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TMDLs (Total Maximum Daily Loads) for Bacteria Impairments

Brian L. Benham, Assistant Professor and Extension Specialist, Department of Biological Systems Engineering, and Director, Center for TMDL and Watershed Studies, Virginia Tech
Sara C. Zeckoski, Watershed Studies Intern, Center for TMDL and Watershed Studies, Virginia Tech

A water-quality "impairment" exists if a body of water is unable to support its *designated uses*. (Italicized terms are defined in the boxes at the bottom of each page.) Virginia's *water-quality standards* specify that surface waters are either designated for "recreational use" (e.g., swimming, fishing, and boating) or "aquatic life use" (e.g., viable fishing populations). To support the "recreational use," the state sets numeric *water-quality criteria* for the maximum amount of bacteria in surface waters (*Escherichia coli (E. coli)*) for fresh water and *enterococci* for marine waters). When the concentration of bacteria exceeds the state-specified water-quality criteria, the water does not support the designated recreational use and is deemed to have a bacteria or pathogen impairment. *E. coli* and enterococci bacteria are found in the intestinal tracts and feces of warm-blooded animals, including humans. High counts of these bacteria indicate the presence of fecal contamination in water.

How are bacteria impairments determined?

Bodies of water in Virginia are monitored regularly in order to test for the presence of fecal coliform bacteria, specifically for the indicator organisms *E. coli* and enterococci, in freshwater and marine environments respectively. The Virginia Department of Environmental Quality (DEQ) evaluates bacteria levels to determine whether they are in compliance with state water-quality standards. Water samples are collected and analyzed for bacteria content at regular intervals. The specific freshwater-quality standard for bacteria set an instantaneous, or single sample, standard of 235 colony forming units of *E. coli* per 100 milliliters (cfu/100mL) of water and a *geometric mean* standard of 126 cfu/100mL if more than two water-quality samples are collected in any given calendar month. In the same way, specific marine water-quality criteria for bacteria set an instan-

designated use - those uses specified in water quality standards for each water body or segment. All Virginia waters are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish. Taken together, these uses are generally stated as "fishable and swimable." Through the protection of these uses, other uses such as industrial water supply, irrigation and navigation also are protected.

E. coli (Escherichia coli) - a subgroup of fecal coliform bacteria that are present in the intestinal tracts and feces of warm-blooded animals. E. *coli* are used as an indicator of the potential presence of pathogens.

enterococci - a subgroup of fecal streptococci bacteria that are present in the intestinal tracts and feces of warm-blooded animals. Enterococci bacteria are used as indicators of the potential presence of pathogens.

water-quality standards - a group of statements that constitute a regulation describing specific water quality requirements. Virginia's water quality standards have the following three components: *designated uses, water quality criteria to protect designated uses, and an antidegredation policy.*

water quality criteria - include general narrative statements that describe good water quality and specific numeric criteria that are based on specific levels of pollutants that, if exceeded, would result in a water body not supporting a desginated use. The numerical and narrative criteria taken together describe water quality necessary to protect designated uses.

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taneous standard of 104 colony forming units of enterococci per 100 milliliters of water and a geometric mean standard of 35 cfu/100mL for more than two water-quality samples in any given calendar month. If more than 10 percent of the samples collected within a given assessment period exceed the instantaneous standard, the water body is placed on the state's *303(d) list* of impaired waters. (Because the DEQ normally collects samples on a monthly or quarterly basis, the geometric mean criterion is not generally used to include waters on the state's 303(d) list of impaired waters.) The DEQ is then responsible for developing a Total Maximum Daily Load (TMDL) for waters on the 303(d) list. The 2004 303(d) list included 5,474 miles of streams and rivers, 2,876 acres of lakes, and 117 square miles of estuaries impaired by bacteria.

What is a TMDL?

A TMDL defines the total pollutant load a water body can receive and still meet the applicable water-quality standards. The TMDL development process includes three phases: identifying the sources of the pollutants causing water-quality impairments; quantifying the pollutant contribution from each source; and determining the pollutant reduction from each source required to meet applicable water-quality criteria. The final two phases often are accomplished with the aid of a watershed model. Watershed models are computer programs that allow the user to simulate specific hydrologic and water-quality processes and conditions. Hydrologic and water-quality models relate "inputs" like watershed characteristics (land use, topography, soil type, and pollutant sources) to "outputs" like runoff and in-stream pollutant loads (Figure 1).

TMDLs must take into account current pollutant sources and where appropriate, estimate future pollution loads. Although bacteria TMDLs are developed using the best available science, some uncertainty is inherent in the source description and modeling process. Because of this, all TMDLs must include a *margin of safety*. Specifically, in Virginia, bacteria TMDLs are developed to include an implicit or a "built-in" margin of safety. To establish this margin of safety, conservative choices are made while developing the TMDL with respect to bac-

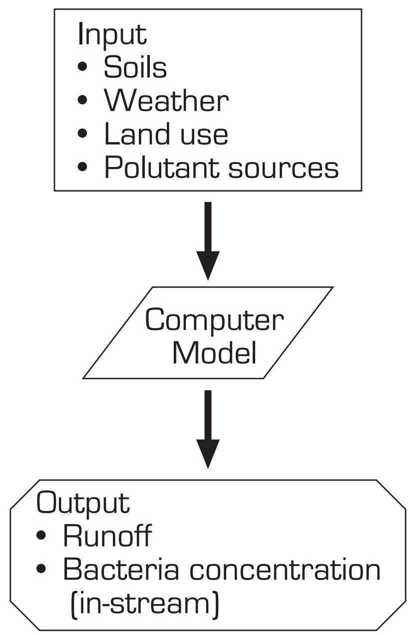

Figure 1. Illustration of hydrologic simulation models relating watershed characteristics to pollutant loads.

303(d) list - Section 303(d) of the Federal Clean Water Act requires states to identify waters that do not meet applicable water-quality standards or do not fully support their designated uses. States are required to submit this prioritized list of impaired waters, known as the 303(d) List, to the U.S. Environmental Protection Agency.

geometric mean – the n^{th} root of the product of n values. Mathematically the geometric mean is expressed as

$$\textit{Geometric Mean} = \sqrt[n]{x_1 x\, x_2 x \ldots x_n}$$

where n is the number of samples, and $x_1, x_2, etc.$ are the values of some parameter, i.e. E. coli concentrations. Compared to an average or simple mean, the geometric mean lessens the impact of extremely high or low values greater than zero. For example, consider the following set of five E. coli measurements with units of cfu/100ml, 150, 600, 50, 120, 195. A simple mean of these values produces:

$$\textit{Simple Mean} = \frac{150+600+50+120+195}{5} = 223 \text{ cfu/100ml}$$

The geometric mean for these measurements would be:

$$\textit{Geometric Mean} = \sqrt[5]{150x600x50x120x195} = 160 \text{ cfu/100ml}$$

margin of safety (MOS) - a required component of the TMDL that accounts for the uncertainty in calculations of pollutant loading from point, nonpoint, and background sources.

teria source description and model development. This approach offers a tangible but unquantified margin of safety.

How is a TMDL developed for a bacteria impairment?

In Virginia, TMDLs are developed by contractors (private consultants and/or university researchers) hired by the DEQ. TMDL contractors are typically engineers or scientists with experience in hydrology and watershed management. University researchers' involvement with TMDLs stems from the need to improve the science and procedures used to develop TMDLs. The first step a contractor should take when developing a TMDL is to characterize the impaired watershed. Watershed characterization involves determining the distribution of land uses within the watershed and, to the extent possible, accounting for all sources of fecal bacteria. Potential fecal coliform sources include:

- Direct deposition of animal feces from livestock, pets, and wildlife into the water body;
- Rural runoff polluted by fecal matter from livestock, pets, and wildlife;
- Urban runoff polluted by fecal matter from pets, stray animals, wildlife, and garbage that has not been disposed of properly;
- Failing septic systems;
- Straight pipes that deposit sewage directly in the water body; and
- Permitted discharges.

Powerful geographic information system (GIS) computer software simplifies watershed characterization in a number of ways. For example: it is known that failing septic systems can be potential sources of bacteria contaminating a water body; data indicate that the age of a dwelling is correlated with its septic system's failure; and data on the location and age (within a range of years) of dwellings with septic systems in the watershed are available.

The GIS software can use these facts and data to estimate bacteria loads coming from failing septic systems within the watershed. GIS software can also be used to delineate and quantify land uses in a watershed; this information can be used to develop spatially distributed bacterial loadings. Figure 2 shows an example land-use map contractors might generate during a TMDL study.

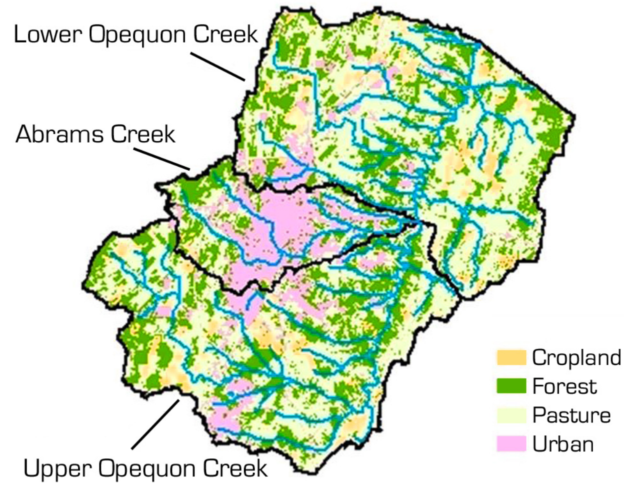

Figure 2. Land-use distribution information used in the development of a bacteria TMDL in Upper and Lower Opequon and Abrams Creeks in Northern Virginia (Mostaghimi et al., 2003).

Once the basic watershed characterization is completed, the existing bacteria load can be determined. For bacteria TMDLs, the TMDL target load is the average annual bacteria *loading capacity* (cfu/year) that the impaired water body can assimilate and still meet the water-quality standard. For bacteria impairment TMDLs, computer models are used to simulate the fate and transport of bacteria in the target watershed and impaired water body in response to precipitation and other climate conditions. Using the watershed model developed for the impaired watershed, several different pollutant-management or load-reduction scenarios can be evaluated. The final load reduction scenario must ensure that the TMDL target load and concentration is not exceeded. Reducing the pollutant load in the impaired watershed to the TMDL target load is expected to ensure that water-quality standards are being achieved.

According to guidance outlined in the federal Clean Water Act, the final load-reduction scenario should be economically feasible, practical, and acceptable to stakeholders. Therefore, the load-reduction scenarios

loading capacity (LC) - the greatest amount of pollutant loading a waterbody can receive without violating water quality standards. (see assimilative capacity)

best management practices (BMPs) - reasonable and cost-effective means to reduce the likelihood of pollutants entering a water body. BMPs include riparian buffer strips, filter strips, nutrient management plans, conservation tillage, etc.

distribute necessary pollutant-load reductions among the different fecal coliform sources and generally involve reducing or eliminating the bacteria source. An example could be an upland, rural watershed where livestock are the primary bacteria source. Cattle may have unrestricted access to a stream and the direct deposition of feces and bacteria into the stream result in water-quality criteria violations. One plan to reduce the bacteria source in this example would be to implement *Best Management Practices (BMPs)* such as off-stream watering along with exclusionary fencing to keep the cattle out of the stream (see Figure 3).

When a bacteria impairment is an issue in urban or suburban watersheds, BMPs must be tailored to address different conditions and circumstances than those found in agricultural watersheds. For instance, the BMPs often used in urban and urbanizing areas to reduce human bacteria loading from failing septic systems and leaking sewer lines include education about proper septic system maintenance and a sanitary sewer inspection and management program. Other practices that can reduce bacteria loads in developed areas are improving garbage collection and street cleaning, as well as encouraging pet owners, through educational programs or ordinances, to pick up pet waste.

Figure 3. Examples of exclusionary fencing and off-stream watering designed to keep cattle from loitering and defecating directly into the stream.
Photos by Tom Turner, John Marshall Soil and Water Conservation District.

What happens after a TMDL is developed?

According to Virginia law, a TMDL Implementation Plan must be developed for each approved TMDL. Implementing a TMDL involves putting into practice the specific pollution control and land-use management practices that will restore water quality. An implementation plan must specify the necessary steps to achieve the load allocations set forth in the TMDL. These plans are developed as a cooperative effort among stakeholders and local and state government agencies.

A typical TMDL Implementation Plan includes:

- A review of the TMDL and the final load reduction scenario;
- A description of local stakeholder participation in developing the implementation plan;
- A detailed description of the necessary pollution-control measures required to restore the water quality in the impaired body of water;
- A cost/benefit analysis of the pollution control measures specified in the implementation plan;
- A schedule of implementation milestones; and
- A plan for continued water-quality monitoring to document water-quality improvements over time.

After the TMDL Implementation Plan is completed and fully implemented, it still may take several years for water quality to improve. Once monitoring data indicate water quality has sufficiently improved, the DEQ can request that the EPA “de-list” the water body (i.e., remove it from the 303(d) list). Theoretically, an impaired body of water can be de-listed during any stage of the TMDL process if legally and scientifically valid reasons can be documented. The reasons may include new data, results using new monitoring procedures or new standards, or simply errors in the initial listing. Removal from the 303(d) list simply means that the water body has either met its TMDL requirements or no longer requires the development of a TMDL.

What role do citizens play?

Citizens can become involved in the TMDL process through stakeholder participation. A stakeholder may be either an individual or organization (public or private) that is concerned with water quality or has an economic interest in the watershed. Stakeholders can provide input in the TMDL process by asking questions, offering feedback during public meetings, and supplying information to the TMDL developers. Active citizen stakeholder involvement is critical during the watershed characterization phase of TMDL development. Local stakeholders know the watershed, and they are a crucial source of both current and historical information that a TMDL contractor will undoubtedly find useful. Often stakeholder input is provided through local *watershed advisory groups*.

Generally, two public meetings are held by DEQ during the TMDL development process to keep stakeholders informed about the TMDL goals and procedures and to continue seeking stakeholder input. The purpose of these public meetings is to discuss and explain the TMDL development process to stakeholders and clarify any portions which they may not understand. Both public meetings are publicized within the watershed and announced in the Virginia Register of Regulations (*http://legis.state.va.us/codecomm/register/regindex.htm*).

At the initial public meeting, the DEQ staff introduces the TMDL process and explains the specific water-quality impairment. At this time, stakeholders are given the opportunity to be a part of a *Technical Advisory Committee (TAC)*. Throughout the TMDL process, TMDL developers and DEQ representatives will organize two to four TAC meetings during which the various technical aspects and details of the TMDL will be presented and discussed. Participating on a TAC is an excellent way for stakeholders to provide input and work with the TMDL developers. The purpose of the TAC meetings is to discuss the technical aspects of the TMDL and to receive input from the stakeholders on all aspects of the TMDL development.

At the final public meeting, the DEQ presents the draft TMDL. After the draft TMDL is presented, the public has 30 days to provide comments about the TMDL to the DEQ. After addressing any comments, the TMDL report, with comments, is submitted to the EPA for review. After the EPA approves the TMDL, it is presented to the Virginia State Water Control Board for adoption. Following its adoption by the board, the approved TMDL becomes a part of the Water Quality Management Plan for the watershed where the impaired river or stream is located.

Where can I find additional information?

The DEQ is the state agency leading the TMDL process. Questions about specific TMDLs can be directed to your regional DEQ office. The DEQ receives support from other state agencies. The Virginia Department of Conservation and Recreation (DCR) provides guidance on voluntary nonpoint source pollution controls and offers financial incentives to implement BMPs. The DCR is the state agency charged with leading the TMDL Implementation Planning process.

World Wide Web Resources

U.S. EPA: Total Maximum Daily Load Program Description

http://www.epa.gov/OWOW/tmdl/

Virginia Department of Environmental Quality TMDL Homepage

http://www.deq.virginia.gov/tmdl/

Virginia Department of Conservation and Recreation

http://www.dcr.virginia.gov/sw/

USDA Cooperative States Research, Education, and Extension – Mid-Atlantic Regional Water Quality Project

http://www.mawaterquality.org/

watershed advisory group - a group of interested stakeholders whose authority is largely derived from its ability to express the needs of the community within the constraints of the law and whose purpose is to advise the TMDL contractor.

technical advisory committee (TAC) - a group of informed, interested stakeholders who assist the TMDL process by providing information and advice to the TMDL developer. TAC members may include agricultural producers, urban residents, Cooperative Extension agents, nongovernmental organizations, and local government officials.

Companion Virginia Cooperative Extension Publications

A Glossary of Water-Related Terms, Virginia Cooperative Extension publication 442-758

http://pubs.ext.vt.edu/442-758/

TMDLs (Total Maximum Daily Loads) - Terms and Definitions, Virginia Cooperative Extension publication 442-550

http://pubs.ext.vt.edu/442-550/

TMDLs (Total Maximum Daily Loads) for Benthic Impairments, Virginia Cooperative Extension publication 442-556

http://pubs.ext.vt.edu/442-556/

Complete listing of Virginia Cooperative Extension fact sheets and bulletins

http://www.ext.vt.edu/resources.

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