SOME "PROS AND CONS" OF ALTERNATIVE METHODS OF DEFINING INSTREAM FLOW REQUIREMENTS

Mary C. Freeman

AUTHOR: Mary C. Freeman, USGS Patuxent Wildlife Research Unit, Athens, Georgia 30602, Mary_Freeman@usgs.gov
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Abstract. The most widely-used approaches for establishing required instream flows to protect stream ecosystems, including standard-setting, incremental methodologies, and hydrologic variability analyses, can be assessed in terms of scientific support and ease in application. Together, these characteristics likely predict the efficacy of application to instream flow policy. Standard-setting approaches are the easiest to apply but least supported biologically. All of the commonly used approaches are necessarily based on generally untested assumptions that simplify the underlying complexity of relations between flow regimes and biological processes in fluvial systems. Combinations of differing methods, tailored to the management issues of specific stream systems and implemented along with monitoring to validate method assumptions, could provide one approach to developing scientifically sound instream flow requirements.

INTRODUCTION

Establishing instream flow requirements that will protect aquatic ecosystems while accommodating other societal uses of freshwater poses a substantial challenge to resource managers nationwide. The problem really is two-fold, societal and ecological. Society depends on aquatic ecosystems for water supply, waste dilution and assimilation, hydropower generation, and commercial navigation – all commonly recognized services supplied by streams and rivers. Society also depends on riverine systems, that is, streams and rivers and their adjoining riparian areas, to absorb floods, provide recreation, and support fisheries, wildlife, and biological diversity. Instream flow requirements, generally established by state regulatory agencies, are broadly intended to prevent other water uses from impairing ecological function. The societal component of the problem stems in part from a lack of public understanding and appreciation of the values derived from ecologically intact riverine systems. Additionally, legal and institutional frameworks may not be adequate or sufficiently developed to support establishment of flow requirements (Annear et al. 2004). The ecological component of the issue stems from the complex dependence of riverine ecosystems on flow regimes, and thus the difficulty of establishing simple flow requirements.

The complexity inherent in defining instream flow requirements, along with the regional diversity of water and resource protection issues, has resulted in a broad array of methodological approaches. A recent, comprehensive review of the topic (Annear et al. 2004) provides an overview of 34 instream flow assessment tools. My purpose is to provide a brief overview of the types of approaches that may be applicable in Georgia, with respect to strengths and weaknesses relative to the goal of sustaining ecosystem integrity, including the ability of systems to support naturally occurring diversity and abundances of animals and plants dependent on riverine systems.

Basis for Evaluating Methods for Establishing Instream Flow Requirements

To successfully protect the integrity of riverine ecosystems, an instream flow requirement must provide for the aspects of flow regimes that shape and support ecological function, and they must be doable (that is, capable of being defined and implemented, given available information and resources). Thus, below I consider differing approaches with respect to three criteria: 1) how comprehensively the requirements address ecosystem needs; 2) scientific support, in the form of validated relations between flow requirements and ecosystem benefit; and 3) effort required to develop and implement requirements.

Comprehensively addressing ecological flow needs requires recognizing the importance of natural flow variability, within and among years, to sustaining ecological processes in riverine systems. Although maintaining natural flow variability is only one component necessary to sustaining riverine systems (i.e., adequate water quality, channel maintenance and connectivity among parts of the river system are also essential), ecologists consider maintaining natural variability key to supporting ecosystem function (Poff et al. 1997). Addressing flow needs to support native species often also requires an understanding of how flows influence habitat availability for specific species or life stages, e.g., for differing guilds composing aquatic communities or for rare or imperiled species. Flow-habitat relations are essential for recognizing flow changes that could have relatively large effects on habitat (i.e., thresholds), and generally are site-specific.

The issue of scientific support relates to assumptions underlying each approach and the extent to which these have been tested by observation or experiment. Required effort refers to the amount and type of data and analyses needed to develop a flow recommendation.

APPROACHES TO ESTABLISHING INSTREAM FLOW REQUIREMENTS

Ecologists and managers generally categorize approaches for deriving flow requirements as standard-setting, incremental or "diagnostic" (Stalnaker et al. 1995, Annear et al. 2004). The only diagnostic method discussed by Annear et al. that is directly useful for prescribing flow regimes is based on assessing hydrologic variability. I discuss each of these categories below.

Standard-setting

Approaches that establish flows intended to protect one or more biological functions in streams, and below which flows cannot be diverted, are termed "standard setting". These include many approaches used by regulatory agencies, such as the Tennant, wetted perimeter, R2-Cross, and New England Aquatic Base Flow (ABF) methods. Each method relates one or more features of instream habitat to discharge and seeks to identify a threshold flow, most often a minimum flow, below which instream conditions are considered unsatisfactory for sustaining aquatic biota. For example, the ABF sets the August median flow as a minimum flow requirement on the assumption that average low flows during the naturally lowest flow period (generally August in New England) represent a limiting condition to which native fauna and flora have adapted. The ABF may similarly set other median flows as minimum requirements, e.g., during April and May to protect spawning habitat for fishes (Annear et al. 2004).

Advantages. Generally low cost to establish, requiring hydrologic records and in some cases, site-specific field measurements to relate hydraulic conditions to flow level.

Limitations. Standard-setting approaches do not address the need for inter-annual flow variability, or even variability within years except to the extent that different seasonal minimums are established. Minimum flows also do not protect functions provided by high flows, including channel scouring and floodplain inundation. Requirements are based on protecting some minimum level of habitat availability for biota, and do not generally evaluate habitat needs for particular species or processes. It also is assumed that the established standards are both sufficient and necessary for protecting stream biota, without providing the information needed to examine effects of incrementally varying flow requirements.

Incremental

The need to evaluate the consequences of different instream flow requirements, particularly in the context of negotiated flow settlements, led to the development of analytical approaches such as the Instream Flow Incremental Methodology (IFIM) and its Physical Habitat Simulation (PHABSIM) component (Stalnaker et al. 1995). Incremental approaches use analysis of one or more instream variables in relation to flow to assess alternative proposed flow management scenarios.

Advantages. Incremental approaches allow managers to ask "what if" a lower or higher flow requirement is set, in terms of effects on habitat availability for particular species and life-stages.

Limitations. Generally require extensive field measurements and analyses of habitat conditions in relation to flow level, and data to describe habitat (or hydraulic) conditions required by the targeted species and life stages, *in addition to* hydrologic records to allow comparison of proposed alternatives to baseline habitat conditions. Incremental methods are not advised for setting minimum flow requirements, but rather for comparing habitat effects of management alternatives (e.g., withdrawal levels or flow releases from a dam). Setting flow requirements based on incremental analyses assumes that one can identify (and thus avoid) habitat "bottlenecks". Although habitat needs for particular species are incorporated, protection of natural flow variability generally is not (i.e., except through the explicit analysis of multiple processes such as channel-formation, floodplain inundation, or periodic habitat provision for widely differing species).

Hydrologic Variability

Recognition of the importance of natural variation in flow through time in shaping and maintaining riverine ecosystems, and the difficulty of specifying flow requirements to meet the needs of the myriad species and component processes of aquatic ecosystems, led to development of the Range of Variability (RVA) approach for setting river management targets (Richter et al. 1997). The approach uses daily flow records (naturalized if necessary) to characterize natural variation in 32 hydrologic variables (such as monthly mean flows and low and high flows of certain durations), and prescribes river flow targets that protect natural levels of variability in these parameters. The US Fish and Wildlife Service and US Environmental Protection Agency used a similar approach to develop flow guidelines for use in the

Table 1. Summary of approaches for defining instream flow requirements with respect to consideration of flow variability and habitat needs of specific organisms, data required to implement, and major ecological assumptions.

Approach	Addresses natural flow variability?	Addresses species habitat needs?	Data requirements	Major assumptions
Standard-setting *e.g., Tennant, ABF, wetted perimeter, R2-cross*	No	No	Hydrologic records, limited field measurements	Biological function is conserved by protecting certain minimum flow levels
Incremental *e.g., IFIM, PHABSIM, floodplain inundation, hydraulic modeling*	No	Yes	Hydrologic records, extensive field measurements to quantify habitat-flow relations *and* species habitat needs	Biological function relates directly to habitat availability; can identify "habitat bottlenecks"
Hydrologic variability *e.g., RVA, EPA/USFWS guidelines for the use in the ACT and ACF systems*	Yes	No	Hydrologic records sufficient to estimate natural flow patterns	Providing natural variability in specified flow parameters will conserve ecological integrity

Alabama and Apalachicola river (i.e, ACT/ACF) systems. These guidelines specify levels of variability to be maintained in monthly average, low and high flow occurrences as water resources are developed (USFWS and USEPA 1999).

Advantages. Explicit consideration is given to maintaining natural hydrologic variability. Proposed flow alterations can be evaluated with relatively low cost provided that hydrologic records are available or can be synthesized.

Limitations. These approaches do not provide a single flow requirement, but rather a set of flow conditions to be met. It is assumed that the hydrologic variables used to set the requirements capture the ecologically relevant features of the flow regime. The methods also require that natural flow patterns can be quantified – generally requiring historical records of daily flow unaltered by dams or diversions. The methods further assume that the stream channel has not been substantially altered; providing a natural flow regime to an altered channel would not necessarily provide the conditions required to support the river ecosystem.

SUMMARY AND CONSIDERATIONS

All of the approaches commonly used to set instream flow requirements are limited in their comprehensiveness and rely on generally untested assumptions. One of the assumptions underlying standard-setting, that protecting minimum flows can protect biological functions, is not supported by our understanding of the ecological importance of flow variability. The assumed linkages between habitat and biota underlying incremental approaches have been supported in some case studies of population variation (Stalnaker et al. 1995). However, in typical applications the manager still must regulate with scant information to assess when a projected change in habitat (because of flow alteration) is unacceptable. Recommendations based on preserving hydrologic variability assume that we have identified the most ecologically-relevant flow parameters and the requisite amount of variability. Extensive research has established the relevance of parameters such as flow seasonality and the frequency and duration of high and low flow pulses to various ecological processes (Poff et al. 1997). However, available data are not typically sufficient to predict quantitative ecological responses to altered variability in these flow parameters in a particular stream. Testing any of these assumptions will require measuring ecological responses (e.g., changes in biotic assemblages, in populations of imperiled species, or in productivity) to measured changes in hydrology and instream habitat conditions. This kind of monitoring needs to extend for a sufficient period to allow detection of responses that lag changes in flow regime, and should continue as long as management changes continue.

Developing flow management policies that meet the goals of supplying human needs for offstream use and sustaining ecological integrity of streams and rivers will require explicit recognition of the complex relationships between flow and biological processes in fluvial ecosystems. Managers and scientists can approach this complexity on a site- or river-specific basis by developing flow recommendations from hypothesized levels and durations of differing flow parameters necessary to support specific ecological processes (Postel and Richter 2003). For example, seasonal high and low flow recommendations for improving ecological function in the lower Savannah River (downstream from Thurmond Dam) have been developed through such an approach (Richter et al. 2003).

In the context of developing statewide policies, no single method of setting flow requirements is likely to address adequately the flow needs for ecological sustainability balanced with human uses. In particular, standard-setting approaches can only be supported scientifically if coupled with other management actions (e.g., limits on water withdrawals, provisions for high-flow pulses) that protect natural levels of flow variability. Combinations of approaches tailored to meet the issues in specific stream systems may provide workable, scientifically supportable approaches.

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