TMDL IMPLEMENTATION: LESSONS LEARNED

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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 detail, stakeholder participation, and success. In order to identify the specific characteristics and approaches that facilitated implementation and water quality improvement, case studies of watersheds undergoing successful implementation were developed. Factors that positively and negatively affected implementation efforts were identified and summarized 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: adequate funding, government agency interest and involvement; stakeholder meetings during TMDL development; stakeholder interest and involvement; 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. 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 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 is the maximum 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

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described in detail in a TMDL report is required by federal law (40 CFR 130 and section 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.

TMDLs and TMDL implementation plans are being developed across the country using a variety of approaches, with varying levels of detail, stakeholder participation, and success. Many ‘TMDL implementation plans’ are not stand alone plans, but are instead part of another watershed effort, and are not explicitly identified as TMDL implementation plans. The objective of this study was to identify key factors of these varied TMDL implementation efforts that have led to successful implementation and improvements in water quality.

METHODOLOGY

This study included three phases: identification and selection of the case study watersheds, development of the project case studies, and identification and synthesis of characteristics that have led to successful TMDL implementation.

The agency responsible for the TMDL program in each of the 50 states was contacted via email or telephone to obtain information about the current status of TMDLs and TMDL implementation in the state. Representatives from each state agency responsible for TMDL development 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 Section 319 Success Stories website (USEPA, 2006a) and the EPA TMDL Case Studies website (USEPA, 2006b). A list of forty-four candidate watersheds was identified for an initial review. Information was then collected to assess available evidence to support water quality improvement that resulted from TMDL implementation or other related watershed planning efforts in each of these candidate watersheds.

The list of candidate watersheds for each state was then sent to state agency personnel and EPA regional personnel with specific questions to help determine whether a detailed case study review of the watershed would be performed. The questions sent to state agencies and EPA regional offices inquired about the developer 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 perform a 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 responsible state agencies, or if improvement was either not shown or was indeterminate. Following this procedure, seventeen watersheds were selected for additional, detailed case-study review

(Table 1).

Figure 1 – Locations of Case Study Watersheds

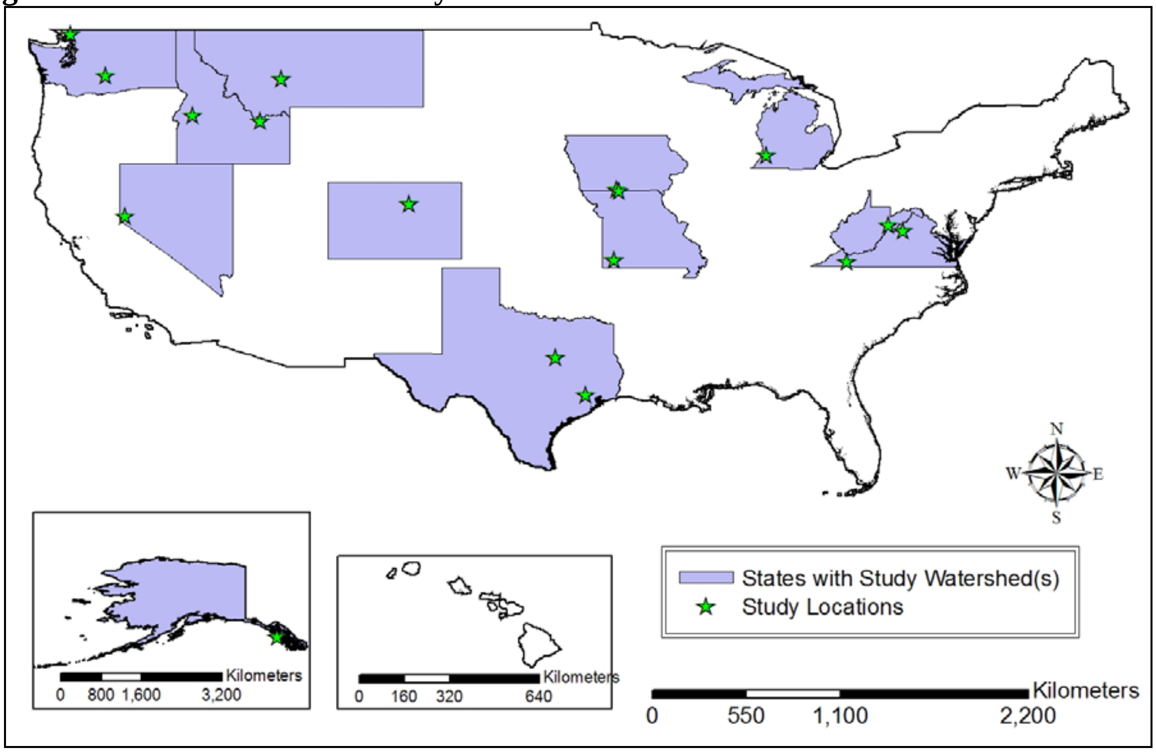

Table 1 – Selected Study Watersheds

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 and data were obtained from the internet and from agency personnel to support case study development. Each case study addressed fifteen key points of interest that described specific aspects of the watershed projects. The key points of interest were:

a. Applicable water quality standards
b. Degree of impairment in terms of applicable water quality standards
c. Approach used to develop the TMDL (modeling or other, specific model(s), developer, stakeholder involvement, etc.)
d. Actual TMDL and supporting loading and concentration data in terms of spatial loadings
e. Scientific reasonableness of proposed reductions (are they likely to be attainable)
f. Public involvement during the TMDL development process (degree of active participation)
g. Approach used to develop the implementation plan and differences from the approach used to develop the TMDL (modeling or other, specific model(s), developer, stakeholder involvement)
h. Usefulness of data and information from the TMDL study in the development of the implementation plan
i. Public involvement during the implementation plan development process
j. Implementation plan loading reductions and phases (temporal and spatial loading reductions, specificity of plan in terms of contributors, etc.)
k. Scientific reasonableness of proposed implementation plan reductions (phases, likelihood of attainment of proposed water quality improvements)
l. Identification and availability of required resources
m. Proposed water quality and progress monitoring system
n. Progress towards implementation (actions taken, water quality improvements)
o. Degree to which the implementation plan is facilitating implementation (strengths and weaknesses).

After compiling the detailed case studies, factors were identified that aided or hindered successful implementation. Watersheds were assigned to categories according to the type of impairment, presence or absence of a permitted discharger and the influence thereof, and degree of pollutant reduction required by the TMDL. Several factors of interest were identified, and each watershed was classified as possessing or not possessing each characteristic. Some of the characteristics were drawn from details of the fifteen key points of interest above. Other common factors surfaced during the compilation 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 pollution. Eight of the seventeen watersheds contained at least one permitted discharger, and four of the watersheds were point source 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) (six watersheds), followed by nutrients (five watersheds), low dissolved oxygen (four watersheds), toxic chemicals (e.g., atrazine, chlordane, chlorine, DDT) (four watersheds), bacteria (three watersheds), elevated temperature (three watersheds), ammonia (two watersheds), pH (one watershed), and solid waste (one watershed). The impairment characteristics of the case study watersheds are shown in Table 2.

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. The magnitude of the pollutant 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 that aided implementation efforts. Negative factors, which hindered implementation efforts, are also summarized in Table 3. Table 4 presents more detailed descriptions of the factors presented in Table 3. Benham et al. (2006) provides a more detailed synopsis of these results.

The most common positive factors were (in order): adequate funding, government agency interest and involvement; stakeholder meetings during TMDL development; stakeholder interest and involvement; 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 surveyed watersheds. The primary factors that hindered successful implementation were lack of data and lack of funding.

In addition to the positive and negative factors listed in Table 3, several watersheds contained particularly unique beneficial features. In Segment 15 of the South Platte River in Colorado, the ‘Metro District,’ a permitted discharger, funded many of the implementation efforts, conducted water quality studies, and produced watershed 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 active clean-up of debris in watershed. In Nine Eagles Lake, Iowa, the Department of Natural Resources and the Department of Forestry worked together to reduce sources of sediment 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.

Table 2. Impairment characteristics of the case study watersheds

Characteristic	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	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?†	Y	N	Y	N	N	N	Y	N	N	Y	Y	Y	N	Y	N	Y	N
Point Source Dominated?†	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‡																	
<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

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

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	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[§]																	
Watershed Strategy: Implementation Plan (IP), Workplan (WP), TMDL section (TMDL), or Summary Implementation Strategy (SIS)	IP	IP	IP	IP	TMDL & WP	IP	TMDL	IP	TMDL	IP	WP	TMDL	TMDL	TMDL & WP	TMDL & WP	TMDL	SIS
TMDL development method: (M=watershed model, LD=load duration, Eq=simple equation(s), Stat=statistical methods)	M	na[†]	M	na[†]	na[†]	M	LD	na[†]	Eq	Stat	M	na[†]	Eq	M	na[†]	M	Stat
Funding	X	X	X		X	X	X	X	X	X	X		X	X	X	X	X
Agency Interest/Involvement	X	X	X	X	X	X		X	X	X	X		X	X	X		X
Stakeholder meetings during TMDL development	X	X	X		X	X	X	X	X	X		X	X	X	X		X
Stakeholder Interest/Involvement	X	X	X		X	X	X	X		X	X			X	X		
Targeted Implementation	X		X	X	X	X		X	X			X	X	X			
Staged/Phased Implementation	X	X				X		X		X	X			X	X		X
Outreach/Educational Activities	X	X	X		X	X	X				X				X		X
Monitoring or other Spatial Data used to Identify Pollution Sources		X	X		X	X	X	X			X						
Leadership Structure	X		X		X			X			X						
Point Source Interest/Involvement	X						X[‡]					X		X		X	

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

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	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[§] cont.																	
Technical Assistance	X	X				X					X						X
NPS Regulations			X							X					X		X
Pre-Existing Watershed Group							X	X			X			X			
Stakeholder meetings during planning	X		X			X					X						
Watershed Group Created as a Result of TMDL																	X
Water Quality Trading	X															P[*]	
Negative Factors[§]																	
Lack of data (M=monitoring data to track or demonstrate success, C=watershed characterization data to reevaluate watershed models)	M			M					M			M		C			
Loss of Funding			X		X					X							X
Natural Disasters					X									X			
Lack of pre-TMDL monitoring data				X													
Leadership Structure	X																
State of the science	X																

[§]see Table 4 for characteristics key; [†]na=not applicable, calculations did not play a large part in determination of TMDL or load reductions; [‡]point source in this watershed simply complied with newly imposed regulations; [*]water quality trading has been proposed in this watershed

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

Factors	Description
Positive Factors	These factors aided implementation efforts
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 treatment plant upgrade was already ongoing before development of the TMDL
Agency Interest/Involvement	Indicates that there was significant interest, involvement, and cooperation between local, tribal, state, regional, and/or federal agencies. Due to the nature of the TMDL process, there was at least minimal involvement of agencies in all TMDLs, but the watersheds marked for this characteristic exhibited stronger 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 Interest/Involvement	Indicates that there was significant interest, involvement, and cooperation of watershed stakeholders.
Targeted Implementation	Indicates that the watershed strategy provided specific guidance to target implementation efforts at specific polluters and/or specific locations in need of remediation
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
Monitoring or other Spatial Data used to Identify Pollution Sources	Indicates that additional monitoring data were collected specifically during the TMDL study to help identify spatial distributions of pollution (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 provided some assessment of the spatially-distributed sources of pollution
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 the implementation of BMPs was integral to implementation. Although technical assistance was likely provided in most of these watersheds, only the 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 development of the TMDL.
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 as a Result of TMDL	Indicates a watershed group was created as a result of the development of the TMDL and/or watershed strategy.
Water Quality Trading	Indicates that water quality trading has been a part of the implementation effort
Negative factors	These factors hindered implementation efforts
Lack of data (M=monitoring data to track or demonstrate success, C=watershed characterization data to reevaluate watershed models)	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 caused atypical water quality behavior 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 watershed reviewed was unique, most possessed several common characteristics that 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;
- Diversity of approaches to address sources;
- Adequate Resources
    - to implement voluntary incentive-based corrective measures, and
    - to provide technical assistance and conduct educational efforts.

Factors that hindered implementation included:

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

CONCLUSIONS

The seventeen case study watersheds and their sources of impairments varied in complexity. The most common positive factors were (in order): adequate funding, government agency interest and involvement; stakeholder meetings during TMDL development; stakeholder interest and involvement; 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 surveyed watersheds. The primary factors that hindered successful implementation were lack of data and lack of funding.

In general, watersheds with a very specific pollutant source (e.g., point source or legacy pollutant) or watersheds comprised primarily of publicly owned lands exhibited fewer of the factors listed shown 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 overarching message gleaned from this study was that every watershed is unique, and no one approach can guarantee success in all watersheds. There are several lessons to be learned from this study:

- One size implementation plan 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 accelerated attainment of water quality standards.
- 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 at the same time as the TMDL study provides for better continuity in stakeholder involvement.
- 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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