Fecal Coliform Total Maximum Daily Loads (TMDLs): Implications for Virginia

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INTRODUCTION

The concept of Total Maximum Daily Loads, or TMDLs, is not new. TMDLs were first introduced in the 1972 Clean Water Act. The section 303(d) of the Clean Water Act established the TMDL process for identification of impaired water bodies and restoration of the quality of these waters. The Act required states to identify water bodies that violate state water quality standards and to develop TMDLs for them. However, this provision of the Water Quality Act was not aggressively pursued, until a series of legal actions were taken against the U.S. Environmental Protection Agency (EPA) and the states about 10 years ago. Currently the EPA is under court order/consent decree to ensure TMDLs are established in many states.

A TMDL, by definition, is a calculation of the maximum amount of pollutant (such as bacteria or nitrogen) that a water body can receive and still meet the water quality standards. A TMDL is pollutant specific, so if a stream segment has multiple impairments then a TMDL will have to be individually developed for each impairment and the causative pollutant. A TMDL should consider all possible sources of pollutant. Pollutant sources include point sources, such as sewage treatment plant discharges or industrial waste, nonpoint sources such as agricultural and urban runoff, and background pollution from wildlife or natural sources. A TMDL must identify all pollution sources; quantify the pollutant loads contributed by each source and specify the reductions in loads needed to attain water quality standards.

The TMDL process involves three major steps. The first step in the process is to identify water bodies that do not meet water quality standards (Quality Limited Water). All states, including Virginia, should submit a list of impaired waters ((303(d) list)) to EPA for approval on a biannual basis. The next step is to prioritize water/watersheds for TMDL development. The water bodies/watersheds that are given a high priority rank in the 303(d) list are scheduled for TMDL development in the biannual. The waters are ranked based on the severity of the impairment, relative importance or value of the water body, and availability of data and information needed to develop TMDL. The final step in the TMDL process is to develop TMDL for listed waters. The purpose of TMDL is to establish a path, which will lead to expeditious attainment of water quality standards. Watershed stakeholders have opportunities to provide input and to participate in the development of the TMDL and the implementation plan.

Commonwealth of Virginia needs to develop 648 TMDLs for 600 water bodies. Some water bodies are impaired by several pollutants for which multiple TMDLs should be developed. Of the total 2,166 impaired stream miles in Virginia, 1,165 miles, or 54%, are impaired by fecal coliform. Nonpoint source pollution is suspected to be the major cause of water quality impairment in Virginia.

Several stream segments in the North River watershed, located near Harrisonburg, were identified as impaired in Virginia's 1998 303(d) TMDL Priority List for violation of the water quality standards for fecal coliform bacteria. In 1999, researchers at the Biological Systems Engineering at Virginia Tech were contracted to develop TMDLs for nine watersheds, including the three stream segments in the North River watershed (Mostaghimi et al., 2000). In the following section a brief description of the TMDL plan developed for Pleasant Run is presented as a case study. Furthermore, the key lessons learned from these investigations are discussed.

TMDL CASE STUDY: PLEASANT RUN

Background

Located in Rockingham County, Virginia, the Pleasant Run watershed (5,309 acres) is about 2 miles south-southeast of city of Harrisonburg. Pleasant Run is a tributary of North River. The North River is a tributary of the South Fork of the Shenandoah River, which in turn, is a tributary of the Potomac River. The Potomac River discharges into the Chesapeake Bay.

Water quality samples collected by Virginia DEQ personnel in Pleasant Run, over five years indicated that 84% of the samples violated the instantaneous water quality standard pertaining to fecal coliform. Virginia's instantaneous standard specifies that fecal coliform concentration in the stream water shall not exceed 1,000 colony forming units (cfu) per 100 mL. Due to the high frequency of water quality violations, Pleasant Run was placed on Virginia's 1998 303(d) list of impaired waterbodies for fecal coliform (USEPA, 1998a, 1998b). The impairment starts at the headwaters and continues downstream to its confluence with North River, for a total of 6.30 stream miles.

As a result of the water quality impairment, Pleasant Run was assessed as not supporting the Clean Water Act's swimming use support goal. In order to remedy the water quality impairment pertaining to fecal coliform, a TMDL has been developed, taking into account all sources of fecal coliform and a margin of safety (MOS). Upon implementation, the TMDL for Pleasant Run shall ensure that the water quality standard relating to fecal coliform will be in compliance with the geometric mean standard. The geometric mean standard specifies that the 30-day geometric mean concentration of fecal coliform shall not exceed 200 cfu/100mL.

Objectives

The objective of the project was to develop a TMDL for the Pleasant Run watershed. The plan should account for both point and nonpoint source pollutant loadings and should incorporate a margin of safety to meet state fecal coliform standards for non-shellfish waters with respect to the geometric mean standard. The following steps were taken to achieve the project objective:

- Identified potential fecal coliform sources, including background sources, and estimated the magnitude of each source in cooperation with stakeholders;
- Quantified fecal coliform production from each source;
- Simulated attenuation of fecal coliform during transport from deposited locations to water bodies;
- Accounted for variations in precipitation, hydrology, and land-use in simulating fecal coliform deposition in streams;
- Estimated fecal coliform concentrations in waterbodies under present conditions;

- Explored multiple scenarios to reduce fecal coliform concentrations to meet the geometric mean standard;
- Selected a TMDL that can be realistically implemented and is socially acceptable; and
- Incorporated a margin of safety into the TMDL.

Sources of Fecal Coliform

Since there are no permitted point sources of fecal coliform in the Pleasant Run watershed, the fecal coliform load is entirely originated from nonpoint sources. The nonpoint sources of fecal coliform are mainly agricultural, such as, land-applied animal waste and manure deposited on pastures by cattle. A significant fecal coliform load comes from cattle directly depositing in streams. Wildlife contributed to fecal coliform loadings on pasture, forest, and stream. Non-agricultural nonpoint sources of fecal coliform loadings include failing septic systems and pet waste. The amounts of fecal coliform produced in different locations (e.g., confinement, pasture, forest) were estimated on a monthly basis to account for seasonal variability in production and practices, considering factors such as the fraction of time cattle are in confinement, time spent in streams, and manure storage and spreading schedules (Mostaghimi et al., 2000).

Modeling

The Hydrologic Simulation Program – FORTRAN (HSPF) was used to simulate the fate and transport of fecal coliform bacteria in the Pleasant Run watershed (Bicknell et al., 1993; Donigian et al., 1994). Due to the short period of flow record available for Pleasant Run, the hydrology component of HSPF was calibrated for Linville Creek, a tributary of North Fork of the Shenandoah River, which had a longer period of record. The Pleasant Run and Linville Creek watersheds have similar land-use characteristics.

The water quality component of HSPF was calibrated using three years of fecal coliform data collected in the watershed (Lumb et al., 1993). A comparison of simulated and observed fecal coliform loadings in the stream indicated that the model adequately simulated the fate of fecal coliform in the watershed. Based on amounts of fecal coliform produced in different locations, monthly fecal coliform loadings to different land-use categories were calculated for each subwatershed for input into the model. Fecal coliform content of stored waste was adjusted to account for die-off during storage prior to land application. Similarly, fecal coliform die-off on land was taken into account, as was the reduction in fecal coliform available for surface wash-off due to incorporation following waste application on cropland. Direct seasonal fecal coliform loading to streams by cattle was calculated for pastures adjacent to streams. Fecal coliform loadings to streams and land by wildlife were estimated for deer, raccoon, and muskrat. Fecal coliform loadings to land from failing septic systems were estimated based on number and age of houses. Fecal coliform contribution from pet waste was also considered (Mostaghimi et al., 2000).

Contributions from various sources were represented in HSPF to establish the existing conditions for the representative hydrologic period of about three years. The simulation results indicated nearly 93% of the fecal coliform concentration in the stream originates from cattle directly depositing in the stream, 5% from upland areas due to runoff, while contribution from milking parlor wash-water and wildlife defecating in the stream accounts for the remaining 2%. The fecal coliform concentrations exceeded the 30-day geometric mean water quality standard more frequently during low flow periods and the summer. During the summer when stream flow was lower, cattle spent more time in streams, and thereby, increased direct fecal coliform deposition to streams (Mostaghimi et al., 2000).

Margin of Safety

While developing allocation scenarios to implement the TMDL, an explicit margin of safety (MOS) of 5% was used. Hence, the maximum 30-day geometric mean target for the allocation scenario was 190 cfu/100 mL, 5% below the standard (200 cfu/100 mL). It is expected that a MOS of 5% will account for any uncertainty involved in the accuracy of the input data used in the model.

Allocation Scenarios

After calibrating to the existing water quality conditions, different scenarios were evaluated to identify implementable scenarios that meet the 30-day geometric mean standard, including a margin of safety, (190 cfu/100 mL) with no violations. The selected scenario is presented in Table 1.

Table 1. Allocation scenarios for Pleasant Run watershed

Percent reduction in loading from existing condition					
Direct wildlife deposits	Direct cattle deposits	NPS from pervious land segments	NPS from impervious land segments	Milking parlor wash-off	Percentage of days with 30-day GM > 190 cfu/100mL
10	100	25	0	100	0.0

Results clearly indicated that direct cattle deposit in the stream has a significant impact on fecal coliform concentrations. Nonpoint source loading from upland areas is a minor source of fecal coliform compared to cattle in stream. The selected allocation scenario requires 25% reduction in fecal coliform loads from pervious, upland sources and 10% reduction from wildlife. Further, complete exclusion of cattle from streams and elimination of direct wash-water discharge of the one milk parlor to the stream are required to meet the TMDL goal. The 30-day geometric mean fecal coliform concentrations resulting from the selected allocation scenario, as well as the existing conditions, are presented graphically in Figure 1 (Mostaghimi et al., 2000).

Phased Implementation

An alternative scenario was evaluated that requires less drastic changes in management practices and achieves smaller reduction in fecal coliform concentration in the stream. The implementation of such a transitional scenario, or Phase I implementation, will allow for an evaluation of the effectiveness of management practices and accuracy of model assumptions through data collection. Phase I implementation was developed for a maximum of 10% violations of the instantaneous standard (1,000 cfu/100 mL) based on monthly sampling frequency. Phase I implementation requires a 98.5% reduction in direct fecal coliform loading by cattle into the stream and elimination of direct discharge of wash-water from milking parlors into streams. Also, a 25% reduction in fecal coliform loadings from the pervious, upland areas is required. The Phase I implementation requires no reductions from wildlife.

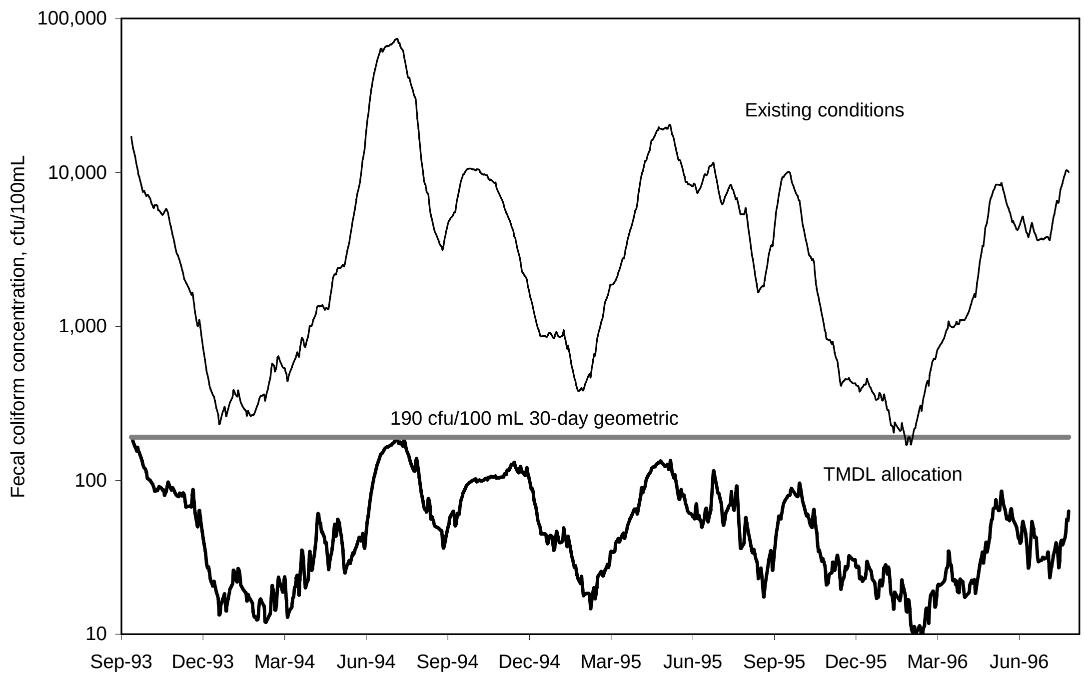

Figure 1. Successful TMDL allocation, 190cfu/100mL geometric mean goal, and existing conditions for Pleasant Run.

The phased TMDL implementation allows for the interim evaluation of the effectiveness of the proposed TMDL implementation while progressing toward compliance with Virginia's water quality standard. Phase I implementation allows for the evaluation of the effectiveness of management practices through stream monitoring on a monthly basis. Also, data collection during this phase allows for the quantification of uncertainties that affect TMDL development. By accounting for such uncertainties, the TMDL can be improved for the final implementation phase that requires full compliance with the 200 cfu/100 mL geometric mean water quality standard.

Public Participation

Public participation was elicited at every stage of the TMDL development in order to receive inputs from stakeholders and to apprise the stakeholders of the progress made. Three public meetings were organized for this purpose. The first public meeting was organized to inform the stakeholders of TMDL development process and to obtain feedback on animal numbers and other landuse activities in the watershed. Results of the hydrologic calibration and animal population, and fecal production estimates were discussed in the second public meeting. The draft TMDL report was discussed at the third public meeting prior to submission of the report to EPA.

LESSONS AND RAMIFICATIONS

The TMDL plan developed for Pleasant Run was approved by U.S. EPA in June, 2000. A BMP implementation plan is being developed by the Department of Conservation and Recreation. The

Pleasant Run TMDL plan, as well as all other fecal TMDLs developed in Virginia, indicate cattle in the stream is a consistent problem and that Virginia's fecal coliform standards may not be realistic for nonpoint sources. In some of the streams fecal coliform bacteria counts from wildlife alone resulted in violation of the standard, particularly during low flow conditions. As a result many of these streams will not be able to attain fecal coliform standards without some reductions in wildlife. All Fecal Coliform TMDL plans call for drastic reductions in bacteria loadings from various sources. Such drastic reductions may be neither scientifically possible nor socially acceptable to the landowners and therefore would not meet the EPA's guidance for reasonable assurance.

Currently, all waters in Virginia are designated as "primary contact" for the swimming use, regardless of their size, depth, location, water quality or actual use. For a non-shellfish supporting water body to be in compliance with the Virginia fecal coliform standards for contact recreational use two criteria are specified: 1) instantaneous (single sample), which specifies no violation of 1000 cfu/100 mL at any time, and 2) geometric mean, which specifies that the geometric mean of two or more water quality samples taken within a 30-day period shall not exceed 200 cfu/100 mL. The standards are to be met during all stream conditions and do not consider background fecal coliform levels in the stream, such as those contributed by wildlife.

As a result of the TMDL studies the Commonwealth of Virginia established an academic advisory committee to re-evaluate the suitability of its fecal coliform standards. The proposed standards contain three criteria (fecal coliform, E. Coli, and entrococci) for primary contact recreation. The previous 200 cfu/100 mL geometric mean for fecal coliform remains the same, but was changed to apply to a calendar month rather than to a 30-day average. The instantaneous fecal coliform criteria (zero violation of 1000 cfu/100 mL) has been modified to match the U.S. EPA's coliform criterion of not more than 10% violation of the 400 cfu/100 mL. The proposed entrococci and E. Coli criteria geometric means are the same as the EPA's 1986 criteria. Three levels of primary contacts specified in the proposed standards include: "designated swimming beaches", "occasional swimming beaches", and "infrequent swimming". Also, the proposed standards allow for waters to be designated as secondary, but these waters would be adopted individually based on their characteristics. The criteria for secondary contact waters are relaxed as compared with the primary contacts. Public meetings are being held to discuss these draft amendments to the bacteria standards.

In addition to the major impact that the TMDL studies have had on the revision of the bacteria standards in Virginia, the following lessons were also learned from these investigations:

- The existing data on stream flow and water quality are not adequate for model calibration and validation for most Virginia watersheds. Virginia is currently revising its strategy to collect adequate data for TMDL development and implementation.
- There is a high degree of uncertainty involved in the animal population and distribution data within watersheds. There is an immediate need to develop improved methods for more accurate estimation of wildlife as well as domestic animal population.
- There is a need for developing models that simulate the important hydrologic/water quality processes affecting the TMDLs. Most existing models are not able to consider temporal, spatial and economic efficacy of BMPs as related to TMDLs. Furthermore, guidance on model selection, application and interpretation of results is severely lacking.
- There is not enough guidance on the appropriate level of the Margin of safety (MOS) used in the TMDL plans. Most TMDL studies consider a 5-10% MOS to account for assumptions and uncertainties involved in the accuracy of the input data used in the model. This level seems to be hardly accurate for some investigations.

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