VIRGINIA WATER RESOURCES RESEARCH CENTER

ISSUES CONCERNING BIOASSESSMENTS AND THEIR USE WITH NARRATIVE STANDARDS: REPORT OF THE BIOASSESSMENT SUBCOMMITTEE OF THE WATER QUALITY ACADEMIC ADVISORY COMMITTEE

SPECIAL REPORT

Virginia Tech

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
BLACKSBURG, VIRGINIA

2004

This special report is a publication of the Virginia Water Resources Research Center and was published with funds provided in part by the Virginia Department of Environmental Quality. The contents of this publication do not necessarily reflect the views or polices of the Virginia Department of Environmental Quality or the Virginia Water Resources Research Center. The mention of commercial products, trade names, or services does not constitute an endorsement or recommendation.

Additional copies are available while the supply lasts and may be obtained from the
Virginia Water Resources Research Center
23 Agnew Hall
Blacksburg, VA 24061
(540) 231-5624
FAX: (540) 231-6673
e-mail: water@vt.edu
homepage address: http://www.vwrrc.vt.edu

Single copies are free to Virginia residents.

Tamim Younos, Interim Director

ISSUES CONCERNING BIOASSESSMENTS AND THEIR USE WITH NARRATIVE STANDARDS: REPORT OF THE BIOASSESSMENT SUBCOMMITTEE OF THE WATER QUALITY ACADEMIC ADVISORY COMMITTEE

Prepared for the
Virginia Department of Environmental Quality,
Division of Water Quality Programs

Leonard A. Smock (Chair)
Department of Biology
Virginia Commonwealth University

E. Fred Benfield
Department of Biology
Virginia Tech

Theo Dillaha
Department of Biological Systems Engineering
Virginia Tech

Saied Mostaghimi
Department of Biological Systems Engineering
Virginia Tech

Leonard A. Shabman
Virginia Water Resources Research Center
Virginia Tech

Eric P. Smith
Department of Statistics
Virginia Tech

Tamim Younos
Virginia Water Resources Research Center
Virginia Tech

Carl E. Zipper
Department of Crop and Soil Environmental Sciences
Virginia Tech

Virginia Water Resources Research Center
23 Agnew Hall
Virginia Tech
Blacksburg, VA 24061

June 2002

VWRRC Special Report No. SR 23-2004

TABLE OF CONTENTS

Issues Concerning Bioassessments and Their Use With Narrative Standards: Report of the Bioassessment Subcommittee of the Water Quality Academic Advisory Committee

Introduction

In the 1997 *Water Quality Monitoring, Information and Restoration Act (WQMIR)*, the Virginia General Assembly directed the Virginia Department of Environmental Quality (DEQ) to develop the EPA-required 303(d) and 305(b) reports in consultation with experts from the state's universities. Also, the WQMIR requires the DEQ to "develop and publish a procedure governing its process for defining and determining impaired waters and shall provide for public comment on the procedure" with the assumption that these 303(d) procedures will be developed after consultation with scientists from the state's universities. To meet the WQMIR academic consultation requirements, DEQ asked the Virginia Water Resources Research Center (VWRRC) to organize and coordinate a Water Quality Academic Advisory Committee (AAC) as an independent advisory body.

In 1997-1998, the AAC reviewed and evaluated the scientific merits of the DEQ's existing and evolving water quality assessment procedures for the 305(b) and 303(d) reports. The AAC's 1997-1998 findings submitted to DEQ are documented in VWRRC Special Report No. SR-8-1998. In 1999-2000, the AAC addressed topics of concern to the DEQ in three general areas: issues relating to biological monitoring protocols; modeling techniques and other methods relating stressor to benthic degradation and fecal contamination; and water quality goals and setting water quality standards. The report of the AAC to DEQ for years 1999 and 2000 is VWRRC Special Report No. SR18-2000. Electronic copies of the special reports are available from the VWRRC Website: www.vwrrc.vt.edu.

The Water Quality Academic Advisory Committee work effort for 2001-2002 is a logical extension of the previous work efforts. The fiscal year 2002 work plan was organized around a review of, and report on water quality standards and the assessment of their attainment. This report summarizes the efforts of the AAC's Bioassessment Subcommittee in addressing issues concerning bioassessments and their use with Virginia's narrative General Standard.

Purpose

The responsibility of the AAC Bioassessment Subcommittee in 2001-2002 was to address the following four issues relating to the scientific merits of DEQ's benthic bioassessments:

1. Reference stations as *de facto* standards
2. Can narrative standards be used with biological data?
3. Standards for low-flow streams
4. Appropriate methods for using benthic data in TMDL development?

Procedure

The Water Quality Academic Advisory Committee (AAC) met with DEQ staff in Charlottesville on October 5, 2001 to determine issues to be addressed by the AAC for DEQ. From this meeting, there developed four issues that concerned benthic bioassessments. The issues focused on questions of methodology and the use of benthic data in terms of narrative water quality standards and in the development and assessment of TMDLs. The Bioassessment Subcommittee of the AAC was asked to address the four issues.

All subcommittee members were requested to provide written responses concerning the four issues, to include an analysis of the problem, related issues, and possible recommendations to DEQ for both short-term and long-term actions. Those responses were synthesized and provided to all members. The subcommittee then met, along with DEQ personnel, on April 5, 2002, at which time each issue was discussed in depth. The report that follows presents a synthesis of the issues and recommendations developed by the subcommittee. The individuals who participated in the April 5 meeting were:

AAC Subcommittee Members:

- Dr. Leonard A. Smock (Chair)
- Dr. E. Fred Benfield
- Dr. Saied Mostaghimi
- Dr. Eric Smith
- Dr. Leonard Shabman
- Dr. Tamim Younos
- Dr. Carl Zipper

DEQ Staff:

- Ms. Jean Gregory
- Mr. Charles Martin

Other Attendees:

- Ms. Jane Walker
- Dr. Gene Yagow

1. Reference stations as *de facto* standards

Background Information

Bioassessments are conducted to measure the "health" of a stream, that is, the biological community reflects the wide variety of conditions in a stream that together are perceived as indicting water and habitat quality. Reference stations, benchmarks against which other streams are compared in terms of water and habitat condition, are used in conjunction with the biological assessments of benthic macroinvertebrates for 305(b) listing.

In Virginia, at present, individuals charged with conducting biomonitoring typically attempt to use a reference station that is considered to be "pristine." Pristine, or presettlement, conditions are used for reference stations because observed differences in the monitoring data of a pristine stream and the stream in question are expected to be most pronounced and thus stressor impacts more easily detected. Many areas do not support pristine streams because of past and present land uses. Therefore, biomonitors typically select as reference stations streams that have the "best available" quality for a given region.

Under the present approach used by DEQ, the selection of a reference stream implicitly sets the desired water quality goal. More specifically, the desired quality is based on the professional judgment of a single field biologist who is seeking what, in his/her judgment, is the least impacted stream in a given area. A selection process that relies on individuals leads to much variability in the chosen site, ranging from somewhat disturbed to little disturbed depending on regional conditions. This potential for considerable subjectivity in reference station selection can lead to possible inaccuracies in stressor identification in the benthic bioassessment process.

The current DEQ approach for selection and use of a reference condition also poses a problem to the use of bioassessment for water quality management and developing TMDL reports. In the 303(d) listing process, waters are listed as impaired if the benthic community does not score within a given range of the reference station. As such, the reference stations have become *de facto* water quality standards used for 303(d) listing and may result in the requirement of the development of a TMDL for a stream segment with the implied goal of achieving the benthic community comparable to the least impacted site previously identified as the reference station.

The present approach for selecting and using reference streams begs several questions. Does the best available reference stream actually reflect the quality desired for streams in a given region? Does the best available stream have a sufficiently high quality that matches the desired quality, or are streams in a given region being held to a standard lower than desired? Or does the best available stream have a quality that is higher than can ever reasonably be attained by other streams in the region?

The justification for the use of the least impacted reference station as a *de facto* standard was a question posed for review to the AAC. DEQ requested an analysis of this approach to listing and sought recommendations on how to best apply the use of references stations in the assessment of water quality using benthic communities. There are two primary, interconnected points associated with this issue. The first concerns how reference stations are chosen. The second concerns what condition a reference station should reflect and, thus, the standard to which other streams are held.

AAC Approach to Address the Issue

To address the questions posed to the AAC, the AAC was guided by two EPA documents: the EPA document defining the bioassessment policy (EPA 1991) and the EPA document recommending the bioassessment approach (EPA 1990). According to EPA guidance, the selection of "pristine" or "least impacted" sites as references is not always desirable, especially

within highly developed areas. EPA (1991) states that: "Biological criteria can be quantitatively developed by identifying unimpaired or least-impacted reference waters that operationally represent the best attainable conditions." In highly developed areas, in-stream conditions represented by a pristine forest may not represent "best attainable." EPA documentation (1990, Chapter 5) reflects this reality: "An important benefit of a regional reference system is the establishment of a baseline condition for the least impacted surface waters within the dominant land use pattern of the region. In many areas a return to pristine, or presettlement, conditions is impossible, and goals for waterbodies in extensively developed regions could reflect this." EPA's documentation cautions that selection of a "least impacted" site as a reference within a region where all water bodies have been degraded – and therefore setting a standard that is less than "best attainable" – should be avoided. However, the documentation also states that the selection of references based on "minimally-impacted sites [that] are not typical of most sites in the region and may have remained unimpaired precisely because they are unique" should be avoided because such practice will result in unrealistic standards. Furthermore, the AAC took into consideration the different degrees of water quality or health that might be desired for different waterbodies.

AAC Recommendation: Processes for Defining a Reference Condition

There are several ways by which variability and subjectivity in reference condition selection can be overcome. The AAC recommends the short-term and long-term approaches described below.

In the short term, the AAC recommends that the DEQ should develop a specific protocol addressing how reference stations are chosen across all regions. Once a protocol is developed, there should be training in the use of that protocol and occasional review of the field staff use of the approach. At the very least, reference stations should be chosen using best professional judgment by an advisory committee rather than by only one or a few individuals, as presently done. Such a procedure would be more defensible because it would reflect a professional and agency consensus on the sites. The advisory committee could consist of individuals both internal and external to DEQ, for example, including DEQ's regional biologists charged with conducting bioassessments and other individuals with expertise in bioassessments.

In the long term, the AAC recommends an alternative approach: the development of reference conditions. In this approach, a suite of streams in a region would be sampled and benthic metrics for all sites would be calculated. A subset of those streams typical of the region and with the highest quality, as indicated by the metrics, would be used to calculate mean values for each metric. These values thus would provide a statistically based mean and variance that define the benthic characteristics of a model reference stream for that region. This approach is far better than a single station approach in that it incorporates and reflects the natural variability associated with streams throughout a region based on differences in stream geomorphology, hydrology and other characteristics that together determine the structure of the benthic community. Such an approach could be applied to develop models appropriate for different regions of ecological similarity, hydrologic regimes (*e.g.*, flow/watershed size categories), and seasons.

Once developed, regional reference conditions could be incorporated into accepted protocols, or possibly standards (see below), making them more defensible. The specific benthic metric values against which other streams would be compared thus would be predetermined, rather than at present where reference metric values change each time a reference stream is sampled or a new reference stream is chosen. This latter point is important in that using a model approach removes the problem often seen whereby a reference site chosen one year becomes no longer suitable later because of changes in land use or inputs to the stream.

AAC Recommendation: Reference Conditions, Aquatic Communities and Standard Setting

A critical point generally not discussed is the level of quality desired for a given stream or for streams in a given region. Presently, the level of quality is set implicitly by the selection of a reference station. The desired quality, however, should be a policy decision, rather than being set by field biologists whose goal typically is to use what, in their judgment, is the least impacted stream in a given area.

Whether a single site or a number of sites are used to create a reference, the choice of sites needs to be made in recognition of their use in 303(d) listing. If the sites are being chosen as a way to identify all possible stressors then the least impacted sites might be selected. However, if the reference will be used as the basis for a 303(d) listing then a reference more "typical of the region" may be needed. It is this later use, and most likely use, that make the question of what conditions a reference station should reflect more complex.

The desired reference condition for a stream should be linked to the designated use of the stream, incorporating a basin perspective. Specifically, the desired use should reflect not only in-stream uses such as drinking water or aquatic life, but also the land use practices in the basin. The designated use of a stream flowing through an urban area or an area with high agricultural use thus might be different than for one flowing through a heavily forested basin.

EPA documentation refers to a process called “refining aquatic habitat use classifications” as an essential component of biological criteria development (EPA 1990, Chapter 4). This process could be adapted to reflect land-use conditions within watersheds. According to this documentation, it is acceptable for the states to establish subcategories of uses within the act’s general categories on the basis of factors essential to aquatic community structure, such as attainable habitat. DEQ should consider proposing the predominant terrestrial ecosystem structure as a designated use refinement. Aquatic communities within streams draining forested watersheds can be expected to differ from those in non-forested watersheds (agricultural and urban) as a result of terrestrial ecosystem structure.

One way for DEQ to approach the challenge of appropriate designated uses is to determine the values of benthic metrics necessary in order for a stream to have the quality needed to support the designated use. The reference model or mean reference condition would reflect the best possible condition a stream could have in the region. Then, a stream with a designated use requiring high quality would need to have benthic metrics that closely approached or equaled those of the reference condition. A stream with a designated use requiring lower quality would

need to meet metric values something less than fully equal to the reference condition, for example, 75% or 50% of the reference condition. Such a system has been developed and applied in Ohio.

However, a different approach to using the benthic assessment for listing may have more merit than the selection of a percentage without explicit consideration of specific watershed conditions. This approach would treat the reference model condition as a first level screen that then triggers further inquiry into the conditions of a waterbody before listing the water as impaired. Specifically, if the benthic community in a waterbody is at least equivalent to the mean reference condition then the waterbody is not listed as impaired. If the benthic community is of lower quality then this finding is treated as 1) evidence of unusual stressors in the region and 2) a requirement for a more detailed assessment of the specific waterbody situation and specification of an aquatic life support use appropriate to the waterbody. It may be discovered upon further investigation that some features of the land use that are irreversible may be the cause of the difference. In that case, the current benthic condition in the waterbody (existing use) might be made the criterion in the water quality standard to represent the designated use of aquatic life support for that stream segment. However, if no unusual land use conditions exist, there is a need to identify the stressors and determine the best response to stressor reduction. In this case, the waterbody would need to be listed as impaired, and a TMDL would be needed for the identified stressor(s).

Once the stressors are isolated, the benthic community condition to be achieved might be developed as a part of the watershed water quality planning process. This planning step allows for consideration of the stressors effects in the immediate water body, as well as downstream. Consider the following example. A waterbody may have an impaired benthic community because of elevated ammonia levels. It may be determined that the elevated levels are not having unacceptable adverse consequences on the recreation or fishery uses of the stream. On this basis it may be determined that the condition of the benthic community, which has adjusted to the elevated ammonia level, is acceptable for the stream. However, it might also be the case that downstream areas suffer from nutrient enrichment that is affecting a valuable estuary. In this case reducing the ammonia levels may be seen as a way to reduce nitrogen loadings to the estuary below the segment. The response of the benthic community to reduced ammonia levels in the segment might be a measure of the success of the ammonia reduction effort. Note the reason for seeking the ammonia reduction is not because of the localized effects on the benthic community, but that the condition of the benthic community serves as a signal of a stressor that needs reduction because of its effect outside the local area. This approach uses the condition of the benthic community as a guide to listing and water quality management, but the condition of the benthic community does not default to being a standard.

Such a procedure would link water and land use policy with a science-based approach to biological assessment, something that generally is lacking at present. The required quality of water in a stream and in downstream areas would be defined by making reference to a criterion that measures the condition of the benthic community. In conjunction with development of a model reference stream, the metric values necessary to form a foundation for the use of benthic criteria in water quality management would be clearly defined.

2. Can narrative standards be used with biological data?

Background Information

Waters defined as impaired for such reasons as dissolved oxygen, pH, or fecal coliforms are in violation of numeric standards. Waters defined as impaired based on biological assessments, however, are in violation of narrative water quality criteria. As such, surface waters thus may violate Virginia's narrative General Standard:

> *All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life* (9 VAC 25-260-20).

Waters may also violate narrative standards associated with the designated uses of the water. For example, Virginia's aquatic life use includes "the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit" the waters (9 VAC 25-260-10).

It has been argued that these narrative standards are too vague and imprecise to be used as standards for the identification and 303(d) listing of biologically impaired streams. However, EPA requires that states use their biological monitoring data in assessments, even if the state only has narrative biological criteria and does not have numeric biocriteria in its regulations. Given that Virginia only has narrative standards relevant to biological assessment, the state must develop its biological assessment program to be usable and defensible with those standards.

DEQ requested that the AAC address the question of how to apply, in a technically defensible fashion, results using the EPA's Rapid Bioassessment Protocols (RBP) under the existing narrative standards.

AAC Recommendations

The AAC did not focus on the appropriateness of the designated uses or the appropriateness of the existing narrative standards. The AAC does recommend that DEQ examine the narrative biological criteria in the water quality standards to determine how they could be re-written to recognize differences in physiographic region, watershed conditions, and current and prospective human uses. Only in this way can numerical biocriteria begin to be defined.

A key point in the use of bioassessments, either with narrative or numerical standards, is that probabilistic sampling and analytical protocols are accepted by the bioassessment community and in particular EPA, that they are strictly adhered to, and that they are clearly detailed. While DEQ presently uses the EPA's initial RBP protocols (Plafkin *et al*. 1989), it has not adopted the revised protocols (Barbour *et al*. 1999). Those protocols present detailed information on sampling procedures and data analysis. The AAC recommends that DEQ move quickly to fully implement strict adherence to these revised protocols, thereby making use of bioassessments more defensible.

The revised protocols allow some flexibility in how and where samples are taken, for example continuing to sample the most productive habitat in a stream versus compositing samples from habitats proportional to their relative abundance in a stream. The AAC recommends that DEQ review the sampling options to determine which is most appropriate for each DEQ region. However, the AAC also recommends that DEQ not change its sampling procedures unless necessary, thereby allowing data collected previously to be consistent with data collected in the future and thereby facilitating trend analysis.

The new protocols also call for a determination of the most appropriate metrics to be used for the analysis of the data and for their calibration such that the degree of existing impairment can be accurately determined. Whereas the old protocol provided specific metrics to calculate, the new protocol provides a suite of metrics of which only some should be used for data analysis. Determining the appropriate metrics to be used, and the determination of thresholds between condition classifications, requires studies done on an ecoregion basis. The Tetra Tech report "A stream condition index for Virginia non-coastal streams," reviewed in draft form (Draft 1.0, May 2002) by the AAC, provides the basis for implementing this recommendation.

The AAC suggests that DEQ evaluate its approach for 303(d) listing and that DEQ collect a basic set of information at both impaired and unimpaired streams to help develop a database for future use. When listing streams, error rates derived from the collected data should be considered, as should the quality and use of the data. A final point is that the AAC does not believe that one benthic sample should be sufficient to cause a site to be designated as impaired. The high variability associated with environmental factors that can affect benthic communities is such that we recommend additional sampling be conducted to confirm the status of the stream condition. We suggest that once a stream is flagged as potentially being impaired by a benthic bioassessment, that it first be placed on a watch list whereby the stream receives a high priority for re-sampling. Consecutive samples that classify the stream as being impaired could then cause it to be listed as impaired.

3. Standards for low-flow streams

Background Information

Benthic communities are greatly influenced by flow conditions in streams, low flow being a natural stressor of those communities. Biological assessments of streams with naturally occurring low flow conditions may reflect the impact of low flow, and those impacts may obscure or compound the effects of anthropogenic inputs on the benthic community. Currently, the general water quality standard applies to all Virginia waters except where site-specific variances are issued. The question of the issuance of variances for stream segments with naturally low flow thus arises.

AAC Recommendations

Streams with naturally occurring low flows and droughts are natural stressors of benthic communities, similar to the low dissolved oxygen concentrations often observed in swamp waters. As such these natural stresses owing to low flows should not cause a stream to be listed as impaired.

The conclusions drawn from bioassessments can be greatly influenced by naturally occurring low flow conditions. Key to the assessment of streams experiencing low flow is having a reference stream that has the same flow regime as the stream being assessed. The accuracy of the bioassessment can be called into question when the hydrologic regimes of the study and reference stations cannot be closely matched. In such a case, it may be advisable to have a threshold value for rainfall, groundwater levels, or stream flow that indicate drought conditions. Under such conditions, streams assessed as failing to achieve the reference condition would be placed on a watch list with a high priority for re-sampling under non-drought conditions. Other alternatives include revising the narrative standard to specifically address drought conditions. For example, the narrative could read that "two or more samples under non-drought conditions are required" or that "two samples taken at flow conditions greater than 7Q10 are required" to cause a stream to be listed as impaired.

The assessment of effluent dependent streams should be tied to the designated use of the stream. It may well be that no reference condition for effluent dependent streams can be developed. In that situation the state of the benthic community can only be judged by explicitly translating a designated use (example, warm water fishery) into a benthic criterion for determining if that use is being attained. Whether the use of an effluent dependent stream should be based on the pre-discharge or post-discharge flows is a policy matter, and therefore the AAC did not address this issue.

4. Appropriate methods for using benthic data in TMDL development?

Background Information

For Total Maximum Daily Load (TMDL) development, it is necessary to know the effect of specific pollutants on the benthic macroinvertebrate community. However, the benthic community typically is reacting to multiple stressors and thus cumulative impacts. In such situations, it can be difficult or impossible to determine the extent of the effects of specific pollutants. Probable critical stressors may be identified by using published data on the tolerances or responses of benthic organisms to specific water quality parameters, but such information generally is lacking in a useful form. Probable critical stressors may also be determined by comparing biological, chemical, and physical data obtained from the impaired watershed to those obtained in a reference watershed. Regression analysis can likewise be used to establish a link between stressors and benthic community measures.

Once the probable critical stressors have been identified, the TMDL target loads (endpoints) for streams with benthic impairments need to be made. DEQ currently uses two approaches to set

the TMDL endpoints for streams with benthic impairments. One method uses a reference watershed, in which the water quality of a reference stream within the reference watershed is used to set the endpoints for the impaired stream. The goal is to attain aquatic support equivalent to that in the reference stream. The other approach employs regression equations relating benthic data to stressor parameters, the equations providing endpoints for inputs of those stressors such that benthic impairment will not occur.

DEQ requested an analysis of and recommendations concerning the pros and cons of the different methods by which benthic data are employed to develop TMDLs, including specifically the watershed and regression equation approaches. An additional aspect of this issue focuses on how to apply benthic data, within the context of a narrative standard, to the development of a TMDL endpoint.

AAC Recommendations

The AAC recommends that in addition to collecting benthic data, DEQ should also collect data on covariates for all reference stations and streams being assessed. Such data are needed when using either the reference watershed approach or regression analysis.

For the reference watershed approach, selection of the reference watershed is perhaps the most critical component of the TMDL process. An ideal reference watershed should have similar size, geology, topography, and natural stream water quality characteristics to those of the impaired watershed. The primary challenge is to find such a watershed, which in many geographic areas is nearly or completely impossible. The DEQ needs to also consider the natural variability among watersheds, determine the extent of that variability, and incorporate the variability into the TMDL process. While this natural variability necessitates development of complex models to compare pollutant loads between watersheds, it also allows for the development of more realistic and defensible TMDLs.

A second option used in the TMDL process is to use regression analysis to establish a link between stressors and benthic community measures. The strength of this method is that the regression equation theoretically establishes a direct relationship between differences in stressor concentrations and variations in the benthic community. For example, regression analysis has proved successful for streams in Southwest Virginia where acid drainage is the predominate stressor. Finding a statistically strong relationship between specific stressors and benthic community measures, however, is expected to be a difficult task for streams with multiple stressors, and the ACC considers it unlikely that the regression approach will apply as neatly in streams with several critical stressors.

A potential problem in applying the regression approach is that the stressor impact on benthic macroinvertebrates cannot necessarily be quantified from simultaneous water sampling and macroinvertebrate sampling data. For example, consider the impact of waterborne sediment on macroinvertebrates. Because in-stream sediment concentration is flow dependent and highly variable, sediment and macroinvertebrate samples normally collected during moderate-to-low-flow conditions would not adequately reflect the true stressor impacts. In order for the

regression approach to be successful, the AAC expects that water quality data representing the full range of flow conditions will be necessary.

The AAC found that it had insufficient information to choose either the reference watershed approach or the regression analysis approach over the other method. The Committee recommends that a thorough analysis of the two methods be conducted. Such an analysis could include using both methods to simultaneously develop a TMDL for a given watershed. Members of this advisory committee or others could then evaluate the process, outcome, and confidence level for each method. An additional comment is that if the reference watershed approach is to be used, a database must be developed to determine the mean and range of target conditions (See Question 1).

How to apply benthic data, especially within the context of a narrative standard, to the development of a TMDL endpoint is a related issue. The key point here is that, at present, benthic metric scores provide a cumulative measure of stream health. They have not, however, been calibrated to a narrative standard and have not been sufficiently related to changing concentrations and thus impacts of specific stressors. Specific benthic metric scores thus should not be used as an endpoint goal of a TMDL. Rather, the ACC believes that it is best to use bioassessments as a flag that triggers a TMDL process that is focused on reaching target goals of specific stressors. The specific stressors affecting the benthic community would be identified and the extent to which those stressors must be reduced to allow the benthic community to develop back to an unimpaired condition would be determined. Following implementation of the TMDL, monitoring of the benthic community would indicate if the stressors have been reduced to an appropriate level.

References

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish*. Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency, Office of Water. Washington, D.C.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. *Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish*. EPA 440-4-89-001. U.S. Environmental Protection Agency, Office of Water Regulations and Standards. Washington, D.C.

U.S. EPA. 1991. "Policy on the use of biological assessments and criteria in the water quality program." in *Water Quality Standards Handbook*. Second Edition. Appendix R. http://www.epa.gov/waterscience/library/wqstandards/handbookappx.pdf

U.S. EPA. 1990. *Biological Criteria: National Program Guidance for Surface Waters.* http://www.epa.gov/bioindicators/html/biolcont.html

Appendix A: Members of the 2001-2002 Academic Advisory Committee

Dr. Leonard A. Shabman (Chair)
Director, VWRRC
Virginia Tech
10 Sandy Hall (0444)
Virginia Tech
Blacksburg, VA 24061
540-231-6844
Fax: 540-231-6673
E-mail: shabman@vt.edu

Dr. E. Fred Benfield
Department of Biology
Virginia Tech
2125 Derring Hall (0406)
Blacksburg, VA 24061
540-231-5802
Fax: 540-231-9307
E-mail: benfield@vt.edu

Dr. Theo Dillaha
Department of Biological Systems Engineering
Virginia Tech
200 Seitz Hall (0303)
Blacksburg, VA 24061
540-231-6813
Fax: 540-231-3199
E-mail: dillaha@vt.edu

Dr. Carl Hershner
Chair, Resource Management & Policy
Virginia Institute of Marine Science
P.O. Box 1346
Gloucester Point, VA 23062-1346
804-642-7387
Fax: 804-642-7182
E-mail: carl@vims.edu

Dr. Howard I. Kator
Biological Sciences
Virginia Institute of Marine Science
P.O. Box 1346
Gloucester Point, VA 23062-1346
804-684-7341
Fax: 804-642-7399
E-mail: kator@vims.edu

Dr. Saied Mostaghimi
H.E. and Elizabeth F. Alphin Professor
Department of Biological Systems Engineering
Virginia Tech
200 Seitz Hall (0303)
Blacksburg, VA 24061
540-231-7605
Fax: 540-231-3199
E-Mail: smostagh@vt.edu

Dr. Eric P. Smith
Department of Statistics
Virginia Tech
406-A Hutcheson Hall (0439)
Blacksburg, VA 24061
540-231-7929
Fax: 540-231-3863
E-mail: epsmith@vt.edu

Dr. Leonard A. Smock
Chair, Department of Biology
Virginia Commonwealth University
P.O. Box 84201
Richmond, VA 23284-2012
804-828-1562
Fax: 804-828-0503
E-mail: lsmock@saturn.vcu.edu

Dr. Tamim Younos
Associate Director & Research Scientist
VWRRC
Virginia Tech
10 Sandy Hall (0444)
Blacksburg, VA 24061
540-231-8039
Fax: 540-231-6673
E-mail: tyounos@vt.edu

Dr. Carl E. Zipper
Department of Crop and Soil Environmental Sciences (0404)
Virginia Tech
330 Smyth Hall (0404)
Blacksburg, VA 24061
540-231-9782
Fax: 540-231-3075
E-mail: czip@vt.edu