Chapter 3
Values in Participatory Modeling: Theory and Practice

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3.1 Introduction

The popularity of participatory modeling has grown in recent years (Voinov and Bousquet 2010) since it is particularly compatible with new environmental management paradigms that focus on ecosystem-based management, integrated water resources management, and adaptive management. All of these incorporate systems theory and aim to protect and improve ecological resources while considering economic and social concerns in the community. New inclusive modeling approaches have emerged that have been adopted by, among others, the Water Framework Directive of the European Commission, the Malawi Principles in the Convention on Biological Diversity (UNEP), and the National Center for Environmental Decision-Making Research (NCEDR) in the United States. The latter recommends that the processes of analysis and deliberation be integrated in such a way that systematic analysis is combined with community values critical to decision-making. This is because participatory modeling provides a platform for integrating scientific knowledge with local knowledge, and when executed well, provides an objective, transparent and flexible workplace for a diverse group of stakeholders to contribute information regarding an ecosystem of interest. Recognition that effective ecological management requires input from both scientific and social processes is key to developing effective partnerships between scientists who know the theory and research methods and stakeholders who live and work within an ecosystem.

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Participatory modeling (also known as "mediated modeling," "shared vision planning," "group model building," etc.) draws on the theory of post-normal science, which dictates that in problems characteristic of highly complex systems—when facts are uncertain, values are in dispute, stakes are high and decisions are urgent—there is no one, correct, value-neutral solution (Funtowicz and Ravetz 1993). Many ecological and environmental problems are characterized by these challenges. Under such circumstances, standard scientific activities are inadequate and must be reinforced with local knowledge and iterative participatory interactions to derive solutions that are well understood, politically feasible, and scientifically sound.

Stakeholder participation in these types of situations—such as those common to ecological research and management—has, therefore, been justified for multiple reasons. This is because stakeholder participation in the decision-making process supports democratic principles, promotes learning, integrates information about social and natural processes, adds legitimacy to the process, and can lead participants in moving forward toward an agreed agenda. The extent to which the public or representative stakeholder group can effectively participate in ecological research and management is determined by the methods employed in engaging stakeholders, inclusion of diverse groups, group size, incorporation of local knowledge and expertise, and the time available for the process to develop. The development of unique, practical, and affordable solutions to ecological problems is often best accomplished by engaging stakeholders and decision makers in the research process (Seidl et al. 2013; Tàbara and Chabay 2013).

However, we still see little progress is solving some of today's most urgent environmental problems. Even with an increase in the popularity of participation in environmental decision-making in general and the use of participatory modeling specifically, there are still questions about how to best structure the model-building process with stakeholders. In this chapter, we reflect on some of our experiences as modelers engaged in participatory modeling by outlining some of the lessons we learned through our experiences and (1) reflect on some problems of the science-policy interface that we see as preventing the solution to some crucial problems humanity faces, (2) outline best practices for modelers seeking to engage in the process and (3) conclude by presenting an example of a project that uses some of the more innovative techniques of participation.

3.2 Philosophy of Participatory Modeling: Integrating Values, Not Just Knowledge

One of the main promises of participatory modeling has always been the idea that by bringing modeling to the hands of stakeholders and by making sure that they understand and appreciate the modeling tool developed, we can actually expect better decisions and management practices to be implemented and better policies to be adopted. However, in many cases we do not see this outcome.

On a large scale, Rockstrom et al. (2009) have clearly shown that several of the planetary boundaries, or critical indicators such as biodiversity loss, or climate change, or the nitrogen biogeochemical flow, have been already exceeded, while several others are about to be passed. There is evidence that new conflicts are emerging because of limited resources such as food, water, energy, and land (Daily and Ehrlich 1996; Homer-Dixon 1999). It has been shown that climate change, and loss of biodiversity and ecosystem function can be detrimental to our life-support systems (Balvanera et al. 2006). There has been some success fixing smaller issues on local scales (Ettiene 2014; Bousquet and Voinov 2010), but the results are hardly encouraging despite broad stakeholder involvement. While certain watersheds get improved riparian zones and point pollution is contained, the Chesapeake Bay does not show much improvement (Paolisso et al. 2013); while large reductions of phosphorus inputs are attained in the St. Albans Bay, Lake Champlain still has increasing levels of eutrophication (Gaddis et al. 2010a, b).

There are probably different reasons each time the management practices or policies do not work out as intended. On large-scale projects, participatory efforts may be quite prohibitive; it remains unproven that large-scale participation can work. We have not yet developed appropriate tools to allow participation of numerous stakeholders rather than a dozen people meeting for a workshop. There are many technical issues that need to be resolved to provide adequate facilitation and information sharing in big groups. In fact, it is yet to be shown that such large-scale participation can even work. Certainly in all scales, projects are dependent upon funding and funding is rarely available to monitor project outcomes and to follow-up on projects after they are finished. In many instances we find that the participatory process that goes well *during* the study is mostly forgotten *afterwards* when the funding has ended, reports are written, papers are published and researchers are back home.

We argue that the problem is not only how the participatory process is organized and conducted, but concerns the larger issue of how science and policy interact and what role is left for science in this interaction. Many still believe that science is, and should be, value neutral. For example, Robert Lackey, former chief of the US Environmental Protection Agency (EPA) Lab in Corvallis, Oregon, states: "science, although an important part of policy debates, remains but one element, and often a minor one, in the decision-making process," and that "scientists can assess the ecological consequences of various policy options, but in the end it is up to society to prioritize those options and make their choices accordingly" (Lackey 2013). The idea is that society—directly or through its elected or appointed representatives—formulates a task for science. Science—which is expected to act as though removed from society—then takes action by solving the problem and presenting the answer, which society, through its representatives, will consider and either implement or ignore.

This sequence does not seem to work for today's complex problems that are controversial, have no single and simple solutions, and, most importantly, infringe on and depend upon the values and priorities of the parties involved. Such is the case with climate change, with shale oil and fracking, or with alternative renewable energy (wind, solar), etc. Today's environmental problems go beyond technological solutions and mostly depend upon the behavioral choices that the society assumes, the priorities and values that drive those choices, and the way those values are communicated and understood.

Direct engagement in the value-setting process is necessary to instigate action and change. We argue that including value-setting in an iterative cycle of co-design of knowledge with users and stakeholders is crucial for the success of any exercise in participatory modeling. If we want models to be useful, we must acknowledge that their users exist within a socio-political system, and, therefore, including users' values both in models and in the modeling process and providing results based on stakeholder requirements becomes essential. In doing so we must admit that modelers are also stakeholders in the modeling process and have their own values (Voinov et al. 2014). In fact, people are more likely to acquire their scientific knowledge by consulting those who share their values and whom they, therefore, trust and understand (Kahan 2012). How will we expect them to associate with scientifically laden values if science is expected to be value neutral? Trying to convince people only with scientific arguments can be an uphill battle against their values and intentions that were set by the media and advertising and is prone to societal inertia. There is no reason to hide our values when engaging in a participatory modeling exercise, and even less reason to pretend that we, as scientists, hold no values as human beings. We do, and the fact that our human values are usually influenced by the many facts at our disposal as scientists, only makes our scientifically grounded values that much more important to share.

In participatory modeling, we make some important steps in the direction of transparent, science-based tools for decision-making. The definition of project goals becomes one of the stages of the modeling process, which is revisited as many times as needed with active interaction between scientists and stakeholders. Modeling helps define these goals and clarify values, intentions, and actions; potentially, changing them at the same time. Modeling engages stakeholders in a process of social learning (Tàbara and Chabay 2013) and co-design of knowledge (Glaser 2012) that includes a critical self-control feedback. Similarly, in the analysis of the model results, stakeholders are engaged to ensure that their expectations are met and the results can be used in a transdisciplinary framework (Seidl et al. 2013). This helps to bridge different disciplines and appropriately account for human values in modeling (Valkering et al. 2009). Yet, in most cases of participatory modeling, the scientists and modelers still are assumed to be "objective" and "value-neutral" (Voinov and Gaddis 2008). Moreover, they are expected to remain so and the value-neutrality of scientists in the modeling process is recommended as a prerequisite of "good" science.

Science in general, and modeling in particular, still rarely lead to action and is not expected to do so: policy makers are now supposed to make things happen (Lackey 2013). Stakeholders, when left on their own, quickly realize that running models—not to mention improving and adjusting them—is much more difficult than when scientists did the work. Policy makers become interested in their next fund-raising cycle very quickly, and forget to take action recommended by scientists.

Despite the realization of the importance of visualizations and the progress in developing persuasive and powerful visualization tools, presenting scientific evidence from model-based future scenarios and reflecting upon the need for changing societal values, intentions and actions remains elusive. Hence, one of the reasons that scientific understanding and knowledge does not readily translate into actions may be the target audience. Communication of model results should not be limited to the final stage of decision-making and the small group of policy decision makers.

We argue that by divorcing the modeling process from the problem formulation stage and by ending our modeling exercises with a delivery of a solution then disengaging from the actual implementation of this solution, we are not helping the overall decision-making process. Modeling is not an end, it is an evolutionary process of learning to better adapt to the continuing change that societies and ecological systems face (Tàbara and Pahl-Wostl 2007). If we expect actual decisions to be made outside of the modeling process, we are ignoring the power that models have: first, in framing the problems, asking the questions, comparing alternatives, identifying the contexts and boundaries; and second, in determining the actual value sets that lead to action through successful management or governance.

In fact, problem framing and definition are already results of modeling and the problem is most likely to be modified as a result of further modeling. Values and intentions are not static; instead they are constantly changing, and can and should be influenced by the results of models that we build. It is the responsibility of modelers to communicate the results in such a way that they can be understood by the public and are best framed to influence the values in an appropriate way.

To make sure that it is not only knowledge that is integrated in the participatory modeling process but also the values of stakeholders, including scientists, that should be incorporated and should inform the process, we suggest an amended version of the participatory workflow that ensures that scientists play a role in defining the problems to be solved and stay involved until actual action is taken to implement the solutions (Fig. 3.1).

In this regard, the participatory modeling process offers excellent opportunities for such engagement of scientists. However it is still important that scientists are ready to accept this role of setting the values and communicating the results of the modeling process in such a way that they can be understood by the public and are best framed to influence values in an appropriate way.

3.3 Revisiting Best Practices of Participatory Modeling

Participatory modeling is a practice that continues to evolve as it is applied to new, complex problems. Previously, Voinov and Gaddis (2008) presented a series of lessons based on experience working with stakeholder groups to develop watershed and water quality models to address water resource issues in a variety of locations. These lessons in participatory modeling, discussed from our perspective as scientists and modelers engaged in applied watershed issues, are informative to others working to achieve successful participatory modeling efforts elsewhere. Here, we review these lessons as they relate to a wider, more general audience that describes considerations for those seeking to engage in the modeling process with stakeholders, and explore how they may be amended to recognize the importance of values in modeling and participatory science.

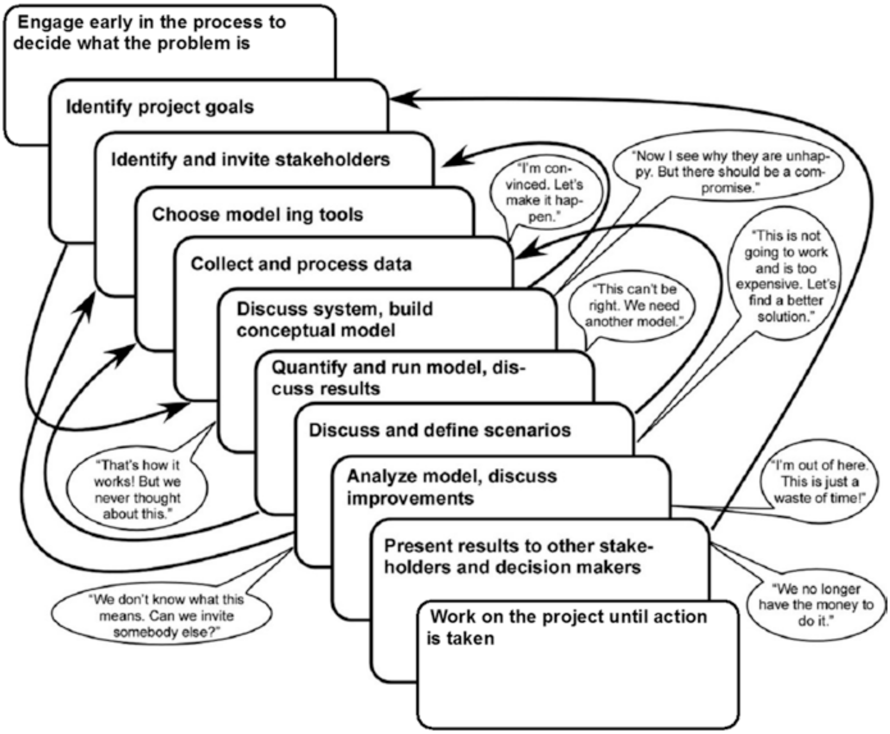

Fig. 3.1 A revised workflow in participatory modeling. Based on Voinov and Bousquet (2010). Scientists and modelers are expected to take a more proactive role in defining the problems and tasks for scientific inquiry rather than only serve the policy makers in providing answers to questions asked. At the end, also more participation in the actual action-taking is essential

- **Identify a Clear Problem and Lead Stakeholders**

  Although most natural resource management decisions benefit from stakeholder input and involvement, some issues might not have raised the interest of a wide group of stakeholders. If the problem is not understood or considered to be important by stakeholders, then it will be very difficult to solicit involvement in a participatory exercise. In many cases, the problem identification stage should go beyond just understanding what stakeholders want. Realization of a problem comes with education; with learning about facts and data. This is the role that science should play early in the process, perhaps even before the problem is defined.

- **Engage Stakeholders as Early and Often as Possible**

  A key to success with any participatory approach, is that the community participating in the research be consulted from the initiation of the project and help to set the goals for the project and specific issues to be studied (Beirele and Cayford 2002). Engaging participants in as many phases of the work as possible and as early as possible—beginning with setting the goals for the project—drastically improves the value of the resulting model in terms of its usefulness to decision makers, its educational potential for the public, and its credibility within the community (Korfmacher 2001).

- **Create an Appropriately Representative Working Group**

  Participatory modeling may be initiated by local decision makers, governmental bodies, citizen activists, or scientific researchers. In some projects, stakeholders are sought for their known "stake" in a problem or decision and invited to join a working group. In other cases, involvement in the working group may be open to any member of the public. Regardless of the method used to solicit stakeholder involvement, every attempt should be made to involve a diverse group of stakeholders who represent a variety of interests regarding the question at hand. This adds to the public acceptance and respect of the results of the analysis.

- **Gain Trust and Establish Neutrality as a Scientist**

  Although participatory modeling incorporates values, the scientific components of the model must adhere to standard scientific practice and objectivity. This criterion is essential for the model to maintain credibility among decision makers, scientists, stakeholders, and the public. Thus, while participants may determine the questions that the model should answer and may supply key model parameters and processes, the structure of the model must be scientifically sound and defensible. This does not necessarily mean that scientists will and should come into the process as value-neutral and totally "objective" players. Scientists are also human, which means that they are always driven by a certain set of values and preferences. Concealing them and pretending to be value-less would be dishonest and can result in loss of trust in the process. On the contrary, admitting adherence to certain values, while demonstrating willingness to discuss them and being open to criticism and disagreement, can only help in the process of co-learning and co-education.

- **Know Your Stakeholders and Acknowledge Conflict**

  In some cases, stakeholders may have historical disagreements with one another. One purpose of engaging in participatory modeling is to provide a neutral platform upon which disputing parties can contribute information and see the perspectives of other stakeholders engaged in the decision-making process. However, it is important to watch for historic conflicts and external issues that may overshadow the process.

- **Select Appropriate Modeling Tools to Answer Questions That Are Clearly Identified**

  A critical step, early in the participatory modeling process, is the development of research questions and goals for the process. The questions identified should be answerable given the time and funding available to the process. In addition, it is important that all stakeholders agree on the goals of the process such that a clear research direction is embraced by the entire group before detailed modeling begins. Selecting the correct modeling tool is one of the most important phases of any modeling exercise (Kelly et al. 2013). Model selection should be determined based on the goals of the participants, the availability of data, project deadlines, and funding limitations rather than determined by scientists' preferred modeling platform and methodology (which, unfortunately is often the case). Modelers should have a robust set of tools available for the process and be clear with stakeholders about the trade-offs of using tools with varied spatial and temporal resolution and complexity.

- **Incorporate All Forms of Stakeholder Knowledge**

  The knowledge, data, and priorities of stakeholders should have a real—not just cursory—impact on model development both in terms of selecting a modeling platform and in setting model assumptions and parameters. Stakeholders contribute existing data to a research process or actively participate in the collection of new data. Some stakeholders, particularly from governmental agencies, may have access to data that is otherwise unavailable to the public because of privacy restrictions or confidentiality agreements. These data can often be provided to researchers if it is aggregated to protect privacy concerns or if permission is granted from private citizens. Stakeholders may be aware of data sources that are more specific to the study area such as locally collected climatic data. Stakeholders can also be very helpful in identifying whether there are important processes or factors that have been neglected in the model structure or verify basic assumptions about the dynamics, history, and patterns of both the natural and socioeconomic system. The stakeholders themselves may be important elements of the model, representing the behavior choices and patterns that are important to include in the model. The modeling process should be flexible and adjustable to accommodate new knowledge and understanding that comes from the stakeholder workshops.

- **Gain Acceptance of Modeling Methodology Before Presenting Model Results**

  Giving stakeholders the opportunity to contribute and challenge model assumptions before results are reported also creates a sense of ownership of the process and gives them more confidence in model-based results. This can only occur, however, if the models developed are transparent and well understood by the public or stakeholder group (Korfmacher 2001). Transparency is not only critical to gaining trust among stakeholders and establishing model credibility with decision makers, it is also key to the educational goals often associated with participatory modeling.

- **Engage Stakeholders in Discussions Regarding Uncertainty**

  Many scientific questions, especially those that incorporate socio-economic processes, require analysis of complex systems. As problem complexity increases, model results become less certain. Understanding scientific uncertainty is critically linked to the expectations of real world results associated with decisions made as a result of the modeling process. This issue is best communicated through direct participation in the modeling process itself. Stakeholders who participated in all stages of the model-building activities develop trust in the model and generally have more confidence in model results. Primarily that is because they know all the model assumptions, know the extent of model reliability, know that the model incorporated the best available knowledge and data, and acknowledge that there is always uncertainty associated with scientific model results.

- **Interpret Results with Stakeholders and Develop Scenarios That Are Politically Feasible**

  A primary goal of a participatory modeling exercise is to resolve the difference between perceived and more objective understanding of issues associated with environmental problems (Korfmacher 2001). Given that stakeholders may propose scenarios based on their perceptions of the problem, they may be adept at proposing new policy alternatives following initial model results from a scenario modeling exercise (Carr and Halvorsen 2001). The participatory modeling process can further facilitate development of new policies through development of a collaborative network of stakeholders throughout the research process (Beirele and Cayford 2002). Stakeholders are important communication agents to deliver the findings and decision alternatives to decision makers in the federal, state, or local governments. Stakeholders are best placed to pose solutions to a problem. Many of them have decision-making power and influence in the community. They understand the relative feasibility and cost-effectiveness of proposed solutions. In addition, engaging local decision makers in the scenario modeling stage of the research process can lead to development of more innovative solutions that may not have been considered using scientific knowledge alone (Carr and Halvorsen 2001).

- **Involve Stakeholders When Presenting Results to Decision Makers and the Public**

  An important final step in the participatory modeling method is dissemination of results and conclusions to the wider community. Presentations to larger stakeholder groups, decision makers, and the press should be made by a member of the stakeholder working group. This solidifies acceptance of the model results and cooperation between stakeholders that was established during the participatory modeling exercise.

3.4 An Example: Can Optimization Help with Value-Setting?

Consider the following example of employing a participatory modeling approach in the St. Albans Bay watershed, Vermont to identify new solutions to water resource problems that have historically been locally controversial and divisive (Gaddis et al. 2010a, b). Lake Champlain has received excess nutrient runoff for the past 50 years (VTANR and NYDEC 2002) due to modern agricultural practices and rapid development of open space for residential uses (Hyde et al. 1994). The dramatic effect of excess nutrients has been especially prominent in St. Albans Bay, which exhibits eutrophic algal blooms every August (Hyde et al. 1994). The Lake Champlain Total Maximum Daily Load (TMDL), established by the Vermont Agency of Natural Resources and the New York Department of Environmental Conservation, allocated a phosphorus load to the St. Albans Bay watershed that would require a 33 % reduction of total phosphorus input.

The watershed feeding St. Albans Bay is dominated by agriculture at the same time that the urban area is growing. In the 1980s, urban point sources of pollution were reduced by upgrading the St. Alban's sewage treatment plant. During this period, agricultural non-point sources were also addressed through implementation of "Best Management Practices" (BMPs) on 60 % of the farms in the watershed at a cost of $2.2 million (USDA 1991). Despite the considerable amount of money and attention paid to phosphorus loading into St. Albans Bay, it remains a problem today. The historic focus of those working on this problem has been primarily on agricultural practices in the watershed. This has caused considerable tension between farmers, city dwellers, and landowners with lake-front property.

In this case, participatory modeling was considered not only as a means for integrating scientific knowledge with local knowledge but also as a place for a diverse group of stakeholders to share varied forms of knowledge and as a platform for stakeholder interaction and dispute resolution. An objective of this study was to determine if participatory modeling facilitated more cooperation and reduced conflict between stakeholders in the St. Albans Bay watershed.

There are several places where stakeholder values and perceptions played an important role. All stakeholders came to the process with their perceived knowledge about the system, vested interests, and priorities. These made the stakeholders biased and subjective. For example, the committee was dominated by citizen volunteers and agency representatives; this led to solutions that would be implemented either through volunteer efforts or funded through existing agency programs. The transparency of the modeling process revealed these biases and helped to find common ground. Giving stakeholders the opportunity to contribute and challenge model assumptions before results are reported created a sense of engagement in, and ownership of, the process that made results more credible in the future. This can only occur, however, if the models developed are transparent and well understood by the stakeholder group and, later, the public. Some stakeholders complained that the modeling tools where too complex for them to grasp.

We came to the project believing that facilitators of a participatory modeling exercise must be trusted by the stakeholder community as being objective and impartial, and therefore should not themselves be direct stakeholders. In this regard, facilitation by university researchers or outside consultants, if established as neutral parties, was meant to reduce the incorporation of stakeholder biases into the scientific components of the model. It was also assumed to be essential that stakeholders trust the science used in the project. A track record in the local area and perhaps even recognition of researchers by the local stakeholders based on past research or involvement was helpful in building relationships between the stakeholders and the facilitators. However, it was apparent quickly that scientists could not be totally devoid of certain values and priorities. Even when starting the monitoring part of the project, which was conducted with local school students and their teacher, it quickly became obvious that scientists were deeply concerned about the state of Lake Champlain and held certain values. On the positive side, we had no preferences regarding the major conflict in the project: the standoff between the farmers and the urban residents.

We made every effort to make the model development process transparent to the stakeholders. The stakeholder working group discussed and agreed on model assumptions for some parameters and validated other model assumptions. Stakeholders were asked to verify assumptions about the dynamics, history, and patterns of the watershed system. This approach is based on the assumption that those who live and work in a system or watershed may be better informed about its processes and may have observed phenomena that would not be captured by scientists who live elsewhere. Farmers and homeowners possessed important local knowledge about the biophysical and socio-economic system.

Stakeholders identified processes or pollutant sources that had been neglected in past research for the watershed. For example, farmers identified field drainage of lowland fields as a potentially important process for understanding the flow of water and nutrients through the agricultural landscape. In addition, community stakeholders provided information about typical human behavior in the watershed. Many were important inputs to the simulation model (i.e., frequency of lawn fertilizer application) and have helped us formulate various scenarios for the model. Scenarios in this case were combinations of control factors (BMPs) administered at various spatial and temporal allocations. These scenarios could be then compared in terms of their efficiency by running them through the model. Stakeholders were especially instrumental in formulating these scenarios, since they had a very good feel for what was and was not possible in the watershed.

Again, we as modelers also had values at stake, which we tried not to involve in the discussions at first. We had an overall understanding from previous studies that the phosphorus budget of the watershed was vastly skewed and that more had to be done by all parties to improve the situation. Fortunately, these feelings were not contrary to any particular group among the stakeholders, which allowed us to maintain some "middle ground." Also, it helped that stakeholder-derived scenarios were supplemented by an optimization routine applied to a spatially explicit dynamic model of phosphorus transport.

Optimization, if considered from the point of view of the values involved, has the advantage of internalizing some of the values that may be driving the choice of the scenarios. On the one hand, optimization makes certain values implicit when the objective function and the conditions and constraints are set. For example, we can optimize for the lowest cost, while deciding that certain environmental conditions are to be met. Alternatively, we can optimize for the best possible environmental conditions to be achieved while the maximum allowed expenditures are fixed. On the other hand, once selected, the rest is composed of entirely internal computer computations where values are no longer involved.

This is in contrast to the more widely used scenario-based approach, where management scenarios are chosen as a result of stakeholder deliberations and can be heavily value-laden and contain vested interests that are not necessarily clearly exposed. Whereas stakeholder-derived scenarios represented the most obvious or socially accepted solutions to the problem, model results suggested that they were less cost-effective than solutions derived using an optimization algorithm. In fact, although the stakeholder-developed watershed solution showed similar phosphorus reduction, the cost of their preferred management plan was almost 3.5 times the cost of the solution generated by the optimization algorithm. The optimal solutions ranged in total cost for the watershed from $418,400 to 976,417 ($138 to 321 USD/ha) and represented a range in diffuse phosphorus load reduction from 0.89 to 1.13 mtP/year (0.29 to 0.38 kg/ha). The maximum diffuse phosphorus load reduction was found to be 1.25 mtP/year using the most cost-effective technologies for each diffuse source at a cost of $3,464,260. However, 1.13 mtP/year could be reduced at a much lower cost of $976,417 using the interventions selected by the optimization routine. This solution represented the practical upper limit of achievable diffuse phosphorus reduction for the Stevens Brook watershed. That is, there is a clear threshold of cost-effectiveness around $1 million, after which additional spending would not result in substantially more phosphorus reduction. Selecting solutions from the steep side of the Pareto curve provides the most cost-effective approach to reduce phosphorus at the watershed scale. On the steep slope, the marginal costs for additional phosphorus reduction are the lowest (Fig 3.2).

Of course, the results of the optimization runs are by no means binding. In fact there are numerous assumptions and uncertainties in the model, which mean that the modeling results should be always treated with some skepticism, and the optimization results are good only as an estimate of what is possible under certain ideal conditions. The next step is to reconcile stakeholder preferences and model results—a kind of critical assessment of what has been produced so far.

Watershed managers could use the results of the optimization runs to select the best combinations of watershed interventions along a Pareto optimal curve based on

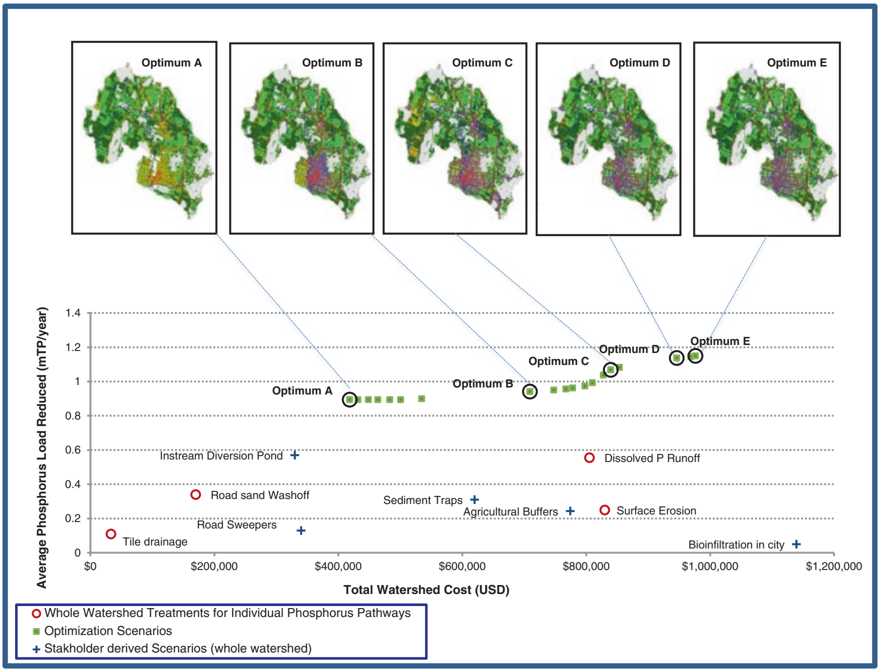

Fig. 3.2 The cost efficiency of various strategies of watershed management. The figure clearly indicates the differences between the stakeholder-selected solutions formulated as scenarios and the optimal solutions derived from the optimization procedure with the objective of minimizing the phosphorus load to the estuary. Connecting the optimum solutions creates the so-called Pareto optimal curve that shows what could be achieved under some ideal optimal conditions

a water quality goal or available funds. Each solution could also be used to inform where in the landscape implementation will be most cost-effective through detailed analysis of the BMP map output with each optimum. In our case, the results demonstrated the power of using spatial optimization methods to arrive at a cost-effective distribution of BMPs across a landscape. However the stakeholders should always be—and were in our case—informed that the "optimal" solutions we produced are good only as idealized targets that can inform the process of decision making, but by no means are actually guaranteed to produce exactly the kind of outcomes that the model showed.

While there is a big difference between solving applied problems using scenario modeling vs. optimization, and while this is something yet to be appreciated by stakeholders who are rarely involved in modeling exercises that include an optimization component, there is not much difference in terms of the associated uncertainties. In both cases we base our decisions on model runs, and models are always built on approximations, simplifications, assumptions, and always contain imprecise data.

In fact, a model that has been used within an optimization framework is likely to be more robust than a model that has been used only to run scenarios. That is because optimization requires that the model performs well over a much more densely populated parameter space—instead of only a few points described by a few scenarios, we now run hundreds or thousands of parameter combinations to choose the optimal one.

Although many of the stakeholders involved in the St. Albans Bay watershed participatory modeling process were decision makers who influence policy and implementation of watershed interventions at multiple scales, there was no direct mechanism by which model results would be used in any decision-making process. Through qualitative discussions, however, several stakeholders indicated that they intended to use the information gleaned from the project to direct existing funding sources and adapt policies to the extent possible to address the most significant phosphorus transport processes and sources in the watershed. Clearly, stakeholders are often limited in appropriating money and influence towards new projects, since other projects may have support for other reasons or are mandated by policies developed at higher bureaucratic levels, especially in the case of federally funded projects. Changing programs and policies of governmental agencies, especially to adapt to local conditions and problems takes time.

The issue of future use of the model was a focus of concern during several interviews. Initially the model was to be put on the Internet so community members could continue to use it after the modeling process concluded. Due to a lack of resources, this did not occur. Although the future use of the model by the community will be extremely limited due to its complexity and lack of continued support by the university, many of the stakeholders were under the impression that they would be able to use it. Unfortunately, since the end of the participatory modeling process, the stakeholder group has not had the capacity to work with the model. However, they have continued to draw on results from the modeling exercise conducted over the course of the project. Several stakeholders participated in the presentation of model results to the local press and general public in May 2006.

There are several specific examples of watershed management changes that have emerged from this project. In addition, several partnerships have been created or strengthened and trust developed between previously opposing groups as a result of the participatory-modeling exercises. In addition to management changes, stakeholders offered other recommendations and observations. A new focus on local decision making was suggested by a state employee as well as a town official. A member of the watershed alliance suggested a move away from adversarial relationships with the farming community. Another focus, echoing others' sentiments, is that information should be expressed in terms that people can understand. Several stakeholders suggested that education of the public was necessary in order to make important community-wide changes to deal with diverse water pollution issues.

3.5 Conclusions

Recent focus on ecological management that is adaptive, participatory, and collaborative has given rise to new approaches to scientific research and the incorporation of stakeholder knowledge and values into scientific models used for decision making. Participatory modeling incorporates input from stakeholders and decision makers into scientific models that support decisions involving complex ecological questions. The process supports democratic principles, is educational, integrates social and natural processes, can legitimize a local decision-making process, and can lead participants to be instrumental in implementing an agreed upon agenda. Modeling tools employed include indices, statistical models, spatial models, temporal models, and spatially explicit dynamic models. Stakeholder participants engage in the modeling research process in the form of model selection and development, data collection and integration, scenario development, interpretation of results, and development of policy alternatives. Variations of participatory modeling are distinguished by who initiates the process, how stakeholders are enlisted and engaged in the process, the breadth of research questions addressed, and the mechanism by which modeling results are incorporated into decision making—all of which can significantly influence model-based and social outcomes. Criteria of successful participatory modeling include scientific credibility, objectivity, transparency, understanding uncertainty, model adaptability, representative involvement, incorporation of stakeholder knowledge, and usefulness in decision making.

Both policy makers and academic researchers frequently engage the public and stakeholders in an outreach process that aims to inform or educate about a new policy or application of a scientific finding. Public comments may be solicited on agency-developed documents that bridge the science-policy interface; but responses to such comments are too often dismissive therefore not resulting in meaningful changes to policy. Such outreach efforts are substantively different than genuine participation in a modeling process. The best practices outlined above, if adhered to, should result in a process by which stakeholders feel that they have been heard, their knowledge objectively considered, and that the final results reflect a deliberative process that has been inclusive of multiple perspectives and all available data. The goal should be a bidirectional process resulting in true collaboration rather than an effort to “teach” the public and stakeholders. The learning should be mutual and not only address knowledge sharing, but also value sharing which has been an area of participatory modeling that is vastly understudied.

Most importantly, we expect true participation to play an important value-setting role, which becomes quite crucial in the state of the world today.

In addition to general recommendations related to practices associated with participatory modeling, we have experienced fine-scale issues that, to date, have not been considered adequately by the literature. For example: What kind of models should be built in the participatory process? How detailed, or how simple they should be? Should stakeholders be able to understand all aspects of the model or just key inputs and outputs? What should stakeholders be exposed to and what can stay “behind the scenes” (Voinov and Bousquet 2010)? Answers to these questions depend upon the resource management problem and the stakeholder group involved. We found, however, from our own experience that even some very complicated modeling tools that include optimization can still be successfully employed and provide important information for the stakeholder process, while also benefiting from the collaboration that takes place (Gaddis et al. 2010a, b, 2014).

In conclusion, it appears that science in general, and modeling in particular, are assigned a certain niche in society and are tolerated as long as they stay within that niche. In fact, many scientists are quite comfortable with this role because it may safeguard them from direct responsibility alternatives, identifying the contexts and boundaries, and determining the actual value sets that lead to action through successful management or governance.

Participatory modeling has the potential to integrate meaningful input from stakeholders and decision makers into the modeling process. When executed well it provides an objective, value-neutral place for a diverse group of stakeholders to contribute information regarding an ecosystem of interest. Even more important is the flow of information from science towards stakeholders, from theory to practice, and to action. One of the main problems facing society today is our lack of action on some of the crucial issues that have been identified by scientific research, but science fails to communicate the urgency and need for action to the rest of society. This disconnect remains serious and threatening in several contexts that endanger our future (e.g., climate change, biodiversity, etc.).

We argue that nowhere else can science and practice come as close together as in the process of participatory modeling. When stakeholders are already involved in the scientific process, as in the participatory modeling process, and when scientists are already directly and actively communicating and collaborating with stakeholders, it takes only a few more steps to directly engage in the political and decision-making process. Scientists should not shy away from taking a more proactive role in identifying the most urgent problems, and then making sure that action is taken to implement the solutions they have identified in real life.

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