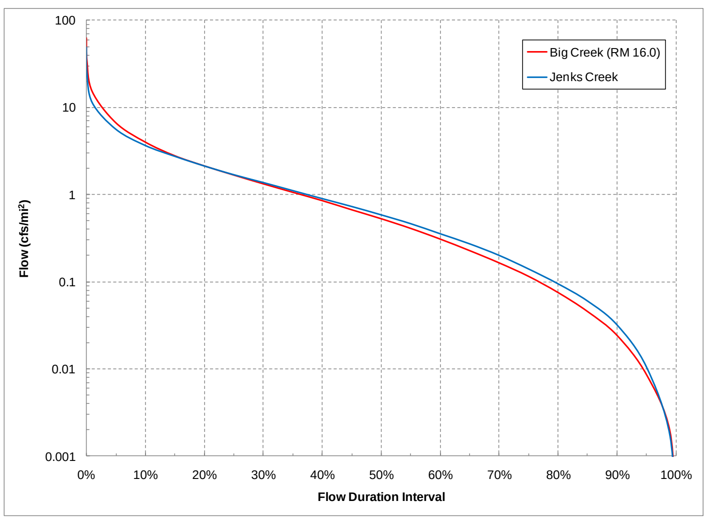
Evaluate Reference Data and Set Targets

Hydrologic targets that will lead to attaining the ALU designation in the lower Grand River watershed are based on a reference, or attainment, stream approach. The hydrologic targets are provided in the form of a reference flow duration curve based upon unit area to allow for the comparison of varying-sized streams.



The first step taken to identify the potential reference streams for use in the flow regime TMDLs was to determine which streams Ohio EPA had assessed and which of those streams are fully attaining their ALU designation. The next step was to compile available data that characterized the watersheds (e.g., level IV ecoregions, levels of development). Flow duration curves for each of the potential reference streams were created, and the impacts of urban development and impervious cover on the flow duration curves were evaluated.

The final step compared potential reference streams with the impaired stream to determine which potential reference stream was best representative of reference conditions for the impaired stream. This included evaluating the following factors: ALU attainment, location, size, land cover (watershed and riparian buffer) and soils. Those evaluations were performed on a case-by-case basis. The unit area flow duration curves for Jenks Creek (reference stream) and Big Creek (impaired stream) are displayed below.

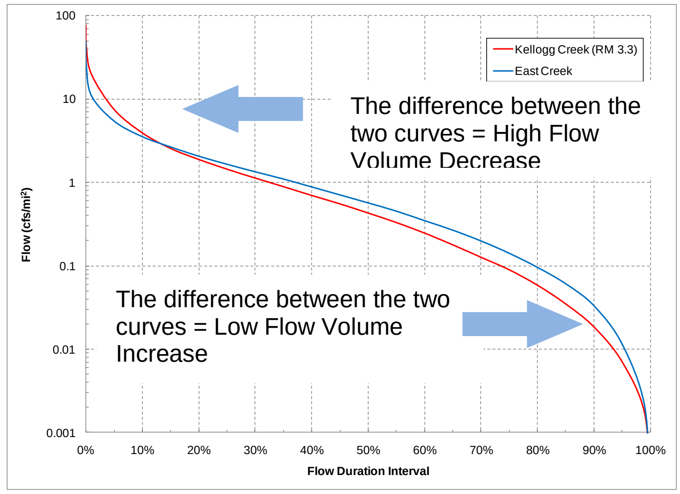


Flow duration curves for the impaired stream Big Creek (RM 16.0) and the reference stream Jenks Creek.

TMDL and Allocations

TMDLs are typically expressed as mass per unit time. In the case of the lower Grand River TMDLs, the TMDL is expressed as percent reductions in flow rates. The reduction is calculated as the difference between an impaired stream's flow and a reference stream's flow during all flow conditions. The necessary percent reduction will control high flows and water quality degradation associated with increased levels of imperviousness caused by urbanization.

In addition, recommendations are presented to increase flow during low-flow conditions in order to help communicate the overall aim and expected result of the TMDL, which is to match the reference stream's flow duration curve. The low-flow recommendations are not TMDLs but provide the basis to ensure that future storm water permits for the TMDL area comply with the antidegradation criteria in OAC 3745-1-05.



Graphical description of TMDL

Allocations between point sources and nonpoint sources are determined based on source. Most of the storm water sources such as agricultural runoff and regulated MS4 storm water are required to reduce flow equally. They are assigned a load allocation or wasteload allocation equal to the TMDL reduction. An example flow regime TMDL and flow regime recommendation are presented in the following tables.

Flow reduction (%)	Flow Duration Interval			
	High	Moist		
	0–10	10–20	20–30	30–40
TMDL	28%	12%	8%	3%

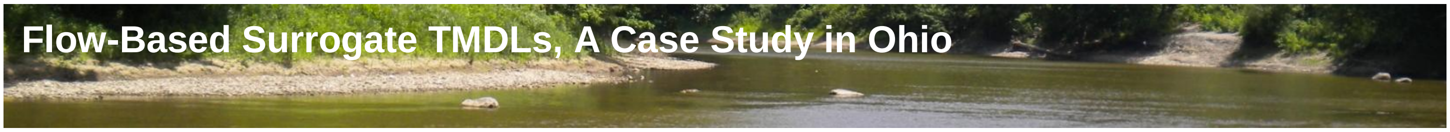
Flow regime TMDL for Red Creek

Flow increase (%)	Flow Duration Interval					
	Mid-range		Dry			Low
	40–50	50–60	60–70	70–80	80–90	90–100
Flow increase (%)	1%	5%	11%	13%	19%	18%

Flow regime recommendations for Red Creek

Critical Elements

There are several critical elements that are needed to ensure that development of a flow-based surrogate TMDL results in an approvable and defensible TMDL. These critical elements are taken from lessons learned during development of the lower Grand River watershed TMDLs and are presented below.



Sufficiency of Data

The ability of the available data to effectively link a surrogate to the impairment is critical. The typical data collected during biological and water quality surveys are generally insufficient to support a flow-based surrogate TMDL. Key datasets that are recommended include:

- Current local land use and impervious cover datasets. National-level datasets do not always provide the recommended level of accuracy to evaluate flow-based impairments.
- Flow measurements in both impaired and reference streams. A minimum of one year of continuous flow measurements should be collected in both locations to allow for an accurate representation of flow conditions and to support target setting. There are limitations with hydrologic modeling that can be avoided with accurate calibration data.
- Stream sampling of toxic urban pollutants such as PAHs and pesticides will provide for an effective source assessment and linkage analysis for urban sources that may contribute toxic substances. In addition, whole effluent testing for point sources should be conducted and should be used to refute possible evidence that suggests point sources are causing the toxicity in the stream.
- In-stream sediment analysis to provide a sufficient and representative dataset to evaluate sediment transport in the impaired streams is recommended. This will likely entail sampling beyond the typical biological and water quality surveys. Such data should be sampled across varying hydrologic conditions at multiple locations to characterize in-stream siltation and sedimentation.
- Focused QHEI data could be collected in impaired streams once the listing and initial causes of impairments are determined. Having QHEI data that are representative of the causes of impairment (e.g., storm water) will enable a strong habitat linkage in the flow-based TMDL.

Availability of Reference Stream Data

An initial evaluation of reference stream availability is needed to ensure that appropriate hydrologic targets can be derived. A gradient of streams (from poor to excellent aquatic community health) that have similar physical characteristics (e.g., size, ecoregion) is preferred. If no nearby streams are attaining designated uses or are significantly different from the impaired stream (e.g., headwaters attaining stream and impaired large river), then the reference stream approach likely cannot be used.

Form of TMDL

A flow-based surrogate TMDL can be presented in various formats, including percent reduction, flow volume decrease, and peak flow rate decrease. A measureable TMDL is desired, and therefore a flow volume or peak flow rate is preferable. However, depending upon the available data and the source of flow data, the percent reduction allows for uncertainty associated with actual flow rates and volumes to be normalized.

An increase in pollutants is not allowed by U.S. EPA, and therefore any increase in flow conditions that may be desired, such as increases in base flow, are required to be included as recommendations only.

References

Bunn, S. and A. Arthington. 2002. Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity. Environmental Management 30: 492-507.

Burton, G. and R. Pitt. 2002. Stormwater Effects Handbook, A Toolbox for Watershed Managers, Scientists, and Engineers. Lewis Publishers, Boca Raton, FL.

Schueler, T. 1994. The Importance of Imperviousness. Watershed Protection Techniques 1 (3):100-111.

U.S. EPA. 1998. Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program. EPA 100-R-98-006. Federal Advisory Committee on the TMDL Program, the National Advisory Council for Environmental Policy and Technology.

For More Information

The lower Grand River TMDL and associated documentation can be found at:
http://www.epa.ohio.gov/dsw/tmdl/GrandRiver.aspx

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