Lessons Learned from TMDL Implementation Case Studies

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ABSTRACT

Total Maximum Daily Loads (TMDLs) and TMDL implementation plans are being developed across the country using a variety of approaches with varying levels of success. Case studies of watersheds undergoing successful implementation were developed to identify specific characteristics and approaches that facilitated implementation and water quality improvement. Factors that positively and negatively affected implementation efforts were identified based on these case studies. The results of the assessment showed that each watershed presented unique resources and problems, and thus no one approach will guarantee success in all watersheds. However, there are several factors that seem to aid effective implementation; the most common of these were available funding, government agency interest and involvement; stakeholder engagement; and the presence of a TMDL where the pollutant and needed reductions were systematically assessed and quantified. The most common factors negatively affecting implementation efforts in the assessed watersheds included lack of data and lack of funding.

KEYWORDS: TMDL Implementation, TMDL Development, Case Studies.

INTRODUCTION

The Clean Water Act classifies water bodies that do not meet water quality standards as "impaired," and requires Total Maximum Daily Loads (TMDLs) to bring impaired waters into compliance with water quality standards. According to the U.S. Environmental Protection Agency (EPA), over 40% of the assessed waters in the U.S. (some 20,000 river or stream segments, lakes, and estuaries) are impaired, primarily because of NPS pollution (USEPA, 2004). A TMDL specifies the amount of a specific pollutant that a water body can receive without violating applicable water quality standards. Although the identification of the acceptable level of pollutants described in detail in a TMDL report is required by federal law (40 CFR 130 and §303(d) of the Clean Water Act), the development of plans to implement changes to attain the acceptable level of pollutants ('TMDL Implementation') is not. The goal of the TMDL program is to improve water quality. Developing plans that specify the type and quantity of corrective measures needed to achieve the pollutant loads calculated in a TMDL and implementing those plans will help to achieve that goal.

Total Maximum Daily Loads and TMDL implementation plans are being developed across the country using a variety of approaches, with varying levels of detail, and success. There is a need to enhance implementation effectiveness by identifying features of previously developed TMDLs and TMDL implementation plans that facilitate the implementation process. The study examined two hypotheses. First, the success of implementation planning and execution is a function of the focus and detail provided in the underlying TMDL. Second, successful implementation and water quality improvement is a function of the focus and detail of the TMDL implementation plan and the plan development process, particularly with respect to stakeholder engagement. The objective of this study was to review on-going TMDL implementation efforts across the country and their associated TMDLs and implementation plans to identify factors that contribute to successful implementation.

METHODOLOGY

A case study approach was applied to a series of watersheds for which TMDLs and TMDL implementation plans have been developed to identify the characteristics and approaches that facilitate implementation and water quality improvement. The study included three phases: identification and selection of case study watersheds, development of detailed watershed case studies, and identification and synthesis of characteristics that led to successful TMDL implementation as measured by documented improvements in water quality.

The agency responsible for each State's TMDL program was contacted via email or by telephone to obtain information about the current status of TMDLs and TMDL implementation in the state. State agencies were asked to provide the names of waterbodies where they believed a TMDL implementation or other watershed planning success story existed. Additional candidate watersheds were found by searching the EPA §319 Success Stories website (USEPA, 2006a) and the EPA TMDL Case Studies website (USEPA, 2000). A list of forty-four candidate watersheds was identified for initial review. Information about these candidate watersheds was collected to assess available evidence to support water quality improvement that resulted from TMDL implementation or other related watershed planning efforts.

The list of candidate watersheds for each state was then sent to the appropriate state agency and EPA regional personnel with specific questions to help determine whether a detailed case study of the watershed would be developed. The questions sent to state agency and EPA regional personnel inquired about the development of the implementation plan, documentation of the project, availability of reports and/or data documenting water quality improvement, and the link between water quality improvement and TMDL implementation activities. The decision to further evaluate a watershed and develop a detailed case study was based upon the availability of data demonstrating an improvement in water quality directly resulting from implementation activities and existing documentation. Watersheds were removed from the candidate list if no formal TMDL study had been conducted, if water quality improvement occurred prior to TMDL implementation, if insufficient data were available to verify water quality improvement, if there was no response or insufficient response from the queried agency, or if water quality improvement was either not shown or was indeterminate. Following this procedure, seventeen watersheds were selected for additional review and detailed case-study development (Figure 1, Table 1).

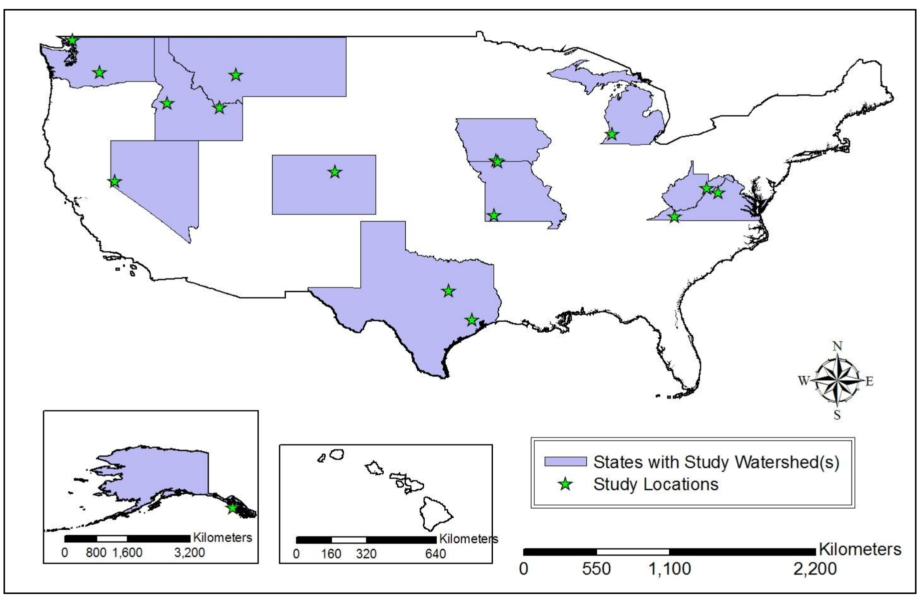

Figure 1. Locations of Case Study Watersheds.

Table 1. Selected Case Study Watersheds.

Watershed	State	Reference(s)
Lake Allegan	Michigan	Carter and Anderson, 2005; KRLATIC, 2002
Aquilla Reservoir	Texas	TCEQ, 2003
Cascade Reservoir	Idaho	IDEQ, 1996, 1998, 2000
Clear Creek	Texas	TNRCC, 2001
Deep Creek	Montana	Endicott and McMahon, 1996; Hydrotech, 1998, 1999
Hutton Creek	Virginia	CH2MHILL, 2000; MapTech, 2001
James River	Missouri	MDNR, 2001, 2004
Medicine Lodge Creek	Idaho	McKinley and Reaney, 2003; Traher, 2002
Nine Eagles Lake	Iowa	IDNR, 2000
Lower Nooksack River	Washington	Hood, 2002
North Fork of the South Branch of the Potomac River	West Virginia	USEPA, 1998
Quail Run	Virginia	VADEQ, 2003
Slip Bluff Lake	Iowa	IDNR, 2001
South Platte River	Colorado	CDPHE, 2000
Swan Lake	Alaska	Redburn, 2000a, 2000b
Truckee River	Nevada	NDEP, 1994
Lower Yakima River	Washington	WSDOE, 1997

Documents (the TMDL study report, the TMDL implementation plan, additional relevant reports) and water quality monitoring data were obtained from the internet and from state agencies to support case study development. In addition, when possible, persons directly involved with each case study were interviewed via the telephone. The relevant documents and notes from the case-study interviews were used to develop the seventeen case studies (Benham *et al*. 2006) and to identify the factors that facilitated implementation and water quality improvement. Each case study addressed fifteen key points of interest that described specific aspects of the watershed projects:

- Applicable water quality standards
- Degree of impairment in terms of applicable water quality standards
- Approach used to develop the TMDL (e.g., modeling or other, specific model(s), entity responsible for developing the TMDL, stakeholder engagement)
- TMDL report and supporting loading and concentration data in terms of spatial loadings
- Scientific reasonableness of proposed reductions (are proposed reductions attainable)
- Public involvement during the TMDL development process (degree/nature of stakeholder engagement)
- Approach used to develop the implementation plan and differences from the approach used to develop the TMDL (e.g., modeling or other, specific model(s), entity responsible for developing the TMDL, stakeholder engagement)
- Utility of data and information used for/contained in the TMDL study in the development of the implementation plan
- Stakeholder engagement during the implementation plan development process
- Implementation plan loading reductions and phases (specificity of temporal and spatial loading reductions called for)
- Scientific reasonableness of proposed implementation plan reductions (implementation phasing, likelihood of attainment of proposed water quality improvements)
- Identification and availability of resources required execute implementation plan
- Proposed water quality and implementation progress monitoring system
- Progress towards implementation (actions taken, observed water quality improvement)
- Degree to which the implementation plan is facilitating implementation (strengths and weaknesses).

After compiling the implementation case studies, several recurring ‘factors’ emerged that, in the judgment of the authors, had either aided or hindered successful implementation. Most of the factors were associated with the one or more of the fifteen key points of interest mentioned previously. Several factors of interest were used to identified, and, based on the judgment of the authors, each watershed was classified as possessing or not possessing each characteristic. Some of the factors were drawn from details of the fifteen key points of interest above. Other factors of interest emerged during the compilation and review of the case studies.

RESULTS

Seventeen TMDL implementation watershed case studies were developed as a part of this study. Most of these watersheds were dominated by nonpoint source (NPS) pollution. Eight of the seventeen watersheds contained at least one permitted discharger, and four of the watersheds were point source (PS) dominated, meaning that the permitted discharge facilities in the watershed were the primary pollutant sources. The most common cause of impairment in the watersheds was some form of sediment/solids (e.g., total suspended solids, total dissolved solids, turbidity), followed by nutrients, low dissolved oxygen (DO), toxic chemicals (e.g., atrazine, chlordane, chlorine, DDT), bacteria, elevated temperature, ammonia, pH, and solid waste. The mature of the impairment in the case study watersheds and the level of pollutant reduction called for in the TMDL are shown in Table 2.

Table 2. Impairment characteristics of the case study watersheds.

Characteristic	LLake Allegan, Michigan	Aquilla Reservoir, Texas	Cascade Reservoir, Idaho	Clear Creek, Texas	Deep Creek, Montana	Hutton Creek, Virginia	James River, Missouri	Medicine Lodge Creek, Idaho	Nine Eagles Lake, Iowa	Lower Nooksack River Basin, Washington	North Fork of the South Branch of the Potomac River, West Virginia	Quail Run, Virginia	Slip Bluff Lake, Iowa	South Platte River, Colorado	Swan Lake, Alaska	Truckee River, Nevada	Lower Yakima River, Washington
Point Sources Present?[a]	Y	N	Y	N	N	N	Y	N	N	Y	Y	Y	N	Y	N	Y	N
Point Source Dominated?[a]	50/50	N	N	N	N	N	Y	N	N	N	N	Y	N	Y	N	Y	N
Targeted Causes of Impairment																	
Nutrients	X		X				X								X	X	
Toxic Chemicals		X		X								X					X
Sediment/Solids (TSS, etc)					X			X	X				X			X	X
Bacteria						X				X	X						
Low DO	X		X											X		X	
Solid Waste															X		
pH			X														
Ammonia												X		X			
Elevated Temperature					X			X								X	
Reductions Called For[b]																	
<25%	X					X		X		X							
25-50%	X	X	X		X			X	X	X	X		X			X	
51-75%								X		X						X	
>75%						X		X		X					X		X

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[a]Y= Yes; N=No; 50/50=approximately equal concern for point and nonpoint sources.
[b]Where more than one category is selected, reductions were varied spatially or required from different constituents.

Some watersheds were impaired by more than one pollutant. Correspondingly, reductions in the TMDLs were frequently specified for multiple pollutants. A few of the less detailed TMDLs did not present specific pollutant load reductions. Of the 13 TMDLs that quantified needed pollutant load reductions, most (10) called for moderate reductions in the 25-50% range; four called for reductions in the 0-24% range; three called for reductions in the 51-75% range; and five called for reductions in the 76-100% range. While the pollutant source (whether it be a single large point source or a harder-to-target diffuse nonpoint source) has a large effect on the difficulty in attaining needed load reductions, the magnitude of the pollutant load reduction gives some idea as to the practicability of achieving the TMDL; larger percent reductions are generally more difficult to achieve.

Table 3 presents what we believe to be those positive and negative factors affecting the success of TMDL implementation planning and execution efforts in the case study watersheds. Positive factors were those that, in our judgment, aided implementation efforts. Negative factors, those that hindered implementation efforts, are also summarized in Table 3. Table 4 presents detailed descriptions of the factors presented in Table 3. Benham *et al*. (2006) provides a more detailed synopsis of these results and presents all seventeen case studies.

The most common positive factors were (in order): available funding, government agency interest and involvement; stakeholder meetings held during TMDL development; stakeholder engagement; the presence of a TMDL where the pollutant and needed reductions were systematically assessed and quantified; targeted implementation; staged/phased implementation; and outreach and/or educational activities. Each of these factors was possessed by more than half of the case study watersheds. In all but 2 of the case studies where available funding was a positive attribute, sources of funds included EPA §319 grants. In many cases, the §319 monies were supplemented by other federal funds (particularly those from USDA Natural Resources Conservation Service programs), state funds, and local funds. The remaining two watersheds in which available funding was an important positive factor relied on private funding from point source polluters.

Although all the case studies assessed herein experienced successful implementation efforts (as demonstrated by improving water quality), many state agency contacts and/or other informed sources that we consulted when developing the case studies indicated that there were some negatives that, in their opinion, hindered implementation. That is, if these negative factors had not been present, the belief was that implementation would have been more successful (in terms of more pollutant control corrective measures put in place and/or greater water quality improvement gains). The negative factors most commonly cited as hindering implementation were lack of data, which affected both TMDL and TMDL implementation plan development, and limited funding for implementing pollutant control corrective measures.

In addition to the positive and negative factors listed in Table 3, several case study watersheds contained particularly unique beneficial features that influenced implementation. In Segment 15 of the South Platte River in Colorado, the 'Metro District,' a permitted discharger, funded much of the implementation effort, conducted water quality studies, and developed watershed management plans. In Swan Lake, Alaska, the local municipality embraced water quality improvement efforts with the establishment of lake clean-up days, which engaged stakeholders in actively cleaning-up debris in the watershed. In Nine Eagles Lake, Iowa, the Department of Natural Resources and the Department of Forestry worked together to reduce sediment losses in the watershed. A watershed group in James River, Missouri, was the main force behind extensive nonpoint source BMP installation, despite a TMDL that focused primarily on the dominant point source polluter in the watershed. In Truckee River, Nevada, the river has been delisted for the pollutant for which a detailed, modeling-based TMDL was completed (nitrogen), while it is still listed for the pollutants for which a less-detailed 'bare bones' TMDL (term used by the Nevada Division of Environmental Protection) was developed.

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Table 3. Factors affecting successful TMDL implementation.

Factor	Lake Allegan, Michigan	Aquilla Reservoir, Texas	Cascade Reservoir, Idaho	Clear Creek, Texas	Deep Creek, Montana	Hutton Creek, Virginia	James River, Missouri	Medicine Lodge Creek, Idaho	Nine Eagles Lake, Iowa
Positive Factors[a]									
Watershed Strategy[b]	IP	IP	IP	IP	TS & WP	IP	TS	IP	TS
TMDL development method[c]	M	na	M	na	na	M	LD	na	Eq
Funding	X	X	X		X	X	X	X	X
Agency Interest/Involvement	X	X	X	X	X	X		X	X
Stakeholder meetings during TMDL development	X	X	X		X	X	X	X	X
Stakeholder Engagement	X	X	X		X	X	X	X	
Targeted Implementation	X		X	X	X	X		X	X
Staged/Phased Implementation	X	X				X		X	
Outreach/Educational Activities	X	X	X		X	X	X		
Spatial Identification of Pollution Sources		X	X		X	X	X	X	
Leadership Structure	X		X		X			X	
Point Source Interest/Involvement	X						X[d]		
Technical Assistance	X	X				X			
NPS Regulations			X						
Pre-Existing Watershed Group							X	X	
Stakeholder meetings during planning	X		X			X			
Watershed group created post-TMDL									
Water Quality Trading	X								
Negative Factors[a]									
Lack of data[e]	M			M					M
Loss of Funding			X		X				
Natural Disasters					X				
Lack of pre-TMDL monitoring data				X					
Leadership Structure	X								
State of the science	X								

[a]see Table 4 for characteristics key
[b]IP=Implementation Plan, WP=Workplan, TS=TMDL section, SIS=Summary Implementation Strategy
[c]M=watershed model, LD=load duration, Eq=simple equation(s), Stat=statistical methods; na=not applicable, calculations did not play a large part in determination of TMDL or load reductions
(table & footnotes continued on next page)

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Table 3. Factors affecting successful TMDL implementation (cont.)

Factor	Lower Nooksack River Basin, Washington	North Fork of the South Branch of the Potomac River, West Virginia	Quail Run, Virginia	Slip Bluff Lake, Iowa	South Platte River, Colorado	Swan Lake, Alaska	Truckee River, Nevada	Lower Yakima River, Washington
Positive Factors[a]								
Watershed Strategy[b]	IP	WP	TS	TS	TS& WP	TS & WP	TS	SIS
TMDL development method[c]	Stat	M	na	Eq	M	na	M	Stat
Funding	X	X		X	X	X	X	X
Agency Interest/Involvement	X	X		X	X	X		X
Stakeholder meetings during TMDL development	X		X	X	X	X		X
Stakeholder Engagement	X	X			X	X		
Targeted Implementation			X	X	X			
Staged/Phased Implementation	X	X			X	X		X
Outreach/Educational Activities		X				X		X
Spatial Identification of Pollution Sources		X						
Leadership Structure		X						
Point Source Interest/Involvement			X		X		X	
Technical Assistance		X						X
NPS Regulations	X					X		X
Pre-Existing Watershed Group		X			X			
Stakeholder meetings during implementation planning		X						
Watershed group created post-TMDL								X
Water Quality Trading							P[f]	
Negative Factors[a]								
Lack of data[d]			M		C			
Loss of Funding	X							X
Natural Disasters					X			
Lack of pre-TMDL monitoring data								
Leadership Structure								
State of the science								

[d]M=monitoring data to track or demonstrate success, C=watershed characterization data to reevaluate watershed models
[e]point source in this watershed simply complied with newly imposed regulations
[f]water quality trading has been proposed in this watershed

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Table 4. Key to factors affecting successful TMDL implementation, see Table 3.

Factors	Description
Positive Factors	These factors aided implementation
Watershed Strategy	Watershed Strategies came in many different varieties, from a formal TMDL Implementation Plan (IP), to a separate Workplan (WP), to a dedicated section in the TMDL section (TMDL), to a separate Summary Implementation Strategy (SIS)
Type of Calculations Used in TMDL, if applicable	Most of the TMDLs were developed based on a set of calculations, whether part of a watershed simulation model (M), a complex statistical evaluation (Stat), load duration (LD), or simple equations such as RUSLE (Eq); those that were not (na) were typically set as more qualitative goals, or simply set at the water quality standards
Funding	Indicates whether funding was available for implementation (sources typically included EPA §319 funds and other watershed improvement funds); the two watersheds without funding checked were: Clear Creek, where implementation consisted of a wait and see approach; and Quail Run, where a wastewater treatment plant upgrade was already ongoing before development of the TMDL
Agency Interest/Involvement	Indicates that there was involvement of and cooperation between local, tribal, state, regional, and/or federal agencies. Due to the nature of the TMDL process, there was some involvement of agencies in all TMDLs, but the watersheds marked for this characteristic exhibited greater interest and/or involvement of agencies.
Stakeholder meetings during TMDL development	Indicates that stakeholder meetings occurred and WERE DOCUMENTED during TMDL development. Unmarked watersheds may have had stakeholder meetings, but they were not documented.
Stakeholder Engagement	Indicates that there was demonstrated interest, involvement, and cooperation of stakeholders. Greater process continuity was noted in cases where the TMDL and implementation planning/watershed management strategy planning were coincident
Targeted Implementation	Indicates that the watershed strategy provided specific guidance to target implementation efforts at specific polluters and/or locations.
Staged Implementation	Indicates that the implementation process followed a staged approach, with interim goals and milestones
Awareness/ Educational Activities	Indicates that awareness and/or educational activities targeted at stakeholders occurred during TMDL implementation.
Spatial Identification of Pollutant Sources	Indicates that additional monitoring data were collected specifically during the TMDL study to help identify spatial pollutant distributions (e.g., Bacterial Source Tracking or Stream Habitat Assessments) OR that pollutant sources were identified according to their location in the watershed (e.g., pollutant sources were quantified on a subwatershed level); both practices indicate that the TMDL study assessed the spatial distribution of pollution sources.
Leadership Structure	Indicates that a single person or entity was specifically identified to lead the implementation project. Many times, a single person was hired as part of the implementation project.
Point Source Interest/Involvement	Indicates that there was significant interest, involvement, and cooperation of permitted dischargers in the watershed. These dischargers often contributed additional resources, motivation, or expertise to the TMDL development and/or implementation effort.

Table 4. Key to factors affecting successful TMDL implementation, see Table 3. (cont.)

Factors	Description
Technical Assistance	Indicates that technical assistance for BMP implementation was integral to implementation. Although technical assistance was provided to some degree in most of the case study watersheds, only those marked watersheds identified this factor as a key feature of implementation.
NPS Regulations	Indicates that regulations on nonpoint sources of pollution already existed or were developed as part of the implementation effort.
Pre-Existing Watershed Group	Indicates a watershed interest group was active prior to the TMDL being developed.
Stakeholder meetings during IP	Indicates that stakeholder meetings occurred and WERE DOCUMENTED during development of the watershed strategy. Unmarked watersheds may have had stakeholder meetings, but they were not documented.
Watershed Group Created post-TMDL	Indicates a watershed group was created as a result of the development of the TMDL and/or watershed management plan.
Water Quality Trading	Indicates that water quality trading has been a part of the implementation effort
Negative factors	These factors hindered implementation
Lack of data	Indicates that data were lacking, either monitoring data to track or demonstrate water quality improvements (M) or watershed characterization data to allow recharacterization of watershed models for reevaluation of the TMDL (C)
Loss of Funding	Indicates that funding was not available or that funding was lost during the implementation process.
Natural Disasters	Indicates that natural disasters, such as floods, droughts, and forest fires produced atypical hydrologic responses that made assessment of water quality improvement or recharacterization of watershed models difficult.
Lack of pre-TMDL monitoring data	Indicates that a lack of monitoring data collected prior to the development of the TMDL made the establishment of a baseline water quality condition difficult.
Leadership Structure	Indicates difficulties in cooperation or a breakdown of the implementation leadership structure.
State of the science	Indicates lack of confidence in the current state of the science for the targeted pollutant.

DISCUSSION

Although each case study watershed was unique, most possessed several common characteristics that either enhanced or hindered implementation. Factors that enhanced implementation included:

- The existence of a watershed plan that was focused and achievable
    - focused on the issues in the watershed,
    - achievable through corrective actions that could be made/adopted with active stakeholder participation;
- Active involvement of stakeholders, local government, and responsible state agencies;
- Coordination of local governments and state agencies;
- A comprehensive approach to address identified pollutant sources;
- Available Resources
    - to implement voluntary incentive-based corrective measures, and
    - to provide technical assistance and conduct educational programming.

Although each case study watershed experienced successful implementation (as demonstrated by improving water quality), there were several factors that in the opinion of local contacts, hindered implementation:

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- Lack of sufficient data to characterize the watershed and pollutant sources through modeling and/or monitoring activities;
- Lack of communication and coordination between local governments and responsible agencies; and
- Lack of funding, particularly cuts that occurred during the implementation effort.

CONCLUSIONS

The seventeen case study watersheds developed for this project varied in complexity, impairment and pollutant source. The most common factors that aided TMDL implementation were (in order): funding availability, government agency interest and involvement; stakeholder meetings during TMDL development; stakeholder engagement; the presence of a TMDL where the pollutant and needed reductions were systematically assessed and quantified; targeted implementation; staged/phased implementation; and outreach and/or educational activities. Each of these factors was possessed by more than half of the case study watersheds. The negative factors most commonly cited as hindering implementation were lack of data, which affected both TMDL and TMDL implementation plan development, and limited funding for implementing pollutant control corrective measures.

In general, watersheds with very specific pollutant sources (e.g., point sources or legacy pollutants) or watersheds comprised primarily of publicly owned lands exhibited fewer of the factors listed in Tables 3 and 4 (both positive and negative). However, despite this, implementation in these watersheds was at times more successful in achieving water quality goals compared to the more complex watersheds.

The case studies developed for this study are reminders that every watershed is unique, and no one approach can guarantee success in all watersheds. The results from this study reinforce the following with respect to TMDL implementation:

- One size doesn't fit all
  - For nonpoint source dominated watersheds:
    - stakeholder engagement was crucial on privately owned lands.
    - implementation on publicly owned lands was often more straight forward as there was typically a single stakeholder.
  - For point source dominated watersheds:
    - active engagement of point source dischargers produced water quality improvement.
- A focused, relevant, achievable watershed plan facilitated implementation.
  - A stand-alone TMDL implementation plan was not the only approach, and was not a prerequisite to successful implementation.
  - Developing an implementation plan coincident with the TMDL study provides for better continuity in stakeholder engagement.
- The existence of watershed activist/interest group promoted implementation.
  - These groups often have a strong local citizen base, are well-informed regarding watershed issues, and have the knowledge and experience to aid in early and successful implementation.
- The identification of a responsible party or entity to execute and track implementation helped to coordinate the efforts of all involved and ensured that someone would keep the project on target.
- Adequate resources were necessary.
  - Funding was needed to implement corrective actions and to monitor progress.
  - Human resources were required to educate stakeholders, to manage the project, and to implement corrective actions.

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