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# **Effective engagement of stakeholders in Total Maximum Daily Load development and implementation**

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**Abstract:** Total Maximum Daily Loads (TMDLs) identify the maximum amount of pollution that a water body can receive and still support its designated uses and allocates the maximum load to specific sources in the watershed. In the United States, The Clean Water Act requires public participation in the process of TMDL development. This requirement has been met through simple presentation of results at public meetings, strategic partnerships with key stakeholders, and/or to advisory committees in which stakeholders participate in critical decisions about TMDL definition and implementation. These decisions include model selection and assumptions, selection of water quality endpoints, load allocations, TMDL review, and implementation planning. In this article, we discuss the benefits and challenges of early and targeted engagement of stakeholders in TMDL development through a participatory modelling process based on our experience in Utah and Vermont.

**Keywords:** TMDL, water quality, public participation, participatory modelling, decision support, point and non-point pollution

## **1. INTRODUCTION**

Water resource issues are becoming more common and complex as the interaction between natural and human systems intensifies. Under such circumstances, scientific knowledge, data, and models must be linked with local knowledge and stakeholder input to derive solutions which are appropriate, well-understood, feasible, and scientifically sound. In recent years, there has been a shift towards water resources planning processes that involve collaboration between stakeholders, scientists and resource managers. Participation in watershed research and management supports democratic principles, is educational, integrates social and natural processes, can legitimate a decision making process, and can lead to implementation of an agreed agenda of environmental objectives (Roberts 2004).

### **1.1 The Total Maximum Daily Load Process**

One example of stakeholder engagement in water resources is through Total Maximum Daily Load (TMDL) processes, required under the Clean Water Act (CWA) in the United States. The CWA aims to improve and protect water quality through restoration and maintenance of the physical, chemical, and biological integrity of the nation's waterways. The CWA provides a mechanism to evaluate the status of the nation's waters, designate beneficial uses for specific waterbodies, and establish criteria for water quality to protect

those uses. For waters that do not meet criteria associated with their designated uses, the Clean Water Act requires a TMDL study for each pollutant responsible for the impairment.

A TMDL study outlines a watershed-wide pollution budget for a waterbody. It describes the amount (load) of an identified pollutant that a specific stream, lake, river, or other waterbody can contain while preserving its beneficial uses and maintaining water quality standards. This is referred to as that waterbody's pollutant loading capacity and acts as a 'cap' for the amount of pollution that can be tolerated within a waterbody. TMDLs are developed using available water quality, hydrologic, and biological data as well as empirical and mechanistic models. Calculations for pollutant loading capacity take into account seasonal variations, natural and background sources of loading, and a margin of safety to account for uncertainty in the analysis. Once the loading capacity is determined, sources of the pollutants are considered, and each known source is allocated a permissible load or quota. In specific cases, trading of pollutant load allocations between sources may provide cost savings and achieve load reductions more quickly than otherwise realized. Loads allocated to point sources through a TMDL, such as wastewater treatment plants, are legally binding and enforced through a discharge permitting process. There are currently no regulatory mechanisms for enforcement of non-point source load allocations. Rather, these sources are controlled through voluntary, incentive-based, and educational programs.

## **1.2 Public Participation in the Context of TMDL Development**

Public involvement is a required component of the TMDL process under the Clean Water Act. This requirement has been met through simple presentation of results at public meetings, strategic partnerships with stakeholders, partnerships with existing watershed groups, and/or through technical advisory committees in which stakeholders participate in critical decisions of TMDL development. Although the total acceptable load is determined through scientific analyses, stakeholders can affect the process through water quality endpoint selection (how protective of water quality must we be), determination of study boundaries, model selection, data collection and integration, interpretation of results, and implementation planning. It is generally recognized that engaging participants in as many of these phases and as early as possible, beginning with setting the goals for the project, drastically improves the value of the results in terms to resource managers, its educational potential for the public, and its credibility within the community (Korfmacher, 2001). It is also crucial for the implementation stage, especially when dealing with non-point source pollution that has no support from any legally binding control mechanisms, and entirely depends on voluntary actions.

In many watersheds there is momentum and interest in water quality issues formalized in the creation of locally led watershed groups. Technical advisory committees, often composed of stakeholders and/or experts in the watershed, participate and negotiate critical TMDL model assumptions, water quality endpoints, methodologies, and load allocations. In many cases, more direct partnerships with agencies and other stakeholders is necessary to gather all the data available in the watershed and summarize past implementation work. Finally, public meetings are a formal step in the TMDL process in which TMDL results are presented in draft form to the public in an effort to solicit input for the final TMDL report.

## **1.3 Strategies for Effective Stakeholder Engagement in TMDLs**

In a prior article, we presented a summary of the lessons associated with participatory modelling (Voinov and Gaddis 2008). They are summarized below.

1. *Identify a clear problem and lead stakeholders.*
2. *Engage stakeholders as early and often as possible.*
3. *Create an appropriately representative working group.*
4. *Gain trust and establish neutrality as a scientist.*
5. *Know your stakeholders and acknowledge conflict.*
6. *Select appropriate modelling tools to answer questions that are clearly identified.*
7. *Incorporate all forms of stakeholder knowledge.*
8. *Gain acceptance of modelling methodology before presenting model results.*

9. *Engage stakeholders in discussions regarding uncertainty.*
10. *Develop scenarios that are both politically feasible and most effective.*
11. *Interpret results in conjunction with stakeholder group.*
12. *Involve stakeholders when presenting results to decision makers and the public.*

## **1.4 Objectives**

In this article, we present a summary of benefits associated with working with stakeholders and the public to develop and implement TMDLs to address water resource issues in Vermont and Utah. We have selected three specific projects to describe some of the key benefits and challenges associated with our efforts. In all of the projects described here, we have engaged stakeholders according to the 12 lessons or recommendations that are described above and in detail elsewhere (Voinov and Gaddis 2008). We present these findings from our perspective as scientists and resource managers engaged in applied water resource issues.

## **2. CASE STUDIES OF STAKEHOLDER PARTICIPATION IN TMDLS**

### **2.1 Lake Champlain TMDL Implementation Planning**

Recently, the Lake Champlain Phosphorus TMDL allocated a phosphorus load to the St. Albans Bay watershed that requires a 33% reduction of total phosphorus to the bay (VTANR and NYDEC, 2002). The watershed feeding St. Albans Bay is dominated by agriculture at the same time that the urban area is growing. Since the 1980s, considerable amounts of money and effort have been used to improve point and non-point sources throughout the watershed. Nonetheless, eutrophication in St. Albans Bay remains a problem today. The focus on agricultural sources in the watershed has caused considerable tension between farmers, city dwellers, and landowners with lake front property

During the basin planning process that followed the TMDL, we initiated a participatory modeling effort to apportion the total load of phosphorus among all sources, including non-point source transport pathways, and identify the most cost-effective interventions to achieve target reductions. A group of stakeholders that represented agencies, citizens, agricultural interests, and municipalities were invited to participate in the two-year process and were engaged in the study at multiple levels including water quality monitoring, soil phosphorus sampling, model development, scenario analysis, and policy development.

Statistical, mass-balance, and dynamic landscape simulation models were used to assess the state of the watershed, the long-term accumulation of phosphorus in the watershed, and the distribution of phosphorus load to streams in terms of space, time, and transport process. Watershed interventions, matched to the most significant phosphorus sources and transport processes, were identified with stakeholders' input and evaluated with the landscape model. Modelling results suggested that the St. Albans Bay watershed accumulates phosphorus over the long-term, primarily in agricultural soils. Dissolved phosphorus in surface runoff from the agricultural landscape, driven by high soil phosphorus concentrations, accounts for 41% of the total load to watershed streams. Direct discharge from farmsteads and stormwater loads, primarily from road sand washoff, were also found to be significant.

### **2.2 Cutler Reservoir and Bear River TMDLs, Utah**

Cutler Reservoir, in Northern Utah, has impounded the Bear, Logan, and Little Bear Rivers since 1927 through Cutler Dam which is operated by PacifiCorp to provide water for agricultural use and power generation. Cutler Reservoir is a shallow reservoir with extensive wetlands. Inflows to the reservoir include municipal, irrigation, and industrial discharges, as well as stormwater. Cutler Reservoir supports recreational uses and a warm water fishery while providing habitat for waterfowl. It was identified as impaired due to low dissolved oxygen and excess phosphorus loading. The Utah Division of Water Quality initiated the process of developing a Total Maximum Daily Load (TMDL) for Cutler Reservoir and the upstream section of the Bear River in 2004 with the goal of restoring and maintaining water quality to a level that protects all beneficial uses.

Participation from local stakeholders was formalized in the development of the Bear River/Cutler Reservoir Technical Advisory Committee (TAC), which has representation from all the major sectors and interests of the local community including agricultural interests, environmental concerns, recreational interests, municipalities, irrigation districts, industry, and wildlife. During the establishment of the TAC the Utah Division of Water Quality took care to find representatives from all groups affected by the TMDL process. Since Cache Valley is a small community, most committee members represent more than one interest. The advisory committee has been meeting frequently since August 2005 and informed the TMDL process by contributing data and knowledge of processes in the watershed, providing input on methodology selection, negotiating water quality endpoints, and identifying solutions to help reduce pollution sources.

The BATHTUB reservoir model was used to predict nutrient and algal concentrations under alternative nutrient loading scenarios. The model incorporates estimates of internal nutrient loading, tributary loads, and reservoir morphometry. Total phosphorus endpoints were derived using a weight-of-evidence approach based on seven different lines of evidence (UDWQ 2010). Separate total phosphorus endpoints were selected for the shallow southern section (0.09 mg/l) of the reservoir than for the narrow and deeper northern section of the reservoir (0.07 mg/l). The endpoints focused on the open water (lacustrine) areas of the reservoir because most of the data available to the TMDL process were from these areas.

There was significant uncertainty in the Cutler Reservoir TMDL associated with the quantitative linkage between total phosphorus and dissolved oxygen, the unique nature and complexity of the shallow reservoir system, and the varying status of previously completed TMDL studies on tributaries to the reservoir. This uncertainty was openly acknowledged and discussed with the Technical Advisory Committee (TAC) and formed the basis for the selection of analytical methods for the TMDL study as well as the decision to submit a phased TMDL to the EPA. A phased TMDL requires identifies milestones tied with monitoring to ensure progress is made in water quality despite analytical and environmental uncertainty. It also outlines a process for updating the TMDL once additional data are available.

Moving forward, the TAC will assist with implementation of the management plan by setting priorities for restoration and BMP projects and by periodically reviewing progress toward water quality improvement goals.

### **2.3 East Canyon Reservoir and Creek TMDLs, Utah**

East Canyon Reservoir impounds East Canyon Creek, a stream that originates near Park City, Utah. The East Canyon watershed is dominated by forest, historic ranches, and recent developments. The watershed also includes several ski resorts, golf-courses, and hiking and mountain biking trails.

A TMDL was completed for both East Canyon Reservoir and East Canyon Creek in 2001 to address low dissolved oxygen impairments related to excess total phosphorus. Since 2000, the largest point source in the watershed, the East Canyon Creek Water Reclamation Facility, has significantly reduced nutrient loads to East Canyon Creek and Reservoir. In addition, BMPs have been implemented to reduce nutrient runoff from non-point sources throughout the watershed. In 2008, the Utah Division of Water Quality revised the TMDLs for these water bodies to incorporate new information and data available for the system. These included a nutrient spiraling study, a dissolved oxygen flux model for the creek, and better understanding of the hydrodynamics in the reservoir. Incorporation of internal reservoir dynamics that govern phosphorus sedimentation and sediment nutrient release was critical to this re-assessment. This required the development of a reservoir model that accounts for internal processes and incorporates the more comprehensive dataset now available to the TMDL process. CE-QUAL-W2 was the modelling platform selected for this project. The revised TMDL identified processes other than water column phosphorus as the driver for low dissolved oxygen in the creek such as lack of shade, low flow, and bank erosion (all contributing to the growth of rooted macrophytes in the creek). As a result

revised load allocations were calculated for the East Canyon Creek TMDL that are still protective of designated uses in the reservoir but provide more flexibility for discharge to the creek (e.g. annual v. seasonal load allocations).

In the case of the East Canyon watershed, there was an existing committee group made up of all the major sectors and water quality interests including agriculture, water conservancy districts, conservation districts, state agencies, environmental interests, and recreational users. The East Canyon Watershed Committee holds quarterly meetings to discuss water resource issues in the basin. Numerous members of the committee have contributed data, information, and valuable input to the TMDL process. A presentation on the findings of the TMDL was made to this committee during the draft stage of the process and the group hosted the public meeting for the TMDL.

### **3. BENEFITS OF EFFECTIVE STAKEHOLDER ENGAGEMENT**

#### **3.1 Improved Data for TMDL Analysis**

Stakeholders often play a key role in TMDL development by contributing data to the study or by participating in the collection of new data. In addition, some stakeholders are aware of data sources that are more specific to the watershed such as locally collected climatic data. In the case of the Cutler Reservoir and Bear River TMDLs, water quality data was provided by the Utah Division of Water Quality, PacifiCorp, USGS, Utah State University, and the City of Logan. The availability of this wide range of data allowed for the analysis of water quality in several tributaries to the reservoir. Similarly, in the East Canyon TMDLs, water quality and hydrologic data was provided by the Bureau of Reclamation, USGS, Utah Division of Water Quality, and the Snyderville Basin Water Reclamation District.

In the St. Albans Bay project (Lake Champlain TMDL implementation planning) and the Cutler Reservoir and Bear River TMDLs, local NRCS offices contributed important data associated with livestock sources in the watershed. In all three project examples, municipalities or water reclamation districts provided point source data associated with stormwater, wastewater, and future growth. In the East Canyon TMDLs, implementation planning and source information was also provided by ski resorts and golf courses in the watershed. All of this information led to a more appropriate apportionment of current loads in the watershed and identification of the most effective implementation measures.

Stakeholders can also engage in water quality sampling and monitoring. In the St. Albans Bay project, a community water quality monitoring program was organized to collect water quality samples around the watershed. Citizen volunteer lived close to monitoring sites and had access to private property that allowed for more extensive and frequent monitoring.

#### **3.2 Appropriate Model Selection and Assumptions**

Stakeholders are very helpful in identifying processes and pollutant sources that should be captured by the selected TMDL methodology or model. In the case of the East Canyon Reservoir TMDL, the CE-QUAL-W2 model was selected to capture the unique dam structure and hydrodynamics of the reservoir. These issues were identified by a former Bureau of Reclamation (BOR) scientist who had also already developed the selected model for the reservoir. The model was also able to predict the distribution of algal species, which was of concern due to dominance by harmful cyanobacteria in the past.

Stakeholders can also verify basic assumptions about the dynamics, history, and patterns of the watershed. Farmers and residents possess important local knowledge about the biophysical and socio-economic system being researched that would not be captured by itinerant observers. For example, in the St. Albans Bay watershed stakeholders were able to describe typical fertilizer frequency for households and farms. This type of knowledge when combined with technical knowledge of watershed processes is key to identifying new and more appropriate solutions to environmental problems (Webler and Tuler, 1999).

#### **3.3 Reduction in TMDL Controversy and Improved Acceptance of TMDLs**

Discussion of TMDL methodologies, prior to analysis and results reporting has led to reduced controversy in some cases, since model assumptions are often less controversial than model results. In the case of the Cutler Reservoir TMDL, there was significant controversy surrounding the complexity and associated uncertainty in the reservoir system. Some stakeholders, representing regulated point sources in the watershed, felt that the uncertainty associated with the data and the analysis warranted postponement of the TMDL. However, the Clean Water Act states that lack of optimal data cannot delay TMDL development (40 CFR 130.2(g)). The transparent and inclusive process used in the Cutler Reservoir TMDL process contributed to a quicker resolution leading to the adoption of the TMDL by the Advisory Committee. In the case of the East Canyon TMDLs, stakeholders accepted the results of the revised TMDL even though it required additional pollutant reductions and other implementation actions throughout the watershed. This was likely due to their involvement in the process from the beginning, they were consulted regarding critical TMDL assumptions and decisions, and the process was transparent.

### **3.4 Development of Protective and Attainable Water Quality Endpoints**

Setting water quality endpoints is an important step in the TMDL process because endpoints define total load allocations and the temporal and spatial units for the load analysis. In some cases TMDLs are developed for pollutants that do not have numeric water quality standards requiring either interpretation of a narrative standard (e.g. nuisance algal scum) or linkage between a numeric standard and a pollutant (e.g. dissolved oxygen and phosphorus). Stakeholder input on water quality endpoints often includes appropriate measures and methods to identify them, negotiations on endpoints that are both protective of the designated use and attainable, and identification of the seasonality and appropriate spatial scales for specific water quality endpoints.

For the East Canyon Reservoir TMDL, site-specific water quality endpoints were selected that would be protective of the cold-water fishery but also attainable given the physical constraints of the reservoir. During periods when the reservoir is stratified, the upper layer of the reservoir has sufficient oxygen but exceeds the temperature standard for cold-water fish species. During this same period, the lower portions (hypolimnion) of the water column maintain appropriate temperatures for fish but have insufficient oxygen. An appropriate water quality endpoint was needed to provide fish with refugia where both temperature and oxygen conditions are maintained. The endpoints were negotiated in consultation with the Utah Division of Water Quality, the Utah Division of Wildlife Resources, and Snyderville Basin Water Reclamation District (the only permitted source in the watershed). To protect the fishery from the intersecting pressures of high temperature and low DO, the following endpoint was selected for this TMDL: During periods of thermal stratification, the minimum DO criteria of 4.0 mg/L and maximum temperature of 20°C shall be maintained in a 2-m layer across the reservoir to provide adequate refuge for cold water game fish.

In the case of Cutler Reservoir, selection of water quality endpoints and compliance points was a subject of intense discussion in the TAC. There was a concern among the environmental community that selection of compliance points at only the outfall of the reservoir could lead to sacrificing water quality in the southern areas of the reservoir that are heavily used by birds and for boating. The majority of point source loading occurs in the southern reservoir. Representatives of the point sources were concerned that the selection of separate endpoints for the southern and northern portions of the reservoir would limit the potential ability of sources to 'trade' their allocated load with one another. Sources can only buy pollutant credits from other sources upstream of their discharge point, not downstream. In the end, separate endpoints were identified for the north and the south but only one compliance point (rather than 2 or 3) was selected for each section of the reservoir.

### **3.5 Negotiation of fair load allocations**

Stakeholders play an important role in negotiating an equitable allocation of pollutant loads that will also facilitate attainment of water quality endpoints in the future. Allocation of the

acceptable load to each identified point and non-point source in a watershed can be accomplished in several ways. Reductions could be made proportionally across all sources based on current loads from each source, or more reductions could be identified for regulated sources that have dedicated sources of funding. In some cases, small sources are not required to reduce loads due to an inequitable cost-burden associated with reduction and/or a small incremental improvement in water quality associated with the reduction. In the East Canyon Reservoir TMDL, phosphorus load allocations were adjusted from the previously approved TMDL to provide for population growth and the resulting increases in flow from the local wastewater treatment system. This resulted in the need for additional reductions from non-point sources in the watershed. The point sources in the watershed are currently funding many of these projects.

In the case of the Cutler Reservoir TMDL, load allocations were based on current loads in the watershed. Equal load reductions were assigned to each of the sources contributing to the southern and northern sections of the reservoir respectively. However, a small point source (representing less than 1% of the total load), a fisheries experiment station, found that the load reduction required by the draft TMDL would be too expensive to implement, especially in light of recent improvements to the facility. Indeed, the equal load reduction approach to allocations punishes those that have already made improvements. Their load allocation was adjusted correspondingly to reflect that effort in the final TMDL.

### **3.6 Identification of New Solutions to Old Problems**

In St. Albans Bay we identified different solutions than had previously been assumed to be the most important for phosphorus reduction. The participatory approach led to community acceptance and utility of model results as evidenced by local decision makers now moving forward to implement some of the solutions identified to be most cost-effective.

In the East Canyon TMDLs, the low dissolved oxygen in the creek was linked to reduced stream flow, lack of shade and excess fine sediments providing for macrophyte growth along the stream bottom. The original TMDL focused on water column phosphorus as the driver for the low dissolved oxygen impairment. Through discussions with the stakeholder community, new and unconventional solutions to the impairment in the creek were identified in the revised TMDL. These included acquiring and enforcing water rights to increase base flow in the creek and riparian habitat restoration to reduce macrophyte growth in the creek through increased shading and filtration of sediment from upland runoff.

## **4. CHALLENGES ENCOUNTERED IN STAKEHOLDER ENGAGEMENT**

Despite all the benefits described in the previous section, there are also difficulties and challenges associated with stakeholder engagement during the TMDL process.

*Schedule:* Accommodating the input and contributions of stakeholders can make the TMDL process longer. This can delay implementation of water quality projects. Longer TMDL processes also make it difficult to keep a large group of voluntary stakeholders involved throughout the process. Further, representation from some interests may change during a long TMDL development process.

*Continuity:* The lack of funding for on-going research can leave the resulting TMDL without access to additional research to reduce uncertainty in the future. This can be mitigated in part through the efforts of state funded watershed planners and coordinators. However, this requires close coordination with the contractor or researcher to ensure that the tools used can be adapted into the future.

*Trust:* Participatory modelling requires developing trust that all parties are working towards a common goal of identifying real solutions for improving water quality. In some cases, it is simply unrealistic to expect all stakeholders to have improvement of water quality as their first priority. This can lead to irresolvable conflicts.

*Focus:* The natural environment is constantly changing and incomprehensibly complex. Maintaining focus on the parameters of concern and recognizing the regulatory limits of the TMDL process can be challenging for some stakeholders. Furthermore devising



solutions to the targeted pollutants is complicated at times by false perceptions of the causes of poor water quality and by intersecting regulatory frameworks (e.g. fisheries management and water rights) that lie outside of the traditional purview of water quality programs.

*Uncertainty:* Humans are naturally averse to risk. Stakeholder participation in the modelling process brings to light all of the uncertainty and assumptions inherent in scientific study. Uncertainty in model predictions and effectiveness of control measures tend to drive some stakeholders to want to study the problem indefinitely. A common refrain might be “How can you expect us (stakeholders) to change our practices or spend money on upgrades if you can’t tell us with absolute certainty that what you’re proposing will work?” Communicating the need to manage a resource in the face of uncertainty is an important challenge to working with some stakeholders.

*Frustration:* Somewhat related to uncertainty is the added responsibility that comes from the expectation that TMDLs will indeed make a difference. After stakeholders invest their time and efforts in developing and implementing TMDLs they do expect them to work, and produce better water quality. It may create much frustration and future disconnect with stakeholders if the TMDLs do not deliver the results that are expected.

#### 4. CONCLUSIONS

The participatory modelling approach that we have taken in the TMDLs described in this paper is strongly recommended for future TMDL processes. Effective engagement of stakeholders is important because of the implications of TMDLs on communities including binding load allocations for point sources. Completed TMDLs can also lead to additional funding to reduce non-point sources in a watershed. Specifically, the benefits of participatory modelling in the context of TMDLs include improved data for the analysis, appropriate model selection, reduction in TMDL controversy, improved acceptance of TMDLs, attainable water quality endpoints, negotiation of fair load allocations, and identification of new solutions to old problems.

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