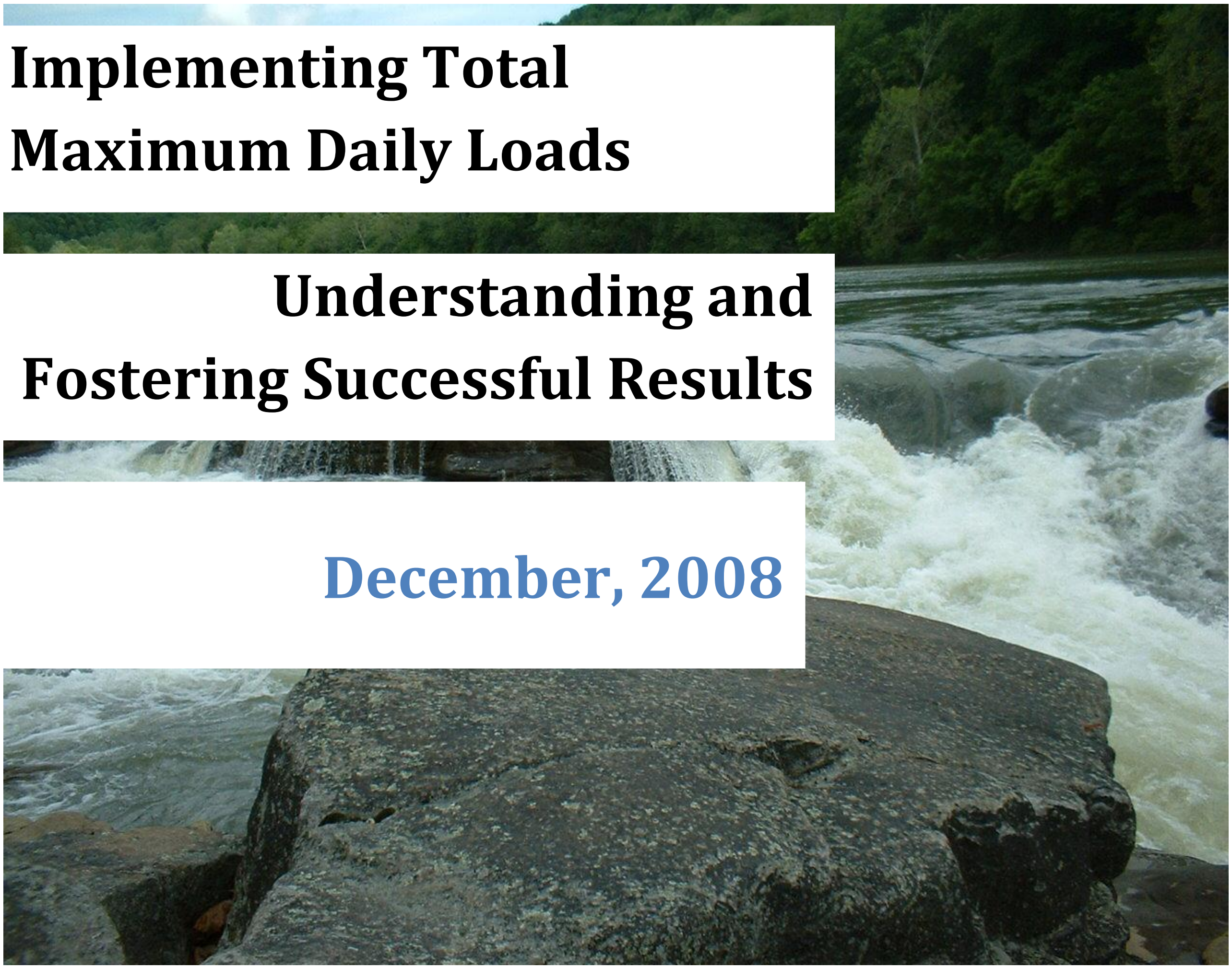
Implementing Total Maximum Daily Loads

Understanding and Fostering Successful Results

December, 2008



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Executive Summary
Implementing Total Maximum Daily Loads: Understanding and Fostering Successful Results

Over the last decade, state governments throughout the United States have developed Total Maximum Daily Loads (TMDLs) for impaired (eg. polluted) water bodies. These TMDLs identify the amount of a pollutant that a water body can receive and still comply with water quality standards. The US EPA has now approved TMDLs for thousands of stream segments and water bodies throughout the country. However, there have been only limited efforts to assess the extent to which TMDLs are being implemented. This study assesses the implementation of US EPA approved TMDLs in Ohio and West Virginia. It concludes that both states have made progress in implementing recommendations called for in TMDLs, but it also suggests that more can be done to accelerate progress and foster TMDL implementation.

The study results address three specific questions. The first question addressed is: To what extent are TMDLs being implemented in Ohio and West Virginia? The second question focuses on identifying factors that facilitate progress in the implementation of TMDLs in these two states. And the third question relates to steps that can be taken to facilitate further progress in the implementation of TMDLs.

To address these questions, the research team reviewed 63 US EPA-approved TMDL reports for impaired waters in Ohio and West Virginia. The TMDLs contained in these reports were approved by the US EPA between 1998 and September 2006, and they address a total of 174 specific report-pollutant combinations. The researchers' review focused on identifying pollutants and their sources, and on collecting information that could be used to assess TMDL implementation progress. The information contained in these reports is analyzed in combination with information from other sources to assess implementation progress at the report level (rather than by individual stream segment) for the 174 pollutants and 63 watersheds addressed in the study.

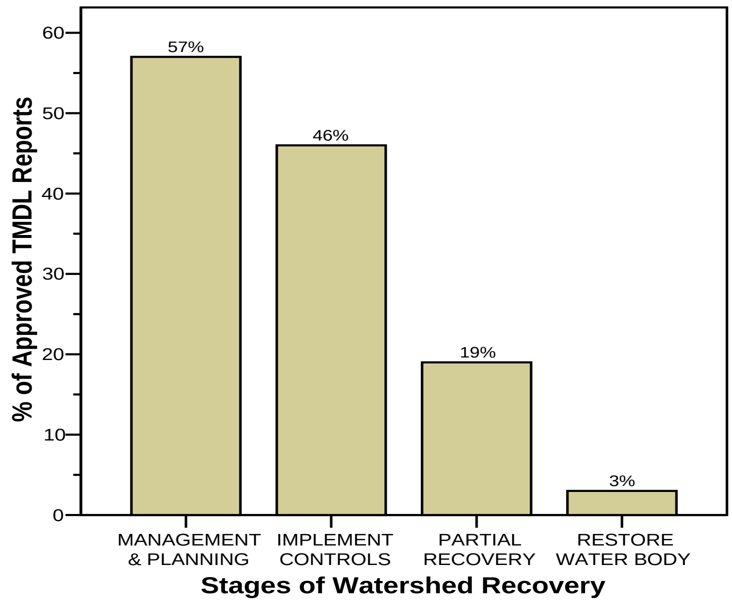
The researchers also reviewed publicly available documents relevant to TMDL implementation in Ohio and West Virginia, surveyed state staff members involved in developing TMDLs, and interviewed knowledgeable state officials regarding implementation progress in TMDL-limited watersheds in the two states. The researchers also reviewed major National Pollutant Discharge Elimination System (NPDES) permits limiting wastewater discharges in TMDL-limited watersheds. These reviews were undertaken to determine if recommendations from approved TMDLs have been incorporated into NPDES permits. Consequently, the study relies on written information and the knowledge and perceptions of state environmental officials – rather than environmental sampling and analysis – to develop its findings and reach its conclusions.

The study measures implementation progress based on four stages of the "TMDL Program Pipeline", a conceptual framework developed by US EPA to understand ways in which TMDLs can contribute to water quality restoration efforts. The first stage of the TMDL Program Pipeline relates to planning and management, and this study finds that these kinds of activities have been implemented in over one-half of the TMDL-limited watersheds studied. For example, at least one state official is knowledgeable regarding TMDL implementation activities in 71% of the watersheds studied, and at least one project is under way in 65% of these watersheds. Fifty-seven percent of the watersheds have at least one local or regional group that is working to implement TMDL-recommended actions.

The second stage of the TMDL Program Pipeline focuses on the implementation of controls on pollutants released to TMDL limited waters. This study finds that knowledgeable state officials know or believe that pollutant loading reductions have occurred in 46% of the TMDL-limited watersheds assessed. It also finds that more stringent NPDES effluent limits are implemented most of the time when effluent limit reductions are clearly targeted by TMDLs.

The state officials interviewed also identify progress in the third stage of the TMDL Program Pipeline, a stage that focuses on identifying incremental improvements in water quality that fall short of full water quality standard compliance. More specifically, these officials identify improvements in water or sediment quality in 19% of the watersheds studied. At the fourth stage of the TMDL Program Pipeline, the study finds two cases of full water body restoration, and these two cases constitute 3% of the watersheds studied. The figure below summarizes key elements of these results.

Executive Summary -- Figure
Implementation Progress in Ohio and West Virginia



The study also assesses potential driving factors for TMDL implementation progress. A statistical analysis is used to assess potential driving factors for TMDL implementation that have been identified in past studies and research. The analysis focuses on measures relating to the first two stages of the TMDL Program Pipeline: (1) whether there is a group taking responsibility to foster TMDL implementation progress, and (2) whether there are (perceived) reductions in pollutant loadings occurring as a result of identified implementation activities. Because there are relatively few cases of partial water body recovery and full water body restoration, statistical analyses are not used to assess driving factors for these two latter stages in the TMDL Program Pipeline.

The analyses suggest that the following factors are useful predictors of whether a TMDL-limited watershed will have a group taking responsibility for TMDL implementation:

1. The existence of a state grant to support a watershed coordinator;
2. Local/regional group participation in TMDL development;
3. State agency involvement in TMDL implementation, and;
4. The population density in the TMDL area (higher densities appear to make groups *more* likely).

The first three of these factors can be manipulated at the state level to help foster implementation progress, while the fourth factor suggests that groups taking responsibility for TMDL implementation are more likely in urban areas than in rural areas.

The analyses conducted suggest that a different mix of factors are useful predictors of whether knowledgeable state officials perceive that pollutant load reductions are occurring as a result of current implementation activities. These factors include:

1. A group taking responsibility for TMDL implementation;
2. The existence of a state grant to support a watershed coordinator;
3. Approval or endorsement of a watershed plan (for non-point source load reductions only);
4. Time (as months from TMDL approval increase, the likelihood of perceived pollutant loading reductions also increases); and
5. The population density in the TMDL area (in this case, however, higher densities appear to make perceived pollutant loading reductions *less* likely).

Once again, the first three variables can be influenced by state officials and water quality stakeholders. By contrast, the latter two variables reflect circumstances in which pollutant reductions are likely to be identified. They do not appear to be subject to easy policy manipulation.

This research also enables the identification of steps that state administrative officials and water quality stakeholders can take to help accelerate progress in implementing TMDLs. These steps include:

1. Engaging local and regional groups in TMDL development;
2. Providing funding to implement projects to reduce pollutant loads and improve water quality;
3. Engaging state officials in implementation processes;
4. Creating standardized formats for TMDL implementation recommendations and procedures for incorporating TMDL recommendations into subsequent implementation efforts;
5. Developing indicators of implementation progress and tracking progress against them, and;
6. Educating and engaging key audiences in TMDL implementation, and its tracking and management.

National, regional, state, and local efforts in all of these areas appear likely to accelerate progress in developing planning and management capabilities for TMDL implementation and in fostering pollutant loading reductions.

The study also identifies productive areas for further research on TMDL implementation. These areas include:

1. Studies of TMDL implementation in other watersheds, states, and localities, with expanded sample sizes to enable the identification of factors fostering water quality improvement as well as advancements in management capabilities and (perceived) pollutant loading reductions;
2. Assessments that address TMDL implementation progress at both the watershed (TMDL report) and stream segment levels;
3. Analyses of TMDL implementation progress in key economic and policy sectors, and;
4. In depth studies that include not only information from state environmental officials and written reports, but also improved measures of other variables and verification with sampling data on the water bodies being studied.

While this study provides information that can be used to assist government officials and water quality stakeholders in accelerating TMDL implementation progress, future studies can expand upon the results presented here in informative and useful ways. Over the long run, implementation of this study's recommendations and further study in the areas outlined above are likely to foster both TMDL implementation and water quality improvements.

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1. INTRODUCTION

Over the last decade, state and federal environmental agencies have been expending substantial effort and resources to develop Total Maximum Daily Loads (TMDLs) for water bodies that do not meet water quality standards. These TMDLs identify the amount of a pollutant that a water body can receive and still comply with water quality standards. They also distribute the burden of reducing pollutant loads among water pollution sources through the development of numerical targets that seek to guide the implementation of pollutant reduction efforts.

Advocates of strong water pollution policies argue that investments in TMDL development are required by the Clean Water Act and are justified by current water quality conditions. While water quality has improved significantly in a number of American water bodies over the last several decades, substantial water pollution problems remain throughout the United States (US). Over 40% of US waters that have been assessed do not meet applicable water quality standards, and these problems plague nearly 39,000 river segments, lakes, and estuaries (US EPA-OIG, 2007). At the same time, population growth and concerns about the impact of global warming on water resources suggest that threats to America's water resources will increase in the coming years.

Since the mid-1990s, the US Environmental Protection Agency (US EPA) has approved TMDLs contained in state TMDL reports for over 24,000 impaired water bodies (US EPA-OIG, 2007). This has been a massive undertaking. It has been estimated that the cost of the TMDL program to US EPA and the states will reach $1 billion over a fifteen-year period beginning in the early years of the twenty-first century (US EPA-OIG, 2007, p3), and a US EPA Office of the Inspector General (OIG) Report released last year estimates that the US EPA alone invested $53 million in the TMDL program between 2002 and 2006. Even so, our knowledge regarding the extent to which recommendations contained in TMDLs are implemented by states, local governments, and others remains limited.

Ultimately, judgments regarding the value of the TMDL process will turn on whether it leads to viable implementation efforts, reductions in pollutant loadings, improvements in water quality, and—at least eventually— the restoration of impaired water bodies. To a large degree, these judgments will depend on the extent to which state agencies, local governments, and other stakeholders take responsibility for TMDL implementation by undertaking projects that reduce pollutant loads and/or improve the ability of water bodies to assimilate pollutants and improve water quality. This report addresses these TMDL implementation issues for two states: Ohio and West Virginia.

The pages that follow present research findings which confirm that TMDLs are being implemented in both Ohio and West Virginia. The findings relate to implementation activities associated with TMDL reports that were approved by US EPA for Ohio and West Virginia between 1998 and 2006, and they are based on existing information contained in TMDL reports and other sources of written information, as well as surveys and interviews of state environmental officials in Ohio and West Virginia. More specifically, the findings presented in this report provide evidence of: (1) planning and management activities relating to TMDL implementation in over one-half of the watersheds addressed by TMDL reports in this study; (2) suggestions that pollutant loading reductions are occurring in almost one-half of the watersheds addressed by the TMDL reports studied, and; (3) the identification of water quality improvements in almost one-fifth of the cases studied. The findings also include the identification of two cases of full water body recovery. While these results verify that the implementation of TMDLs is occurring on a widespread basis, they also confirm that there is more work to be done to restore impaired waters in both West Virginia and Ohio.

The report also presents information and analyses that can be used to help water quality stakeholders accelerate progress in the implementation of approved TMDLs. Our analyses identify a range of steps that can be taken to increase the likelihood that groups will take responsibility for TMDL implementation. These steps include involving stakeholder groups in TMDL development, engaging state officials in a wide range of implementation related activities, and providing grants to watershed groups to build their ongoing capabilities. Our review also suggests that developing systems for tracking and management of TMDL implementation processes and including more specific information on recommended steps for implementation in TMDL reports is likely to help foster their implementation.

The analyses conducted also suggest that watersheds with groups taking responsibility for TMDL implementation are more likely to yield reductions in pollutant loads than watersheds which do not benefit from these groups (at least as perceived by knowledgeable state officials). Grants to watershed groups and the development and approval of watershed plans also appear to help foster reductions in pollutant loads. These and other suggestions for improving practice and policy are described in Section 7 of this report. The larger conclusion to be reached from this work, however, is that while we are making progress in implementing TMDLs, we can accelerate this progress by developing clearer implementation recommendations and more robust and focused systems for informing and guiding watershed planning and management efforts.

2. BACKGROUND INFORMATION

The federal TMDL program plays a central role in the nation's water quality management efforts. The US EPA's Strategic Plan emphasizes TMDL development and the implementation of watershed management improvements as one of three key national strategies for ensuring clean and safe water (US EPA, 2006, p. 32). State environmental agencies play central roles in developing and implementing TMDLs, and—while they respond to common federal guidelines—they also vary in their approaches. Existing professional literature and scholarly research has not yet focused extensively on TMDL implementation, but several professional studies of TMDL implementation have been conducted and there is a growing body of scholarly research relevant to watershed management.

The subsections that follow review the history of the federal TMDL program and summarize professional and scholarly literature on TMDL implementation and watershed management. The information presented in these subsections is designed to help readers absorb and understand the remaining portions of this report.

2.1 TMDLs: A Brief History and Overview

Prior to World War II, water quality management was viewed as the province of state and local governments. Federal engagement in water pollution policy began shortly after World War II, and grew in piecemeal fashion until 1972. In that year, responding to Earth Day, the environmental movement, the burning of the Cuyahoga River in Ohio, and the Santa Barbara oil spill, Congress re-wrote and passed the Federal Water Pollution Control Act (FWPCA) to emphasize federally imposed technology-based regulatory controls on industrial dischargers and municipal sewerage systems. These controls took the form of a new permitting program, the National Pollutant Discharge Elimination System (NPDES), which required the issuance of permits for all point source discharges to waters of the United States.

At the same time, however, Congress retained language in the new law reflecting the previously used water quality-based approach to water pollution control. This approach relied upon the states to develop water quality standards and sought to use them as a foundation for both assessing the need for water pollution controls and implementing appropriate controls for specific water pollution sources. In the early 1970s, many observers were critical of this approach because it had failed to ensure that states would actually address water pollution problems within their jurisdictions. For even when water quality problems were identified (using a water quality standards-based approach), it often became difficult to identify the specific sources of those problems with enough certainty to impose or facilitate appropriate corrective actions. The language in Section 303 of the new law was nevertheless included in the 1972 law to address water quality problems that remained after technology-based regulatory controls on industries and municipal sewerage systems had been applied.

In subsequent years, the US EPA developed dozens of "effluent guideline" regulations to enable efficient issuance of technology-based permit controls, and it worked with states to issue thousands of permits under the NPDES to control point source water pollution discharges. To a large degree, these technology-based permit controls have been successful, as pollutant loadings from point sources have diminished considerably since the NPDES program was enacted in 1972 (ASIWPCA, 2004). While water quality problems growing from point source discharges of various kinds are still evident, there has been a growing recognition that non-point source water pollution now contributes to a very large proportion of the nation's water quality problems.

In 1987, the federal government took more direct aim at these problems and amended the FWPCA with a new section 319 program, which required states to develop non-point source water quality assessments and then establish management plans to address the problems that were identified. It also included provisions for a new grant program that would supply funds to states to assist them in addressing non-point source water pollution problems. Funding for the 319 grant program increased during the 1990s, and additional funds were added to support non-point source water pollution control projects in watersheds targeted by TMDLs. Since 1972, additional federal programs to address water pollution problems from agriculture and mining activities were also enacted and they now also provide support for projects and activities that help restore impaired water bodies.

For the first twenty years or so of its existence, section 303(d) of the FWPCA lied dormant, and was largely ignored by both US EPA and the states. This section of the FWPCA requires states to identify waters within their borders for which technology-based controls are not sufficient to ensure compliance with water quality standards. It also requires them to establish TMDLs for pollutants in these watersheds and submit them to US EPA for approval. Since the mid-1990s, however, this section of the statute has become increasingly important. Its growing importance is attributable to a continuing need to assess non-point source contributions to water quality problems in approximately 39,000 water bodies (US EPA OIG, 2007, p. 1) and target appropriate non-point source water pollution control actions. A series of court cases also required more complete compliance with section 303(d) of the FWPCA (for background on some of this litigation, see Houck, 1999).

The vast majority of the work involved in assessing water quality problems and in developing TMDLs -- including formal waste-load allocations for point sources and load allocations for non-point sources -- has occurred since the mid-1990s. Since this time, US EPA and states around the country have been working to assess waters to determine whether they are impaired and to develop targets for point and non-point source water pollution loading reductions. These efforts yield TMDL reports for impaired water bodies that specify the impairments, the pollutants, and the stream segments and/or watersheds in which these problems reside. In many cases, TMDL reports may include numerous stream segments or water bodies for which pollutant-specific "TMDLs" are developed. As of summer 2006, when the initial proposal for this research project was written, over 24,000 TMDLs had been completed (US EPA OIG, 2007, p. 1).

It is in this context that interest in the implementation of TMDLs and their impacts on water quality has been increasing. There is a growing need to document the extent to which water pollution control actions recommended in TMDLs are implemented. In addition, increased emphasis is being placed on water quality program impacts and outcomes as a result of requirements stemming from the Government Performance and Results Act (GPRA) and the Program Assessment Rating Tool (PART) processes that have been implemented throughout the federal government. The findings presented in this report respond to the US EPA's expressed interest in TMDL implementation, and they address this interest by describing TMDL implementation progress in Ohio and West Virginia.

2.2 Literature Relevant to TMDL Implementation: An Overview

The literature relevant to the implementation of TMDLs has developed along two tracks. The first track has been pursued by water quality practitioners and is focused on assessing the extent to which TMDL implementation has occurred. The second track is scholarly and emphasizes the establishment, operation, and impacts of watershed groups. In general, the professional literature has found evidence of implementation progress through studies that highlight success stories around the nation and in Washington State, while the scholarly literature has added to these findings by identifying variables that characterize watershed management processes and are likely to influence TMDL implementation progress. These two tracks of inquiry, however, have not been well integrated.

The US EPA has been at the center of efforts ascertain the extent to which TMDLs are being implemented. Through its TMDL Results Analysis Project, it has established a conceptual framework— "the TMDL Program Pipeline" — to guide our understanding of the steps necessary for the implementation of recommendations in TMDL reports and to achieve water quality restorations (Norton, et. al., 2007). The US EPA has also supported research projects to assess TMDL implementation progress and, more recently, to gain insights on ways in which this progress may be accelerated.

The US EPA's Region 10 office in Seattle, in cooperation with the Washington Department of Ecology, undertook a study to assess TMDL implementation progress in the State of Washington (US EPA, 2005). This study concluded that implementation activities were being undertaken in 27 of 28 watersheds identified for study, and that water quality improvements had been verified in 13 of these 28 project areas (US EPA, 2005). The study did not seek to identify factors affecting implementation or water quality improvement, and it did not seek to identify policy changes that could accelerate TMDL implementation. Even so, it did demonstrate that at least one state was experiencing progress in the implementation of recommendations contained in TMDL reports. It also raises questions regarding the extent to which implementation progress is occurring in other areas of the country, as Washington State not only has an historically strong water pollution control program (Hoornbeek, 2005; Ringquist, 1993), but also a specific process for fostering the implementation of recommendations contained in TMDLs. This process includes the development of "Detailed Implementation Plans" within one year after US EPA approval of state-developed TMDLs, as well as post-TMDL monitoring to assess water quality impacts (US EPA, 2005; Onwumere & Plotnikoff, 2003).

The US EPA also funded another study that reviewed cases of "successful" TMDL implementation in a number of different states, and it did identify potential factors that might foster TMDL implementation progress (Benham, et. al., 2006 and 2007). Benham and his colleagues identified a range of potential factors, including active engagement on the part of state agency officials, stakeholder involvement during the process of TMDL development, the severity of the water pollution problem as measured by percentage reduction figures applied to specific pollutants in TMDL reports, and the existence of an accepted watershed strategy and/or implementation plan. However, Benham and his colleagues looked at only seventeen cases of TMDL implementation, and the cases they investigated were hand-selected as examples of "successful" TMDL implementation. As a result, the conclusions it reaches may reflect a biased set of success stories, rather than a representative assessment of TMDL implementation in general. In spite of these limitations, the Benham et. al. (2006 and 2007) study did offer a range of factors that were thought by participants in "successful" cases to contribute to TMDL implementation (Benham et. al, 2006), and these factors provide a useful starting point for additional analyses.

While these two studies have been useful and informative, they have also been limited by the size and nature of the samples of approved TMDLs upon which they are based. Studying TMDL implementation over large numbers of cases can yield a broader picture of TMDL implementation than currently exists. It can also enable the use of statistical techniques to evaluate the impact of key factors affecting the implementation process. These are important pieces of information because they can be used to help TMDL programs maximize the effectiveness with which they enable implementation and improve water quality. Not surprisingly in this context, the US EPA solicited proposals for studies of TMDL implementation that involved larger sample sizes for study during the summer of 2006. The research presented in this report responds to this need, and also seeks to draw insights from a growing literature on watershed management and collaborative decision-making.

The literature on watershed groups and collaborative policymaking mechanisms for watershed management has grown considerably over the last ten years. The thrust of this literature has been on the dynamics of collaborative efforts, and their influence on the environments within which they reside. Lubell and his colleagues studied the emergence of watershed groups, and found that these groups were most likely to develop in "watersheds confronting severe pollution problems associated with agricultural and urban runoff, with low levels of command and control enforcement, and containing the resources to offset transaction costs" (Lubell, et. al., 2002, p. 148). Other studies have sought to characterize watershed groups and their patterns of maturation, and they have generally found that the perceived success of these groups has increased after they had reached an age of at least four years (Leach, et. al., 2002; Leach and Sabatier, 2005). This latter finding highlights the tendency in this body of social scientific literature to focus on *perceptions* of watershed group success, a tendency that is understandable given the central role of belief systems in the Advocacy Coalition Framework (ACF) that has received substantial attention in recent years (Sabatier and Jenkins-Smith, 1993).

However, the collaborative policymaking literature has also sought to address issues associated with the influence of group processes and situational context on actual implementation progress. Sabatier, Leach, and their colleagues (2005) found that the extent to which watershed groups complete watershed restoration projects depends on group characteristics and the receipt of grant funds, both of which are tied to group processes that are based on trust and a feeling of efficaciousness among members of the group. One way to establish these kinds of feelings is through early and full engagement in the watershed management process, and this insight is consistent with Benham et. al.'s (2006 and 2007) suggestion that early stakeholder involvement and engagement by state agency officials may help foster TMDL implementation progress. Social scientific literature has also identified other variables that are thought to influence policymaking and implementation processes, including both group density (Gray and Lowry, 1996) and the strength of group involvement (Ringquist, 1993) in decision-making processes.

Sabatier (2005) and his colleagues also call attention to contextual factors that may affect group development and the extent of watershed management activity. These factors include the extent to which populations are homogeneous and stable, as these kinds of populations are thought to be more likely to develop both trust and workable partnerships that may yield social and material progress, as compared with populations that are not characterized by these traits. When combined with other contextual factors such as wealth, education, and population density that reflect the overall capabilities of the population or areas in question, these factors suggest that implementation progress may turn as much on social and material context, as on group processes or dynamics. Koontz (2005) reaches this finding, and argues that the extent of land use policy change occurring as a result of planning processes in Ohio is associated with contextual factors associated with the areas under study. Still others have been skeptical of the promises of collaborative policymaking altogether, and have pointed out forcefully that consensus-based group processes may not translate into true environmental results (Coglianese, 1999).

The analyses presented in this report draw upon the conclusions and variables highlighted in the literature cited above. They build upon US EPA's TMDL Results Analysis Project by assessing implementation progress according to a range of different measures. They also seek to improve our understanding of factors driving TMDL implementation by using statistical methods to evaluate the impact of both group process and contextual variables that are thought to influence TMDL implementation over relatively large numbers of cases. In so doing, they contribute insights that can be used to identify potential changes in practice and policy that may accelerate TMDL implementation progress.

The discussion that follows highlights the approaches and methods that have been used in this research to measure TMDL implementation progress across a large number of US EPA-approved TMDLs in West Virginia and Ohio.

3. METHODOLOGICAL ISSUES

The research design underlying this report focuses on three questions, each of which builds upon previous studies relating to the implementation of TMDLs:

1. To what extent are US EPA-approved TMDLs being implemented in Ohio and West Virginia?
2. What factors appear to influence implementation progress?
3. What changes in practice and policy might facilitate progress in implementing TMDLs?

The answers to all three questions are important if we are to improve the condition of impaired waters in West Virginia and Ohio, and they may also yield insights that can enable water quality improvements in other states.

While it is important to understand the extent to which US EPA-approved TMDLs are being implemented, determining how best to assess the extent of implementation that is occurring is a challenging task. The polluting activities identified in TMDLs are wide ranging, and a number of them occur as a result of economic, cultural, and social practices that infiltrate almost all aspects of society—both nationally and in West Virginia and Ohio. These activities are also carried out by a wide range of actors and institutions. For example, TMDLs developed for Ohio and West Virginia call for efforts to address water pollution problems stemming from mining operations, agriculture, point source wastewater dischargers, hydrological modifications, urban and municipal land use practices, releases of contaminants from onsite wastewater, combined sewer overflows, legacy sources of pollution from past activities, and other sources. There is—at this point in time—no central repository of information that is broad enough to enable researchers, or anyone else for that matter, to collect information on efforts to reduce pollutant impacts from all of these sources in any one watershed, much less two entire states.

A central question for the design of this research effort, therefore, has been how to identify, compile, and analyze existing information relating to a wide range of pollutant sources and pollution reduction activities across two states in a reasonable amount of time and at a reasonable cost. To address this question, we inventoried approved TMDLs in Ohio and West Virginia since the mid-1990s, coded 63

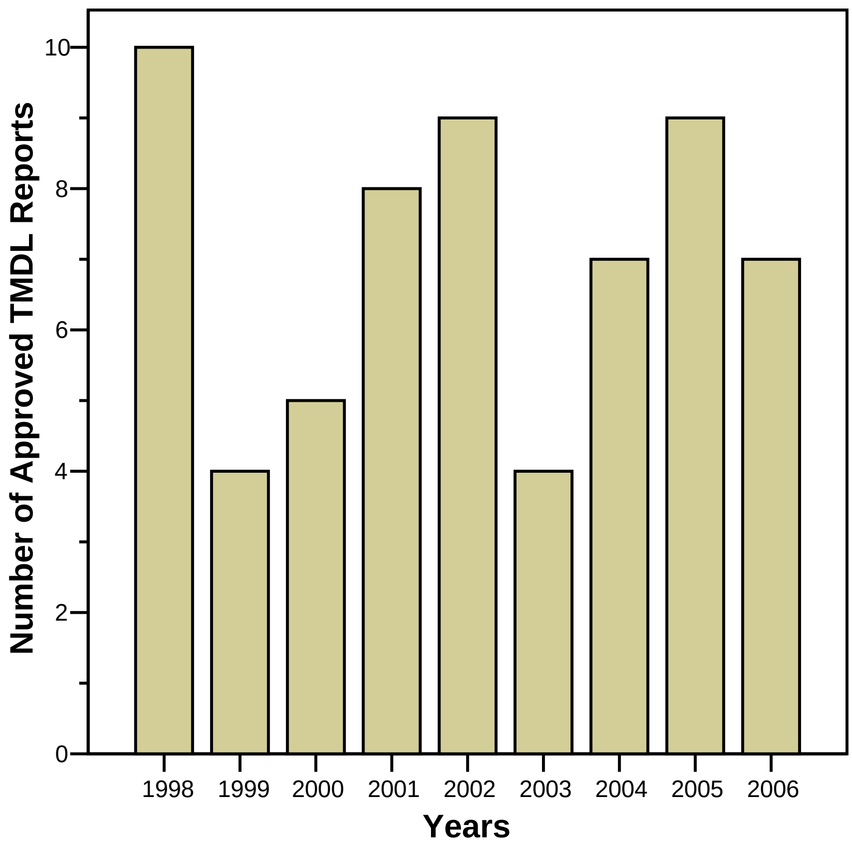
TMDL reports developed for West Virginia and Ohio that were approved by US EPA between 1998 and 2006, and conducted numerous discussions, interviews, and surveys with a range of knowledgeable individuals. These individuals included state TMDL staff, TMDL developers, state agency staff members who are knowledgeable regarding TMDL implementation activities, and other stakeholders. We also identified reports and other sources of information that could help us assess TMDL implementation progress and develop and estimate models to assess the influence of potential factors driving TMDL implementation.

During the course of undertaking these activities, we identified and resolved a series of methodological issues, and the following paragraphs highlight these issues and the ways in which they are addressed in this study. The important issues identified include: (1) the time frames over which EPA-approved TMDLs would be investigated; (2) the optimal units of analysis for study; (3) the measures of TMDL implementation success to be assessed; (4) where and how to access and compile the data to be analyzed, and (5) the analytical methods to be used to identify both likely factors driving TMDL implementation and potential improvements in policy and practice. The following paragraphs describe how these issues are addressed in this study. More detailed and complete descriptions of the research procedures used and analytical strategies employed are included in the Appendices.

There were some individuals we spoke with as we initiated this project who suggested that this study might be premature. The concern they expressed was that most TMDLs in Ohio and West Virginia had been developed and approved only over the past five or six years, and this might be too short a time frame to expect significant progress in implementation, particularly when the clearest measure of progress—the restoration of impaired water bodies—is a complex undertaking that often requires successful implementation efforts of a number of different kinds over extended periods of time.

To address this concern, we inventoried all of the TMDL reports approved by US EPA for the states of Ohio and West Virginia since the mid-1990s. We found that West Virginia’s first TMDL reports were approved by US EPA Region 3 in 1998 and Ohio’s first TMDL reports were approved by US EPA Region 5 in 2000. Between 1998 and September 2006, 63 TMDL reports covering watersheds in the two states were approved, and—taken together—they yielded hundreds of TMDLs for individual stream segments and water bodies. Figure 1 below displays information on the number of Ohio and West Virginia TMDL reports approved in each of the nine years between 1998 and 2006.

Figure 1: TMDL Reports by Year of Approval: Ohio and West Virginia



We chose the TMDLs contained in these reports as the universe for study because they were sufficiently numerous to yield relatively large sample sizes for investigation, and because all of the US EPA-approved reports in this sample would have been in place at least one year prior to the time that information on TMDL implementation would be compiled. While one year is not a long period of time when one thinks about what might be necessary to fully restore an impaired water body, it does seem like a long enough period to initiate a meaningful TMDL implementation effort. We also compiled information on the length of time since EPA approval so this time period could be accounted for in the analyses conducted.

Another important methodological issue involved determining the appropriate units of analysis for study. While we began this project with the idea that we would focus on specific stream segments that were determined to be impaired and in need of restoration, we discarded this approach after several months of preliminary investigation. We did so for two major reasons. First, as we visited with state environmental officials and looked for available sources of information, we found that most people and information sources at the state and local levels focused their thinking and work around the concept of watersheds (or individual TMDL reports covering watersheds or sub-watersheds) rather than individual stream segments. As a practical matter, this meant that information available for compilation and analysis was likely to be both more complete and more reliable at a watershed level than at the level of individual stream segments or water bodies. And secondly, because most people involved in developing and implementing TMDLs were focusing on them from a watershed perspective, it made sense to conduct our driving factors analyses at this level as well. In the end, we chose the TMDL report and TMDL report-pollutant (each TMDL report covered a defined set of pollutants that were then approved for specific segments/water bodies by US EPA) as our units of analysis. While future research efforts may build upon this one and focus productively at the stream segment/water body level, we believe that it was appropriate to begin this process with units of analysis at which information was most likely to be available and which matched up well with the conceptual frameworks used by most participants in the processes being studied.

Another issue to be addressed related to how to measure TMDL implementation progress. While the existence of a fully restored water body is an important and useful measure of TMDL implementation success, it is not the only one—particularly in cases where the amount of time that has elapsed since US EPA approval of a TMDL may not be sufficient to allow for full water body recoveries to occur. And, regardless of the time frames involved, it is useful to have a range of measures of implementation progress, so that management actions can be developed to facilitate ongoing implementation progress. For clarity and consistency, we chose to use US EPA's TMDL Program Pipeline as our analytical framework for the analysis (see Norton et. al., 2007). This framework suggests that implementation processes occurring after TMDL approval flow through four major stages: (1) planning and management, (2) implementation of controls, (3) incremental/partial recovery, and (4) full water body recovery. We then conceptualized potential measures of progress in each of these stages, and designed our data compilation processes to identify available information on these measures.

In the end, we were able to compile information on a range of measures. These include: (1) whether there are state agency officials who are knowledgeable regarding implementation processes in the TMDL-limited watershed; (2) whether there are load reducing projects in place in the watershed; (3) whether a watershed organization (or other group) has taken responsibility to implement recommended actions in the TMDL; (4) whether ambient monitoring has been conducted downstream from implementation actions; (5) whether pollutant loading reductions are believed to be occurring; (6) whether there are identified improvements in water quality; and (7) whether a full water body recovery has occurred. Information on TMDL implementation progress according to all of these measures is provided in Section 5 of this report.

Identifying sources for information on TMDL implementation progress according to these measures was also a major challenge, particularly when one considers the range of potential information sources available and the need to compile comparable information relating to dozens of TMDL reports and 174 report-pollutant combinations across two states. No feasible set of information sources currently available is perfect and complete, so we chose the sources of information that would yield the most comparable information at a reasonable cost. We found two sources that met these criteria. First, we compiled information from written sources. We reviewed and coded all 63 US EPA-approved TMDL reports in our sample to identify major pollutants and pollutant sources to be addressed, and to compile other information relevant to our analyses. Key questions included on the coding form used for these assessments are included in Appendix D to this report. We were also able to identify several key sources of written information above and beyond the TMDL reports themselves. These included reports and other compilations of information on TMDL implementation actions funded by Clean Water Act section 319 grant funds, Office of Surface Mining funds for watershed restoration, and funds made available through Ohio's Water Resource Restoration Sponsor Program.

Our second major information source consists of state environmental officials who are most centrally involved in developing TMDLs and in managing water quality restoration activities in the watersheds being investigated. However, because state TMDL programs are organized differently in Ohio and West Virginia, slightly different approaches were used to identify "lead developers" and "knowledgeable state officials" in the two states. In Ohio, we approached the TMDL Coordinator with a list of individuals who were identified in TMDL reports as lead investigators who had guided TMDL development processes relating to these reports. With the cooperation and assistance of the TMDL Coordinator, we then contacted these people and requested information on state and federal officials who were most knowledgeable regarding TMDL implementation activities in the watersheds covered by the TMDL reports that they had developed. The official noted by the lead developer was then identified as the "knowledgeable state official". This list of knowledgeable state officials was then supplemented by individuals identified the TMDL Coordinator.

In West Virginia, where TMDLs were developed centrally, the TMDL Coordinator was—in effect—the lead developer for all TMDLs created at the state level. To identify knowledgeable state officials, the TMDL Coordinator suggested that we communicate with leaders of the WVDEP Non-point Source Program, because this program funds watershed basin coordinators and interacts with other agencies that implement on-the-ground projects. Through communication with Non-point Source Program leaders, we identified knowledgeable state officials in all cases where they thought such a person exists. In total, we were able to identify "knowledgeable state officials" who were aware of the status of implementation activities for 45 of the 63 TMDL reports being investigated across the two states. There were eighteen watersheds where numerous phone calls and discussions could not yield the identification of an individual who was knowledgeable regarding implementation progress.

We then contacted these knowledgeable state officials and interviewed them about TMDL implementation activities in the watersheds about which they were informed, while drawing on specific information from the TMDL reports that had previously been coded. We used a number of standardized questions to guide the interviews and to ensure comparability of the information compiled. These interviews were detailed in most cases and they produced much of the information we have compiled on the engagement of stakeholder groups in TMDL implementation, implementation projects, loading reductions, and water quality improvements. By implementing this information compilation strategy, we created a set of data that characterize implementation progress in West Virginia and Ohio as of 2008, and provide a basis for analyses of potential driving factors, as well as recommendations for changes in practices and policies that can help foster TMDL implementation progress in the future. While the information we compiled from these knowledgeable state officials forms the core of the analyses presented in this report, it is supplemented by more targeted interviews with watershed group leaders and others, where appropriate.

To characterize TMDL implementation progress in later portions of this report, we present information on each of the TMDL Program Pipeline measures outlined above: (1) the number of US EPA-approved TMDL reports for which state officials are knowledgeable regarding implementation; (2) the number of US EPA-approved TMDL reports for which at least one load reducing project is being undertaken; (3) the number of areas in which groups are taking responsibility for implementation; (4) the number of areas covered by TMDL reports in which ambient monitoring downstream from implementation actions has been undertaken; (5) the number of watersheds within which the knowledgeable state officials we interviewed believe (or know) loading reductions have occurred; (6) the number of watersheds in which these officials said that demonstrated water quality improvements have been created; and (7) the number of watersheds that have been fully restored.

To identify likely driving factors for TMDL implementation, we employ statistical models to ascertain the extent to which predictor variables identified by current literature relevant to TMDL implementation enable improvements in predicting two kinds of measures of implementation progress: the existence of a group to foster TMDL implementation and the estimated occurrence of pollutant load reductions. The results of these analyses—along with insights drawn from our review of TMDL reports, interviews, and other sources—enable the development of a set of potential changes in practices and policies that can be used to help accelerate TMDL implementation progress in the future.

All of these analyses are presented in the results that follow in Sections 5 and 6 of this report. The results focus first on presenting information on the extent of TMDL Program Pipeline progress that has been achieved in watersheds with approved TMDL reports in Ohio and West Virginia. Section 5 presents information on the incorporation of TMDL recommendations in NPDES permits and on the views of state agency officials regarding the extent to which the TMDL process fosters pollutant load reductions and water quality improvements. Section 6 presents the results of statistical analyses designed to enable the identification of factors that are likely to give rise to TMDL implementation progress. Section 7 of the report then discusses potential improvements in practices and policies that are suggested by these analyses. Before that, however, the section that follows provides a description of TMDL-related practices in Ohio and West Virginia, as well as pollutants and pollution sources in the 63 TMDL-limited watersheds addressed in this report.

4. TMDLS, POLLUTANTS, AND POLLUTION SOURCES

The subsections that follow overview TMDL-related practices in Ohio and West Virginia and summarize information compiled on the pollutants and pollution sources in the 63 watersheds addressed by TMDL reports included in this analysis.

4.1 TMDL-Related Practices in West Virginia and Ohio

Both Ohio and West Virginia assess water quality conditions in their respective states, and develop TMDL reports and pollutant loading allocations that are then approved by US EPA's regional offices. Both states also take advantage of assistance and guidance provided by US EPA, although they also differ in their practices and processes.

West Virginia and Ohio developed active TMDL programs during the 1990s and now use basin-wide watershed assessment approaches to identify impaired waters, pollution sources, and potential water quality improvement strategies. To date, both states have also focused more attention on developing TMDLs than on making sure they are implemented. However, the two states also vary in important respects. Water quality standards and assessment methods in the two states differ from one another, as do their processes for developing and writing TMDLs. The two states also employ different approaches to implementation and they receive differing levels of support from state policymakers to implement water quality improvement projects. What follows is a discussion of some of the key similarities and differences in TMDL related practices undertaken in the two states.

4.1.1 Similarities in TMDL-Related Practices in Ohio and West Virginia

TMDL development in both West Virginia and Ohio was initiated in the 1990s. Both states were also subjected to litigation, which required them to focus time and energy on meeting TMDL-related requirements imposed by courts. In West Virginia, US EPA Region 3 assisted the state Department of Environmental Protection (DEP) in developing all of the early TMDLs, although the WV DEP has now taken over the process of TMDL development and has sought to implement a number of improvements since that time. US EPA Region 3 approved the first TMDLs contained in the first ten West Virginia TMDL reports in 1998, and it has approved TMDLs contained in an additional 27 reports between 1999 and 2006. Two West Virginia TMDL reports were developed by the Ohio River Valley Water Sanitation Commission (ORSANCO).

Ohio's first TMDLs were approved by EPA Region 5 in 2000, and—like most other Ohio TMDLs—they were developed by the Ohio EPA. While US EPA Region 5 took a leading role in the development of the Mahoning River Watershed and Wabash TMDL Reports in Ohio and the US Army Corps of Engineers took the lead in developing the acid mine drainage report that yielded the Monday Creek TMDL, other TMDLs developed in Ohio have been created and submitted for approval by Ohio EPA staff. Ohio EPA continues to lead the state's TMDL development efforts to this day.

Both West Virginia and Ohio have also integrated their TMDL programs with basin-wide approaches for assessing watershed health and water quality. This approach enables the two states to address a range of pollution sources and control strategies in more holistic fashion than if assessments were made through other approaches that do not account for the interdependencies that develop at the watershed level. Ohio's basin-wide assessment process was developed around a five-year assessment cycle, but—because of funding limitations—this cycle now operates on approximately a ten-year basis (OEPA, 2006, p. 22). West Virginia's watershed assessment cycle operates on a five-year basis.

Like most states, West Virginia and Ohio face numerous water quality challenges, and this fact—along with timetables for TMDL development ordered as a result of litigation—has required the TMDL programs in both states to focus more on developing TMDLs than on implementing them. However, both state TMDL programs are accompanied by NPDES and section 319 non-point source water pollution management programs, and these programs draw information from completed TMDLs to help foster and focus implementation actions.

Both Ohio and West Virginia also benefit from funding provided by the US Department of Agriculture, which is distributed to agricultural operations to enable them to implement conservation practices on their lands. The US Department of Agriculture also provides funding for technical assistance support, which is being used in Ohio and West Virginia to help foster agricultural best management practices and the development of management programs for storm-water runoff (in Ohio, these programs are administered at the county level). While both states have developed agricultural technical assistance committees to help distribute these funds, discussions with state agriculture and environmental officials suggest that their operations do not appear to be closely coordinated with water quality programs administered by state environmental agencies in either of the two states. In West Virginia, the State Technical Committee had previously linked certain Farm Bill program activities with TMDL priorities, but this approach was later scrapped. Importantly, neither West Virginia nor Ohio has explicit authority to require specific land use changes to foster water quality improvements, and this is an important limitation of authority in both cases. It is particularly evident with respect to agricultural land use practices, which are of importance to effective water quality management in both states.

4.1.2 Differences in TMDL-Related Practices in West Virginia and Ohio

While both Ohio and West Virginia have water quality standards comprised of designated uses, water quality criteria, and anti-degradation policies, their standards differ from one another and this affects the processes they use to assess water quality and develop TMDLs.

Ohio's Water Quality Standards include designated uses for aquatic life, water supply, and recreation (Heitzman, 2004). The state is also known for its prevalent use of biological criteria to support aquatic life uses, and these criteria vary based on a series of habitat classifications that the state has developed over time (exceptional warm-water habitat, coldwater habitat, etc.). The state uses a series of indices to determine whether specific water bodies adhere to their biological criteria, including the Index of Biological Integrity (IBI), the Invertebrate Community Index (ICI), the Modified Index of well-being (MIwb), and the Qualitative Habitat Evaluation Index (QHEI). These criteria for aquatic life are accompanied by chemical-specific criteria. Chemical-specific criteria also exist for water supply and recreational uses. Ohio's anti-degradation policy meets baseline federal requirements, and includes added protections for various categories of outstanding and superior state waters. Notably, the Ohio EPA is in the process of proposing changes to its water quality standards as this report is being written.

In West Virginia, the most important designated uses also include aquatic life (warm water fisheries and trout waters), public water supply, and recreation. Benthic macro-invertebrates are used to measure compliance with a narrative biological criterion, and numerous waters are listed as impaired due to this biological "condition not allowable." Other water quality criteria that result in significant numbers of listings include fecal coliform and acid mine drainage-related criteria: pH, iron, aluminum, and manganese. The state's anti-degradation policy also meets federal requirements, and includes three tiers of protection: Tier 1, Tier 2, and Tier 3. Water quality standards undergo major overhauls during triennial reviews, and they are typically adjusted by the legislature each year.

While both states adhere to TMDL processes recommended by the US EPA, the two states differ in the processes they use to develop TMDLs. In general, after initially relying on US EPA Region 3 to develop TMDLs in the years surrounding the turn of the century, the West Virginia DEP now develops TMDLs out of its central office in Charleston, under the supervision of a TMDL coordinator who has made substantial efforts to ensure consistency and improve the quality of West Virginia TMDLs over time. While the TMDLs themselves are written by a contracting firm, WV DEP staff members in Charleston oversee the process. As a result, while one can discern changes in the ways in which West Virginia TMDLs have been written over time, there now appears to be a fair amount of consistency in their preparation.

The Ohio EPA takes a more decentralized approach in developing its TMDLs. Because it possesses a reasonably robust administrative infrastructure of five district offices (Northeast District, Northwest District, Central District, Southeast District, and Southwest District), the Ohio EPA often relies on its district office staff to develop TMDLs, which are then submitted to a staff of three persons in Columbus who appear to guide the overall process, compile data, and review and then submit individual TMDL reports to US EPA Region 5 for approval. Probably as a result of this somewhat decentralized process, one tends to see more variation in Ohio's TMDL reports compared with West Virginia. For example, while TMDLs developed in West Virginia in recent years appear to consistently break out waste-load allocations for individual NPDES permits on individual stream segments, Ohio's TMDLs appear to vary somewhat with respect to the ways in which they apply waste-load allocations to individual point sources dischargers. In some cases (and particularly those involving storm-water discharges), the Ohio TMDLs specify aggregate waste-load allocations, which might apply to a range of similar discharges. In other cases, they include specific permit limits for individual NPDES dischargers. In spite of this variation, a review of the Ohio TMDL reports developed since 2000 reveals a change from a focus on individual stream segments and water bodies to the use of individual watershed assessment units.

West Virginia and Ohio also differ in the mechanisms they have established for enabling information from TMDL reports to be incorporated into local and regional water quality improvement efforts. In West Virginia, the TMDL Program appears to view its responsibilities as limited to the development of TMDLs, which are then to be implemented by others. For point sources, these others are housed in the WV DEP's permitting offices for wastewater, industrial, and mining permits. For non-point sources, the WV DEP relies on five watershed basin coordinators who are responsible for coordinating with watershed organizations and guiding watershed improvement efforts throughout the entire state. Both of these sets of implementing agents are responsible for incorporating information from approved TMDLs into their implementation activities.

In Ohio, the TMDL program staff members appear to have a somewhat greater level of engagement in issues associated with implementation, even though the bulk of their past efforts have focused on TMDL development. TMDL implementation processes in Ohio, like the state's TMDL development processes, are managed through Ohio EPA's five district offices. While only one of these five offices (the Northeast District) has an individual who specifically serves as a TMDL coordinator, all five have individuals who implement waste-load allocations in NPDES permits and manage non-point source water pollution control projects and activities. As in West Virginia, these individuals can draw on information in TMDL reports as they carry out their activities.

The two states also differ with respect to the resources they have available to help foster the implementation of recommendations contained in TMDL reports. Both states can draw on federal section 319 funds to facilitate a range of TMDL implementation activities, and they both also have access to federal funds to address acid mine drainage (AMD) problems through the US Department of Interior (DOI) Office of Surface Mining. Some of these DOI funds flow to the states to address AMD problems; other funds flow to watershed groups. However, while Ohio has access to several other sources of funding to support watershed management and TMDL implementation, West Virginia's supplemental resources appear to be limited to its Stream Partners Program, which can provide project grants of up to $5000.

Ohio, by contrast, benefits from a number of additional funding programs that can be used to help foster TMDL implementation. These programs include specific funds to protect the Lake Erie watershed that are provided by the US EPA Great Lakes Program and the state's Lake Erie Commission, as well as the Clean Ohio bond fund and Environmental Education grant programs. The Ohio EPA also operates the Water Resource Restoration Sponsor Program (WRRSP) as a part of its State Revolving Fund, and this enables municipalities and others taking out loans to fund water infrastructure projects to target portions of the interest they pay to fund watershed projects within the state. Since 2001, funding made available for watershed restoration projects under this program has ranged from $3.5 to $19 million each year. Another potentially important source of funding that is available in Ohio (but not in West Virginia) is the Ohio Watershed Coordinator Grant Program, which is funded with 319 grant monies and operated by the Ohio Department of Natural Resources. This program provides funding to enable watershed groups to hire a watershed coordinator to develop and implement watershed action plans. It therefore serves as a baseline funding source to help build local and regional capabilities to improve water quality in Ohio.

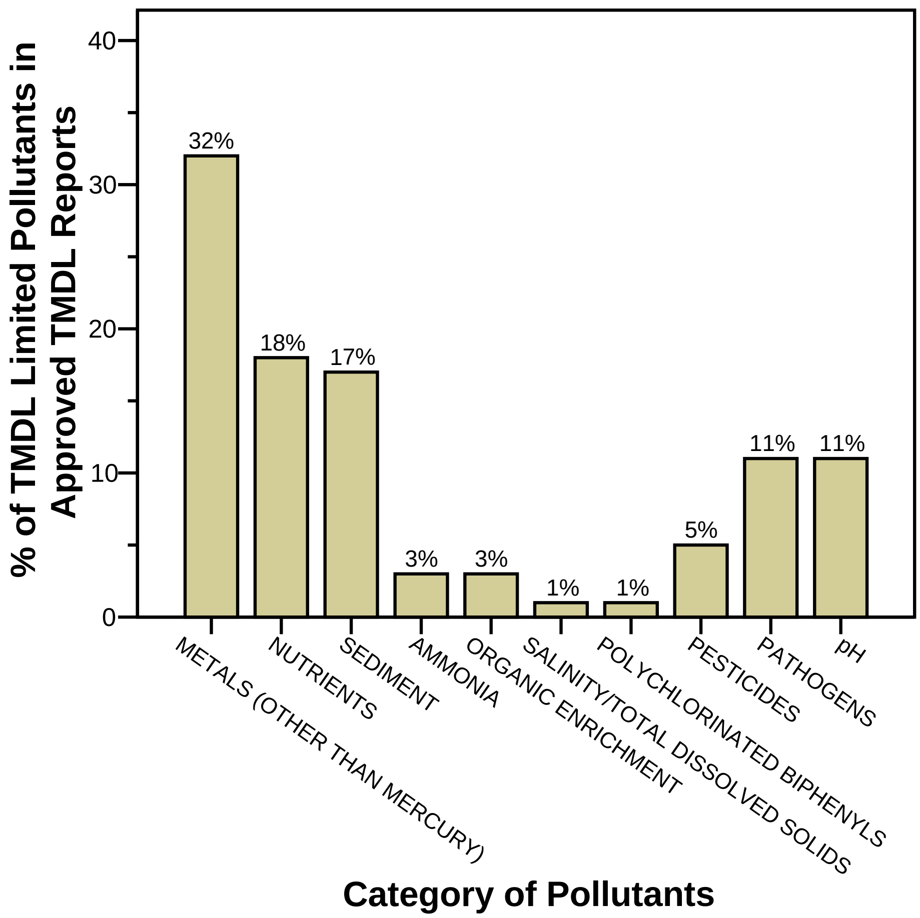
Thus, both West Virginia and Ohio draw on USDA and US DOI assistance, as well as support from the federal TMDL, NPDES, and 319 grant programs. However, the two states differ in their water quality criteria and assessment procedures, as well as in the ways in which they develop TMDLs and facilitate their implementation. Some of these differences may highlight factors that are relevant to fostering accelerated progress in implementing TMDLs—a point to which we will return in Section 6 of this report.

4.2 Characteristics of Ohio and West Virginia Watersheds

As noted above, our investigation of TMDL reports approved by US EPA between 1998 and 2006 in Ohio and West Virginia identified 63 approved TMDL reports. These reports, in turn, yielded a total of 174 approved report-pollutant combinations (in effect, this is the number of cases in which a pollutant is targeted for implementation efforts in these 63 TMDL reports). This subsection overviews the pollutants and pollutant sources addressed in the TMDLs that were included in this study. A more detailed summary of the TMDL reports and the pollutant and pollutant sources associated with them is provided in Appendix E.

The TMDL reports developed for West Virginia and Ohio used a variety of names for similar pollutants (sediment and siltation, for example). To simplify the presentation and analysis, we divide pollutants into categories and characterize pollutants based on these pollutant categories. The breakout of specific pollutant names into the ten pollutant categories used in this analysis is presented in the Appendix A, and it is generally consistent with the categorizations used by the US EPA. Figure 2 displays the distribution of pollutants (by pollutant category) addressed in Ohio and West Virginia TMDL reports approved by US EPA between 1998 and 2006.

Figure 2: Distribution of Pollutants in Watersheds with Approved TMDL Reports*: Ohio and West Virginia, 1998 – 2006



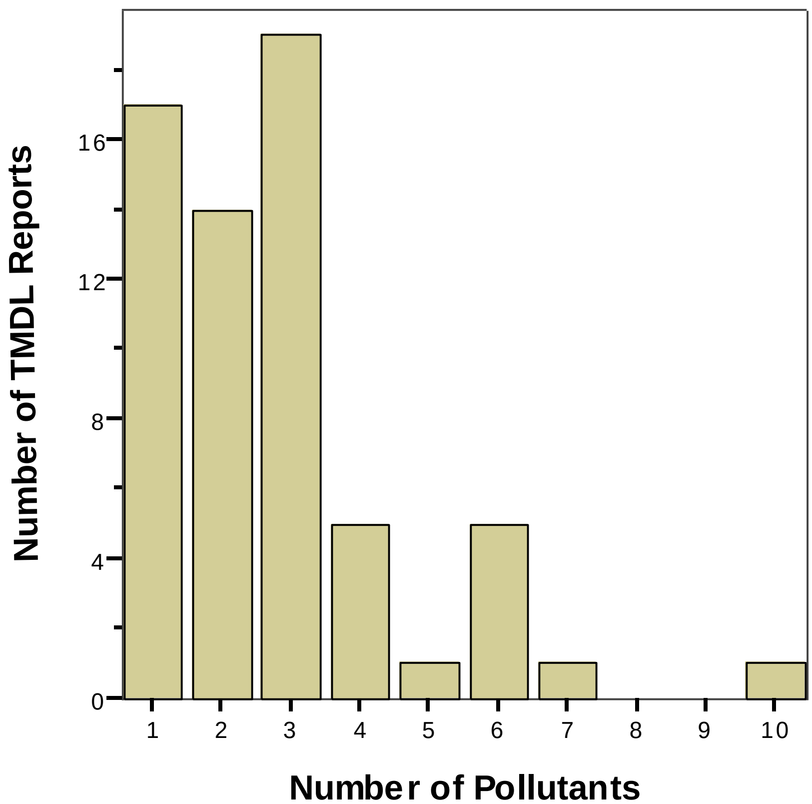
* Figures in this chart do not add to 100% due to rounding.

As Figure 2 shows, metals were the most common pollutant category found in the TMDLs investigated, and this is not surprising given the widespread presence of mining operations in West Virginia and in southeast Ohio. A total of 32% (55 of the 174 reported pollutants) were metals, and aluminum, manganese, and iron dominated this pollutant category. Because most of these releases of metals were associated with AMD, pH was also a common category of pollutant (11% or 19 report-pollutant combinations). Nutrients (18%, or 31 of 174 reported pollutants) and sediment (17%, or 29 of 174 reported pollutants) were also quite common because agriculture and storm-water runoff in developed areas are common sources of nutrients and are also common sources of water quality problems in the two states. Pathogens are also a common pollutant (11%, or 19 report-pollutant combinations), and they tend to result from failing onsite wastewater systems and/or runoff from agricultural operations. As one can see from Figure 2, the remaining pollutants in the sample are less abundant, and include pesticides (5%/8 of 174), organic enrichment (3%/5 of 174), ammonia (3%/5 of 174), PCBs (1%/2 of 174), and salinity (1%/1 of 174).

A total of 34 of these pollutants (20%) represent potential threats to human health (a summary of pollutants that represent potential threats to human health is provided in Appendix A). Threats relating to the remaining 140 pollutants are primarily related to ecosystem impacts. Notably, however, 27 of the 63 EPA-approved TMDL reports in Ohio and West Virginia (43%) addressed at least one pollutant that posed a potential threat to human health.

Across the two states, the number of pollutants addressed in the 63 TMDL reports investigated ranged from one to ten. Figure 3 below shows the distribution of the number of pollutants addressed across the 63 TMDL reports.

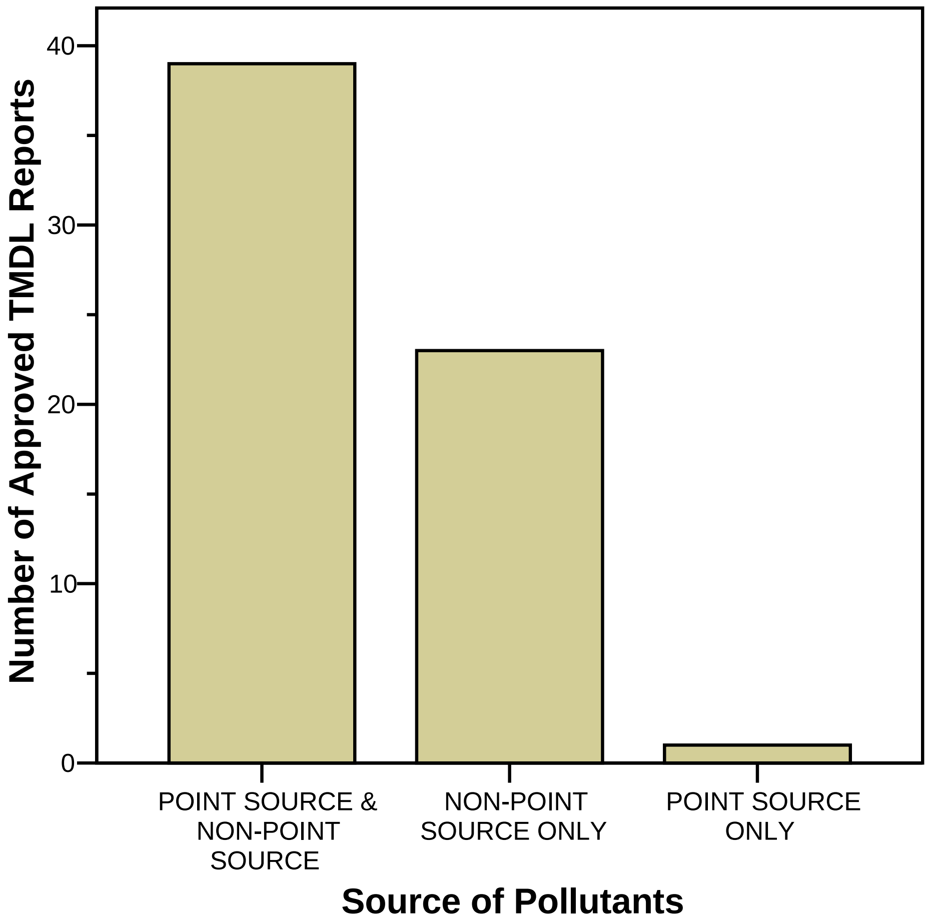
Figure 3: Number of Pollutants per TMDL Report



The vast majority of TMDL reports address one, two, or three pollutants (79%), although one TMDL report—the Mill Creek Scioto TMDL report in Ohio—addresses ten pollutants. Six of these ten pollutants were pesticides that were found in sediment, much of which was subsequently removed by the company responsible for the contamination after completion of the TMDL.

While the approved TMDLs targeted both point and non-point sources, non-point sources were far more prevalent than point sources. Twenty-three of the 63 US EPA-approved TMDL reports (37%) targeted only non-point sources, and implementation actions targeted for 71 of the 174 pollutants addressed in these reports (41%) focused only on non-point sources. Most of the US EPA-approved TMDL reports (39 of 63, or 62%) targeted both point and non-point sources, and this was also the case for the pollutants addressed in these reports (97/174, or 56%). One TMDL report in West Virginia addressed only point sources.[1] Figure 4 below shows the distribution of TMDL reports with implementation actions targeted for three pollutant source categories (both point and non-point sources, non-point sources only, and point sources only, respectively).

Figure 4: Distribution of Pollutant Sources in Approved TMDL Reports: Ohio and West Virginia, 1998 – 2006

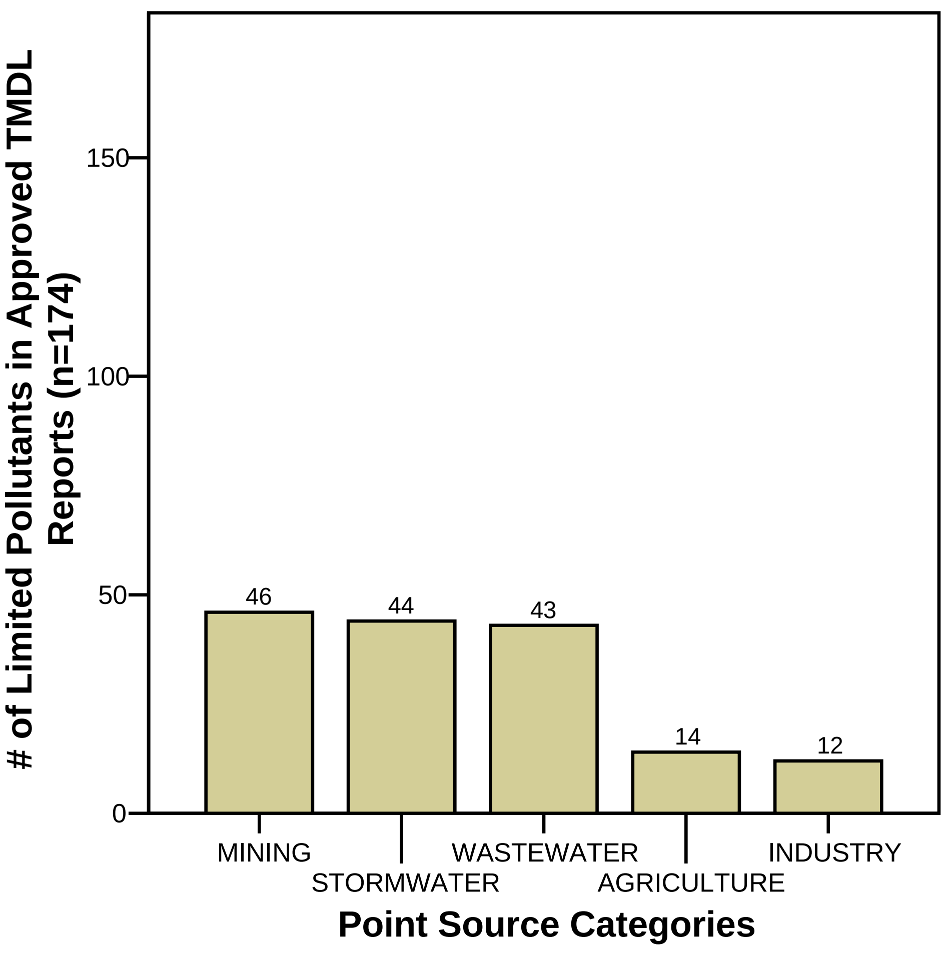


While a range of point source water pollution sources are targeted for action in the TMDL reports investigated for this study, the vast majority of pollutants targeted *from point sources* were from mining operations (46 of 174 total pollutants, or 26%), storm-water sources (44 of 174 total pollutants, or 25%; these point sources include communities subject to storm-water Phase I and II requirements, and

[1] This TMDL, for low dissolved oxygen in the Blackwater River in West Virginia, removed unused waste-load allocations from potential point source dischargers.

construction and industrial storm-water permit holders), and wastewater treatment plants (43 of 174 pollutants, or 25%) with targeted effluent loading reductions and/or control requirements for Combined and/or Sanitary Sewer Overflows (CSOs and SSOs). Figure 5 below displays the number of targeted pollutants from specific kinds of point sources that were targeted for action in the approved TMDL reports analyzed for this study.

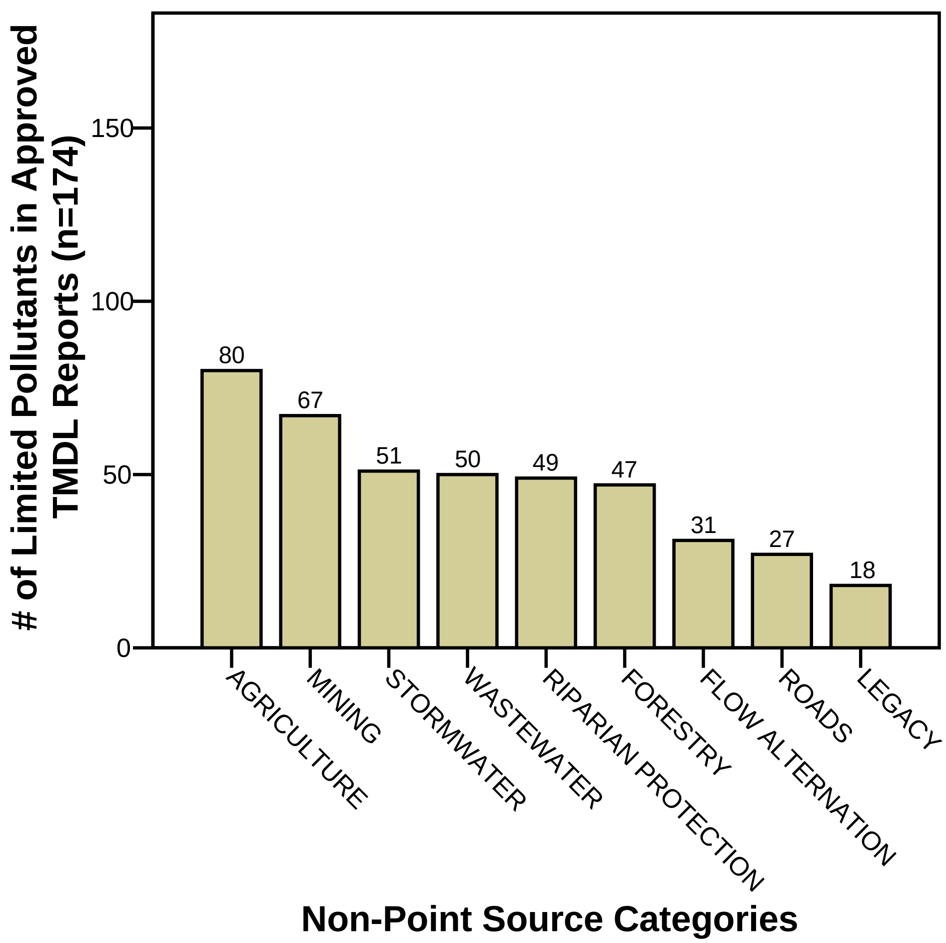
Figure 5: Distribution of Point Sources in Watersheds with Approved TMDL Reports: Ohio and West Virginia, 1998 – 2006*



* This chart reflects the total number of pollutants addressed in this study sample that emanate from the specified types of point sources. The bars are relatively small in comparison to the height of the y-axis because most pollutants targeted by TMDLs addressed in this study emanate from non-point sources.

The non-point sources targeted for action varied considerably. Almost half (80 of 174, or 47%) of the pollutants targeted for action addressed agricultural sources. Over one-third of the pollutants addressed (67 of 174, or 39%) are from mining sources. Non-point source storm-water runoff, onsite wastewater systems, inadequate riparian protections, and inadequate forest management operations were also targeted for action in a number of these TMDL reports. Figure 6 below summarizes the relative prevalence of these sources in the TMDL reports addressed in this study.

Figure 6: Distribution of Non-point Sources in Watersheds with Approved TMDL Reports: Ohio and West Virginia, 1998 – 2006



* This chart reflects the total number of pollutants addressed in this study sample that emanate from the specified types of non-point sources.

As one can see, flow alterations in hydrological systems (dams, stream corridor restoration projects, etc.), road management practice improvements, and legacy pollutants from past economic activities were also targeted for action to address a number of the pollutants identified for action in the TMDLs studied.

5. FINDINGS ON IMPLEMENTATION PROGRESS

Two sets of findings grow from this research. The first set of findings addresses the extent to which TMDLs are implemented after their approval by US EPA. This set of findings focuses on implementation actions to address non-point and point source water pollution sources, as well as effluent limit changes in major NPDES permits. It also includes findings relating to the opinions of state officials regarding the role of TMDLs in facilitating pollutant loading reductions, water quality improvements, and other benefits.

A second set of findings identifies factors that appear to foster TMDL implementation in Ohio and West Virginia. These factors are identified through a series of statistical analyses that are presented in Section 6 (and are supplemented in the appendices). Both of these sets of findings — along with other insights gained through this research— support suggested steps that can be taken to accelerate TMDL implementation progress in the future. These steps are described in Section 7, and are followed by suggestions for future research (Section 8) and a short concluding section that describes what we have learned through this research.

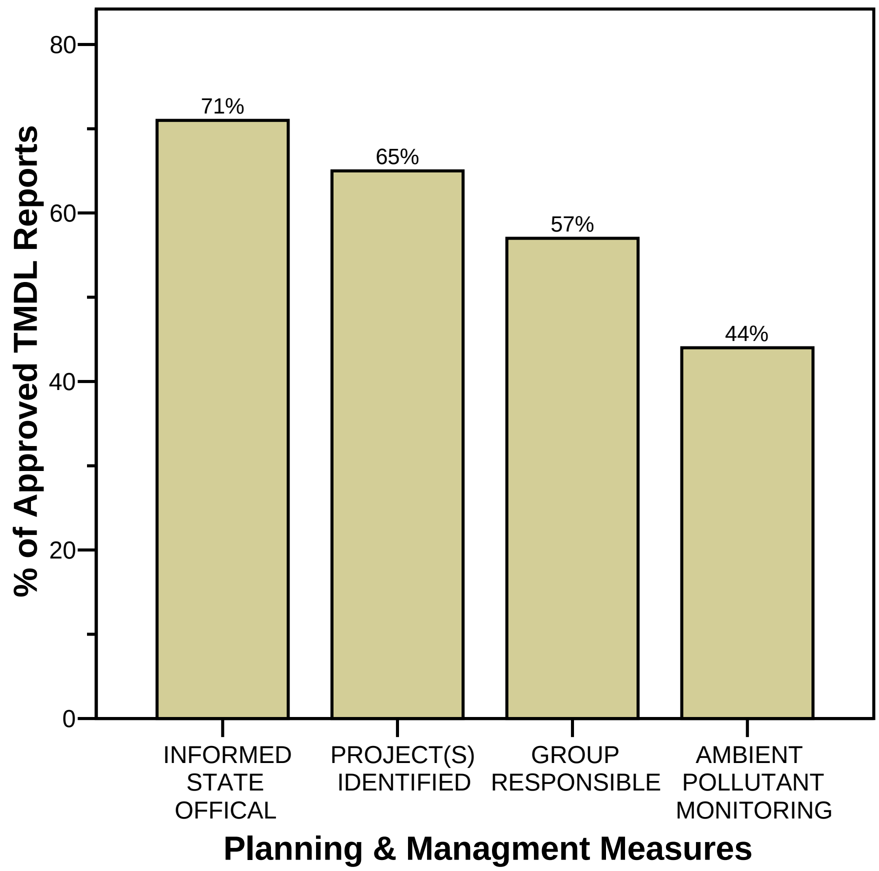
5.1 Progress on the TMDL Program Pipeline: West Virginia and Ohio

Our compilation of information from interviews with knowledgeable state environmental officials and reviews of written documents identifies activities that address pollutants and pollution sources that are targeted for action in approved TMDL reports. While we focus on non-point source implementation efforts because they are more prevalent sources of impairment than point sources, we also ask questions and compile information relevant to point sources. We find TMDL implementation efforts being undertaken in many cases, but we also identify a number of TMDL limited watersheds in which TMDL implementation efforts are not apparent.

The TMDL Program Pipeline model developed by US EPA envisions four major stages for TMDL implementation (Norton, et. al., 2007), and we compile information for at least one measure of implementation progress for each of these stages. At the ***planning and management*** stage of the TMDL implementation process, we find officials who are knowledgeable about TMDL implementation activities for 45 of the 63 TMDL reports in our sample (71%). Through interviews with these knowledgeable individuals and reviews of written documents, we identify TMDL implementation projects that are underway in at least 41 of the 63 watersheds covered by the TMDL reports in our sample (65%). We also identify whether there are groups in the affected watersheds that are taking responsibility to foster the implementation of recommendations made in TMDLs. To compile this information, we relied on the judgment of the state officials who we interviewed about TMDL implementation progress. They identified groups taking responsibility for TMDL implementation in 36 of the 63 watersheds in our sample (57%). To gain a sense of the extent to which these implementation efforts are focused on meaningful improvements in water quality in these watersheds, we also asked whether pollutants addressed in the TMDL had been the focus of ambient water quality monitoring efforts since approval of the TMDL. The responses of the officials we interviewed indicated that ambient monitoring had been conducted for at least one pollutant addressed in the TMDLs in 28 of the 63 watersheds covered by TMDL reports in our sample (44%).[2] The chart below provides a graphic picture of the planning and management processes in place for watershed addressed in the 63 TMDL reports included in this study.

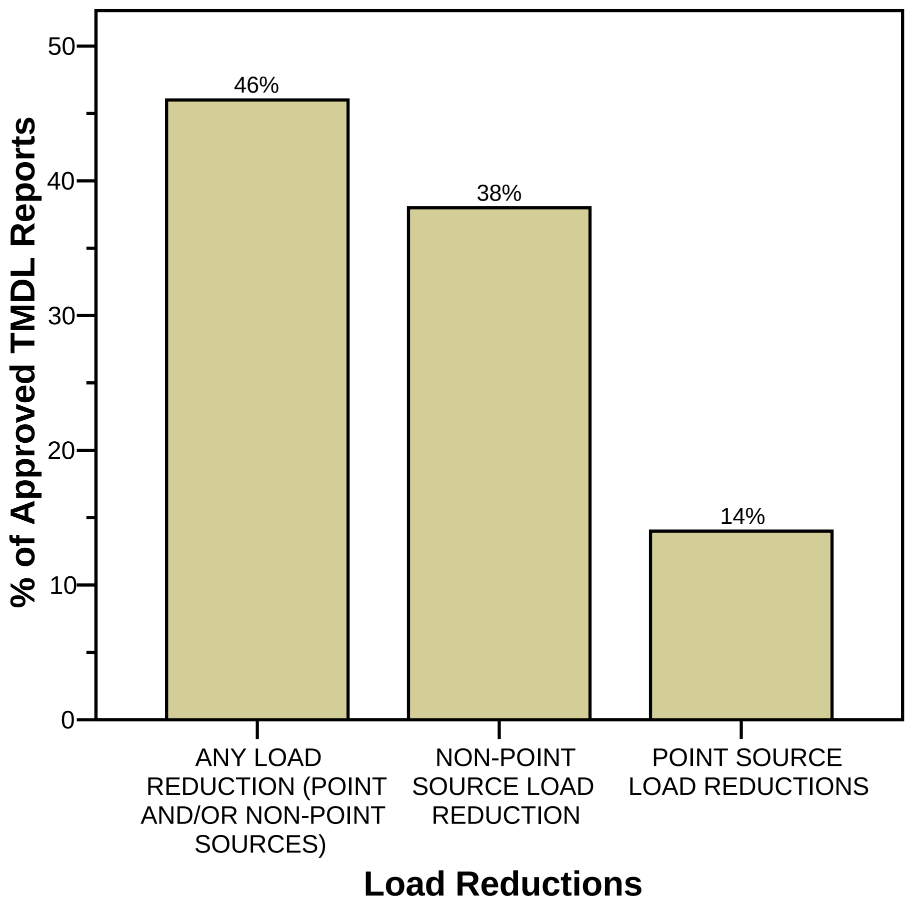
[2] More specifically, we focused on monitoring downstream from TMDL implementation activities.

Figure 7: Watershed Planning & Management Measures for Approved TMDL Reports: Ohio and West Virginia, 1998 – 2006



To gain an understanding of the extent to which the implementation actions being carried out are leading to the ***implementation of controls*** on pollutant releases to impaired water bodies, we asked state officials if they believed that pollutant loading reductions had been achieved by the implementation actions undertaken to date. The questions we asked focused on their level of certainty regarding whether pollutant loading reductions that had been achieved for both non-point and point sources. The specific wording of these questions is provided in Appendix D. The responses indicated that the state officials interviewed knew of or believed that pollutant loading reductions (for at least one pollutant) had been achieved in 29 of the 63 watersheds addressed by the TMDLs in our sample (46%). For non-point sources, those interviewed knew of or believed that pollutant loading reductions had occurred in 24 of the 63 watersheds studied (38%), while pollutant loading reductions were believed to have occurred in 9 of the 63 watersheds through the implementation of point source controls (14%). Figure 8 summarizes this information on pollutant loading reductions. It shows that most of the loading reductions identified are occurring through non-point source pollutant reduction efforts.

Figure 8: Estimated Load Reductions in Watersheds with Approved TMDL Reports: Ohio and West Virginia, 1998 – 2006

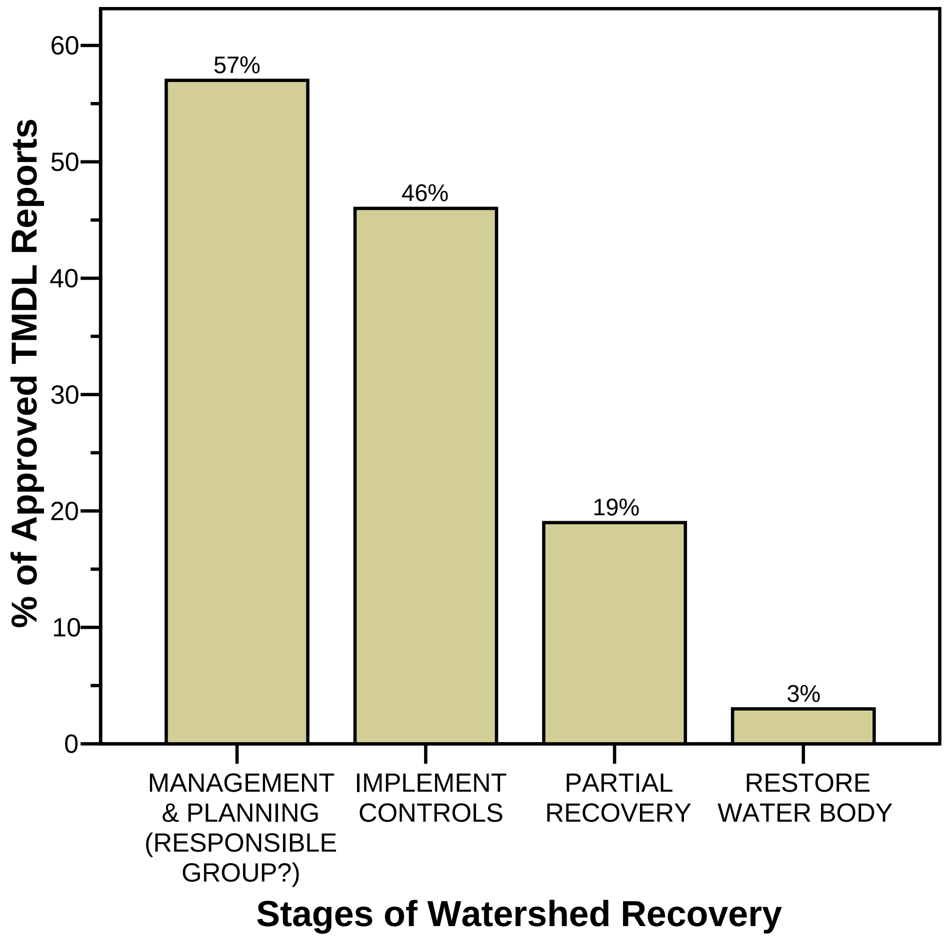


Our research procedures also called for an effort to identify cases where ***partial water body recoveries*** had occurred or were underway. A partial water body recovery occurs in cases where ambient water quality (and/or stream sediment condition) improves for one or more pollutants, but does so in a way that does not result in full compliance with state water quality standards. This situation could occur in a variety of ways, such as water quality improvements that are notable but not of sufficient magnitude to achieve water quality standards, achievement of water quality standards for one or more pollutants (or habitat conditions) but not for all, and/or water quality improvements that are limited in geographic scope (e.g., do not cover a sufficiently large geographic area to result in a state declaration of water quality standard compliance). To ascertain whether one or more of these conditions might have been achieved in watersheds addressed by our sample, we asked a series of questions of the officials we interviewed which sought to identify whether water quality improvements had been identified in locations downstream of locations where TMDL implementation activities had occurred since US EPA approval of the TMDL. The responses indicated that measured improvements in ambient water quality had occurred in at least one location downstream from a TMDL implementation action for at least one pollutant in 12 of the 63 watersheds addressed in our study (19%).

We also assessed whether there have been ***full water body recoveries*** for any of the 63 watersheds in our sample. This is a rather straightforward exercise because states track full water body recoveries in the combined 303(d)/305(b) reports they submit to the US EPA every two years. Only two of the 63 (3%) watersheds in our sample were declared as recovered by WV DEP or OEPA. Both of these watersheds addressed pathogen contamination in the Potomac River basin in eastern West Virginia.

To summarize the discussion above, planning and management processes are underway in well over half of the watersheds studied in Ohio and West Virginia. In these watersheds, we find state agency officials who are knowledgeable regarding implementation processes at the watershed level (71%), one or more pollution-reducing projects underway (65%), and groups taking responsibility for TMDL implementation (57%). In a substantial subset of these cases, we were also able to identify ambient water quality monitoring efforts being undertaken for one or more pollutants (44%). The knowledgeable state officials we interviewed believed that efforts being undertaken have yielded pollutant loading reductions in close to half (46%) of the watersheds addressed in the EPA-approved TMDL reports. And, in almost one-fifth of the watersheds (19%), it appears that there is evidence of water quality improvement. However, in only two of the 63 watersheds studied does that evidence suggest full water body restoration. Figure 9 below summarizes the discussion above, as well as progress on the “TMDL Program Pipeline” in Ohio and West Virginia.

Figure 9: Implementation Progress in TMDL-limited Watersheds



A review of Figure 9 shows clearly that TMDLs are being implemented in many watersheds in Ohio and West Virginia. However, it also suggests that there is substantial room for improvement in the extent to which implementation is occurring. Forty-three percent of the TMDL-limited watersheds in this sample do not appear to have any group working to foster TMDL implementation (100% - 57% with a responsible group = 43%). Some groups are just getting started, and have not yet implemented effective (eg. load reducing) controls. In addition, it is clear that the implementation of controls does not necessarily lead to noticeable water quality improvements, at least in the time periods to date. And finally, even when water quality improvements are identified, they are frequently just a first step in a longer road to water body restoration. Thus, while the results here are encouraging in some respects, they also suggest that there is much work to be done if we are to restore watersheds throughout Ohio and West Virginia.

5.2 TMDL Implementation Progress and Major NPDES Permits

While the discussion in the previous section suggests that progress is occurring in the implementation of TMDLs for both non-point and point source pollution sources, it does not assess the extent to which recommendations contained in US EPA-approved TMDL reports are incorporated into NPDES permits. The discussion that follows addresses this issue.

While it is clear that non-point source water pollution problems are more prevalent than point source problems in both West Virginia and Ohio, an inventory of NPDES permits in the affected watersheds reveals that there are still hundreds of point sources that contribute pollutants to the waters of both states. Of these point sources, 51 permits classified as "majors" discharge to the watersheds addressed in TMDL reports in our sample universe. The vast majority of these 51 major permits are in Ohio. Members of our project team reviewed provisions in US EPA-approved TMDL reports for these 51 major permits, and were able to identify 38 major permits that were targeted for action in some way. The remaining 13 major permits in these TMDL limited watersheds do not appear to have been targeted for action in the approved TMDL reports. Of the 38 targeted for action, 27 were major permits for which TMDL reports appeared to recommend effluent limit changes (the remaining 11 focused on other NPDES actions, such as CSOs and/or storm-water runoff). However, only 19 of these 27 contained clearly stated recommended permit limits and/or individualized waste-load allocations that could be directly translated into more stringent effluent limits in NPDES permits. A review of current NPDES permits for these 19 major point sources reveals a picture of TMDL implementation for point sources in these two states.

Our review of recommended effluent limits for these 19 permits uses three criteria for assessing whether implementation has occurred. First, we determine whether these 19 permits have been re-issued with more stringent permit limits for at least one TMDL-limited pollutant since US EPA approval of the TMDL. Of the 19 major NPDES permits for which TMDL reports recommended specific levels of effluent reduction, 17 had been re-issued since the date of TMDL approval and also contained more stringent permit limits for at least one pollutant that was limited in the TMDL report. As of summer 2008, both of the facilities that had not received a new permit since TMDL approval were in Ohio, and in both cases the existing permits were five or more years old. This finding makes it clear that there is an intersection between TMDL approval dates and permit issuance cycles that can affect TMDL implementation.

The second criterion we use to assess TMDL implementation in NPDES permits is broader, and requires that permit limits for *all* TMDL-limited pollutants be at least as stringent as recommended in the TMDL. Of the 17 major permits that had been re-issued since EPA approval of the TMDL, 14 had effluent limits for all TMDL-limited pollutants that were at least as stringent as required by the TMDL. A review of the ***three*** permits in which this was not the case is instructive. The first of these three permits contained effluent limits that are more lenient than those recommended in the TMDL for three pollutants: dissolved oxygen (DO), carbonaceous biochemical oxygen demand (CBOD), and ammonia. This permit also contains a compliance schedule requiring expanded wastewater treatment facilities, but it does not appear to include new permit limits which take effect after completion of the required construction. This is the case because the permitted facility is scheduled to be closed and replaced by a new wastewater treatment facility in another location. This new facility has permit limits for DO, CBOD, and ammonia, but they are based on Best Available Demonstrated Control Technology (BADCT) rather than a TMDL generated waste-load allocation. In this case, it appears, long-term TMDL compliance by a specific wastewater treatment facility is likely to be achieved by closure of the facility, and this – in turn – has given rise to a need for a new facility and judgments regarding a new set of effluent limits.

The two remaining major permits that have been re-issued with at least one effluent limit that is more lenient than the effluent limits called for in the TMDL report appear as though they may deviate from the recommended limits because of changes in the quality of water in the receiving stream, rather than implementation delays or uncertainties or disagreements regarding appropriate effluent limits. These two permits enable discharges of oxygen-demanding substances to a river that has seen significant water quality improvements for dissolved oxygen since the implementation of other measures called for in the TMDL (Tuckerman & Zawiski, 2007). Consequently, in these cases, more stringent limits on CBOD may no longer be warranted by the condition of the receiving stream. This raises another question regarding proper steps and measures for TMDL implementation: If implementation steps that have already been taken are successful in restoring water quality, does it really make sense to stick rigidly to the effluent limits recommended in the TMDL? If adaptive management is the process through which water quality problems are best addressed, then measures of implementation progress may need to account for changing water quality conditions, as well as recommendations contained in TMDL reports and current permit limits.

The third and final criterion used here to assess TMDL implementation for point sources is more restrictive still, and requires that all *current* permit limits be consistent with TMDL recommendations. Of the 19 major permits in our sample with clearly stated requirements for more restrictive effluent limits, 10 contained current limits that were fully consistent with recommendations contained in TMDLs. In total, four of the 19 major permits analyzed contained compliance schedules in which more stringent permit limits are being phased in over time, a rather common permitting practice in cases where new facilities must be constructed or existing facilities upgraded.

Table 1 summarizes the discussion above, and yields several broad insights regarding the implementation of TMDLs for point sources. First, while non-point sources now contribute to more water quality impairments than point sources, NPDES dischargers continue to discharge pollutants that must be managed in ways that incorporate requirements from US EPA-approved TMDL reports. Second, based on the small sample of major permits analyzed here, it appears that TMDLs are being implemented largely as envisioned in major NPDES permits in many cases, although there are some inconsistencies between recommendations made in TMDL reports and subsequent effluent limits imposed in NPDES permits upon re-issuance. There are also cases in which delays in permit re-issuance give rise to delays in TMDL implementation. And finally, it is clear that there are a range of criteria that might be used to assess whether TMDL implementation for point sources has occurred, and differences in these criteria in part reflect variable conceptions of the extent to which permit writers should deviate from TMDL recommendations due to differences in judgment, changes in circumstances, and/or new information.

Table 1: NPDES Permit Limit Implementation in Major Permits (number of permits)

	Total
Major Permits	51
Targeted for Action?	38
Targeted for Effluent Limit Changes	27
Targeted with Clearly Recommended Effluent Limit Reductions*	19
Major Permits with Clearly Recommended Reductions which have been re-issued and made more stringent since TMDL approval**	17
Re-issued major permits which will be fully consistent with TMDL after phase in period.	14
Re-issued major permits with *current* effluents limits that are consistent with recommendations in the TMDL Report	10

* Major permits with clearly recommended effluent limit reductions are those for which the TMDL report made it clear that the recommended limits/allocations are more stringent than those which existed at the time the TMDL was written and provided sufficient information to enable a review of the permit for consistency with the language of the TMDL.
** Determinations regarding the stringency of the permit are based on concentration limits and/or limits on aggregate pollutant loads.

Writing and issuing NPDES permits can be a complex process, and in some cases it can be controversial. When recommendations from TMDL reports are involved, clear language regarding appropriate limits within the TMDLs and communication between writers of TMDLs and NPDES permit writers can become important. It is possible that some of the major permits discussed above were informed by new information that made permit limits that are more lenient than those specified in the TMDL report appropriate (as appears to be the case for at least two of the permits noted above). It is also possible, however, that this is not always the case and that more stringent permit limits are appropriate. As a result, the suggestions for potential program improvements specified in Section 8 suggest that it is appropriate for environmental agencies to review their procedures for describing waste-load allocations and permit limits in TMDL reports and their processes for ensuring that recommendations emanating from TMDLs are properly incorporated into NPDES permits.

5.3 Individual Evaluations of the TMDL Process

While the analyses above suggest clearly that TMDLs are being implemented in many cases through both non-point source water pollution control efforts and NPDES permits, they do not demonstrate—in and of themselves—that the existence of an approved TMDL is important to the progress that is being achieved. To demonstrate this kind of impact, one would have to develop a research design that somehow compared implementation progress in watersheds for which TMDLs are developed and approved with impaired watersheds in which TMDL processes have not been undertaken. This would be a significant undertaking, and it is outside of the scope of this project.

However, we did include two questions in many of our interviews with state environmental officials that sought to assess the role and value of TMDLs in fostering reductions in pollutant loads and/or improving water quality. In our first question, we asked whether the TMDL process helps foster pollutant loading reductions and/or water quality improvements. We asked this question of 21 state officials in West Virginia and Ohio who were knowledgeable regarding TMDL implementation progress, and all of them answered this question in the affirmative (100%). While those interviewed shared a range of reasons for their responses, they generally suggested that the process of developing TMDLs enabled a specification of pollutant sources to be targeted and addressed, and this specification was thought to be particularly important as agencies, localities, and stakeholders seek to address highly variable non-point sources of water quality impairment.

We also asked these same 21 individuals whether the TMDL process yielded benefits above and beyond their encouragement of loading reductions and water quality improvements. More specifically, we asked them to identify up to two additional benefits provided through this process. The table below summarizes the responses they provided.

Table 2: Benefits of TMDLs Above and Beyond Pollutant Loading Reductions: Responses of State Environmental Officials in Ohio and West Virginia

Other Benefits of TMDLs	Number of Responses (N=21)	Percentage of Responses
No other benefits	0	0.0%
Provides a scientific basis for reaching agreement	11	52.4%
Provides a way to determine loading reductions	7	33.3%
Provides a regulatory incentive that is needed	3	14.3%
Enables needed funds	13	61.9%
Draws attention of key stakeholders	8	38.1%

The responses to these questions suggest that state environmental officials believe that the TMDL process contributes to pollutant loading reductions, and that it carries other benefits that support water quality goals. They also draw attention to the value of targeting funds toward water bodies that are known to be impaired, and to the value of providing a scientific basis for discussions of water quality improvements.

5.4 Summary of Findings on Implementation Progress

The findings presented in this section make it clear that recommendations in approved TMDLs are being implemented in Ohio and West Virginia. Well over half of the TMDL limited watersheds assessed have planning and management efforts underway, and pollutant loading reductions are believed to be occurring in almost half of the watersheds studied. However, measured improvements in water quality appear to occur less frequently – 19% of the cases in this sample, and full water body restorations are rarer still (3% of the cases studied). The findings presented here also suggest that effluent limit recommendations for NPDES permits are being implemented in many -- but not all -- of the cases studied. This finding, and the realization that judgments may differ and circumstances may change between the date of TMDL approval and the re-issuance of targeted NPDES permits, raise questions about the appropriate procedures to be used in incorporating TMDL recommendations into NPDES permits. And finally, while this study is not specifically designed to assess the impact of the TMDL itself on subsequent implementation, it does find a strong view among state regulatory officials that the TMDL process contributes positively to the effectiveness of subsequent water quality improvement efforts.

6. FINDINGS ON FACTORS AFFECTING IMPLEMENTATION

While it is important to determine the extent to which TMDLs are being implemented, identifying factors that affect implementation progress is also important if we are to take steps to maximize implementation progress in the future. In this section of the report, we present summary analyses that identify driving factors which – based on the data compiled for this study – appear to be strong predictors of implementation progress. While statistical approaches such as the ones used here do not and cannot directly prove the existence of specific causal relationships, they do provide evidence that can be used to improve our understanding of the sequences of events which are likely to unfold during the process of TMDL implementation. And, because the factors identified here are based on existing theories, literature, and previous analyses, there is a high probability that the factors highlighted do indeed help foster progress in the implementation of TMDLs.

We can assess the factors affecting implementation of TMDLs at two levels of aggregation. First, we might focus on each individual pollutant addressed in each TMDL report (Section 4 of this document illustrates that the TMDL reports in our sample address between one and ten pollutants). Second, we might examine the overall TMDL reports themselves. We choose the former strategy because the beneficial traits of the statistical models used here rely upon asymptotic properties and using TMDLs for individual pollutants as the unit of aggregation gives us a sample size of 174, whereas using TMDL reports generates a much smaller sample of 63.[3] All of the models reported here, then, employ a TMDL/pollutant dyad as the unit of analysis.[4]

We assess the importance of a number of factors that may affect TMDL implementation progress. Most of these factors are derived from previous scholarly work examining policy implementation in general and the implementation of TMDLs and watershed management policies in particular. The

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[3] The technical aspects of the statistical models used here are presented in Appendix B. Since our data contain multiple observations for many TMDL reports and the observations within each report are not independent of one another, we estimate parameter standard errors by clustering observations within each report.
[4] Where possible, we also estimated our models using the TMDL report as the unit of analysis. The results were highly consistent with those reported here.

purpose of this investigation, however, is primarily practical in that identifying factors affecting TMDL implementation progress might help officials and stakeholders make greater progress in this area. There are at least two avenues through which identifying factors affecting TMDL implementation might help encourage greater implementation. First, we might identify actions of officials and other stakeholders that help predict greater progress through the TMDL implementation pipeline. Second, we might identify specific characteristics of watersheds or water quality problems that are associated with an increased probability of success at different stages of the TMDL implementation pipeline. The first set of factors can be manipulated, and their identification might help inform TMDL program management. The second set of factors, by contrast, are generally fixed (and cannot be manipulated easily), but identifying them might help federal, state, and/or local officials target TMDL implementation efforts to particular watersheds and/or water quality problems. The concluding portion of this sub-section summarizes its findings with regard to these two sets of factors.

6.1 An Overview of Models Used to Evaluate Factors Affecting Implementation

The models used here predict the probability of success at two stages of the TMDL implementation process. First, we measure progress in planning and management activities (stage 1 in the implementation pipeline) using an indicator of *whether there is a group that has taken responsibility for fostering the implementation of the TMDL.* This measure is taken from our interviews with state officials. Second, we measure the implementation of water quality controls (stage 2 in the implementation pipeline) using indicators of (1) *whether state officials know and/or believe that there have been non-point source load reductions associated with particular pollutants addressed in the TMDL, and (2) whether state officials know and/or believe that there have been any point or non-point source load reductions associated with particular pollutants addressed in the TMDL.* These measures are also taken from our interviews with knowledgeable state officials. Descriptions of these variables are found in Appendix A.

Our models test four general categories of hypotheses.

1. Hypotheses testing the proposition of positive feedback across different stages of the TMDL implementation pipeline: i.e., that progress in earlier stages of the pipeline increases the probability of progress in later stages. Given the small number of observations for stages 3 and 4 (i.e., few documented water quality improvements and fewer full recoveries), the quantitative models in Section 5.2.3 examine only the linkage between planning and management activities and the implementation of controls. In the discussion that follows, we refer to indicators of progress in prior stages of the TMDL implementation pipeline as *endogenous variables* when they are used to predict success in later stages of implementation.
2. Hypotheses testing the proposition that actions of state officials and other stakeholders can influence the probability of successful TMDL implementation. We refer to indicators of these actions as *group process variables.*
3. Hypotheses testing the proposition that the characteristics of watersheds and water quality problems can influence the probability of successful TMDL implementation. We refer to indicators of these characteristics as *contextual variables*.
4. Hypotheses associated with control variables used in the statistical models to assess the impact of time and watershed size on implementation progress.

We use several variables to operationalize the four categories of hypotheses identified above. Specifically, we employ ten independent variables in our models predicting the presence of a group overseeing TMDL implementation, and 13 independent variables in our models predicting perceived pollutant load reductions. This number of variables is too large from both a modeling perspective (i.e., it violates the principle of parsimony) and from a statistical perspective (i.e., our sample may be too small to obtain consistent estimates of this many parameters from the Probit models used here). Therefore, we employ a series of preliminary analyses to reduce the number of variables used in our final multivariate models of implementation progress (the results from these preliminary analyses are presented in Appendix B).

Briefly, we first estimate a series of simple Probit models that use each independent variable individually to predict the presence of an implementation group or perceived pollutant load reductions. Next, we conduct a series of likelihood ratio tests that assess jointly the predictive power of the variables used to represent four general types of hypotheses. Third, we estimate unrestricted models where all of the independent variables are used to predict the presence of an implementation group or perceived pollutant load reductions. Independent variables that perform poorly in these preliminary analyses are removed from the final multivariate models. In this section, we simply present the multivariate models for which we have the greatest confidence in the consistency and robustness of the results.

6.2 Evaluating Factors Affecting Planning and Management Activities

We measure whether there is a group responsible for fostering or overseeing implementation actions for a particular TMDL as our indicator of progress in planning and management activities. This is a dichotomous indicator, so the models are estimated using Probit. We test the following hypotheses in these models (complete variable descriptions are presented in Appendix A).

Hypotheses Associated with Group Process Variables. Our models predicting the presence of an implementation group employ three group process variables. First, we measure the degree of stakeholder involvement in TMDL development. Previous research strongly indicates that stakeholder involvement in policy development helps pave the way for more effective policy implementation (Beierle and Cayford, 2002; Sabatier et. al., 2005; Benham et. al., 2007). This leads to the following hypothesis:

H1: Greater stakeholder involvement in TMDL development increases the probability that a group will foster implementation of the TMDL.

Second, we measure the degree to which officials in state agencies are engaged in TMDL implementation. Previous research strongly indicates that agency involvement in implementation is crucial for implementation success (Mazmanian and Sabatier, 1983). This leads to the following hypothesis:

H2: Greater agency involvement in TMDL implementation increases the probability that a group will foster implementation of the TMDL.

Third, we identify whether the state government offers grants to support the creation and maintenance of watershed groups (Ohio offers these grants, West Virginia does not).[5] Somewhat obviously, if a state supports the development of watershed groups, the probability that these groups will emerge to oversee TMDL implementation increases. More generally, funding is one of the key components of successful policy implementation (Mazmanian and Sabatier, 1983). This leads to the following hypothesis:

H3: Providing state grants to support the development of watershed management capabilities increases the probability that a group will foster implementation of the TMDL.

Hypotheses Associated with Contextual Variables. We use five variables to represent the context within which TMDL implementation takes place. The first three variables reflect the resources or capacity of affected communities in the watershed (i.e., socioeconomic status, potential social capital, and population density). These variables come from the 2000 U.S. Census of population, and are measured at the 8-digit HUC level. The fourth and fifth variables reflect the severity of the water pollution problem present in the watershed, and come from the TMDL reports.

We measure socioeconomic status using (a) the percentage of households in each 8-digit HUC with incomes above $50,000 and (b) the percentage of adults in the 8-digit HUC who have earned a college diploma. Since income and education covary strongly, these two measures were combined into a single principle components factor score representing socioeconomic status. Participation in groups is strongly related to socioeconomic resources, as are perceptions of political efficacy that lead citizens to participate in public policy. This leads to the following hypotheses:

[5] While West Virginia offers Stream Partners grants to watershed groups of up to $5,000 per year, these grants are small compared with Ohio and are generally project-specific.

H4: High levels of socioeconomic status among watershed residents increase the probability that a group will foster implementation of the TMDL.

Our second contextual variable measures the population density of the watershed covered by each TMDL (measured in hundreds of persons per square mile). Population density is expected to have a positive effect on the group development, as these groups are more likely to arise in highly developed areas.

H5: High levels of population density within a watershed increase the probability that a group will foster implementation of the TMDL.

Our third contextual variable represents the potential social capital present in communities within watersheds. We measure social capital using (a) the percentage of homeowners in the 8-digit HUC containing the watershed (i.e., residential stability) and (b) the percentage of white residents in the 8-digit HUC containing the watershed (i.e., racial diversity). The percentage of homeowners and the percentage of white residents were found to covary, so these two measures were combined into a single principle components factor score representing the degree of potential social capital present in the 8-digit HUC. Previous research in sociology and political science has illustrated that the production of social capital is positively related to residential stability (homeowners are less likely to move and have higher levels of civic engagement than do renters) and negatively related to racial diversity (Nan, 2000; Hero, 2003; Teachman, et. al., 1997; Putnam, 1995). In turn, social capital is positively associated with the creation of groups and levels of group activity in watersheds (Sabatier et. al., 2005). This leads to the following hypotheses:

H6: High levels of potential social capital among watershed residents increase the probability that a group will foster implementation of the TMDL.

Problem severity, sometimes referred to as "tractability," has a clear effect on successful policy implementation (Mazmanian and Sabatier, 1983). Therefore, the fourth and fifth contextual variables represent the severity of the water pollution problem addressed by the TMDL. Specifically, the fourth variable measures the percentage reduction in current pollutant levels required to meet the TMDL for that pollutant as stipulated in the TMDL report, while the fifth variable is a dichotomous indicator of whether the pollutant poses a threat to human health. Expectations regarding the effect of problem severity lead to the following hypotheses:

H7: Large required pollution reductions (i.e., high problem severity) increase the probability that a group will foster implementation of the TMDL.

H8: Pollutants with substantial human health effects (i.e., high problem severity) increase the probability that a group will foster implementation of the TMDL.

Hypotheses Associated with Control Variables. Implementation of TMDLs takes place across space and over time, and our models should control for these factors. Specifically, we include measures of watershed size (i.e., the total area of the watershed in square miles, logged) and the time since approval of the TMDL (in months). Our expectations regarding these variables are not critical. As control variables, their primary purpose is to allow us to obtain more precise parameter estimates for the group process and contextual variables described above.

Model Results. The full unrestricted model predicting the presence of implementation groups is presented in Appendix B**.** Table 3 (below) summarizes the results from the best, most parsimonious multivariate model. We begin the discussion of results with one caveat. Table 3 does not contain an estimate of the effect of watershed coordinator grants on the presence of implementation groups. This is not because watershed grants are unimportant. To the contrary, these grants appear to be so important that we are unable to estimate their effect. In every TMDL receiving a watershed coordinator grant there is a group responsible for TMDL implementation. Statistically, this means we cannot obtain an estimate for the effect of these grants on implementation progress (i.e., for every case where the watershed coordinator grant variable equals 1, the dependent variable also equals 1, and Probit cannot estimate parameters under these circumstances). Practically, this means that these grants are a sufficient condition for encouraging groups to oversee implementation of the TMDL.

We can conclude from Table 3 that the likelihood of finding a group fostering TMDL implementation is best predicted as a function stakeholder involvement in TMDL development, state agency involvement in the implementation process, population density within the watershed, the size of the watershed, and the age of the TMDL. The first four variables have a positive effect on the presence of an implementation group, while the last has a negative effect. Moreover, this model has substantial explanatory power, as evidenced by the pseudo-R^2 of 0.66.

Table 3: Results from Multivariate Probit Model Predicting Probability that there is a Group Responsible for Overseeing TMDL Implementation

Variable	Probit Coefficient	Asymptotic Z-Score
Stakeholder Involvement	1.11***	3.37
State Agency Involvement	0.65***	2.80
Population Density	0.01***	2.55
Watershed Area	0.69***	2.68
TMDL Age	-0.02*	-1.75
Constant	-2.75`	
Pseudo-R^2	0.66	
Sample Size	166	

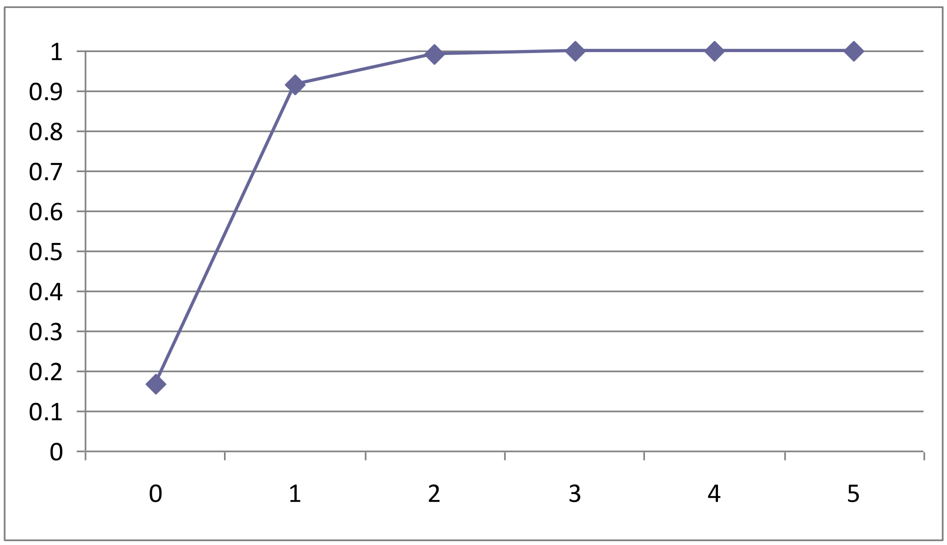
* p<.10, **p<.05, *** p<.01, two-tailed tests

Probit coefficients like those in Table 3 are difficult to interpret, so Figures 10 through 12 illustrate the effect of stakeholder involvement, state agency involvement, and population density on the probability that there is a group responsible for overseeing implementation of the TMDL, holding all other variables at their respective means (we do not graph the effect of the two control variables).[6] Figure 10 illustrates that if stakeholders are not involved in TMDL development, the probability that we will see a group fostering TMDL implementation is roughly 0.17. However, as stakeholders become more involved in TMDL development, this probability increases to 0.99, a virtual certainty. Figure 11 illustrates that if state agencies are not engaged in TMDL implementation, the probability that we will see

[6] Figures 10 through 12 are actually linear representations of nonlinear marginal effects.

a group overseeing TMDL implementation is roughly 0.17. If state agencies engage at the maximum observed level, however, this probability increases to .99; again, a virtual certainty. Figure 12 illustrates the influence of population density: with population density at its observed minimum value (20 persons per square mile), the probability that we will see a group fostering TMDL implementation is roughly 0.21. At the maximum observed value of 1273 persons per square mile, however, this probability increases once again to 0.99, a near certainty.

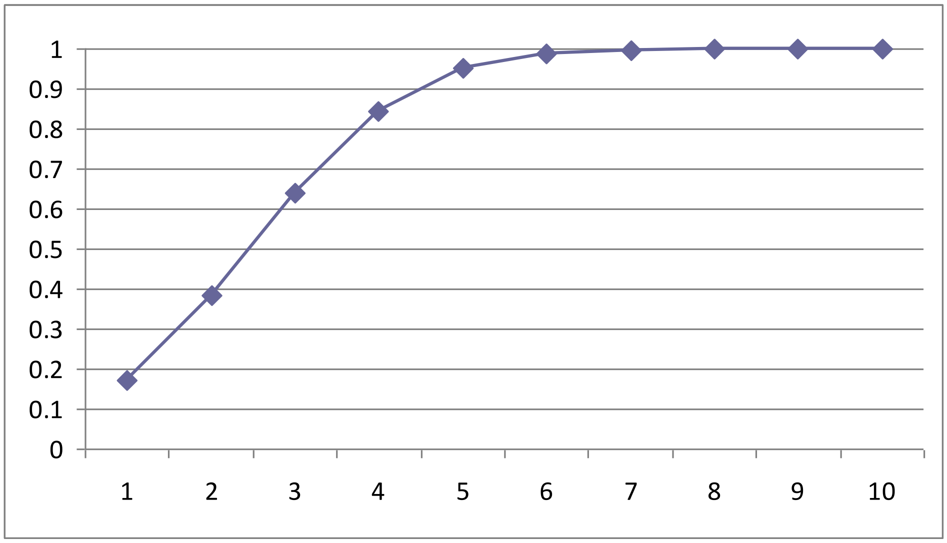
Figure 10: Effect of Stakeholder Involvement in TMDL Development on Probability of Observing Implementation Group



Note:

The horizontal (x) axis shows the number of ways in which stakeholder groups participated in the TMDL development process (attending meetings, writing letters, etc.), and the vertical (y) axis reflects the probability of observing an implementation group in the watershed.

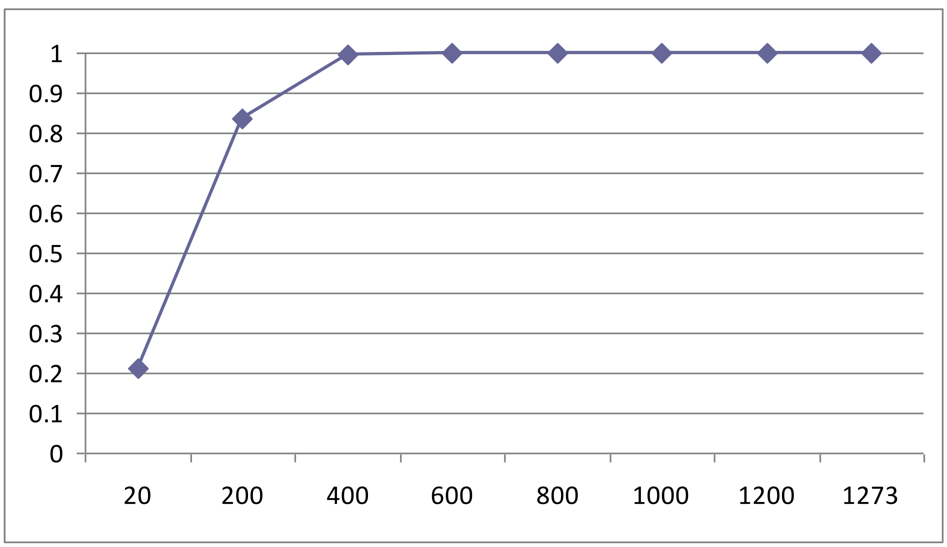
Figure 11: Effect of State Agency Involvement in Implementation on Probability of Observing Implementation Group.



Note:

The horizontal (x) axis is a measure of the extent of state agency involvement in TMDL implementation, while the vertical (y) axis reflects the probability of observing an implementation group.

Figure 12: Effect of Population Density on Probability of Observing Implementation Group



Note:

The horizontal (x) axis shows population density per square mile, while the vertical (y) axis reflects the probability of observing an implementation group in the watershed.

6.3 Evaluating Factors Affecting (Perceived) Pollutant Loading Reductions

Our two indicators of the implementation of controls are whether state officials perceive any reduction in non-point source pollutants associated with a TMDL, and whether these same officials perceive load reductions in any pollutant (from point and/or non-point sources) associated with a TMDL. According to our surveys, non-point source load reductions were documented or perceived in 56 of the 169 TMDLs addressing non-point pollutants (33%). Point and/or non-point source load reductions were documented or perceived in 66 of the 174 TMDLs in our sample (38%). Since our dependent variable is dichotomous (i.e., a perceived load reduction has or has not occurred), we use Probit analysis to test hypotheses regarding what factors are associated with these perceived load reductions.

The Probit models used to predict perceived pollutant load reductions, however, are different from those used in Section 6.2. The technical specifics of the models used to predict perceived pollutant load reductions are presented in Appendix B. We only summarize these approaches here. First, hypothesis H9 predicts that the presence of an implementation group will be positively related to the probability that state officials perceive pollutant load reductions. Since the presence of implementation groups is the dependent variable from the model summarized in Table 3, it is endogenous, and therefore violates one of the core assumptions associated with predictor variables in general linear models. Moreover, the presence of implementation groups and the perception of pollutant load reductions may be jointly determined. In these situations, the proper approach is to obtain parameter estimates using Seemingly Unrelated Bivariate Probit (SUBP) models (Poirie, 1980; Green, 1993). Models estimated using SUPB models are summarized in Table 4.

Second, state officials can only perceive pollutant load reductions for TMDLs with which they are familiar. If officials are unfamiliar with or know little about implementation of the TMDL, they have no information on which to base their perception regarding loading reductions. Since state officials are in fact unfamiliar with the implementation of a number of the TMDLs studied, perceived potential load reductions remain unobserved for a portion of our sample of TMDLs. In the SUBP models, TMDLs about which state officials have little or no knowledge are treated as having no perceived pollutant load reductions. Alternatively, we could treat these TMDLs as missing data and estimate the models using only those TMDLs for which state officials have sufficient familiarity to render a judgment on pollutant load reductions. Similar to the SUBP models, however, the factors that affect whether state officials are familiar with the TMDLs may also affect whether load reductions are perceived in these TMDLs (i.e., they may be jointly determined). In these situations, the proper approach is to obtain parameter estimates using Bivariate Probit models with sample selection (BPSS) (Van de Ven and Van Pragg, 1981). Models estimated using this approach are summarized in Table 5.

Hypotheses Associated with Endogenous Variables. Recall that we expect progress in the earlier stages of the TMDL implementation pipeline to affect progress in later stages. This expectation leads to the following hypotheses:

H9: The presence of a group fostering TMDL implementation increases the probability of perceived pollutant load reductions associated with that TMDL.

Hypotheses Associated with Group Process Variables. We employ six group process variables in the perceived pollutant load reduction models. The first three are identical to those used in the implementation group model. Therefore:

H10: Greater stakeholder involvement in TMDL development increases the probability of perceived pollutant load reductions associated with that TMDL.

H11: Greater agency involvement in TMDL implementation increases the probability of perceived pollutant load reductions associated with that TMDL.

H12: Providing state grants to support the development of watershed groups increases the probability of perceived pollutant load reductions associated with that TMDL.

The fourth and fifth group process variables measure the characteristics of watershed groups in the area covered by the TMDL. Specifically, we measure the number or density of confirmed watershed groups operating in the area covered by the TMDL, and we identify the highest level of engagement in implementation exhibited by any of these watershed groups (i.e., the intensity of group involvement in the implementation process). These variables come from our interviews with state officials familiar with TMDL implementation in the watersheds studied. These officials are unfamiliar with several cases of TMDL implementation, however, which leads to missing data for these variables in over 25 percent of our cases. Common practice when faced with missing data is to (a) drop these observations from the analysis (i.e., listwise deletion), or (b) replace missing observations with the sample mean. The first strategy generally produces severely biased estimates, however, while the latter preserves the sample size without contributing additional information to the sample. A superior strategy is to impute (i.e., predict) values for these missing cases, and there are several accepted strategies for imputation (King et. al., 2001). We impute missing values for the two watershed group variables using the standard imputation algorithm in the Stata statistical package. Both the density of watershed groups and the intensity of their involvement have been shown to positively affect watershed management practices. This leads to the following hypotheses:

H13: As the density of watershed groups in the area covered by the TMDL increases, the probability of perceived pollutant load reductions in that area will also increase.

H14: As the intensity of watershed group participation increases, the probability of perceived pollutant load reductions in that area will also increase.

Finally, we identify whether an endorsed non-point source watershed plan was in place during any part of the TMDL implementation period. These plans provide a framework in which planning for watershed restoration can take place, and—in this sense—are consistent with the concept behind TMDL implementation plans that are cited by Benham et. al. as a potential driving factor for TMDL implementation progress. Endorsements of these plans by state agencies are required in Ohio and West Virginia as a pre-condition for the disbursement of certain grant funds under section 319 of the Clean Water Act. This leads to the following hypothesis:

H15: The presence of an endorsed NPS watershed plan increases the probability of perceived pollutant load reductions in the area covered by a TMDL.

Hypotheses Associated with Contextual Variables. We use the same five contextual variables from the implementation group models. Therefore:

H16: High levels of socioeconomic status increase the probability of perceived pollutant load reductions associated with a TMDL.

H17: High levels of social capital among watershed residents increase the probability of perceived pollutant load reductions associated with a TMDL.

H18: Large required pollution reductions (i.e., high problem severity) increase the probability of perceived pollutant load reductions associated with a TMDL.

H19: Pollutants with substantial human health effects (i.e., high problem severity) increase the probability of nonpoint source load reductions associated with a TMDL.

Our expectation regarding the fifth contextual variable is different in the load reductions models than in the implementation group model. Population density may have a negative effect on pollution load reductions, since reducing pollution is often more difficult in densely settled watersheds. Therefore, we hypothesize that:

H20: High levels of population density within a watershed decrease the probability of perceived pollutant load reductions associated with a TMDL.

Hypotheses Associated with Control Variables. Again, we include measures of watershed size (i.e., the total area of the watershed in square miles, logged) and the time since approval of the TMDL (in months). Our expectations regarding these variables are not critical. As control variables, their primary purpose is to allow us to obtain more precise parameter estimates for the group process and contextual variables described above.

Results from the Multivariate Models Predicting Perceived Load Reductions. Table 4 reports the results from the SUBP models, while Table 5 reports the results from the BPSS models. We discuss these models together because their conclusions are highly consistent. Recall that both SUBP and BPSS are two-equation models. In SUBP, the first equation predicts the probability that we will see a group responsible for overseeing implementation associated with a TMDL. Therefore, the variables in this model are the same as those reported in Table 3. In the BPSS models, the first equation predicts the probability that state officials are familiar with a TMDL, and therefore capable of rendering a judgment on pollutant load reductions. It predicts state official familiarity with TMDL implementation as a function of stakeholder involvement in the development of TMDLs, state agency involvement in TMDL implementation, the presence of a watershed coordinator grant (since the grant application process provides a mechanism through which officials become aware of the TMDL), the size of the watershed, and the age of the TMDL (familiarity should increase with size and with the age of the approved TMDL report).

Table 4: Final Seemingly Unrelated Bivariate Probit Models for Perceived Pollutant Load Reductions

Variables	Nonpoint Source Pollutant Load Reduction Parameters	Asymptotic Z-scores	Any Pollutant Load Reduction Parameters	Asymptotic Z-scores
Perceived Load Reduction Model				
Implementation Group	2.426***	4.37	1.688*	1.76
State Agency Involvement	NA		0.187*	1.93
Watershed Coordinator Grant	1.109***	2.72	0.952***	2.82
Watershed Group Density	-0.194	-1.64	-0.291**	-2.57
Watershed Group Intensity			0.587**	2.22
Approved Watershed Plan	0.751**	1.58	0.364	0.79
Potential Social Capital	-0.816***	-3.49	-0.528***	-3.35
Population Density	-0.290***	-3.36	-0.162***	-2.73
Watershed Area	0.286*	1.90		
Age of TMDL	0.036***	3.57	0.032***	4.05
Constant	-5.989***	-5.49	-5.183***	-6.25
Implementation Group Model				
Stakeholder Involvement	1.067***	2.96	1.066***	2.97
State Agency Involvement	0.699***	2.84	0.689***	2.82
Population Density	1.092***	2.68	1.011***	2.68
Watershed Area	0.768***	3.00	0.757***	2.76
TMDL Age	-0.020*	-1.87	-0.019*	-1.80
Constant	-7.882***	-3.03	-7.718***	-3.01

* p<.10, **p<.05, *** p<.01, two-tailed tests

Table 5: Final Bivariate Probit Model with Sample Selection for Perceived Pollutant Load Reductions

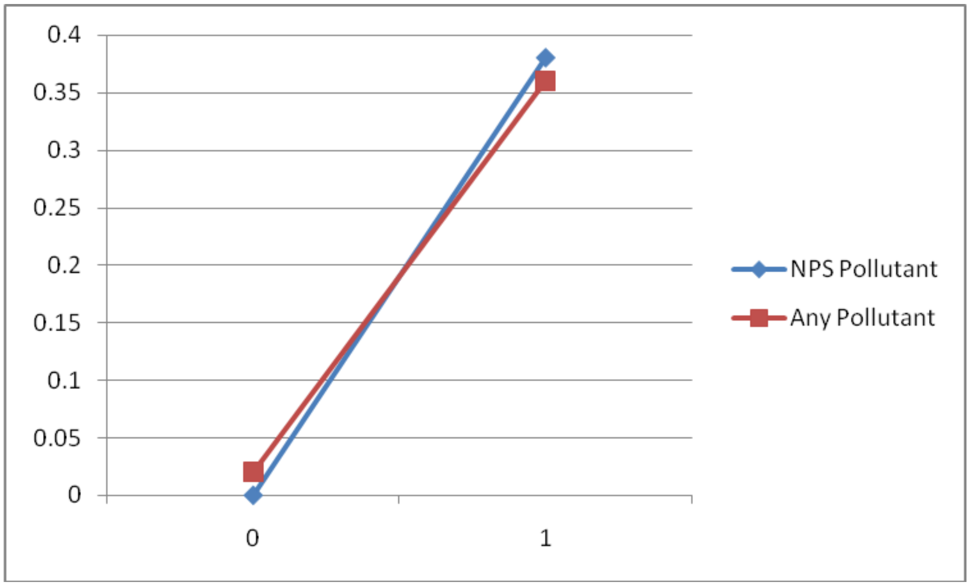
Variables	Nonpoint Source Pollutant Load Reduction Parameters	Asymptotic Z-scores	Any Pollutant Load Reduction Parameters	Asymptotic Z-scores
Perceived Load Reduction Model				
Implementation Group	0.436	0.51	0.948	0.82
State Agency Involvement			0.321***	3.03
Watershed Coordinator Grant	0.993*	1.68	1.232***	3.34
Watershed Group Density			-0.244**	-2.31
Watershed Group Intensity			0.276	0.75
Approved Watershed Plan	1.376**	2.21	0.507	0.86
Socioeconomic Class	0.400**	2.05		
Potential Social Capital	-0.639*	-1.85	-0.543***	-3.39
Population Density	-0.373***	-3.50	-0.185***	-2.71
Age of TMDL	0.030*	1.92	0.032***	3.63
Constant	-2.161	-1.60	-4.177***	-4.62
Selection Model				
Stakeholder Involvement	0.512***	3.08	0.586***	3.54
State Agency Involvement	0.380***	4.31	0.358***	4.62
Watershed Coordinator Grant	0.527	1.20	0.794	1.58
Age of TMDL	0.008*	1.23	0.004	0.82
Constant	-2.320***	-3.78	-2.126***	-3.86

* p<.10, **p<.05, *** p<.01, two-tailed tests

The results from the SUBP models confirm our expectation that success at one stage of the implementation pipeline (the presence of an implementation group) increases the probability of success at later stages of the implementation pipeline (perceptions of pollutant load reductions). Figure 13 graphs this relationship, and shows that holding all other factors constant, the presence of an implementation group increases the probability of a perceived pollutant load reduction from virtually zero to 38 percent in the non-point source model, and from 3 percent to 36 percent in the any pollutant model.[7] Substantively, then, the effect of implementation groups on perceived load reductions appears quite large. The results from the BPSS models also show a positive relationship between implementation groups and perceived pollutant load reductions, but these parameter estimates are not significantly different from zero.

[7] Again, these figures are linear depictions of nonlinear marginal effects.

Figure 13: Effect of the Presence of an Implementation Group on the Probability of Perceived Pollutant Load Reductions in the SUBP Models

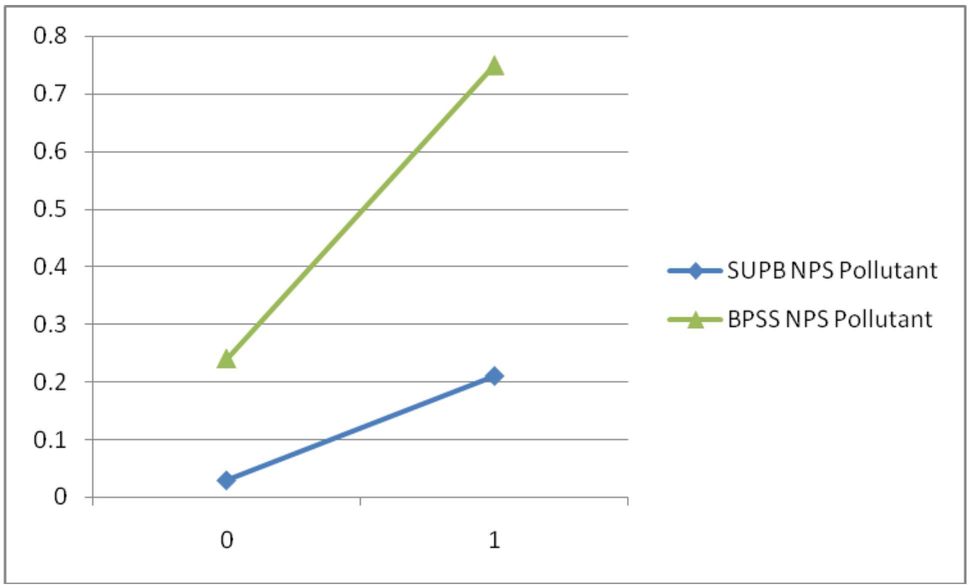


Note:

The horizontal (x) axis reflects the presence (1) or absence (0) of an implementation group, while the vertical axis reflects the probability of observing a pollutant loading reduction.

Both the SUBP and the BPSS models illustrate that group process variables significantly affect the probability that state officials perceive pollutant load reductions. Specifically, all four models show that perceived load reductions are more likely to be associated with TMDLs where there is an approved watershed plan, and with TMDLs receiving a watershed coordinator grant (though the watershed plan parameters are statistically significant only in the non-point source models). When we graph these relationships, Figure 14 shows that the presence of an approved watershed plan increases the probability of a perceived load reduction from a minimum of 19 percent (increasing from 2 percent to 21 percent in the SUBP model for non-point source reductions) to a maximum of 52 percent (increasing from 22 percent to 74 percent in the BPSS model for non-point source reductions). Figure 15 shows that watershed coordinator grants increase the probability of a perceived load reduction from a minimum of 29 percent (increasing from 10 percent to 39 percent in the SUBP model for any load reduction) to a maximum of 40 percent (increasing from 11 percent to 51 percent in the BPSS model for any load reduction). Our results for the density of watershed groups and the intensity with which these groups participate in TMDL implementation are less consistent. Group density displays a significant negative relationship with perceived load reductions in both SUBP models and in the BPSS model for any pollutant reductions, but the intensity of watershed group involvement displays a positive relationship with any pollutant reductions, but not for non-point source pollution reductions in both the SUBP and BPSS models. Moreover, the negative coefficient for group density is contrary to our expectations.

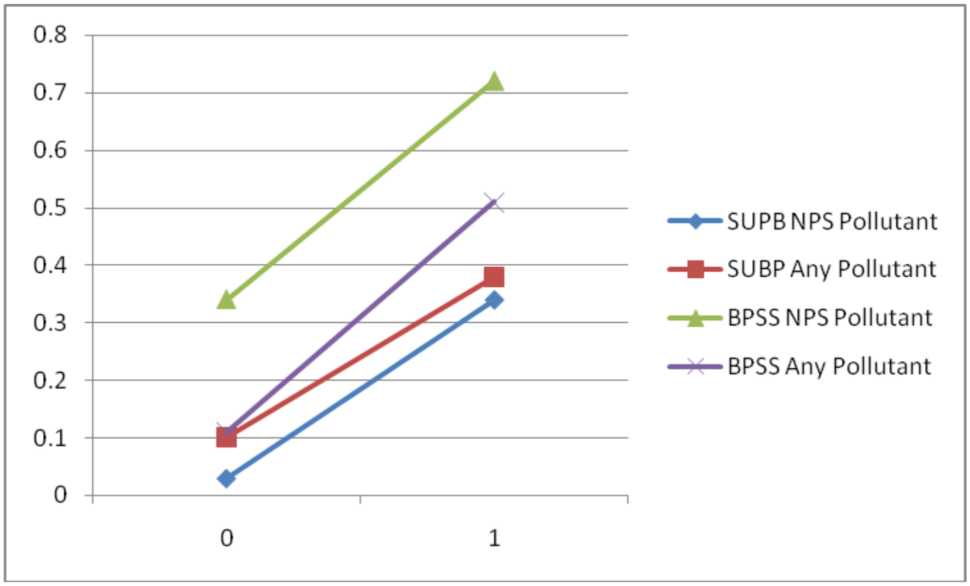
Figure 14: Effect of the Presence of an Approved Watershed Plan on the Probability of Perceived Pollutant Load Reductions



Note:

The horizontal (x) axis shows whether or not there is an approved watershed plan for addressing water quality concerns in the TMDL limited watershed, while the vertical (y) axis the probability of observing a non-point source pollutant reduction.

Figure 15: Effect of the Watershed Coordinator Grants on the Probability of Perceived Pollutant Load Reductions



Note:

The horizontal (x) axis identifies whether (1) or not (0) there is a watershed coordinator grant in place, while the vertical (y) axis reflects the probability of observing a pollutant reduction.

Only two of the contextual variables, potential social capital and population density, are consistently and significantly related to the probability that state officials will perceive pollutant load reductions. The potential social capital relationship is negative, contrary to our expectation. Consistent with our expectations, however, the probability of perceiving pollutant load reductions drops as population density (one measure of problem severity) increases. We also observe a positive relationship between socioeconomic class and perceived pollutant load reductions, but this relationship is only meaningful in the BPSS model for non-point source pollutants and does not surface in statistically significant fashion in either of the unrestricted models presented in Appendix B. Finally, one of our control variables, the age of the TMDL, is consistently related to perceived pollutant load reductions. As expected, load reductions are more likely to be perceived for older TMDLs. The implementation of load reduction projects takes time; therefore, the probability of perceiving their effects increases with time. Watershed size is weakly related to perceived load reductions, but only in the SUBP model for non point sources of pollution.

6.4 Factors Driving TMDL Implementation: A Brief Summary

When viewed as a whole, the model results described in this sub-section (and in Appendix B) provide insights that may be useful to federal, state, and local officials and stakeholders who are seeking to foster TMDL implementation progress. They provide evidence that efforts to foster group involvement in TMDL implementation by offering watershed coordinator grants, involving stakeholders in TMDL development processes, and engaging state officials in the implementation processes appear to be effective means to help ensure that groups can and will take responsibility for TMDL implementation. The analyses in this subsection also suggest that efforts to foster responsibility for TMDL implementation may be particularly effective in areas with higher population densities.

The analyses presented here also suggest factors that are likely to yield (perceived) pollutant loading reductions. The results above suggest that several group process variables are potentially useful predictors of pollutant loading reductions. These variables include the presence of a group taking responsibility for TMDL implementation, the presence of an endorsed watershed plan, and the issuance of a watershed coordinator grant, all of which appear to be systematically related to perceptions of pollutant loading reductions on the part of knowledgeable state officials in at least two of the final models presented. Notably, we also see that high levels of population density appear to make pollutant load reductions less likely. And, as one might expect, the likelihood of perceived load reductions also increases over time.

7. POTENTIAL CHANGES IN PRACTICE AND POLICY

This report and the research underlying it suggest several ways in which TMDL implementation progress can be accelerated. They involve changes in current TMDL-related practices that can foster higher levels of implementation progress in the short term (over the next several years), as well as potential alterations in federal and state policies to improve TMDL implementation over the long term. The following discussions review more specific ideas in these two areas.

7.1 Changing Practices to Foster TMDL Implementation

Over the coming months, there are a number of steps that could be taken by federal, state, and/or regional and local stakeholders to accelerate TMDL implementation progress. Some of these suggestions apply to the process of developing TMDLs and others apply after their completion and approval. The subsections below focus on five suggestions in these areas.

7.1.1 Engage local and regional groups in the TMDL development process

In a number of cases, agency staff members involved in developing TMDLs have solicited and engaged local and regional groups in the process of developing TMDLs. It appears that this is a useful practice. The driving factors analysis presented above suggests that higher levels of group engagement in the TMDL development process increases the likelihood of a group taking responsibility for implementation activities after a TMDL is approved by US EPA. The analysis also suggests that the presence of a group taking responsibility for TMDL implementation activities increases the likelihood that knowledgeable state environmental officials will be able to identify cases in which pollutant loading reductions have been achieved. External engagement in TMDL development thus appears to foster implementation, so it seems advisable to facilitate stakeholder involvement in TMDL development whenever possible.

7.1.2 Standardize the formats used in TMDL reports to recommend implementation actions

TMDL reports typically include reasonable assurances that their recommendations will be implemented. In both Ohio and West Virginia, TMDL reports also contain sections that provide recommendations for implementation actions of various kinds. And in some cases in Ohio, these recommendations are referred to as draft implementation plans.

The 63 TMDL reports we reviewed used a range of different formats to describe suggested implementation activities, and—in some cases—this can make interpreting and understanding specific recommendations somewhat difficult. For example, the level of detail provided for suggested implementation actions varied. In some cases, suggested implementation activities were rather generic (e.g., "implement storm water Phase II programs"), while they were reasonably detailed in other cases. While variation is useful at early stages of new programs when best management practices are being developed, it also means that individuals seeking to incorporate information from TMDLs into their ongoing activities may have difficulty finding and interpreting the information they need to implement the TMDL properly.

Users of TMDL reports are likely to find it easier to implement their recommendations if there is a standard format that would allow grant applicants, funding organizations, and permit writers to access the information they need to implement the recommendations which apply to them. While the optimal format may vary by state or EPA Region, those designing the formats to be used may want to consider the following potential elements.

- A prioritization of implementation steps so that agency officials and local stakeholders can quickly identify what are believed to be the most effective means to address water quality impairments identified in the TMDL. While some of the TMDL reports we reviewed included clear statements about high priority problems, very few—if any—were systematic in suggesting high, medium, and low implementation priorities. The professionals involved in assessing watersheds during TMDL development processes are in a good position to recommend implementation priorities, and watershed assessment protocols and formats for TMDL reports might be able to take better advantage of this opportunity. If they did, then permit writers and those funding and implementing non-point source water pollution projects would be in a better position to implement recommended actions that are likely to yield water quality improvements.

- Assess and improve (where appropriate) processes for translating recommendations in TMDL reports into appropriate provisions in NPDES permits. Potential improvements include the use a specific and consistent format for presenting information relevant to future changes in NPDES permits, including waste-load allocations and recommended effluent limits for individual point source discharges. These formats might also take more specific account of other follow up actions that might be taken, including steps to address combined sewer overflows, sanitary sewer overflows, Phase I and Phase II storm-water management program elements, best management practices, and other requirements that are not addressed by effluent limit calculations. It might also be beneficial to identify the assumptions underlying recommended permit limits and requirements clearly and systematically, so permit writers could clearly understand when it is (and is not) appropriate to deviate from recommendations contained in TMDLs. While TMDL implementation processes are likely to require adaptive management approaches that in turn require subsequent adjustments of TMDL recommendations based on new information, these alterations are likely to be applied more sensibly if the assumptions underlying existing recommendations are clearly and consistently presented. Procedural steps in which NPDES permits are reviewed for consistency with TMDL recommendations might also be considered.
- Another potential formatting element to be considered relates to the geographic scope of the implementation actions that are suggested. In some cases, recommended implementation actions might apply to an entire watershed, such as recommendations for stringent limits on total phosphorus in nutrient-enriched areas. Other recommendations may apply only to one or two locations, or to one single stream segment. By clearly specifying the geographic scope of each recommended implementation action, those preparing the TMDL will facilitate an understanding

of the recommendations being provided while also encouraging later use of those recommendations at scales that are appropriate to the problems identified. It may also enable easier and more cost-effective tracking of problems and implementation steps at varying geographic scales. This, in turn, can result in more effective targeting of implementation actions and monetary resources.

These are three examples of ways in which standardized formats might contribute positively to implementation improvements. There may very well be others. While developing standardized formats for TMDL preparation may take time and effort, it will also make TMDL implementation both easier to carry out and more effective. The point here is that after roughly a decade of experience, state and federal TMDL program managers are now in a position to look at the processes that they have developed, and make formatting changes that will facilitate not only TMDL development, but also implementation of their recommendations and—eventually—improvements in water quality.

7.1.3 Engage state agency staff members in efforts to foster implementation of TMDLs

As the driving factors analysis suggests, the engagement of state agency officials in TMDL implementation is associated with an increase in the likelihood of groups taking responsibility for TMDL implementation. And, the existence of responsible groups, in turn, appears to increase the likelihood of perceived pollutant loading reductions. While one might argue that state environmental officials become engaged in TMDL implementation because they respond to implementation interests of local and regional stakeholders, it seems clear that state agency engagement is a valued part of the implementation process. For this reason, we would encourage state agency staff to become actively involved in TMDL implementation where possible and appropriate. We would also suggest that agencies consider involving multiple individuals in these processes because the data compiled for this project suggest that many different kinds of engagement are beneficial. For example, state agency staff involved in issuing and overseeing grants, writing NPDES permits, and/or carrying out water quality monitoring studies can all make positive contributions to implementation processes. Additional monitoring of TMDL limited water bodies would be particularly valuable, as it can provide useful feedback to organizations and groups implementing restoration efforts about the impacts and effectiveness of their actions.

7.1.4 Develop indicators for TMDL implementation and track progress based on them

It has been said that one manages what is measured and measures what is managed. If we want to ensure that progress occurs in the implementation of TMDLs, then we should consider developing measures of progress, track them, and report regularly on the results so others can learn from the process.

While US EPA's TMDL program pipeline provides a useful conceptual framework, there are no widely accepted and implemented systems for measuring and managing TMDL implementation progress in the two states addressed in this report. Indeed, at this point in time, we do not have specific knowledge of well developed measurement systems for TMDL implementation progress anywhere in the United States (although we are aware that Washington State and Minnesota have relatively active TMDL implementation efforts under way, and these efforts may include well developed performance measurement systems). Partially as a result, the development and assessment of measures used in this analysis required a fair amount of work, and compiling information on the implementation of multiple TMDLs was a long and resource-intensive process. By developing a series of accepted and widely used measures of implementation progress, federal and/or state agencies, as well as other stakeholders, can begin to develop systems for understanding key steps in the implementation process. Doing this effectively will require a concerted effort on the part of a range of stakeholders, a user-friendly system for reporting on progress, and a commitment to making information on progress widely available.

7.1.5 Educate and engage key audiences in implementation tracking and management

As was noted in the introduction to this report, TMDL implementation requires actions on a wide range of problems by numerous segments of society. While it is clear that environmental officials are making efforts to engage key audiences in efforts to implement recommendations contained in TMDL reports, it is equally clear that much more needs to be done to facilitate active TMDL implementation efforts on the part of farmers, municipal storm-water program managers, county health officials, and owners and users of home sewage treatment systems, as well as a range of other audiences whose behaviors affect water quality. While this may seem like an endless chore, it is also one that is necessary over the long term if federal and state programs are to improve and preserve the quality of the nation's surface waters. In the end, implementing TMDLs is about changing behavior, and this can only be done through education and active engagement.

7.2 Potential Policy Changes

During the conduct of this research, we encountered situations in which effective TMDL implementation appeared to have been inhibited by policy decisions that have been made over time at the federal and state levels. We offer four suggestions for consideration by policymakers involved in future revisions to federal and state laws and policies relevant to TMDL implementation.

7.2.1 Increase funding and/or expand efforts to target expenditures

Throughout the course of this project, there was an elephant in the room that no one spoke about, but (we think) everyone knew existed. There is a substantial mismatch between statutory goals for water quality and the resources available to achieve them. While the federal Clean Water Act seeks to restore the biological, chemical, and physical integrity of the nation's waters, funding allocations provided by federal, state, and local governments do not appear to be sufficient to accomplish this goal.

In conducting this research, we encountered many cases where resource constraints appear to limit progress in implementing TMDLs. We identified eighteen watersheds with approved TMDLs in which we could not identify a state or federal official with significant knowledge relevant to implementation in that watershed. We identified twenty-two watersheds in which we have not been able to identify any projects implementing approved TMDLs, and twenty-seven watersheds in which we could not locate any group which had taken responsibility for encouraging TMDL implementation. We also found that, in some cases, a single state official appeared to have primary responsibility for fostering TMDL implementation in multiple watersheds spanning hundreds of miles.

We also found evidence that resources do matter when they are applied to implementing TMDLs, as they are associated with the establishment of implementation capabilities, the conduct of water pollution reduction projects, and with the general accomplishment of progress on the TMDL Program Pipeline. Nearly all of those watersheds in which projects implementing TMDLs were identified had benefited from grant funds of some kind from federal and/or state agencies. And our driving factors analysis suggested that the Ohio Watershed Coordinator grant program is positively associated with both the existence of groups to implement TMDLs and with perceptions of pollutant loading reductions on the part of knowledgeable state officials. State officials involved in implementation also noted that a major benefit of the TMDL process was that it facilitated access to additional funding resources. And, while watershed groups are becoming an increasingly important part of state and national level water quality improvement efforts, current systems for funding their activities appear haphazard and inconsistent.

While this mismatch between water quality goals and available resources is not a surprising or novel conclusion, the findings here do reinforce the fact that adequate financial resources do aid in the accomplishment of progress in TMDL implementation. And, to the extent that additional resources are not available during the trying economic times that now confront the two states studied here and the nation as a whole, these findings reinforce once again the value of targeting investments and efforts toward activities that are most likely to yield implementation progress and water quality improvements. Many of the other suggestions in this section of the report offer potential ways in which this improved targeting might be accomplished.

7.2.2 Amend the federal CWA to focus TMDLs on impairments as well as pollutants

During the course of this research, we encountered impairments in which the primary water quality concern had to do with flows of water and the ways in which they are managed, rather than individual pollutants per se. These flow-related concerns included changes in the flow patterns of waterways in agricultural areas to accommodate irrigation needs, dam and other structures which inhibit stream flows, mining subsidence which re-directs stream flows, and the need to minimize "flashy" overflow events associated with storm-water runoff.

Both Ohio and West Virginia appear to have recognized the growing importance water quality improvement efforts that focus on watershed biology and the ways in which flow regimes may affect it, as they are making increasing use of water quality standards that are based not on individual pollutants but on biological standards and indices. Unfortunately, because the federal CWA focuses TMDL efforts specifically on pollutants, management processes associated with TMDL implementation are often forced to focus on individual pollutants when the true underlying impairment is related to biology and the hydrological flow patterns that affect it.

We adopted the focus on pollutants in this study because—as the federal law is currently written—the reductions called for in TMDLs apply to pollutants and not impairments. If section 303 of the CWA were amended to address corrective actions that address impairments as well as pollutants, it might encourage state and federal agencies to target their programs and activities toward opportunities for water quality improvement that address impairments directly—and in some cases this may enable more efficient efforts to address flow regimes directly, rather than in intermediary fashion through stated formal efforts that focus on individual pollutants.

7.2.3 Focus federal and state resource allocations and regulatory authorities on watersheds.

As it is currently designed (and, to a significant degree, enshrined in statute), the TMDL program's primary role is to provide information to help target non-point source pollution reduction projects and NPDES permitting. To a large degree, the evidence presented in this report suggests that TMDLs are indeed informing many of these efforts. Most of the TMDL-limited watersheds in Ohio and West Virginia that were included in our sample universe have undertaken non-point source water pollution reduction projects that are consistent with recommendations contained in TMDL reports, and most major NPDES permits that are clearly targeted for effluent limit changes appear to have been re-issued with requirements for reduced pollutant loads (or concentrations) for TMDL-limited pollutants. Those interviewed during the course of this project also suggested overwhelmingly that the TMDL process helps yield pollutant load reductions and water quality improvements.

However, in spite of these facts, we still see many cases in which TMDLs are not being implemented. We also see watersheds in which implementation efforts are being undertaken, which have not yet led to pollutant load reductions or water quality improvements. And we also find cases in which identified water quality improvements have not led to full water body restorations. These facts raise an important question. Are the efforts and projects being undertaken truly the ones that are either most important or mostly likely to yield measurable water quality improvements?

While individual staff members at the state and federal levels are clearly focusing on this question, the CWA's separation of funding and authorities based on point and non-point source categories discourages serious system-wide consideration of this question. TMDL program staff members have been held accountable for developing TMDLs, rather then their implementation. The disbursement of grants for non-point source water pollution projects occurs in many different ways (USDA funding, OSM funding, US EPA 319 grant funding, and through other state programs), and there does not appear to be any mechanism for systematically addressing the highest priority water quality improvement projects identified through watershed assessment and TMDL development processes. Likewise, NPDES permitting processes appear to proceed largely along their recommended five year re-issuance cycles, with TMDLs being implemented in sequences that relate more to permitting cycles than to judgments regarding the need for, or urgency of, water quality improvements.

A system-wide approach to addressing these issues might lie in altering authorities and funding flows under the CWA (and/or state water quality statutes) in ways that focus on watershed-level authorities (probably administered in cooperation and under the direction of state environmental agencies and/or regional authorities where/if appropriate). While this kind of change would be large and far-reaching, it would also—over the long term—structure processes of program administration and accountability that would focus on targeting funds and regulatory actions within TMDL-limited watersheds toward projects and activities that are most likely to yield water quality improvements. It might also engender the transformation of the TMDL program from one that is focused primarily on producing information for use by other water quality programs to a program that helps establish coordinated agendas for water quality improvement and restoration, and actively facilitates their implementation.

7.2.4 Create stronger mechanisms for TMDL implementation in other policy sectors

The interviews conducted as a part of this research yielded numerous cases where state environmental officials pointed to activities undertaken in other policy sectors that are tied to TMDL implementation. In most cases, the activities referenced were occurring in the agriculture, home sewage treatment, and municipal storm-water management sectors, all of which contribute pollutants to many of the watersheds investigated in this study. In many cases, however, the interviews and other information sources suggested that the ties between state environmental officials and professionals in these sectors were not as strong as they could or should be.

While the connections between agriculture and home sewage treatment systems and the health of watersheds are widely recognized, it does not appear that they are addressed systematically and forcefully. Federal programs conducted by the USDA contribute billions of dollars to conservation efforts that are focused in part on achieving water quality goals. While State Technical Assistance Committees include federal and state environmental officials and provide a forum with great potential for integrating these environmental and agricultural concerns, we did not encounter evidence of tight coordination and understanding across these sectors in our discussions with state environmental agency and agricultural officials. We also identified useful—but only sporadic—evidence of productive coordination between environmental agency officials and health officials at the county level who are generally responsible for overseeing the regulation of home sewage systems.

Integrating environmental considerations into other policy sectors is one of the great environmental policy challenges of the next decade (see Jordan and Lenschow, 2008), and the research underlying this report suggests that this challenge is important for TMDL implementation. Changes in federal and/or state legislation that establishes both forums for interaction and requirements for specific kinds of progress may help facilitate the implementation of recommendations contained in TMDLs, as well as improved targeting of these implementation activities toward activities that actually lead to water quality improvements.

8. SUGGESTIONS FOR FURTHER RESEARCH

While this report improves our understanding of TMDL implementation, it also highlights areas in which further research is warranted. At an EPA-sponsored conference held last year on the management of sustainable water infrastructure, one speaker suggested that when the stakes are high, investments in knowledge and information enable more cost-effective decision-making. This insight applies to the current situation with TMDL implementation. Nationwide, we are facing a growing range of water quality problems and we are spending millions of dollars every year to prepare TMDL plans for which there is not yet a clear and coordinated process for implementation. While this situation is understandable given the statutory mandates involved and the litigation that has developed around them, it is also a situation that can be improved. By undertaking efforts like US EPA's TMDL Results Analysis Project, we can improve our understanding of current TMDL implementation processes, and improve our ability to make appropriate judgments regarding ways in which we can help foster the implementation of water quality improvement efforts. It is in this context that we offer the following broad recommendations for additional research.

8.1 Study TMDL implementation in other states, watersheds, and localities

While this study has expanded the geographic scope of our knowledge regarding TMDL implementation, it still addresses only two states. Prior to the publication of this report, existing studies of TMDL implementation have either highlighted known successes or they have been focused on a single state. While this study will help alleviate some of the uncertainties associated with this fact, we do not know how representative Ohio and West Virginia are of the country as a whole. And, as our driving factors analysis indicates, small sample sizes remain a limiting factor in our understanding of TMDL implementation processes and activities. Broader studies of many states and studies targeted to assess implementation progress in a set of strategically selected states would be beneficial in improving our knowledge of TMDL implementation progress and the factors that drive it. To its credit, the US EPA has recognized this need and is now undertaking a study of TMDL implementation in the six states contained in EPA Region 5. Additional studies in targeted states (with relatively large sample sizes) would enable further improvements in our understanding of TMDL implementation – particularly at later stages of the TMDL Program Pipeline in which concerns focus on water quality improvement.

8.2 Understand TMDL implementation at the watershed and stream segment levels

This study has focused on TMDL implementation at the watershed level (as defined by the scope of EPA-approved TMDL reports). While we believe this is the appropriate unit of analysis in this particular case, we also understand that TMDLs are currently tracked by the federal government at the segment/water body level. Consequently, there is good reason to study and analyze TMDL implementation at this level as well. At some point, however, it will be appropriate to reconcile findings at these two levels of analysis and determine the extent to which they yield similar findings. Fortunately, the US EPA's recently initiated study of TMDL implementation in EPA Region 5 focuses on implementation progress at the segment/water body level, so it may be possible to carry out initial analyses of this kind for Ohio using both that study and this one as a prism for improving our understanding. Over the long run, these kinds of analyses will help determine whether it is ultimately preferable to manage and track TMDL implementation at the segment or the watershed level.

8.3 Analyze TMDL implementation progress in key economic and policy sectors

While this research project has undertaken a broad-based effort to identify and measure TMDL implementation progress, it can be supplemented productively by more intensive efforts to assess TMDL implementation progress in several areas that are of central importance to long term water quality improvement.

First, there are extensive and reasonably well funded efforts targeted toward improving water quality management activities in the agricultural sector. USDA programs also support storm-water management programs at the county level. However, to date, the impacts of these efforts are not well understood. Additional research focused on the overlap between agricultural conservation activities, USDA funded storm-water assistance, and TMDL implementation would seem appropriate if we are to improve water quality management in this sector and measure the extent to which these activities are yielding positive results.

Second, municipal storm-water programs around the country have now been operating for five or more years (Phases I and II), and we know relatively little about their actual implementation. While we know that urban storm-water runoff is a significant contributor to water quality problems, it would be useful to improve our understanding of the steps that are being taken to address these problems.

And third, home sewage treatments systems are frequent contributors to water quality problems in West Virginia, Ohio, and other states. They are also a frequent target for water quality improvements efforts cited in TMDL reports (at least they are in Ohio and West Virginia). However, because water quality problems stemming from these sources are typically managed by state and local health agencies rather than environmental agencies, there are not well developed systems for understanding the extent to which water quality problems associated with home sewage treatment systems are addressed. Efforts to improve our understandings in these areas would be beneficial in targeting future implementation efforts.

All three of these sectors—agriculture, urban storm-water programs, and home sewage treatment system management—contribute significantly to pollutant loads in Ohio and West Virginia. Further research in these areas in Ohio, West Virginia, and/or other states would yield a useful foundation for future efforts to improve implementation practices relating to each of these pollution sources.

8.4 Conduct targeted in-depth studies of implementation results

This study has relied on educated judgments made by environmental officials, written reports, and existing data to measure implementation progress and to identify factors which contribute to it. While this is a useful strategy for gaining an overall sense of progress and identifying likely factors driving implementation, more in-depth assessments of the relationships among measures of progress in developing implementation capabilities, implementing projects, measuring load reductions, improving water quality, and restoring watersheds would be beneficial. Studying these relationships over relatively long periods of time would be particularly helpful in refining the assessments of potential driving factors for TMDL implementation that are presented earlier this report.

One approach to carrying out this kind of study would involve looking at the Ohio and/or West Virginia watersheds assessed in this study in greater depth. Potentially, this could enable more nuanced understandings of factors which contribute to the development of managerial capabilities, implementation projects, and pollutant loading reductions and water quality improvements. It might also require the collection of new data (rather than just compilations of existing information), and the addition of new cases that enable improved understandings of the full range of ways in which group processes and existing contexts and capabilities may contribute to implementation progress. The new data to be collected in these efforts may include both sampling data relating to pollutants and water quality, as well as more refined measures of social science variables such as demographic characteristics, watershed group engagement, and regulatory interventions.

Two potentially beneficial areas of additional focus would involve looking at watersheds without approved TMDLs to measure the impacts of TMDLs on water quality improvement processes, and the development of more tailored information on contextual variables (problem severity, community stability, wealth, etc.) in individual watersheds. Research in these two areas would enable a more complete assessment of the impacts of TMDLs and the influence of various factors on implementation progress.

9. CONCLUSION

Through the course of this research, we have interviewed numerous state government officials and water quality stakeholders, read and coded dozens of TMDL reports, researched watershed funding streams and TMDL implementation actions, and performed analyses of potential driving factors for TMDL implementation. Based on this work, it is clear that recommendations and requirements contained in TMDL reports are being implemented in both West Virginia and Ohio. It is also clear that information developed during the TMDL development process is being applied to address non-point source water pollution problems and point source water pollution discharges. It also appears that these actions are driven at least in part by the actions of state agency officials and the engagement of groups that have taken an interest in ensuring the health of the particular watersheds within which they reside. And finally, it is also clear that there is a widespread recognition among water quality stakeholders that implementing TMDLs is important for the success of national and state-level water quality improvement efforts.

These conclusions have led us to offer a range of suggestions for ways in which progress in TMDL implementation can be fostered in the months and years ahead. While these suggestions are outlined in some detail in the previous section, it makes sense to restate them here. There are ways in which we can change both TMDL development processes and processes for managing TMDL implementation that are likely to yield positive results. And many of these changes can take place over a relatively short period of time—perhaps over the next two to three years. In addition, there are ways in which federal and state policies may be changed to help foster more effective TMDL implementation in the future, and we have outlined some initial ideas in this area. And finally, while we have spent a substantial portion of the last eighteen months studying TMDL implementation, we still do not know enough about the ways in which TMDLs contribute to the implementation of actions to improve water quality—both across the fifty states and in Ohio and West Virginia. Further research is appropriate to improve our knowledge base and to help us target water quality improvement efforts more effectively.

The TMDL program has been operating in its current form for over ten years, and it is reaching a point where the influences of litigation are subsiding and giving way to a concern about developing workable TMDLs that can be implemented easily and in a cost-effective fashion. This change in thinking about the TMDL program is appropriate, and it sets a useful foundation for re-thinking how we manage water quality nationally, as well as in Ohio and West Virginia. There is an opportunity now for TMDLs to play an important role in facilitating more effective watershed management. It is our hope that this report contributes positively to this effort.

APPENDIX A: METHODOLOGICAL OVERVIEW AND DATA COMPILATION PROCEDURES

As was noted in the body of this report, this study was undertaken to address three questions:

1) To what extent are TMDLs being implemented in Ohio and West Virginia?

2) What factors appear to influence TMDL implementation progress?

3) What changes in practice and policy might foster implementation progress?

While Section 3 of the report outlines key methodological issues, this appendix provides an overview of the methods used to address these questions and the procedures used to compile data. By way of overview, it is useful to begin by outlining two central elements of the overall research effort.

First, in compiling data and information for this research, we focused primarily on information available through state water quality officials. As a result, this study is most appropriately conceived of as an effort to understand TMDL implementation through the water quality management community, rather than an objective assessment of all possible avenues through which TMDL implementation might occur. While there are many potential actors and institutions involved in implementing TMDLs, the TMDL process is fundamentally about protecting water quality. For this reason, state officials with job responsibilities relating to water quality are likely to be the most fully informed potential source(s) of information on TMDL implementation. For this same reason, we also view their perspectives on TMDL implementation as particularly important and worthy of investigation. However, we also sought to identify existing information sources relating to TMDL implementation in the agriculture and home sewage treatment system sectors, but this effort did not yield substantial amounts of specific information on TMDL implementation that is comparable across the two states. As a result, we relied on state environmental officials to provide information on implementation activities in these sectors as well, and supplemented the information that they provided with reviews of written documents and discussions with other stakeholders.

While this approach has enabled the development of a useful picture of the TMDL implementation efforts undertaken in Ohio and West Virginia in a relatively short amount of time, it is appropriate to recognize that it may understate TMDL implementation activities in some areas. For example, while we were able to ascertain that activities associated with USDA farm programs and home sewage treatment system management contribute positively to TMDL implementation in a number of watersheds (those in which they were specifically mentioned in project reports or by those interviewed), we were not able to compile detailed information on the extent of these activities throughout the two states. We encountered similar limitations with respect to the recently administered Phase II municipal storm-water management programs because their implementation efforts had not been investigated comprehensively prior to the time period in which we were compiling information. It is for this reason that we recommend further study of TMDL implementation in all three of these areas – agriculture, home sewage treatment systems, and phase II storm-water programs -- in Section 8 of this report.

A second central element of the overall research effort relates to assuring comparability of information across the two states. To address this concern, project partners from Ohio and West Virginia worked together closely to define the sample universe and identify procedures for compiling data. After defining the initial universe of TMDLs to be investigated, the researchers in the two states communicated regularly regarding both coding procedures and interview/survey processes. They used identical forms for compiling data and participated in joint training sessions on how this compilation was to be conducted. The project team also worked together to make adjustments to questions early in the coding and interview processes in cases where issues were identified that were in need of attention and/or correction. Thus, in spite of some differences in water quality management practices and conditions in the two states, the efforts undertaken through this research assure that the data and information presented are at least as comparable as other cross-state studies in the fields of environmental management and public policy.

With these general elements of the overall research effort described, we now turn to a more detailed description of the procedures used to assess the extent of TMDL implementation. The description that follows addresses three topics: (1) Defining the Universe for Study; (2) Compiling Data and Information, and; (3) Tabulating Results. Appendices B and C describe procedures for analyzing likely factors driving TMDL implementation and developing options for improvements in practice and policies relating to TMDL implementation, respectively.

Defining the Universe for Study

All TMDL reports approved through September, 2006 were included in the sample for this study. In West Virginia, the first TMDLs were approved in 1998, and in Ohio, the first TMDLs were approved in 2000. TMDLs approved in 2007 were not included because our compilation of data commenced in that year and it could not reasonably be expected that implementation activities would have taken place in such a short period of time. Approved TMDLs were obtained from the WVDEP and OEPA Web sites, and were then verified by their state TMDL coordinators. In Ohio, a US EPA Region 5 summary document of approved TMDLs was also used as a reference point.

Within this universe, we also chose the TMDL report and the report-pollutant combinations contained in them as the basic units of analysis. As was noted in Section 3, we did this for two reasons. First, as we visited with state environmental officials and looked for available sources of information during the initial stages of the study, we found that most people and information sources at the state and local levels focused their thinking and work around the concept of watersheds (or individual TMDL reports covering watersheds or sub-watersheds), rather than individual stream segments. As a practical matter, this meant that information available for compilation and analysis was likely to be both more complete and more reliable at a watershed level than at the level of individual stream segments or water bodies. And secondly, because most people involved in developing and implementing TMDLs were focusing on them from a watershed perspective, it made sense to conduct our driving factors analysis at this level as well.

Compiling Data and Information

To investigate the implementation of recommendations contained in TMDL reports, we compiled data from a range of sources. These sources included the TMDL Reports themselves, interviews with key officials and stakeholders, other written sources, and NPDES permits. Throughout this process, we sought existing information, and did not seek to carry out major new information collection efforts. The discussions that follow describe steps taken to retrieve information from each of these sources.

TMDL Reports

During the fall of 2007, we reviewed and coded 63 EPA approved TMDL reports. Through these reviews, we identified key pollutants of concern, point and non-point sources of those pollutants in each watershed, and estimates of problem severity. This coding process provided information that helped guide our efforts to identify TMDL implementation actions. A copy of questions asked on the form used to code these TMDLs is included in Appendix D. The discussion that follows addresses the kinds of information that were obtained through these coding processes, as well as ways in which this information provided guidance for subsequent efforts to identify actions implementing TMDLs.

Defining Pollutants for Study:

One subtlety regarding the 303(d)-listing and the TMDL-development process is the distinction between impairments and pollutants. Waters are listed as impaired if they violate a water quality criterion; however, waters may be impaired for chemical-specific or biological criteria. Solutions to these impairments may involve lowering the discharge of pollutants, or they may involve other actions such as dam removal, stream corridor restoration projects, and/or other efforts to increase the assimilative capacities of the waterways in question. However, Section 303(d) of the Clean Water Act states that TMDLs must be developed for pollutants. Load allocations and waste-load allocations in TMDLs are assigned on a pollutant-by-pollutant basis.

As a result, we focused the analysis on pollutants rather than impairments. In some cases, TMDL reports were written for single pollutants. At most (in this sample universe), one TMDL report includes ten pollutants. On average, the TMDLs reviewed during the course of this project include 2.8 pollutants per report. When waterways were listed as impaired for violations of biological rather than pollutant-specific water quality standards, we used information from the TMDL report (and, in Ohio's case, also EPA Region 5's summary of approved TMDLs) to identify the specific pollutants of concern. In West Virginia, when streams are listed as impaired for biological conditions, the TMDLs include stressor identification analyses to determine which pollutant(s) are harming the benthic macro-invertebrates. TMDLs then require pollutant loading reductions for those specific pollutants.

In Ohio, water bodies are frequently listed as impaired for biological reasons, and these biological conditions are measured through indices – the Index of Biotic Integrity (IBI), the Modified Index of Well Being (MIwb), the Invertebrate Community Index (ICI), and the Qualitative Habitat Evaluation Index (QHEI). In these cases, the TMDL report typically assigns responsibility for these impairments to either particular pollutants or habitat related factors. Where pollutants are specified as the likely cause of impairment, the Ohio TMDLs often draw references from other sources to establish target values for those pollutants. For example, while Ohio EPA does not currently have statewide numeric criteria for phosphorus, the state relies on a 1999 technical report which provides results of a study analyzing the effects of nutrients and other parameters on biological communities in Ohio streams (Ohio EPA, 2006, p. 30-4). Consequently, while violations of biological water quality standards are frequently the targeted impairment in Ohio TMDLs, these impairments are often tied to particular pollutants for which recommended load reductions are calculated. In some cases, however, Ohio has developed what it calls "habitat" TMDLs, and these TMDLs are not tied to any particular pollutant. We did not include these "habitat" TMDLs in our sample because section 303 of the Clean Water Act specifies that loading reductions are to be calculated for pollutants rather than habitat characteristics.

We also excluded several previously approved West Virginia TMDLs for aluminum from our analysis. In West Virginia, the water quality criterion for aluminum was changed from total aluminum to dissolved aluminum after many aluminum TMDLs were completed. Taking our cue from the WVDEP, which no longer enforces the old total aluminum TMDLs, we removed all total aluminum TMDLs from our sample.

In total, over 30 different pollutants were identified during the process of coding the EPA approved TMDL reports addressed in this analysis. To ease the process of analysis and interpretation, these pollutants were divided into ten major pollutant categories. Table 6 documents this categorization.

Table 6: Pollutants and Pollutant Categories

Pollutant Category	Pollutants
Ammonia	Ammonia
Metals (other than Mercury)	Aluminum Iron Manganese Metals Zinc Selenium
Nutrients	Phosphorus Nitrate-N Nitrogen Nitrates
Organic Enrichment/Low Dissolved Oxygen	Biochemical Oxygen Demand (BOD) Dissolved Oxygen (DO) NBOD
Pathogens	Fecal Coliform Pathogens
Pesticides	Aldrin D-BHC Dieldrin Endosulfen Endrin Heptachlor Dioxin
pH	Acidity Alkalinity pH
Polychlorinated Biphenyls (PCBs)	PCBs
Salinity/Total Dissolved Solids/Chlorides/Sulfates	Total Dissolved Solids
Sediment	Sediment Siltation Total Suspended Solids (TSS)

For analytical purposes, we also divided pollutants into those which are likely to impact human health and those which are not. The following pollutants were identified as holding the potential to affect human health: pathogens (fecal coliform); pesticides (aldrin, d-BHC, dieldrin, endosulphan, endrin, heptachlor, and dioxin); nitrate; selenium, and; polychlorinated biphenyls (PCBs). In total, 34 of the 174 (19.5%) pollutants addressed in our sample fell into these health-impacting categories.

Defining Point Sources:

TMDLs typically include information on sources that discharge or release pollutants of concern. In TMDLs and in our analysis, it is useful to consider point and non-point sources separately, because the implementation of point and non-point sources follows different pathways.

Each TMDL report/pollutant combination was coded according to which point sources were targeted. Some TMDLs did not target any point sources, and were coded as "None." Others targeted agriculture, mining, storm-water, wastewater, and/or industrial point sources. "Unknown" and "other" categories were also available if needed. Agriculture point sources include confined animal feeding operations (CAFOs) only. Wherever possible, care was taken to distinguish between these permitted facilities and other un-permitted agricultural operations, based on information contained in the TMDL reports. Mining point sources include permitted coal mines or other mines such as quarries. These are distinguished wherever possible from abandoned mines, which were coded as non-point sources.

Permitted storm-water sources include municipal separate storm sewer systems (MS4s), permitted construction sites, and industrial facilities with storm-water permits. Urban storm-water, therefore, is coded as point source storm-water if the urban area falls within a Phase I or Phase II MS4 permitted area; otherwise, it is coded as non-point source storm-water. Similarly, construction sites are coded as point source storm-water if the site operates under a construction storm-water NPDES permit.

Wastewater point sources include wastewater treatment plants, as well as combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs). CSOs and SSOs were coded as wastewater—not storm-water—point sources because CSOs and SSOs are typically included in wastewater treatment plant and wastewater collection system NPDES permits, not MS4 permits.

Defining Non-point Sources:

Each TMDL report/pollutant combination was also coded according to the types of non-point sources that are targeted for action. One TMDL did not target any non-point sources, and it was coded as "None." Others targeted wastewater, riparian protection, agriculture, legacy sources of pollution, flow alteration, mining, forestry, roads, and/or un-permitted non-point source urban storm-water.

Wastewater non-point sources include septic systems and other wastewater systems that are not permitted through the NPDES. Actions include fixing septic systems, connecting to centralized systems, and getting NPDES permits. Actions to solve riparian protection problems include establishing setbacks and setback requirements, planting appropriate ground cover, or restoring flood plains. Non-point source agriculture sources include all unpermitted farms. Actions required by TMDLs may include nutrient/pathogen management, water management, pesticide management, or planting and tillage practices. Legacy sources of pollution capture situations in which pollution from past sources is causing present impairments. These TMDLs may require actions such as characterizing sources and estimating risks, initiating management, or remediation. We coded flow alteration actions as nonpoint sources. Actions include removing dams, modifying flows from reservoirs or lakes, and modifying or eliminating levees. Mining non-point sources are those at un-permitted facilities. For example, coal mines abandoned prior to 1977 are considered non-point sources. Actions for re-mediating these sites include installing at-source or in-stream treatment systems. Other non-point sources include forestry, roads, and un-permitted non-point source urban storm-water.

Ascertaining Problem Severity:

The severity of the water quality problems requiring each TMDL report submission was estimated based on two criteria. First, the percent reduction for each pollutant was recorded where possible. In many TMDL reports, this percent reduction was stated clearly in the TMDL for each pollutant. In other TMDL reports, it was possible to calculate this percent reduction from the information provided in the TMDL. However, in some TMDL reports, not enough information was provided to calculate the percent reduction required for each pollutant. In all cases, we relied on percentage reduction figures which applied across all impaired segments rather than one or two selected water bodies.

A second measure of problem severity is whether or not the pollutant affects public health. As noted above, the types of pollutants coded as such include pathogens (fecal coliform), pesticides (aldrin, d-BHC, dieldrin, endosulphan, endrin, heptachlor, and dioxin), nitrate, selenium, and polychlorinated biphenyls (PCBs).

Guidance for Identifying TMDL Implementation Actions:

The information coded from the approved TMDL reports was important, as it was used to guide subsequent efforts to identify implementation actions that were taken after US EPA approval. Two kinds of information drawn from these TMDLs were particularly important in this regard.

First, as noted above, the coding process focused specifically on pollutants and their sources, as identified in each US EPA approved TMDL report. As a result, for all 63 reports, we were able to seek out information on implementation actions which specifically addressed both pollutants and sources noted in the TMDL. Our efforts to identify these implementation actions included interviews with knowledgeable officials and stakeholders, as well as reviews of existing written information. And, while our search for implementation actions extended across all targeted non-point sources, our evaluation of NPDES permits was effectively limited to cases in which effluent limits were addressed in major NPDES permits. We did not seek to assess systematically implementation relating to some categories of point source discharges, such as storm-water permits or sewage overflows, for example.

For the analysis of major NPDES permits, we were often able to extract information on specific permits which were targeted for action in the TMDL. In some cases, the information provided came in the form of recommended effluents limitations on pollutants of concern. In other cases, it came as individual waste-load allocations, which could subsequently be translated into effluent limitations. For some permits, we did not find information in the TMDL which was sufficiently specific to enable us to ascertain whether subsequent permit re-issuances were consistent with the TMDL.

Conducting Interviews

We relied on interviews to provide much of the information used to assess TMDL implementation progress in the two states. In total, we communicated with over 70 state officials and water quality stakeholders during the course of the research process. Structured interviews or surveys were conducted with a total of 41 state officials. We conducted two types of structured interviews and surveys with state officials. The first type focused on lead developers of the TMDL reports which had been approved by US EPA. The second type of interview focused on individuals who were identified by TMDL program coordinators, TMDL development leads, or others as particularly “knowledgeable state officials” with regard to the watersheds addressed by each of the 63 TMDLs in our sample. We also conducted targeted interviews with other stakeholders, such as watershed group coordinators and experts from other agencies. Information from these latter interviews is incorporated in the study results in targeted fashion where appropriate.

Surveying TMDL Lead Developers:

Lead developers are defined as the people at OEPA, WVDEP, and/or US EPA with responsibility for developing specific TMDLs. Because of its decentralized method of writing TMDLs, numerous lead developers were identified in Ohio as listed in the TMDLs or on the OEPA Web site. We compiled the list of Ohio lead developers from the TMDL reports themselves and passed it by the Ohio TMDL coordinator before contacting these people. In West Virginia, however, the WVDEP TMDL Coordinator was, in effect, the lead developer for every TMDL.

Lead developers were asked a series of questions regarding watershed group involvement in the TMDL development process. This information was used in the driving factor analysis. It should be noted that in West Virginia, the WVDEP TMDL program did not have the administrative record of the EPA- or ORSANCO-written TMDLs, and therefore was unable to provide information regarding watershed group participation in these TMDL development processes. This information was therefore gathered from US

EPA Region 3, which oversaw the early TMDL development processes in West Virginia. Similarly, a US EPA Region 5 staff member provided information relevant to stakeholder participation in the Wabash and Mahoning River TMDLs in Ohio, both of which were written by US EPA Region 5.

Lead developers were also asked to identify key state and federal agency staff who members who are working to implement each TMDL. These "knowledgeable officials" were then targeted for interviews. In West Virginia, this identification of key state officials was provided by staff at the WVDEP Non-point Source Program, because the TMDL Coordinator was not involved in TMDL implementation. These staff members were knowledgeable regarding TMDL implementation because many of the implementation processes in West Virginia relate to non-point sources. In Ohio, these "knowledgeable officials" were identified by the Lead Developers and the TMDL Coordinator.

Interviews with Knowledgeable State Officials:

Once identified, these "knowledgeable state officials" were a key data source to gauge implementation progress and to help in providing data relevant to potential factors driving implementation progress. We also held discussions with other knowledgeable officials, such as staff from the Ohio DNR and federal mining officials in West Virginia. These interviews were also supplemented with targeted discussions with watershed coordinators, where necessary and appropriate.

These interviews yielded information on a range of variables relevant to TMDL implementation progress and to the factors which drive it, as well as general insights which contributed to our ability to analyze the data we were compiling. Those interviewed provided information on range of important measures of TMDL implementation progress: whether there were state officials engaged in efforts to implement the TMDLs; whether specific projects had been undertaken (this information was supplemented by information from written sources); whether groups in the watershed had taken responsibility to foster TMDL implementation (also supplemented by written information); whether ambient monitoring was being undertaken; whether load reductions were occurring, and; whether there were known instances of water quality improvement subsequent to implementation actions targeted toward pollutants and sources contained in TMDLs. The state officials we interviewed also provided information regarding their views of the impact of TMDLs on efforts to reduce pollutant loads and improve water quality. Key questions used to guide these interviews are listed in Appendix D, along with key questions used in the review and coding of the 63 TMDL reports in our sample.

Written Sources of Information

We also drew upon written sources of information to identify projects which implemented TMDLs and to inform the overall project effort. In addition to the 63 TMDL reports which we coded, we reviewed integrated Section 303/305b report submissions from the two states, information on the nature and structure of TMDL and water quality programs in the two states, and a range of other documents.

We were also able to use several kinds of publicly available documents to identify projects which implemented TMDLs in the two states. These included Section 319 annual summary reports for the two states, as well as listings of watershed projects funded by the Federal Office of Surface Mining. Both of these sources included information which was detailed enough to identify not only that projects were undertaken, but also their geographic relationship to the watersheds associated with the 63 TMDL reports in our sample. In Ohio, we were also able to identify projects from the state's website listing of projects funded by the Water Resource Restoration Sponsorship Program (WRRSP). Information on watershed groups working in particular watersheds was also available in written form from web-based sources.

Assessing TMDL Implementation in NPDES Permits

To address the question of whether recommendations contained in TMDLs are being incorporated into NPDES permits, we decided to focus on major permits located in the 63 TMDL limited watersheds in our sample. We chose this approach because trying to look at all of the NPDES permits issued in these areas would not be possible given the resources and time available for the study. While this approach ignores hundreds of minor permits that may affect water quality in TMDL limited watersheds, it does allow us to get a sense of the manner in which recommendations contained in TMDL Reports are implemented in NPDES permits. We further decided to limit our focus to changes in effluent limits in permits because of the complexities involved in assessing compliance with a wide variety of other NPDES permit provisions.

Through a web-based query of US EPA's NPDES database, we generated a list of major NPDES permits that contributed pollutants to Ohio and West Virginia waters. We then cross-walked this list with the permits that were contained in the 63 TMDL reports we coded. Through this process, we identified a total of 51 major permits in Ohio and West Virginia that are located in the watersheds included in our sample. The vast majority of these major permits -- 49 of the 51 major permits (over 95%) -- are in Ohio.

We then reviewed the TMDL reports within which these major permits were located to determine if they called for reductions in effluent loads for TMDL limited pollutants. Through this process, we were able to identify a total of 27 major permits which targeted effluent limits, and 19 of those contained clear recommendations to reduce effluent loads below those allowed in current permits. One of these two West Virginia major permits targeted effluent limits reductions. It is worth noting in this context that we found variations in the ways in which point source permit reductions were presented in the TMDLs we reviewed and it was difficult in some cases to ascertain whether or not reductions were being recommended. It is possible in this context that there were cases in which permit loading reductions for particular pollutants were appropriate, but we did not identify them as such from the language of the recommendations in the TMDL Report. In the end, we chose to focus more specific permit reviews only on the nineteen major permits which contained clear recommendations for effluent loading reductions.

We then obtained copies of these nineteen permits. In Ohio, we were able to retrieve them from Ohio EPA's worldwide web site. The West Virginia permit targeting effluent limit reductions was obtained from the WV DEP directly, and we then reviewed all of these major permits to ascertain whether they had actually implemented recommendations contained in the TMDL reports. The permits were reviewed from several perspectives. First, we sought to determine whether or not the permit had been re-issued since the date on which US EPA had approved the TMDL. If it had been re-issued, we then sought to determine whether or not it included at least one TMDL targeted permit limit that was more stringent than it had been previously. Second, we sought to determine whether permit limits contained in the re-issued permits were fully consistent with TMDL recommendations (after they were fully implemented following any required phase-in periods). And finally, we sought to ascertain whether the TMDL limited pollutants were fully and currently consistent with the recommendations shown in the TMDL. Through this process, we were able to get an initial sense of the relationship between TMDL recommendations for changes in effluent limits, and their subsequent implementation in NPDES permits.

Tabulating Results

As was noted in Section 3 of this report, we relied on US EPA's TMDL Program Pipeline (Norton, et. al., 2007) to guide our compilation of data measuring TMDL implementation progress in West Virginia and Ohio. The categories in the TMDL Program Pipeline also guided our tabulation of data after it was compiled. The four major categories of implementation progress forwarded by the TMDL Program Pipeline and addressed in this report are: (1) management and planning; (2) the implementation of controls; (3) partial recoveries, or water quality improvements, and; (4) full water body recoveries. The actual measures chosen for tabulation reflect progress in these categories and are identified and described in Table 7. The quantitative results emerging their tabulation are presented in Section 5 of this report.

Table 7: Measures of TMDL Implementation Progress and Information Sources

Measures	Description	Information Source(s)
PLANNING AND MANAGEMENT		
Knowledgeable State Official?	Identifies whether we could identify a state/federal official who was knowledgeable about implementation of the TMDL in question. Coded 1 for yes, and 0 for no.	To determine whether there was such an individual, we consulted the TMDL lead developer, the State TMDL coordinator, and anyone the TMDL coordinator could refer us to.
Projects?	Measures whether there was at least one project identified which seeks to reduce pollutants or improve assimilation of pollutants from sources recommended for action in this TMDL. Coded as 1 for yes, and 0 for no.	Information on projects was retrieved from: Annual Section 319 grant reports for Ohio and WV; watershed group grant lists from the federal Office of Surface Mining; OWRRSP project lists in Ohio, and; interviews with knowledgeable state officials. The state officials were asked if they knew of projects targeting the sources and pollutants identified for action in the TMDL Report.
Responsible Group?	Ascertains whether or not there is a local or regional group that is working to implement the TMDL. Coded as 1 for yes, 0 for no.	Interviews with knowledgeable State Officials – the question asked, was "Is there a local or regional group that is actually working to foster implementation of this TMDL?"
Water Quality Monitoring?	Identifies whether there has been monitoring of water quality for TMDL limited pollutants since approval of the TMDL. Coded 1 for yes, and 0 for no.	Interviews with knowledgeable State Officials – the question asked was, "has any post-TMDL ambient or sediment monitoring been conducted for this pollutant (at locations downstream from implementation actions, but still in the area covered by this TMDL Report?"
IMPLEMENTATION OF CONTROLS		
NPS Load reduction?	Ascertains whether the knowledgeable state official we identified knew of or believed that non-point source loading reductions for pollutants of concern in the TMDL had occurred since EPA approval of the TMDL. Coded 1 for yes, and 0 for no.	Interviews with knowledgeable State Officials – the question asked whether the state official knew of or believed that non-point source load reductions had been achieved for pollutants limited by the TMDL. Those interviewed were also asked to provide the rationale behind their answer. If they answered yes to either of these questions, the answer coded was yes. Question wording can be found in Appendix D.
Any Load Reduction?	Ascertains whether the knowledgeable state official knew of or believed that loading reductions of any kind for pollutants of concern in the TMDL had occurred since EPA approval of the TMDL. Coded 1 for yes, and 0 for no.	Interview with knowledgeable state officials – if the state officials answer yes for the NPS load reduction question above or yes for a similarly worded question applicable to point sources, a loading reduction was coded to have occurred. Question wording can be found in Appendix D.
Effluent Limits in Major Permits?	Ascertains whether effluent limits contained in major NPDES permits reflect TMDL recommendations. Each major permit was assessed according to several criteria for compliance (see discussion in Section 5 text for more detailed information).	Information on recommended effluent limits and/or waste-load allocations was drawn from the applicable TMDL reports. Information on current effluent limits was retrieved from the NPDES permits themselves. Major Ohio NPDES permits were accessed through the Ohio EPA worldwide website. Major NPDES permits in West Virginia were provided by the WV DEP.
Water Quality Improvement?	Identifies whether there was a known improvement in water quality downstream from a TMDL implementation action for a TMDL limited pollutant. Coded 1 for yes and 0 for no.	Interview with knowledgeable State Officials – in cases where post-TMDL monitoring was known to have occurred, the officials were asked if they knew of any improvements in water quality downstream from implementation actions since EPA approval of the TMDL Report.
Water Body Restoration	Ascertains whether the state regulatory agency has declared the water body restored in its integrated 303/305 submission to US EPA.	Information was gathered from the 2006 Ohio and West Virginia integrated reports, and consultations with the State TMDL Coordinators.

We also tabulated results for three other sets of data. First, we tabulated information on a range of characteristics associated with watersheds addressed in the 63 TMDL reports that were used as the basis for the analyses presented in this report. These characteristics include the dates on which reports in our sample universe were approved by US EPA, numbers and types of pollutants addressed in these reports, and the sources of pollutants released into watersheds addressed by these reports. These tabulations are presented in Sections 3 and 4 of this report.

Second, we tabulated results from a question we asked of knowledgeable state officials to ascertain their views regarding whether or not the TMDL process was useful in fostering pollutant loading reductions and/or water quality improvements. We also asked them to tell us whether they perceived any additional benefits from the TMDL process, above and beyond fostering pollutant loading reductions and improving water quality. The results of these tabulations are presented in Section 5 of the report.

And finally, we tabulated information on a number of variables that have been identified in past literature and which may serve as drivers of TMDL implementation progress. These variables relate to the physical and social contexts in which TMDLs are to be implemented, group processes that are potentially subject to manipulation, and two control variables. These three sets of variables and the information sources used to develop measures of them are summarized in tables 8, 9, and 10.

Table 8: Potential Driving Factors – Contextual Variables

Context Variable	Description	Source
Wealth	The percentage of households with income exceeding $50,000 per year in the eight digit Hydrological Unit Code (HUC) area in which the watershed covered by the TMDL report resides. The area in the Upper Little Miami River watershed in Ohio has the largest percentage of people with household income exceeding $50,000 in our sample at 63%, and Tug Fork River Watershed, West Virginia has the lowest percentage of population with household income exceeding $50,000 p.a. at 18%	National Oceanographic and Atmospheric Administration (NOAA) compilation of 2000 census data by eight digit HUC code, accessed through: http://www8.nos.noaa.gov/socioeconomics/
Education	The percentage of the population who graduated from college. The Mahoning River watershed area in Ohio has the highest % population who are college graduates (32%). The Tug Fork River Watershed, West Virginia and Guyandotte River Watershed areas in West Virginia have the lowest % of population who graduated from college (7%).	National Oceanographic and Atmospheric Administration (NOAA) compilation of 2000 census data by eight digit HUC code, accessed through http://www8.nos.noaa.gov/socioeconomics/.
Class	A factor score which reflects a measure of class which is derived from educational and wealth.	A derived score that is based on the wealth and education variables described above.
Population Density	Persons per square mile living in the eight digit HUC area. Population density is highest in the Cuyahoga River Watershed, Ohio at 1273 and lowest in the South Branch (and South Fork) area of the Potomac River in West Virginia at 19.9.	National Oceanographic and Atmospheric Administration (NOAA) compilation of 2000 census data by eight digit HUC code, accessed through: http://www8.nos.noaa.gov/socioeconomics/
Stability	Percentage population who are non-renters in the eight digit HUC area. The percentage of non renters was highest in Lost River Watershed, West Virginia at 84% and lowest in Mill Creek-Ohio River tributary in Ohio (59%).	National Oceanographic and Atmospheric Administration (NOAA) compilation of 2000 census data by eight digit HUC code, accessed through: http://www8.nos.noaa.gov/socioeconomics/
Homogeneity/ Diversity	Percentage population who are white. The highest percentage of homogenous population was found in Lost River Watershed, West Virginia at 98% and lowest percentage of homogenous population was found in Euclid Creek Watershed, Ohio at 66%	National Oceanographic and Atmospheric Administration (NOAA) compilation of 2000 census data by eight digit HUC code, accessed through: http://www8.nos.noaa.gov/socioeconomics/
Social Capital	A factor score which reflects a measure of social capital which is derived from measures of stability and homogeneity.	A derived score that is based on the stability and homogeneity variables described above.
Pollution Severity # 1	Percentage reduction required for a particular pollutant to restore the impaired water bodies/segments within the watershed.	The TMDL Report covering the watershed in question. This is either a given value or a calculated value, depending on the report.
Pollution Severity # 2	A dichotomous measure reflecting whether the TMDL limited pollutant has human health impacts. Coded 1 for yes and 0 for no.	Pollutants identified in TMDL reports were coded as having potential human health impacts by the project team. See discussion earlier in Appendix A for information on these pollutants.

Table 9: Potential Driving Factors: Group Involvement Variables

Group Involvement Variable	Description	Source
Stakeholders involvement in TMDL development	The number of ways in which stakeholder groups were involved in the TMDL development process. The ways tabulated included attending a TMDL development meeting, writing a letter regarding the TMDL report, providing data, writing some or all of the TMDL report, and other forms of involvement that were not specified. The values for this variable can range from 0 for no involvement to 5 for extensive involvement.	Lead TMDL developer survey – state and federal officials who played roles in developing TMDLs were asked to identify the specific ways in which stakeholder groups were involved in TMDL development, and this variable reflects the number of forms of involvement that they identified.
Watershed Group Grants	The Ohio Department of Natural Resources provides grants to fund watershed coordinators for watershed groups in selected watersheds in Ohio. West Virginia does not have a similar program. This variable reflects whether or not a watershed coordinator grant was provided for a group in the area covered by the TMDL. It is coded as 1 for TMDLs with grants and 0 for TMDLs without grants.	Information on watershed groups receiving watershed coordinator grants in Ohio was provided by the Ohio Department of Natural Resources.
Group density	Number of confirmed watershed groups operating in the area covered by the TMDL report. The Lower Cuyahoga River Watershed in Ohio indicated highest level of involvement among Watershed groups with 9. There were a number of watersheds in which no groups were identified.	TMDL Reports, watershed group network websites, and interviews with knowledgeable state officials. For each TMDL, a list of watershed groups in the affected area was compiled based on watershed group network websites and TMDL reports. These lists were then adjusted by input from knowledgeable state officials during the interview process.
Group intensity	A measure of the extent to which the most involved group is engaged in TMDL implementation. Values range from 1 to 3, with 3 meaning major engagement and 1 meaning no engagement.	Knowledgeable official interview – those interviewed were asked to identify the level of engagement of involved watershed groups on a 1 to 3 scale, with 3 meaning major engagement and 1 meaning no engagement.
Extent of State Agency Engagement in TMDL Implementatio n	A measure of the level of involvement of State Officials in TMDL implementation. The response variables take on values between 0 and 9, depending on the number of ways that State Officials are involved in TMDL implementation.	Knowledgeable official interviews. The interviews included questions about the ways in which the implementation leads and other state officials are involved in TMDL implementation. A total of 10 forms of involvement are identified, so the values for this measure could range from 0 to 10.
Endorsement of watershed plan	In both Ohio and West Virginia, state agencies endorse watershed plans for particular watersheds.. Watersheds areas with endorsed watershed plans are coded as 1 and those without endorsed watershed plans are coded as 0.	Information on endorsed watershed plans was provided by the Ohio Department of Natural Resources and the West Virginia Department of Environmental Protection.

Table 10: Potential Driving Factors: Control Variables

Control Variable	Description	Source
Time since EPA Approval	Months since EPA approval of the TMDL. Measured as the number of months between the date of approval, and February 2008 – the month we began compiling data on implementation.	Approval dates for Ohio were drawn from EPA Region 5 document summarizing approved TMDLs in Ohio. West Virginia approval dates were obtained from the TMDL reports themselves.
Size of TMDL Watershed	Number of square miles covered by the TMDL report.	TMDL report.

All of the variables identified in the three preceding tables were used on our statistical analyses of TMDL implementation progress. Appendix B outlines preliminary analyses conducted to support those analyses and describes key steps taken to produce them. The analyses themselves are presented in Section 6 of the report.

APPENDIX B: ANALYZING POTENTIAL DRIVING FACTORS

Section 6 reports the results of our statistical models predicting the likelihood that we observe (1) a group working to foster implementation of a TMDL, and (2) perceived pollutant load reductions associated with TMDL implementation. We identify 10 independent variables that might affect the presence of an implementation group, and 13 variables that might affect perceptions of pollutant load reductions. While the samples sizes addressed in this study exceed those of previous studies of TMDL implementation by a considerable margin, they are not large when viewed in relation to the scope of the analyses undertaken in this study. The remainder of this appendix describes steps taken to assure that the conclusions reached in this study are based on the best statistical evidence possible. Throughout this report, we rely on the preponderance of overall evidence in reaching our conclusions, rather than the results of any single statistical test.

The Probit models we employ to predict the probability of observing our dependent variables rely upon the asymptotic (i.e., very large sample) properties of the estimators. Common rules of thumb suggest that the asymptotic properties of maximum likelihood estimators are not manifest until there are 30-50 observations per parameter estimate (Aldrich and Nelson 1984). Our models predicting the presence of an implementation group potentially include 10 parameters (9 independent variables and a constant). This implies a minimum sample size of at least 300, or almost twice our maximum sample size of 174. Small sample sizes are essentially problems of limited information, and this problem is further exacerbated in our case by the fact that many of our independent variables are dichotomous or categorical (i.e., they contain less information than continuous variables). For these reasons, we should reduce the number of independent variables in our multivariate models. We take a three stage approach to eliminating predictors from our multivariate models (i.e., for imposing what econometricians typically call "exclusion restrictions"). The next three sections describe the results from each of these stages. They are followed by a technical description of the rationale for our effort to estimate Probit Models with Endogenous Regressors.

Simple Probit Models

In the first stage of the preliminary analysis, we estimate a set of simple Probit models where each independent variable is used to predict each dependent variable individually. If the independent variable is unable to predict the presence of an implementation group or a perceived load reduction in this framework, it becomes a candidate for an exclusion restriction. Hypothesis tests are conducted in two ways; using traditional parameter standard errors assumed to be asymptotically normal, and using bootstrapped standard errors that (require multiple re-samples from within our sample universe, thus increasing the overall sample size and) do not rely upon the assumption of normality or the asymptotic properties of the estimator (Mooney and Duval 1999).

For the models predicting the presence of a group taking responsibility for TMDL implementation, the normal and bootstrapped standard errors support the same conclusions. The results from these simple models are presented in Table 11. The simple models suggest that the variables associated with problem severity are good candidates for being excluded from our final multivariate models. Briefly, Table 11 shows that:

- Both group process variables – stakeholder involvement in TMDL development and state agency involvement in implementation -- are positively related to the probability that there is a group responsible for overseeing implementation of the TMDL.
- The probability that there is a group responsible for overseeing implementation of the TMDL increases as the socioeconomic status of watershed residents increases, and as the population density of the watershed increases. Contrary to expectations, however, levels of potential social capital are negatively associated with the probability that there is a group responsible for overseeing implementation of the TMDL.
- Neither measure of problem severity is significantly related to the probability that there is a group responsible for overseeing implementation of the TMDL.

- Larger watersheds appear to be more likely to have a group responsible for overseeing implementation of the TMDL than smaller watersheds.
- The likelihood of a group taking responsibility for TMDL implementation appears to be lower for older TMDLs than for newer ones.

Table 11: Results from Simple Probit Models Predicting Probability that there is a Group Responsible for TMDL Implementation (N=174)

Independent Variable	Parameter Estimate	Asymptotic Z-score	Bootstrapped Z-Score
Stakeholder Involvement in TMDL Development	0.671	3.31***	5.80***
State Agency Involvement	0.493	4.31***	6.61***
Socioeconomic Status	0.322	2.23**	4.63***
Potential Social Capital	-0.429	-2.84***	-5.56***
Population Density	0.004	3.28***	5.60***
Human Health Pollutant	0.149	0.59	0.57
Required Pollution Reduction	0.002	0.42	0.38
Watershed Area	0.324	3.25***	3.52***
Age of TMDL	-0.011	-1.70*	-3.05***

* p<.10, **p<.05, *** p<.01, two-tailed tests. Significance levels should properly be attached to parameter estimates rather than z-scores, but we depart from this convention because parameter estimates are the same in the asymptotic and bootstrapped models.

The first stage in our preliminary analysis of perceived loading reductions follows the same strategy. Recall, however, that we expect success in earlier stages of the TMDL implementation pipeline to positively affect success in later stages. Therefore, the simple models in this stage of the analysis are not bi-variate, but tri-variate (i.e., these models estimate the effect of each group process, contextual, and control variable jointly with the effect of the presence of a group overseeing TMDL implementation). Table 12 presents the results from our models predicting perceived non-point source pollutant load reductions, while Table 13 presents the results from our models of any perceived load reductions. Hypothesis tests are again conducted in two ways; using traditional parameter standard errors assumed to be asymptotically normal, and using bootstrapped standard errors. Only the asymptotic standard errors are reported in Tables 12 and 13. The simple analyses show that after controlling for the presence of an implementation group, we might employ exclusion restrictions for many of the other variables that are candidates for inclusion in the multivariate models of load reductions. Briefly, Tables 12 and 13 show that:

- All models show a positive relationship between the presence of a group responsible for TMDL implementation and the probability that state officials perceive load pollutant load reductions associated with TMDLs. In all of these models (except one, which could not be estimated due to perfect collinearity), this positive effect of TMDL implementation groups on perceived load reductions in statistically different from zero at a 99% confidence level. While we need to be cautious in drawing meaningful conclusions from the simple models, these results indicate a strong positive relationship between stages of the TMDL implementation pipeline.
- Two of the group process variables are statistically significant and help predict the probability that state officials will perceive pollutant load reductions (in at least one of the two models). As expected, the existence of major TMDL implementation efforts on the part of at least one watershed group are positively associated with perceived non-point source and any (point and non-point source) load reductions. The existence of an approved NPS watershed plan is a statistically significant predictor of non-point loading reductions, but not of the any load reductions variable. And, while the watershed coordinator grant variable operates as expected in both models, its z-score is not quite large enough to yield statistical significance in the prediction of either perceived NPS or any load reductions in these models. It is also noteworthy that the variables measuring stakeholder involvement in TMDL development and state agency involvement that were so important in predicting the presence of a group overseeing TMDL implementation do not appear to have strong and independent relationships with the probability of perceived pollutant load reductions.
- None of the contextual variables help predict the probability that state officials will perceive pollutant load reductions in statistically significant fashion, though the population density

variable does display a moderately strong negative relationship with perceived non-point source pollution reductions.

- Neither measure of problem severity appears to be related to the probability that there is a group responsible for overseeing implementation of the TMDL.
- The probability that state officials will perceive a pollutant load reduction increases with the age of the TMDL, but the size of the watershed appears to be unrelated to perceived load reductions.

Table 12: Results from Simple Probit Models Predicting Probability of Known or Perceived Non-point Source Pollutant Load Reductions Associated with TMDLs (N=169)

Independent Variable	Parameter Estimate	Asymptotic Z-score	Implementation Group Parameter Estimate	Asymptotic Z-score
Stakeholder Involvement in TMDL Development	0.677	0.42	2.142***	4.42
State Agency Involvement	0.063	0.79	1.941***	3.34
Watershed Coordinator Grant	0.474	1.31	1.979***	4.14
Density of Watershed Groups	0.066	0.71	2.295***	4.70
Intensity of Watershed Group Participation	0.491***	3.10	1.329***	2.61
Presence of NPS Watershed Plan	0.6.70*	1.78	1.849***	3.71
Socioeconomic Status	0.0.67	0.59	2.123***	4.79
Potential Social Capital	-0.104	-0.94	2.087***	4.63
Population Density	-0.076	-1.51	2.345***	5.18
Human Health Pollutant	-0.011	-0.03	2.177***	4.92
Required Pollution Reduction	-0.001	-0.20	[1]	
Watershed Area	0.063	0.50	2.105***	4.33
Age of TMDL	0.011*	1.68	2.480***	4.84

* p<.10, **p<.05, *** p<.01, two-tailed tests

[1]Unable to obtain parameter estimate due to perfect collinearity.

Table 13: Results from Simple Probit Models Predicting Probability of Known or Perceived Point and/or Non-point (i.e. Any) Source Pollutant Load Reductions Associated with TMDLs (N=174)

Independent Variable	Parameter Estimate	Asymptotic Z-score	Implementation Group Parameter Estimate	Asymptotic Z-score
Stakeholder Involvement in TMDL Development	0.104	0.67	2.342***	4.86
State Agency Involvement	0.108	1.46	2.000***	3.60
Watershed Coordinator Grant	0.235	0.63	2.289***	4.62
Density of Watershed Groups	-0.086	-0.84	2.541***	4.98
Intensity of Watershed Group Participation	0.635***	3.33	1.358***	2.59
Presence of NPS Watershed Plan	0.445	1.10	2.186***	4.25
Socioeconomic Status	0.137	1.10	2.255***	5.13
Potential Social Capital	-0.193	-1.51	2.198***	4.94
Population Density	-0.001	-0.10	2.385***	5.25
Human Health Pollutant	0.018	0.05	2.383***	5.33
Required Pollution Reduction	0.001	0.12	[1]	
Watershed Area	-0.083	-0.58	2.513***	3.55
Age of TMDL	0.190***	2.76	3.105***	4.97

Likelihood Ratio Tests from Multivariate Models

While these results from the simple models are suggestive, we should have limited confidence in their conclusions. Stronger evidence regarding the effect of these factors on implementation progress will come from multivariate models because they control for multiple potential sources of causal influence. The second step in our preliminary analysis is to determine the joint effect of variables representing the same general concepts; i.e., we want to find out if community resources, problem severity, group processes, and/or control variables jointly affect the probability that there is a group responsible for overseeing implementation of the TMDL. In order to estimate these joint effects, we first estimate a model including all of the independent variables from the bi-variate analyses summarized in Table 13 (commonly referred to as the unrestricted model). Next, we estimate a series of models that exclude the group process, community resource, problem severity, and control variables, respectively (commonly referred to as the restricted models). Finally, we conduct likelihood ratio tests comparing the unrestricted model to each restricted model to determine whether these groups of variables jointly help us predict the probability that there is a group responsible for overseeing implementation of the TMDL.

The results of the likelihood ratio tests from models predicting the presence of a group responsible for TMDL implementation are reported in Table 14, and show that while the group process and problem severity variables improve our ability to predict the likelihood that there is a group responsible for TMDL implementation, the community resource variables generally do not. These results indicate that the community resource variables might be excluded from the final multivariate models predicting the presence of an implementation group.

Table 14: Likelihood Ratio Tests for Groups of Variable Predicting Probability that there is a Group Responsible for TMDL Implementation (N=174)

Model	-2LLR[a]	Chi-Squared LR test
Unrestricted Model	162.2	
Group Process Variable Restriction	78.4	83.8***
Community Resource Variable Restriction	159.8[b]	2.4[b]
Problem Severity Variable Restriction	151.8	10.4**
Control Variable Restriction	151.4[b]	10.8**[b]

* p<.10, **p<.05, *** p<.01, two-tailed tests

[a] -2 * Log Likelihood Ratio comparing model estimated to model fit with intercept only.

[b] These restricted models have a few more observations than the unrestricted models, so the likelihood ratio tests are approximate.

The results from the likelihood ratio tests from models predicting perceived load reductions are summarized in Table 15**.** The unrestricted models here include all of the independent variables from Tables 12 and 13, respectively. Table 15 shows that while the group process and control variables improve our ability to predict the likelihood that state officials will perceive (point and/or non point) pollutant load reductions, the problem severity and community resource variables do not do so consistently. They appear to be somewhat helpful in predicting perceived NPS pollutant load reductions, but not in predicting pollutant load reductions from any source. This suggests that these latter variables are candidates for exclusion from the final multivariate models. Note that these results are somewhat different than those from the simple Probit models summarized in Tables 12 and 13, and we should have more confidence in the likelihood ratio tests.

Table 15: Likelihood Ratio Tests for Groups of Variables Predicting Probability of Perceived Pollutant Load Reductions

Model	Perceived Nonpoint Load Reduction -2LLR[a]	Chi-Squared LR Test	Any Perceived Load Reduction -2LLR[a]	Chi-Squared LR Test
Unrestricted Model	107.9		87.1	
Group Process Variable Restriction	61.7[b]	46.9***	53.6[c]	33.5***
Community Resource Variable Restriction	82.4	25.5***	84.8	2.3
Problem Severity Variable Restriction	91.2	16.7**	82.9	4.2
Control Variable Restriction	79.1	28.8***	64.3	22.8***

* p<.10, **p<.05, *** p<.01, two-tailed tests

a -2 * Log Likelihood Ratio comparing model estimated to model fit with intercept only.

b LR test is approximate since group process restriction model has 6 more observations than unrestricted model.

Unrestricted Multivariate Models

The third step in our preliminary analysis is to use our unrestricted models predicting the presence of an implementation group and the perception of pollutant load reductions to identify variables that might be excluded from the final multivariate models. One common rule of thumb is that independent variables displaying substantively small parameter estimates and non-significant parameter test statistics (t-scores or z-scores) can be excluded from multivariate models. Given the relatively small sample sizes used here, there is some concern that the power of this test might be insufficient (i.e., we may exclude too many variables), especially in the multiple equation models used for perceived load reductions (see discussion later in this subsection). Recent monte carlo studies, however, conclude that exclusion restrictions based upon hypothesis tests for individual parameters in multi-equation Probit models are generally unaffected in small samples (Belkar and Fiebig 2008). This same research concludes that the bias produced by not employing these exclusion restrictions in small sample models is far larger than any bias than might arise by employing these exclusion restrictions. Therefore, we are confident that the results of the final multivariate models summarized in the body of this report are both consistent and as robust as we can make them.

Table 16 presents the unrestricted model predicting the probability that we will observe a group responsible for overseeing implementation of a TMDL. Hypothesis tests on the parameters from this model suggest that only the measures of stakeholder involvement in TMDL development, state agency involvement in TMDL implementation, watershed population density, watershed area, and age of the TMDL should be included in the final multivariate model.

Table 16: Results from Unrestricted Multivariate Probit Model Predicting Probability that there is a Group Responsible for TMDL Implementation

Variable	Probit Coefficient	Asymptotic Z-Score
Stakeholder Involvement	1.37***	3.03
State Agency Involvement	0.74***	2.58
Socioeconomic Class	-0.20	-0.51
Potential Social Capital	0.58	0.92
Population Density	0.02*	1.92
Human Health Pollutant	0.65	1.18
Watershed Area	0.66***	2.64
Age of TMDL	-0.02**	-2.20
Constant	-8.76	
Pseudo-R^2	0.75	
Sample Size	163	

* p<.10, **p<.05, *** p<.01, two-tailed tests

Table 17 presents the unrestricted models (SUBP, or Seemingly Unrelated Bivariate Probit Models – see discussion later in this subsection) predicting the probability that state officials perceive (a) reductions in non-point source pollutant loads and (b) reductions in loadings from any pollutants, associated with TMDL implementation. Hypothesis tests on the parameters from this model suggest that the variables representing stakeholder involvement in TMDL development, socioeconomic class, and the public health threat posed by the pollutant can be eliminated from the final multivariate models for both non-point source and any load reductions because they do not show any meaningful or statistically significant relationships to the two dependent variables (NPS Load reduction and Any Load Reduction).

Table 17: Unrestricted SUBP Models for Perceived Pollutant Load Reductions

Variables	Nonpoint Source Pollutant Load Reduction Parameters	Asymptotic Z-scores	Any Pollutant Load Reduction Parameters	Asymptotic Z-scores
Perceived Load Reduction Model				
Implementation Group	1.758**	2.38	1.350	0.77
Stakeholder Involvement	-0.015	-0.04	-0.056	-0.24
State Agency Involvement	0.099	1.20	0.198	1.47
Watershed Coordinator Grant	1.208***	2.67	0.886**	1.96
Watershed Group Density	-0.286**	-1.99	-0.334**	-2.07
Watershed Group Intensity	0.213	0.89	0.650**	2.41
Approved Watershed Plan	0.733**	2.07	0.448	0.63
Socioeconomic Class	0.108	0.58	0.168	0.54
Potential Social Capital	-0.751***	-3.33	-0.500**	-2.45
Population Density	-0.312***	-3.10	-0.170***	-2.61
Human Health Pollutant	-0.182	-0.48	0.109	0.23
Watershed Area	0.287	1.60	0.063	0.38
Age of TMDL	0.034***	3.64	0.034***	3.83
Constant	-5.854***	-4.60	-5.456***	-5.31
Implementation Group Model				
Stakeholder Involvement	1.130***	3.28	1.089***	3.00
State Agency Involvement	0.698***	2.93	0.677**	2.50
Population Density	1.101***	2.78	1.044**	2.41
Watershed Area	0.814***	3.18	0.732**	2.34
Age of TMDL	-0.024**	-2.36	-0.019*	-1.77
Constant	-8.033	-3.15	-7.526***	-2.71

* p<.10, **p<.05, *** p<.01, two-tailed tests

Table 18 presents the unrestricted Bi-variate Probit models with sample selection predicting the probability that state officials perceive (a) reductions in non-point source pollutant loads and (b) reductions in loadings from any pollutants associated with a TMDL. In the non-point source reduction model, hypothesis tests suggest that the variables representing stakeholder involvement in TMDL development, state agency involvement in TMDL implementation, the intensity of watershed group participation, and the presence of a pollutant affecting human health can be eliminated from the final multivariate models. Information scarcity(produced by micro-numerosity and/or high levels of collinearity) prevent us from obtaining parameters for stakeholder involvement in TMDL development, socioeconomic class, and the presence of pollutants which may impact human health in the unrestricted model predicting any perceived pollutant load reduction. These variables show no meaningful or consistent statistically significant relationship with perceived pollutant load reductions in the preliminary analyses in tables 13 and 15, however, so their exclusion from the final multivariate models would appear to be inconsequential.

Table 18: Unrestricted Bivariate Probit Model with Sample Selection for Perceived Pollutant Load Reductions

Variables	Non-point Source Pollutant Load Reduction Parameters	Asymptotic Z-scores	Any Pollutant Load Reduction Parameters	Asymptotic Z-scores
Perceived Load Reduction Model				
Implementation Group	1.269	1.48	1.003	0.87
Stakeholder Involvement	-0.196	-0.83	Na	
State Agency Involvement	0.051	0.46	0.315***	3.12
Watershed Coordinator Grant	1.099**	2.03	1.203***	3.18
Watershed Group Density	-0.098	-0.57	-0.232*	-1.83
Watershed Group Intensity	-0.436	-1.27	0.260	0.76
Approved Watershed Plan	1.356**	2.30	0.523	0.90
Socioeconomic Class	0.226	1.10	Na	
Potential Social Capital	-0.911***	-3.05	-0.510**	-2.54
Population Density	-0.355***	-2.93	-0.179***	-2.65
Human Health Pollutant	-0.383	-0.45	Na	
Watershed Area	0.316	1.51	-0.026	-0.12
Age of TMDL	0.032**	2.51	0.032***	3.41
Constant	-3.462*	-1.89	-4.632***	-3.12
Selection Model				
Stakeholder Involvement	0.459***	2.58	0.502***	3.13
State Agency Involvement	0.360***	4.46	0.337***	4.27
Watershed Coordinator Grant	0.409	1.32	0.792*	1.64
Age of TMDL	0.012*	1.70	0.008	1.34
Small Lake TMDL	-5.951***	-13.42	-6.181***	-12.71
Constant	-2.331***	-3.82	-2.118***	-4.13

* p<.10, **p<.05, *** p<.01, two-tailed tests

Estimating Probit Models with Endogenous Regressors

Seemingly Unrelated Bivariate Probit Models:

Two factors complicate our efforts to predict the probability that state officials perceive pollutant load reductions associated with TMDLs. First, we assume that the outcomes during earlier stages of the TMDL implementation pipeline affect the probability of success at later stages of the pipeline. For the models used here, this means that the presence of a group overseeing TMDL implementation will affect the probability that state officials will perceive pollutant load reductions associated with a TMDL. This assumption has three implications for our analysis.

1. It means that the implementation group variable is endogenous in our models predicting perceived pollutant load reductions. This endogeneity violates the basic tenant of general linear models that all predictor variables are exogenous.
2. If the un-measurable forces influencing whether a group arises to oversee implementation of a TMDL also influence the probability that state officials will perceive pollutant load reductions associated with that TMDL, then the error terms from these two equations will be correlated and the parameter estimates in the models will be inefficient. Since we measure both the presence of implementation groups and the perceptions of load reductions using surveys of the same state officials, such a correlation seems likely.
3. A corollary of implications 1 and 2 is that the endogenous implementation group variable may be more likely to take on a value of 1 for those TMDLs where pollutant load reductions are more likely. In this situation, not only will the parameter estimates in the perceived load reduction models be inefficient, but the parameter estimate associated with the implementation group variable in these models will be biased, compromising our ability to test whether progress at an earlier stage of the implementation pipeline affects progress at later stages.

The most common solution for implications 1 and 2 is to estimate a set of seemingly unrelated bivariate Probit models (SUBP). Using SUBP, we estimate simultaneously a model predicting the probability that an implementation group will exist and a model predicting the probability that state officials will perceive a pollutant load reduction. Moreover, we allow the error terms from these two models to be correlated, and use this correlation to improve the precision of our parameter estimates. The standard SUBP model is attributed to Poirier (1980), and can be represented as:

$$z1 = \sum b1'x1 + e1, \quad y1 = 1 \text{ if } z1 > 0, 0 \text{ otherwise}$$

$z2 = \sum b2'x2 + e2$, $y2 = 1$ if $z2 > 0$, 0 otherwise

$[e1,e2] \sim$ bivariate normal (BVN) $[0,0,1,1,\dot{\rho}]$,

Where [z1,z2] are the unobserved continuous probabilities giving rise to the observed dichotomous dependent variables, and where we have a complete sample on [y1, y2, x1, x2]. In this model, $\dot{\rho}$ represents the correlation between the error terms in the two equations being driven by the shared unobserved factors discussed above. While the Poirier model is generally used to address only implications 1 and 2, Greene (1993) illustrates clearly that the SUBP model also addresses the parameter inconsistency stemming from nonrandom assignment described as implication 3. The results from our SUBP models are summarized in Section 6 of the report.

Bi-variate Probit Models with Sample Selection:

The second complicating factor for our load reduction models stems from the measurement of the dependent variables. As we explain in the main body of the report, the measures of perceived load reductions come from our interviews with state officials. As a result, the variables representing perceived load reductions can take on a value of 0 for two reasons: (1) the state official is knowledgeable about the TMDL's implementation and has no reason to believe that there have been pollutant load reductions, and (2) the state officials has no knowledge of the TMDL's implementation and therefore is unable to perceive a load reduction. In the SUBP models, we make no distinction between these two types of zeros in the perceived load reduction variables. Many observers, including members of the research team, are somewhat uncomfortable equating no knowledge of load reductions with no knowledge of TMDL implementation. A common response to this discomfort would be to eliminate from our sample all ***TMDL reports*** for which state officials have little or no implementation knowledge. In this restricted sample, the perceived load reduction variable would take on a value of 0 only when state officials were knowledgeable about the TMDL and perceived no load reduction. The obvious problem with such an analysis is that it makes the implicit assumption that TMDLs that state officials are familiar with are a random sample of all TMDLs. We view this possibility as quite unlikely. Indeed, we expect that some of the same factors affecting the probability that a TMDL watershed will experience reductions in pollutant loads will also affect the probability that state officials are familiar with the TMDL' s implementation. Samples truncated in this manner – where our ability to observe one variable (e.g., perceived load reductions) is dependent upon the outcome of a second variable (e.g., knowledge of the TMDL's implementation) – are classic cases of selection bias, and models employing such samples produce biased and inconsistent parameter estimates (Heckman 1979).

In a situation like ours where both dependent variables are dichotomous, the standard approach is to use the bivariate Probit model with sample selectivity developed by Van de Ven and Van Pragg (1981). This model can be represented as:

$$z1 = \sum b1'x1 + u1$$

$$z2 = \sum b2'x2 + u2$$

$$y1 = \sum c1'k1 + e1,\ y1=1 \text{ of } z1 > 0,\ 0 \text{ otherwise}$$

$$y2 = \sum c2'k2 + e2,\ y2 = 1 \text{ if } z2 > 0,\ 0 \text{ otherwise}$$

$$[e1,e2] \sim \text{bivariate normal (BVN) } [0,0,1,1,\dot{\rho}],$$

Where [z1] represents the unobserved continuous probability that a state official has knowledge of a TMDL implementation, [z2] represents the unobserved continuous probability that a state official perceived a pollutant load reduction associated with the TMDL's implementation, and where our sample is truncated in that we only observe [y2,k2] when y1=1. In this model, $\dot{\rho}$ represents the correlation between the error terms in the two equations being driven by the shared unobserved factors discussed above (i.e., the correlation between the process generating knowledge of the TMDL and the process generating pollutant load reductions). The results from our Bivariate Probit models with sample selection are summarized in Section 6 of the report.

APPENDIX C: POTENTIAL CHANGES IN PRACTICE AND POLICY

Section 7 of this report outlines a range of potential changes in practice and policy that may foster TMDL implementation progress. These potential changes have been identified throughout the course of this research, and have been derived from several sources. First, as we reviewed and coded TMDL reports from the two states, we did so in an effort to define recommended implementation actions so follow up actions associated with them could be assessed. Through this process, we identified potential changes in TMDL development practices that would help clarify recommended TMDL implementation steps. These potential clarifications are incorporated as potential options for improving implementation. They are based on the assumption that clear recommendations are more likely to be implemented than recommendations that are not clear.

Second, during the interviews conducted as a part of this research, we were able to gather a good deal of information on processes and factors that are likely to foster improvements in TMDL implementation. We were also able to compile data on the extent of implementation progress for various TMDL reports. These interviews, and that data which they yielded, enabled us to identify an additional set of potential recommendations for improvements in practice and policy – all of which seek to facilitate progress along the "TMDL Program Pipeline".

And finally, the driving factors analyses presented in Section 6 (and discussed in Appendix B) provide information on variables that appear to be good predictors of various levels of implementation progress. In so doing, they enable us to focus attention on potential changes in practice which are likely to foster TMDL implementation progress. Some of recommendations presented in Section 7 seek to foster these practices in order to improve the likelihood of TMDL implementation progress.

When viewed as a whole, we believe that these three sources of data and information have allowed us to provide empirically based guidance on steps which may be taken to improve the rate at which implementation progress is achieved.

APPENDIX D: KEY QUESTIONS FROM SURVEYS AND INTERVIEWS

We completed three major standardized information compilation efforts as a part of this research. The first effort involved compiling information from the 63 EPA approved TMDLs in the sample universe. The second effort involved surveying individuals and organizations who had taken a leading role in developing TMDLs. And the third effort involved conducting interviews with state officials who are particularly knowledgeable regarding TMDL implementation activities in the watersheds covered by the approved TMDLs in our sample universe. Key questions for coding stemming from each of these data compilation efforts are show in the subsections that follow.

Key Coding Questions for EPA-Approved TMDL Reports

Data questionnaire for TMDL implementation

The questions in the coding report were split between questions that applied to the entire report, and those that applied only to individual pollutants.

Report-level questions:

1. Full TMDL report name? ______
2. State? _____
3. When was the TMDL approved by US EPA?

Month: ___________ Day: ___________ Year: ___________

4. What HUC(s) overlap the area covered in the TMDL document?

Note: Use HUCs with the most appropriate number of digits to cover the entire TMDL area. You may need to find a different data source to identify HUCs.

5. How many square miles are covered by this TMDL report?

Pollutant-level questions

6. What single pollutant are you focusing on for this data sheet? (Choose one)

☐ No pollutant: Please explain ____
☐ Acid
☐ Aldrin

☐ "Aluminum" or "Aluminum (d)" or "Aluminum (d) (trout)"
☐ "Ammonia" or "Ammonia-N"
☐ "BOD" or "CBOD" or "Biochemical Oxygen Demand" or "Carbonaceous Biochemical Oxygen Demand"
☐ d-BHC
☐ Dieldrin
☐ Dioxin
☐ "DO" or "Dissolved Oxygen" or "Oxygen, Dissolved"
☐ Endosulphan
☐ Endrin
☐ Fecal Coliform
☐ Heptochlor
☐ "Iron" or "Iron (trout)"
☐ Lead
☐ Manganese
☐ Metals
☐ Nitrogen
☐ Nutrients
☐ Pathogens
☐ PCBs
☐ pH
☐ Phosphorus
☐ Sediment
☐ Sedimentation/Siltation
☐ Selenium
☐ "TDS" or "Total Dissolved Solids"
☐ "TSS" or "Total Suspended Solids"
☐ Zinc
☐ Other: Please specify ________________________

7. What percent reduction is required for this pollutant?

Note: Enter the percent reduction for the entire report if that number is provided by the TMDL.

If that number is not provided by the TMDL, then you may be able to calculate it using one of two methods.

The preferred method, if data are available, is to calculate the total maximum daily load across all impaired segments and divide by the existing loads across all impaired segments. Then subtract this number from 1 to get the percent reduction. For example, if the total maximum daily load is 20 lb/day and the existing load is 100 lb/day, then the percent reduction is: 1 – (20/100) = 0.8 = 80%.

If this is not possible, you may calculate an average of percent reductions shown for all impaired segments.

☐ 1. No percent reduction is given and none can be calculated
☐ 2. Percent reduction is given: _________ %
☐ 3. Percent reduction is calculated: _________ %

8. What types of point sources are targeted for action for this pollutant in the TMDL?

- ☐ None
- ☐ Unknown

- ☐ Agriculture
  - ☐ Confined animal feeding operations (CAFOs)

- ☐ Mining (permitted)
  - ☐ Mining: coal
  - ☐ Mining: other than coal

- ☐ Stormwater sources (permitted)
  - ☐ Municipal separate storm sewer system (MS4)
  - ☐ Construction sites (permitted)
  - ☐ Industrial storm water permits

- ☐ Wastewater point sources (permitted)
  - ☐ Wastewater treatment plant
  - ☐ Combined sewer overflow (CSO)
  - ☐ Sanitary sewer overflow (SSO)
  - ☐ Other: _________________

9. What types of non-point sources are targeted for action for this pollutant in the TMDL?

- ☐ None
- ☐ Unknown
- ☐ Wastewater
- ☐ Riparian protection
- ☐ Agriculture
- ☐ Legacy sources of pollution
- ☐ Flow alteration
- ☐ Mining
- ☐ Forestry
- ☐ Roads
- ☐ Unpermitted nonpoint source urban stormwater
- ☐ Other: _________________

Key Survey Questions for TMDL Development Leads

TMDL Report: ___*(insert TMDL report name)*_______________

1. Thinking of all the watershed groups with service areas that overlap the area covered by the above-mentioned TMDL Report, please characterize the involvement of this/these group(s) in the development of this TMDL? (Check all that apply)

☐0-A. Don't know
☐0-B. No groups were involved
☐1. A group/groups attended a TMDL-related meeting
☐2. A group/groups wrote a letter regarding the TMDL report
☐3. A group/groups provided data used in the TMDL
☐4. A group/groups was involved in writing the TMDL
☐5. Other group involvement: Please specify _____________

2. Is there a person at a state agency (for example, OEPA, ODNR, or other state agency) with specific responsibility to help foster implementation of this TMDL?

☐ 1. No
☐ 2. Yes

If Yes:

2.a. Who?

3. Is there a person at a federal agency (for example, NRCS, U.S. Army Corps of Engineers, Office of Surface Mining, or other federal agency) with specific responsibility to help foster implementation of this TMDL?

☐ 1. No
☐ 2. Yes

If Yes:

3.a. Who?

Interviews with Knowledgeable State Officials: Key Questions

Data questionnaire for TMDL implementation

The questions in the standardized interview template were split between questions that applied to the entire report, and those that applied only to individual pollutants.

Report-level questions:

1. Have you personally taken steps to foster implementation of this TMDL?

☐ 1. No
☐ 2. Yes

If Yes, what projects have you been involved in?

2.a What steps have you personally taken? (Choose one or more, and fill in the appropriate blanks)

2.b For each step you have personally taken, how many projects?

2.a Step	2.b How many projects?
☐ 99. Don't know	
☐ 1. Planned project(s)	Number of projects: ____ Please list:
☐ 2. Provided technical assistance to key audiences which are implementing parts of this TMDL	Number of projects: ____ Please list:
☐ 3. Drew funds into the watershed for implementation	Number of projects: ____ Please list:
☐ 4. Project(s) you planned and/or funded were actually implemented	Number of projects: ____ Please list:

☐ 5. Other: Please specify_______________ ___________________	Number of projects: ____ Please list:

3. Have others in your organization (interpreted broadly as your agency and other state agencies as well) taken steps to foster implementation of this TMDL?

☐ 1. No
☐ 2. Yes

If Yes, what projects have they been involved in?

3.a What steps have others in your organization taken? (Choose one or more, and fill in the appropriate blanks)

3.b For each step others in your organization have taken, how many projects?

3.a Step	3.b How many projects?
☐ 99. Don't know	
☐ 1. Planned project(s)	Number of projects: ____ Please list:
☐ 2. Provided technical assistance to key audiences which are implementing parts of this TMDL	Number of projects: ____ Please list:
☐ 3. Drew funds into the watershed for implementation	Number of projects: ____ Please list:
☐ 4. Project(s) you planned and/or funded were actually implemented	Number of projects: ____ Please list:

☐ 5. Other: Please specify______________ __________________	Number of projects: ____ Please list:

4. Is there a local or regional group that is actually working to foster implementation of this TMDL?

☐ 1. No
☐ 2. Yes

If Yes:

4.a. Which group?

4.b. What projects has this group been involved in and what steps has this local or regional group taken to foster implementation? (Choose one or more, and fill in the appropriate blanks)

4.c For each step that this local or regional organization has taken, how many projects?

4.b Step	4.c How many projects?
☐ 99. Don't know	
☐ 1. Planned project(s)	Number of projects: ____ Please list:
☐ 2. Provided technical assistance to key audiences which are implementing parts of this TMDL	Number of projects: ____ Please list:
☐ 3. Drew funds into the watershed for implementation	Number of projects: ____ Please list:
☐ 4. Project(s) you planned and/or funded were actually implemented	Number of projects: ____ Please list:

☐ 5. Other: Please specify_______________ ___________________	Number of projects: ____ Please list:

5. Please consider the list of watershed organizations below, which we believe have service areas that overlap with this TMDL area. Please help us add or remove groups to make this list as accurate as possible. Please make sure that the group you named in Question 3.a is listed as well.

6. What level of effort has each group put into <u>implementing</u> this TMDL, either now or in the past?

Watershed group name (Q 4)	Level of effort (Q 5)
1.	99. ☐ Don't know 3. ☐ Major effort 2. ☐ Some effort 1. ☐ No effort
2.	99. ☐ Don't know 3. ☐ Major effort 2. ☐ Some effort 1. ☐ No effort
3.	99. ☐ Don't know 3. ☐ Major effort 2. ☐ Some effort 1. ☐ No effort
4.	99. ☐ Don't know 3. ☐ Major effort 2. ☐ Some effort 1. ☐ No effort
5.	99. ☐ Don't know 3. ☐ Major effort 2. ☐ Some effort 1. ☐ No effort
6.	99. ☐ Don't know 3. ☐ Major effort 2. ☐ Some effort 1. ☐ No effort

7. Based on your experience, does the TMDL process help foster pollutant loading reductions and/or water quality improvements?
☐ 1. No
☐ 2. Yes

If No:

7.a. Why not? ____

8. Other than loading reductions and/or water quality improvements, what are the two most important benefits of the TMDL process? (Choose up to two)
☐ 99. Don't know
☐ 0. There are no (other) benefits
☐ 1. Provides a scientific basis for reaching agreement on needed actions
☐ 2. Provides a basis for determining needed load reductions
☐ 3. Provides regulatory incentive that is needed
☐ 4. Enables the supply of needed funds for implementation
☐ 5. Forces stakeholders to be attentive to the need for water quality improvements
☐ 6. Other, please specify ____________________________

Pollutant-level questions

9. Has any post-TMDL ambient stream/sediment monitoring been conducted for this pollutant (at locations downstream from implementation actions, but still in the area covered by the TMDL report)?

☐ 99. Don't know
☐ 1. No
☐ 2. Yes

If Yes:

10.a. Who conducted this monitoring? (Choose one or more)

☐ 1. Watershed organization(s)
☐ 2. State agency(ies)
☐ 3. US EPA
☐ 4. University(ies)
☐ 5. Other: Please specify ____

11.b. Please provide contact information for the people who conducted this monitoring.

Name:
Organization/agency:
Phone number:
E-mail address:
Mailing address:

11.c. Please consider the monitoring data you just mentioned and any TMDL implementation actions that have been undertaken. Do you know of any locations downstream from these actions, but still within the TMDL area, where data show water quality improvements for this pollutant since approval of this TMDL?

☐ 99. Don't know
☐ 1. No, don't know of any data that show improvements
☐ 2. Yes, know of data that show improvements

If Yes:

11.c.1. Can you please provide copies of these data?

☐ 1. No
☐ 2. Yes. If Yes, please send it to us.

We will now ask specific questions about each type of non-point source that is targeted by the TMDL for implementation actions.

Note to interviewer: Only include those types of non-point sources that are checked as targeted for action in the TMDL Report checklist, Question 1.

Source: [Write in the Source(s) in this TMDL that apply]

WA-1. Has any implementation occurred for this source and pollutant?

☐ 99. Don't know (Skip the rest of the questions for this source and pollutant)
☐ 1. No (Skip the rest of the questions for this source and pollutant)
☐ 2. Yes

If Yes:

WA-2. Please describe the nonpoint source implementation that has occurred.

WA-3. Please code these implementation actions using the following categories as possible and applicable:

Implementation action (Check all that apply)	Initiated and completed efforts
☐Fix failing septics	Number already initiated or completed: ___ 1. ☐ Initiated 2. ☐ Completed
☐ Eliminate straight pipes (raw wastewater)	Number already initiated or completed: ___ 1. ☐ Initiated 2. ☐ Completed
☐ Connect to centralized system	Number already initiated or completed: ___ 1. ☐ Initiated 2. ☐ Completed
☐ Get NPDES permits	Number already initiated or completed: ___ 1. ☐ Initiated 2. ☐ Completed
☐ Other: Please specify ___________________________	Number already initiated or completed: ___ 1. ☐ Initiated 2. ☐ Completed

WA-4. For this source and pollutant, has a funding commitment been made to carry out nonpoint source implementation?

☐ 99. Don't know
☐ 1. No
☐ 2. Yes

If Yes:
a. What funder(s) have made the commitment(s)?
b. How much money has been committed?

a. Funder	b. Amount
1.	$
2.	$
3.	$

12. Please select one of the following statements which best reflects the state of your knowledge on this question.

12.a. Thinking about the nonpoint source implementation described in the previous questions, do you know the proportion of the total needed reduction in loadings for this pollutant specified in the TMDL report that has been achieved to date as a result of nonpoint source implementation activities undertaken since approval of the TMDL?

☐ 99. I do not know
☐ 1. I have no reason to believe that any reductions in nonpoint source loadings have been achieved to date
☐ 2. Conditions have been put in place that will enable future nonpoint source loading reductions
☐ 3. I believe there have been reduced nonpoint source loadings since EPA approval of the TMDL
☐ 4. I know some reduction in nonpoint source loadings has been achieved to date:
☐ A. I cannot provide an educated estimate of the reduction in nonpoint source loadings achieved to date
☐ B. I can provide an educated estimate of the reduction in nonpoint source loadings achieved to date:
_______ %

12.b. Please provide the rationale for your choice of statements in the previous question.

13. Please select one of the following statements which best reflects the state of your knowledge on this question.

13.a. Thinking about implementation of point source activities, do you know the proportion of the total needed reduction in loadings for this pollutant specified in the TMDL report that has been achieved to date as a result of point source implementation activities undertaken since approval of the TMDL?

☐ 99. I do not know
☐ 1. I have no reason to believe that any reductions in point source loadings have been achieved to date
☐ 2. Conditions have been put in place that will enable future point source loading reductions
☐ 3. I believe there have been reduced point source loadings since EPA approval of the TMDL
☐ 4. I know some reduction in point source loadings has been achieved to date:
☐ A. I cannot provide an educated estimate of the reduction in point source loadings achieved to date
☐ B. I can provide an educated estimate of the reduction in point source loadings achieved to date:
_______ %

13.b. Please provide the rationale for your choice of statements in the previous question.

APPENDIX E: WATERSHED SUMMARIES FOR OHIO AND WEST VIRGINIA

Table 19: Ohio TMDL Reports: A Summary

TMDL	Approval Date	Number of Pollutants	Pollutants	Point Sources	Non-Point Sources
Cuyahoga River Watershed (middle)	10/11/2000	3	Dissolved Oxygen/CBOD Nitrogen Ammonia	Wastewater	Flow Alteration Riparian
Plum Creek (Rocky River) Watershed	12/4/2001	2	Nitrogen Phosphorus	Stormwater Wastewater	Wastewater Riparian protection Agriculture Flow Alteration
Bokes Creek Watershed	9/27/2002	2	Phosphorus Sediment	Agriculture Wastewater Industry (MINOR IMPACTS)	Wastewater Riparian protection Flow Alteration Agriculture
Sugar Creek Watershed	11/20/2002	3	Sediment Phosphorus Nitrogen	Agriculture Wastewater	Riparian protection Agriculture Flow Alteration Mining Forestry Wastewater
Raccoon Creek Watershed (upper)	3/20/2003	2	Acidity Metals	None	Mining
Little Miami River Watershed (upper)	7/2/2002	2	Phosphorus Sediment	Agriculture Wastewater Stormwater	Wastewater Riparian protection Agriculture Stormwater
Mill Creek Watershed (tributary to Scioto River)	9/2/2003	10	CBOD5	Wastewater	Wastewater

TMDL	Approval Date	Number of Pollutants	Pollutants	Point Sources	Non-Point Sources
			Phosphorus Aldrin (Pesticide) d-BHC (Pesticide) Dieldrin (Pesticide) Endosulfan I (Pesticide) Sediment Endrin (Pesticide) Heptachlor (Pesticide) Ammonia-N	Stormwater Industry	Agriculture Legacy Pollution Riparian
Duck Creek Watershed (tributary to Ohio River)	9/23/2003	6	Aluminum Iron Manganese TSS (Siltation) BOD/Dissolved Oxygen Ammonia	None	Mining Riparian protection Agriculture Wastewater
Cuyahoga River Watershed (lower)	9/26/2003	2	Phosphorus Fecal Coliform	Stormwater Wastewater Industry	Riparian protection Flow Alteration Wastewater Stormwater
Stillwater River Watershed	6/15/2004	2	Phosphorus Nitrates	Wastewater Stormwater Agriculture	Wastewater Riparian protection Agriculture Stormwater Other-erosion control
Wabash River Watershed (U.S. EPA TMDL)	7/23/2004	3	Phosphorus Nitrate+Nitrite Total Suspended Solids	Agriculture Wastewater Stormwater	Wastewater Riparian protection Flow Alteration Agriculture
Auglaize River Watershed (upper)	9/23/2004	4	Sediment Phosphorus Ammonia	Wastewater Stormwater	Wastewater Agriculture Riparian protection Flow Alteration

TMDL	Approval Date	Number of Pollutants	Pollutants	Point Sources	Non-Point Sources
			Fecal Coliform		Stormwater
Big Walnut Creek Watershed	9/26/2004	3	Fecal Coliform Phosphorus Sedimentation	Wastewater Stormwater	Wastewater Agriculture Riparian protection Flow Alteration
Cuyahoga River Watershed (upper)	9/27/2004	2	Phosphorus Sediment	Wastewater	Stormwater Riparian protection Wastewater Flow Alteration Agriculture
Mill Creek Watershed (tributary to Ohio River)	4/26/2005	2	Phosphorus Nitrogen	Stormwater - MS4 Wastewater	Agriculture Riparian protection Wastewater Stormwater
Euclid Creek Watershed	9/27/2005	1	Phosphorus	Stormwater Wastewater	Wastewater Riparian protection Flow Alteration
Huron River Watershed	9/28/2005	3	Sediment Nitrate+Nitrite Phosphorus	Stormwater Wastewater Other-Package Plant	Wastewater Agriculture Flow Alteration Riparian protection
Little Beaver Creek Watershed	9/28/2005	4	Phosphorus Ammonia TSS Fecal Coliform	Mining Stormwater Wastewater	Agriculture Flow Alteration Wastewater Riparian protection Stormwater
Old Woman Creek and Chappel Creek Watershed	8/31/2005	1	Sediment	Stormwater	Flow Alteration Agriculture Riparian protection Stormwater
Monday Creek Watershed	9/22/2005	3	Aluminum Iron Acids	None	Mining

TMDL	Approval Date	Number of Pollutants	Pollutants	Point Sources	Non-Point Sources
Big Darby Creek Watershed	3/31/2006	3	Phosphorus Fecal Coliform Sediment	Wastewater Stormwater	Agriculture Flow Alteration Riparian protection Wastewater Other-Development
Toussaint River Watershed	9/22/2006	1	Phosphorus	Stormwater Wastewater	Wastewater Riparian protection Agriculture Flow Alteration
Wakatomika Creek Watershed	9/28/2006	6	Fecal Coliform Iron Manganese Aluminum Alkalinity Total Dissolved Solids	None	Wastewater Agriculture Legacy-Mining Riparian
Mahoning River Watershed (U.S. EPA TMDL)	9/17/2004	1	Pathogens	Wastewater Stormwater	Agriculture Wastewater Riparian protection Stormwater
Sandusky River Watershed (upper)	9/30/2004	3	Pathogens Phosphorus Sediment/QHEI	Wastewater Stormwater Other-DFFO	Wastewater Riparian protection Agriculture Flow Alteration Stormwater
Sunday Creek Watershed	3/31/2006	3	Fecal Coliform Sediments Acids	None	Mining Wastewater Agriculture Riparian protection

Table 20: West Virginia TMDL Reports: A Summary

TMDL	Approval Date	Number of Pollutants	Pollutants	Point Sources	Non-Point Sources
Blackwater River	2/1/1998	2	BOD NBOD	Wastewater	None
South Branch Potomac River	2/1/1998	1	Fecal Coliform	None	Agriculture
South Fork South Branch Potomac River	2/1/1998	1	Fecal Coliform	Industry	Agriculture
Buckhannon River	9/1/1998	2	Iron Manganese	None	Mining
Burches Run Lake	9/1/1998	2	Phosphorus Sediment	None	Agriculture Forestry Stormwater
Hurricane W S Rs	9/1/1998	3	Iron Phosphorus Sediment	None	Agriculture Forestry Stormwater Other - Barren land
Lost River	9/1/1998	1	Fecal Coliform	None	Wastewater Agriculture Other – Forest (wildlife)
Mountwood Park Lake	9/1/1998	1	Sediment	None	Agriculture Forestry Stormwater Other - Barren land
Tenmile Creek	9/1/1998	1	Iron	Mining	Mining
Tomlinson Run Lake	9/1/1998	1	Sediment	None	Riparian protection Agriculture Forestry Stormwater Other - Barren land
Bear Rock Lake	9/1/1999	2	Phosphorus Sediment	None	Wastewater Agriculture Forestry Stormwater
Castleman Run Lake	9/1/1999	2	Phosphorus Sediment	None	Wastewater Agriculture Forestry Stormwater

TMDL	Approval Date	Number of Pollutants	Pollutants	Point Sources	Non-Point Sources
Ridenour Lake	9/1/1999	3	Iron Phosphorus Sediment	None	Wastewater Agriculture Forestry Stormwater
Turkey Run Lake	9/1/1999	3	Iron Phosphorus Sediment	None	Wastewater Agriculture Forestry Stormwater
Saltlick Pond 9	7/1/2000	1	Sediment	None	Agriculture Forestry Roads
Kanawha River, Pocatalico River and Armour Creek	9/1/2000	1	Dioxin	Wastewater	Other - Contaminated groundwater Other - Contaminated soil Other - In-place sediment
Little Kanawha River	9/1/2000	1	Iron	None	Agriculture Mining Forestry Stormwater Roads
Ohio River (Dioxin)	9/1/2000	1	Dioxin	None	Legacy
Cheat River	3/1/2001	4	Iron Manganese pH Zinc	Mining	Mining Stormwater Other – Rural landuses
Tygart Valley River	3/1/2001	3	Iron Manganese pH	Mining	Agriculture Mining Forestry Stormwater
Elk River	9/1/2001	3	Iron Manganese pH	Mining	Agriculture Mining Forestry Stormwater
Flat Fork Creek	9/1/2001	1	PCBs	None	Legacy
Paint Creek	9/1/2001	3	Iron Manganese pH	Mining	Mining

TMDL	Approval Date	Number of Pollutants	Pollutants	Point Sources	Non-Point Sources
Stony River	9/1/2001	3	Iron Manganese pH	Mining	Mining
Unnamed Tributary at Sharon Steel	9/1/2001	2	Iron Manganese	None	Legacy
Dunloup Creek	9/1/2002	4	Fecal Coliform Iron Manganese pH	None	Wastewater Mining
Fourpole Creek	9/1/2002	1	Fecal Coliform	Stormwater	Wastewater
Monongahela River	9/1/2002	3	Iron Manganese pH	Mining	Mining
Ohio River (PCB)	9/1/2002	1	PCBs	None	Legacy
Tug Fork River	9/1/2002	3	Iron Manganese pH	Mining	Mining Forestry Roads Other - Oil and gas
West Fork River	9/1/2002	3	Iron Manganese pH	Mining	Mining
Guyandotte River	3/1/2004	6	Aluminum Fecal Coliform Iron Manganese pH Selenium	Mining Stormwater	Wastewater Agriculture Mining Forestry Roads Stormwater Other - Oil and gas Other - Barren land Other – Other nonpoint sources
Upper Kanawha	1/1/2005	6	Aluminum Fecal Coliform Iron Manganese pH Sediment	Mining	Wastewater Riparian protection Agriculture Mining Forestry Roads
Upper Ohio North	1/1/2005	6	Aluminum Fecal Coliform Iron	Stormwater Wastewater	Wastewater Riparian protection Agriculture

TMDL	Approval Date	Number of Pollutants	Pollutants	Point Sources	Non-Point Sources
			Manganese pH Sediment		Mining Forestry Roads Stormwater
Coal River	9/1/2006	7	Aluminum Fecal Coliform Iron Manganese pH Sediment Selenium	Mining Stormwater Wastewater	Wastewater Riparian protection Agriculture Mining Forestry Roads Stormwater Other - Oil and gas
Lower Kanawha River	9/1/2006	5	Aluminum Fecal Coliform Iron pH Sediment	Stormwater Wastewater	Wastewater Riparian protection Agriculture Mining Forestry Roads Stormwater Other - Oil and gas
North Branch Potomac River	9/1/2006	4	Aluminum Iron pH Sediment	Mining	Riparian protection Agriculture Mining Forestry Roads Other - Oil and gas Other - Barren land

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