Determining Environmental Limits to Streamflow Depletion Across Michigan

By David A. Hamilton and Paul W. Seelbach

Michigan now assesses environmental impact of proposed water withdrawals on nearby streams and limits stream depletion based on ecological characteristics. The scientific framework is the relationship between streamflow reductions and projected impact on resident fish populations. Program development was overseen by an advisory council representing major water interest groups.

Introduction

Michigan has a new process to identify and efficiently authorize surface or groundwater withdrawals that are not likely to cause an adverse resource impact (ARI) to local stream ecosystems. Withdrawals that have a higher risk of causing an ARI are flagged for more detailed, individual review. The process was created to ensure thoughtful management of Michigan's valuable water resources; focusing staff resources and attention to water use proposals with the highest environmental risk to avoid adverse impacts and an overly burdensome permit process.

The key to protecting aquatic ecosystems is to protect the natural, seasonal patterns of streamflows. Interest in protecting streamflow patterns is growing within many regions of the U.S. and the world, recognizing the fundamental needs to base water policy on sound hydro-ecological science, and wisely balance water allocation across a range of uses to achieve sustainable provision of critical services. Emerging work on setting environmental flow standards is documented by The Nature Conservancy's Environmental Flows Program.[1] Great Lakes states have begun developing environmental flow standards through the recent Great Lakes-St. Lawrence River Basin Water Resources Compact.

In 2006, the Michigan legislature charged the Groundwater Conservation Advisory Council—an appointed body representing major water-use interests–to design a process to assess environmental impacts of all proposed large-quantity water withdrawals over 100,000 gallons per day. Michigan's advisory council formed a technical working group to design and develop the process. This group included hydrologists, fisheries ecologists and environmental scientists from a variety of state, federal, university and private entities.

The advisory council provided the vision for a comprehensive state Water Withdrawal Assessment Process.[2] This process combined a foundation of hydrologic and ecological models and maps, with a set of management actions driven by the estimated environmental risks. The resulting process is designed to: 1) prevent adverse resource impacts; 2) provide a better understanding of withdrawal impacts, 3) minimize conflicts over water use, and 4) facilitate planning for sustainable water use and conservation among stakeholders.

The Water Withdrawal Assessment Process contains elements representing both objective science and subjective societal values—the two necessary elements for sound policy development. Scientific elements were agreeable to all parties; societal values required in-depth discussion and ultimately a legislative decision. The science-based components offered an objective template to guide and constrain participants during the social-values negotiations. Legislators and stakeholder workgroups subsequently reached bipartisan agreement, embodied in the new state law.

Process Components

The assessment process must determine when cumulative large quantity water withdrawals would likely cause an unacceptable impact to stream ecosystems. To the extent possible, objective metrics were developed to represent physical and biological aspects of the environment. And scientifically based, ecological-response curves were developed to inform the policy determination process of how much water can be responsibly withdrawn.

Using streamflow as a metric to measure environmental impact

The summer low flow period is one of the most important, biologically stressful periods in the annual streamflow cycle. An index flow, the lowest summer monthly median flow (typically August), was chosen to represent this period. This is the reference point, the flow from which a proposed water withdrawal is subtracted and an assessment is made of potential environmental impacts. The maximum amount of water that can be withdrawn from each stream is calculated as a percentage of the index flow. Index flows must be determined for all the stream segments draining each of approximately 5,000 Water Management Areas (local drainage areas in Michigan).

Stream classification

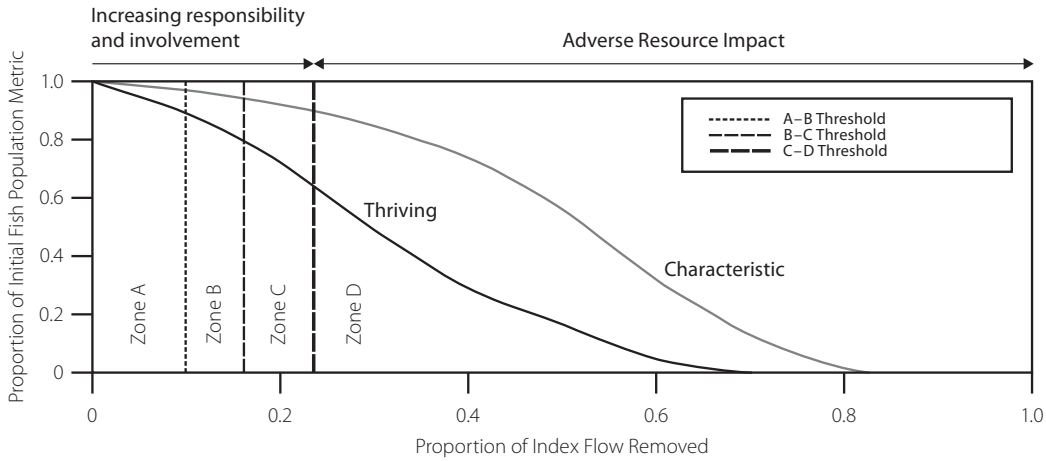
To quantify the impact the withdrawals had on all the stream resources, it was important to classify Michigan streams into types. All Michigan stream segments were assigned to one of 11 types based on size and water temperature—the dominant variables shaping fish populations in Michigan's streams.

This assessment process focuses on the health of the streams, which also provides indirect protection of other headwater streams, lakes and wetlands ecosystems within each larger water management area by limiting the total amount of water withdrawal allowed. Through the classification system and associated water budgets, this process helps sustain the exceptional diversity of natural hydrologic regimes and the resulting aquatic ecosystem types distributed across the Michigan landscape.

Environmental limits based on fish response curves

The fish in the streams are used to help gauge the expected impact of water withdrawals. Fish are at the top of the food chain and reflect the overall health of the aquatic environment. Response curves were developed that represent population and density changes in characteristic fish communities due to reductions in streamflow (Figure A).[3] Each of the 11 stream types has different characteristic fishes, with unique sensitivity to reductions in index flow. For each type, only a proportion of streamflow can be withdrawn before causing an adverse resource

Figure A: Example of Risk-based Water Management Zones



Source: Paul W. Seelbach, Michigan Department of Natural Resources and Environment.
Notes: Example set of response curves of stream fish populations to increasing removal of stream Index Flow. The Thriving Species curve is the most sensitive, "early warning flag." The Characteristic Species curve shows the ultimate decline in fish populations. Also shown are the management zones A–D, for which increasingly protective management actions are prescribed. Zone D is equivalent to the legal standard of Adverse Resource Impact.

impact. With the stream classification and technical response curves in place, the ecological impacts to any specified stream segment in the state can now be effectively assessed.

Risk based management zones

The final policy decisions, formalized in legislation, regarding acceptable impacts were informed by the stream classification system and fish response curves. The flow-fish response curves illustrate a continuum of increasing risks of ARI. There is no sharp threshold of flow reductions between "no impact" and "ARI." So the legislation created a series of management zones representing increasing levels of risk to the environment (Figure A), and prescribed appropriate levels of water management efforts.

Each stream type has different characteristic fish populations that respond differently to the reduction in flow. For each type, the legislation determined a maximum amount of water that can be withdrawn before causing an adverse resource impact, which is prohibited.

Michigan's groundwater-driven, cold streams are a unique resource in North America. Streams designated as cold-transitional are most sensitive to reductions in flow. Relatively small reductions in flow can dramatically alter these ecosystems so that they will no longer support cold water species like trout and salmon. Accordingly, withdrawals from these streams are very limited and any proposed withdrawal requires a site specific review by state agency staff.

Relating water withdrawal to streamflow depletion

Finally, a mechanism is needed to predict how much water will be depleted from any given stream segment by a proposed withdrawal. When a withdrawal is taken directly from a stream, the streamflow is instantly reduced by the same amount that is withdrawn. But when the withdrawal is from a well, the relationship between the withdrawal and actual streamflow depletion is more complex. The factors that must be considered are: location of a well in relation to nearby streams; the connection between the aquifer used by the well and the stream; the aquifer material and the distance and depth of the well screen from the stream. Computer models are used to incorporate these factors into the calculation of the streamflow depletion.

Determining how much is too much

Science cannot answer the question, "How much impact on water resources is too much?" That is a social question decided through the legislative process. State legislation created the water withdrawal assessment process and made the key policy decisions. As discussed before, the index flow is defined, and used as the metric by which water withdrawals are measured. The value of the index flow varies from place to place across the state, but the fact that it represents the lowest summer monthly median flow at that location is fixed. How streams are classified is defined and data on fish responses are adopted for each stream type. The legislature considered competing social values when it set risk-

Table A:
Cumulative Percent Reductions in Stream Index Flow Allowed per 2008 Michigan Legislation, by Ecological Stream Type and Management Zone

	Stream			*Small river*			*Large river*		
	A–B	*B–C*	*ARI*	*A–B*	*B–C*	*ARI*	*A–B*	*B–C*	*ARI*
Cold	14%	14%	20%	10.5%	10.5%	21%	. . .	. . .	. . .
Cold-Transitional	. . .	4	4	. . .	2	2	. . .	3%	3%
Cool	6	15	25	15	19	25	14%	19	25
Warm	10	18	24	8	13	17	10	16	22

Source: David A. Hamilton, Michigan Department of Natural Resources and Environment
Notes: Percent flow reductions denote the threshold lines between management zones A–D (D being equivalent to the legal standard of Adverse Resource Impact). Threshold lines were determined using flow-fish response curves and legislative workgroups.

based water management zones, including ARI, along the response curves for each stream type (Table A). Values for these zones and the ARI are determined as a percentage of the index flow. Index flows are all determined at the downstream end of each water management area. The process applies all these policy decisions to any large-quantity withdrawal at any location in the state.

Process Implementation

Authorizing a water withdrawal

Linking the fish response curves, stream classification map, index flow estimates, and estimated depletion of the water resources provides an answer to "how much water can be responsibly withdrawn" for each proposed large-quantity withdrawal. Every location in the state falls within a larger water management area. The stream segment draining every management area is assigned to a stream type. And for every stream type, the risk management zones are set as a percentage of the index flow. In every proposed scenario the two dynamic elements are: determining index flow and determining the withdrawal's depletion from nearby streamflows. These determinations can be handled in two ways—a site specific review using data developed from the site itself or a more generalized statewide screening model. The proposed water withdrawal is then compared with the amount of water available in the total water management area and the risk management zone is determined.

Based on the zone, certain actions must then be followed. If the result is Zone A, then the applicant may proceed with immediate, online registration. If the result is Zone D (likely to cause an ARI) then the withdrawal will not be allowed. The applicant could propose a measure to prevent harmful effects that would alter the amount of water withdrawal and/or the water temperature such that the proposed withdrawal would no longer cause an ARI. If the proposal results in Zones B or C, then, notifications of other water users and interested parties occurs, user groups may be formed and there may be requirements for water conservation measures.

Internet Screening Tool

In order to focus state agency resources on the most sensitive areas and also to efficiently approve withdrawals in areas where water is readily available, a statewide Internet-based screening tool was developed. The screening tool provides an initial assessment of the impact of a potential water withdrawal on local stream and river ecosystems. It operates within a Geographic Information System running on the Internet and can be used to quickly examine potential withdrawal sites anywhere in the state. It is designed with enough safeguards so that, when a proposed withdrawal clearly poses little or no risk to nearby stream ecosystems, the screening tool can approve and facilitate immediate online state registration of the withdrawal. But when a proposed withdrawal triggers concerns, the screening tool instructs the person to request a more detailed review by state agency staff.

The screening tool considers the geographic variations in Michigan's streamflows and fish communities and mathematical models of streamflow, groundwater dynamics, and fish ecology are used. The streamflow model uses information on soils, geology, land use and precipitation to predict how much flow is available in each stream. The groundwater model uses information about geology, well depth, pumping rate and distance from nearby streams to estimate how much a well will reduce the flow in nearby streams. And the fish ecology model determines how a reduction in streamflow is likely to impact the types and abundance of fish species that live there.

Notes

[1]Program Web page: *http://conserveonline.org/workspaces/eloha*.

[2]Michigan Groundwater Conservation Advisory Council, 2007. Report to the Michigan Legislature in response to 2006 Public Act 34, (2007).

[3]T.G. Zorn, P.W. Seelbach, E.S. Rutherford, T.C. Wills, S.T. Cheng and M.J. Wiley, "A landscape-scale habitat suitability model to evaluate impacts of groundwater withdrawals on fish communities in Michigan streams," *Michigan Department of Natural Resources Fisheries Research Report 2089*, (Ann Arbor, Michigan, 2008). *http://www.michigandnr.com/PUBLICATIONS/PDFS/ifr/ifrlibra/Research/reports/2089/RR2089.pdf*).

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