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A Review of the Technical Approaches Used for TMDLs Development in Mississippi

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Abstract. *A TMDL (Total Maximum Daily Load) is the calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards. Section 303(d) of the Clean Water Act and the EPA's Water Quality Planning and Management Regulations require states to identify and list water quality limited waterbodies, those not meeting state water quality standards, within their boundaries, to prioritize them, and to develop and document TMDLs for the pollutants of concern. In many cases, mathematical models are used during TMDL development, such as to evaluate the relationship between load reduction and compliance with water quality standards. A wide range of models have been used, ranging from simple mass balance calculations to complex integrated watershed, hydrodynamic, and water quality models. While there is considerable guidance on models that may be used in the TMDL process, there is relatively little documentation summarizing which models have been used. A study was conducted to identify the different technical approaches that have been used for TMDL development in Mississippi. The identification is based upon reviewing 253 TMDL reports approved by EPA, which are available on the MDEQ's web page. The water quality modeling approach most commonly used, as reported in 131 surveyed documents (52% of the sample), was the estimation of the TMDL using a simple mass balance equation. Subsequently, for sediments, in 45 of the surveyed TMDLs (18% of the sample), TMDLs were estimated based on reference sediment yields, or targets for each level ecoregion III within Mississippi. STREAM, NPSM, and WASP were used in 33, 16, and 13 TMDL reports (i.e. 13%, 6%, and 5%, respectively). The remaining 6% of the surveyed documents (15 TMDLs) reported the use of AWFWUL1 (3 TMDLs), BATHTUB (3 TMDLs), flow duration curves (3 TMDLs), total toxicity approach (3 TMDLs), AWFWIV1 (1 TMDL), linear regression model (1 TMDL), and QUAL2E (1 TMDL). The type of model used varied with, among other factors, the pollutant of concern and complexity of the waterbody.*

Keywords. *TMDL, water quality, models, water pollution, Mississippi.*

Introduction

Under the Clean Water Act (CWA), specifically the Section 303(d), a TMDL is a process performed to compute the greatest amount of a pollutant that could be discharged into a waterbody without violating its water quality standards. The technical approach used to estimate that maximum allowable load is typically based on simulation tools (here after referred to as models) used to relate loads to water quality targets. A number of critical reviews are available of models potentially applicable to developing TMDLs. For example, Shoemaker et al. (2005) evaluated the capabilities and applicability of more than 65 models for TMDLs development. Borah et al. (2006) examined loading, receiving-water, and watershed models for sediment and nutrient simulations. Vellidis et al. (2006) described models for dissolved-oxygen-related TMDLs. Benham et al. (2006) reviewed models for fecal microorganism fate and transport simulation. However, there is relatively limited information available on what models have actually been selected and used for determining TMDLs.

In this study, we conducted a survey to identify the technical approaches that have been used for TMDL development in Mississippi. The identification was based upon reviewing the TMDL reports approved by EPA, available from the Mississippi Department of Environmental Quality (MDEQ) (http://www.deq.state.ms.us/MDEQ.nsf/page/TWB_Total_Maximum_Daily_Load_Section).

TMDLs and Modeling Approaches

Surveyed TMDLs

The survey examined a total of 253 TMDL reports approved by EPA, available on the MDEQ's web page. Each report was inspected to identify the technical approach used to support the total maximum load calculation. The pollutant of concern and the impaired waterbody's type were also identified, and the applicable information stored in a database for further analysis.

Modeling Approaches

The purpose of this study was to review the current technical approaches used for TMDL development in Mississippi. Figure 1 shows the percentage (%) of TMDL reports relative to the causes of impairments for 303(d) listed waters in Mississippi. Nearly 90% of the documents surveyed report estimated TMDLs for impairment due to conventional pollutants, of which organic enrichment/low DO & nutrients are predominant (37.7%), followed by pathogens (28.8%), sediments (19.7%), and nutrients (12.7%). In comparison, the National Summary of causes of impairment lists pathogens as 14.4 % of the total, nutrients as 10.4 %, organic enrichment/oxygen as 9% and sediments as 9% (http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/).

This survey identified two different approaches for TMDL development: individual and integrated (Figure 2). Individual approaches were all those applications performed without any type of coupling or linkage between or among models (247 TMDLs), and this approach was commonly used in the development of both conventional and non-conventional pollutant TMDLs. Unlike individual approaches the TMDL integrated modeling approach generally consisted of the linkage of watershed, hydrodynamic and/or water quality models. The linked approach was used in the development of six TMDLs for impairments due to conventional pollutants, specifically nutrients, organic enrichment/low DO & nutrients, and pathogens (Figure 2).

Twelve different water quality modeling approaches for TMDL development in Mississippi were identified (Table 2). The water quality modeling approach most commonly used, as reported in 131 surveyed documents (52% of the sample), was based on a simple mass balance equation. A common example computation is (Chapra 1997)

$$C = \frac{1}{Q} W; \quad W = QC \tag{1}$$

where (*W*) is the rate of loading (e.g. TMDL), the assimilative capacity is only due to flow (*Q*), and *C* is the concentration (e.g. the standard). Examples include the computation of the Phase I TMDL for mercury in the Escatawpa River (MDEQ 2000) and Phase One Fecal Coliform TMDL for Cedar Creek (MDEQ 2002).

Other simplified approaches used in the 253 TMDLs surveyed included BATHTUB (3 TMDLs), flow duration curves (3 TMDLs), the total toxicity approach (3 TMDLs), and a linear regression model (1 TMDL). BATHTUB is an empirical, steady-state eutrophication model for reservoirs (Walker, 1985; 1986) developed for the US Army Corps of Engineers. An example of the use of BATHTUB is in the TMDL for in Roebuck Lake Yazoo River Basin Leflore County, Mississippi (MDEQ 2008). Load Duration Curves (USEPA 2007) are a cumulative frequency curve of daily mean flows without regard to chronology of occurrence (Leopold, 1994) converted to load duration by multiplying the flow values by the applicable water quality criterion or target and a conversion factor. An example of the use of load duration curves was the fecal coliform TMDL for Otoucalofa Creek Yazoo River Basin Calhoun, Lafayette, and Yalobusha Counties, Mississippi (MDEQ 2003). An example of the total toxicity approach was the TMDL for the Bowie River for total toxicity (MDEQ 2005), where the TMDL was expressed in terms of chronic and acute toxicity units (TUcs and TUas).

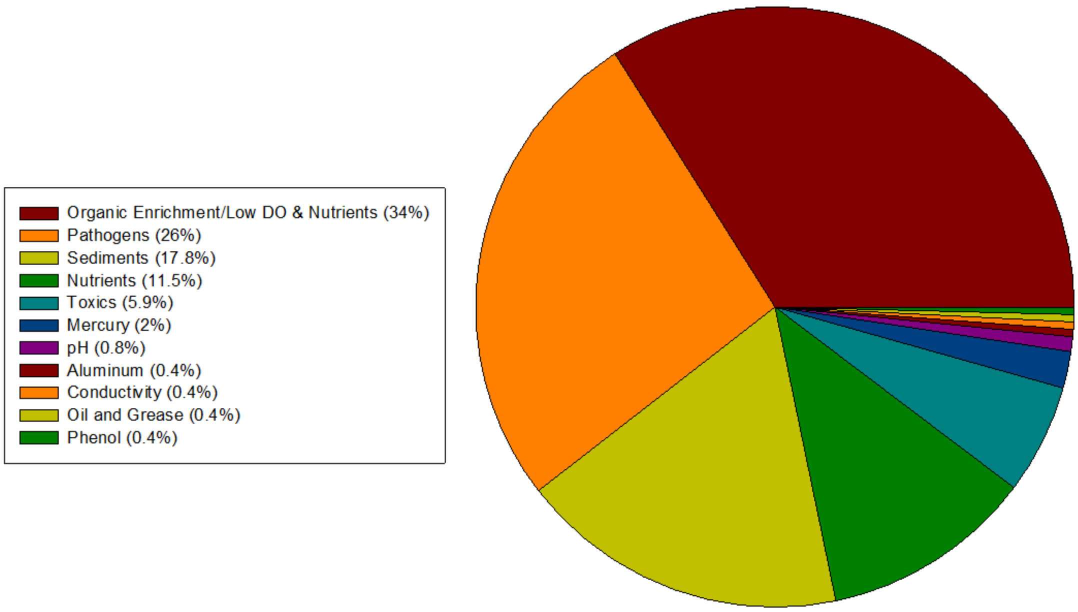

Figure 1. Causes of impairment for 303(d) listed waters in the state of Mississippi according to the TMDL reports available at the MDEQ's web page

TMDLs for impairment due to sediments (18% of the sample) were generally estimated based on reference sediment yields or targets derived from the empirical analysis of historical flow and suspended sediment concentrations for stable streams in each level III ecoregion in Mississippi. A representative example is the TMDL evaluation for the Fannegusha Creek Watershed for biological impairment due to sediment (MDEQ 2004). The methods used to develop the level III reference yields are described in detail by Simon et al (2002) and Simon et al (2002a).

The models STREAM (33 TMDLs), AWFWUL1 (3 TMDLs), and AWFWIV1 (1 TMDL), combined were used for 15% of the studies surveyed. STREAM (MDEQ 2004b) is a steady-state, daily average computer model that utilizes a modified Streeter-Phelps dissolved oxygen sag equation. STREAM is an updated and EPA approved version of the AWFWUL1 and AWFIV1 models, used by MDEQ for many years for wasteload allocations. Caviness et al. (2006) described the application of STREAM to the Big Black River, MS, and compared the results to QUAL2E. QUAL2E (Brown and Barnwell 1987) is a numerical one-dimensional model for conventional pollutions (e.g. dissolved oxygen), assuming steady-flows and was used in 1 of the TMDLs surveyed (TMDL).

The Basin's NPSM (NonPoint Source Model, USEPA. 1998) was used in 16 TMDL applications, such as in (MDEQ 2002) fecal coliform TMDL for The Big Black River Segment 2. The NPSM model simulates nonpoint source runoff from selected watersheds, as well as the transport and flow of the pollutants through stream reaches. The WASP (Water Quality Analysis Simulation program) was used in 13 TMDL applications of the 253 surveyed. WASP is a USEPA, public domain, box model (unstructured grid), that can be applied in 1-3 dimensional model to conventional pollutants, organics, metals, mercury. An example of the use of WASP was in the TMDL for nutrients and organic enrichment / low DO in the Noxubee River, MS (MDEQ 2009). Additional information on WASP and other models described above can be found in Shoemaker et al. (2005) and Martin et al. (2015).

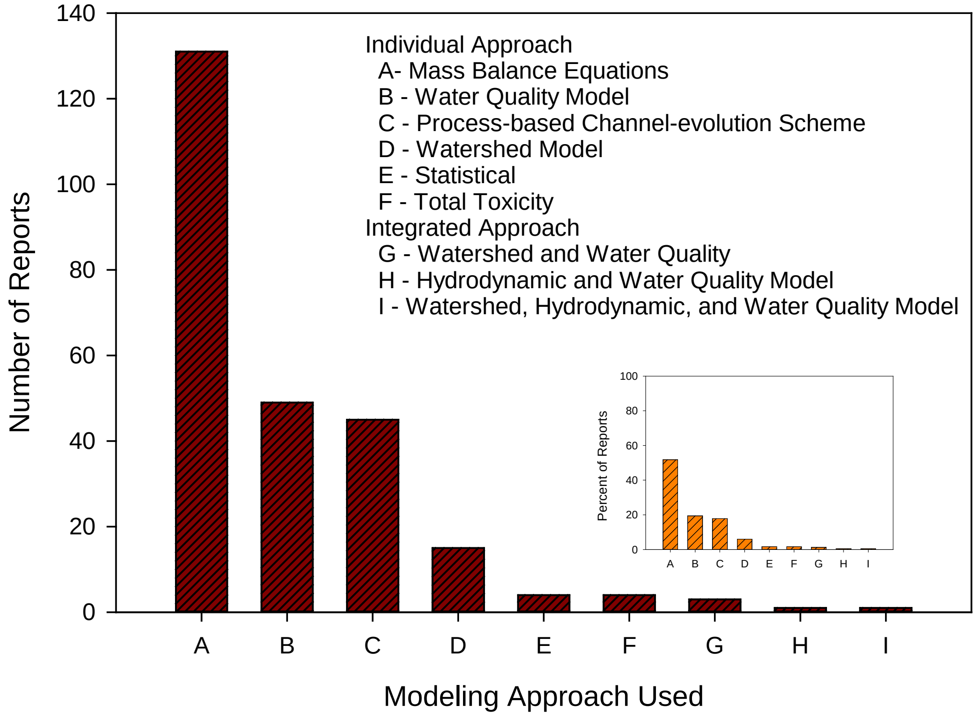

Figure 2. Modeling approach adopted for the development of TMDLs in Mississippi

Table 1. Water Quality Models used for TMDLs development

Water Quality Model	Cause of Impairment											
	Aluminum	Conductivity	Mercury	Nutrients	Oil and Grease	Organic Enrichment/ Low DO & Nutrients	Pathogens	pH	Phenol	Sediment	Toxics	Grand Total
Mass Balance Equations	1	1	5	26	1	39	46		1		11	131
Process-based channel-evolution scheme										45		45
STREAM				1		31	1					33
NPSM							14	2				16
WASP				2		9	1				1	13
AWFWUL1						2	1					3
BATHTUB						3						3
Flow Duration Curves							3					3
Total Toxicity											3	3
AWFWIV1						1						1
Linear regression							1					1
QUAL2E						1						1
Grand Total	1	1	5	29	1	86	67	2	1	45	15	253

Discussion and Conclusion

This study provides a review of the modeling approaches used in the development of Mississippi TMDLs included in 253 reports available at MDEQ's web page. For all of the causes of impairments in Mississippi, simple mass balance equation was the approach most commonly used for TMDLs estimation. Subsequently, the process-based channel-evolution scheme proposed by the USDA-ARS National Sedimentation Laboratory was used to determine TMDLs for waterbodies impaired by sediments. STREAM, NPSM, and WASP were models mainly adopted in the development of TMDLs for streams impaired by organic enrichment/low DO & nutrients, pathogens, three of the most observed causes of impairment throughout the nation.

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