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External Review Draft

A Method to Assess Climate-Relevant Decisions:

Application in the Chesapeake Bay

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Global Change Research Program
National Center for Environmental Assessment
Office of Research and Development
U.S. Environmental Protection Agency
Washington, DC 20460

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PREFACE

The goals of EPA's Global Change Research Program (GCRP) are to assess the potential effects of climate change on water quality, air quality, ecosystem health, and human health, and to provide decision makers with information and tools that enable them to incorporate considerations of climate change into their decision making processes. The emphasis on information and tools useful for decision making requires that assessments be conducted differently than simply defining the problem, collecting and analyzing data, and turning the results over to decision makers. Assessments must be approached through a process of interacting with stakeholders to define important questions, objectives, and endpoints of interest. This process is key to conducting ecological risk assessments and needs to become integral to climate change assessments. The GCRP therefore emphasizes the need to understand the decision context first in order to produce decision-relevant information.

One limitation to this approach is the lack of empirical data about the characteristics, importance, and prevalence of decisions for which climatic changes are relevant. To address this information gap, the GCRP developed an approach for cataloguing and analyzing decisions that will be affected by climate change and tested this approach in a pilot study. This pilot study uses a regional program – the Chesapeake Bay Program –to identify a set of decisions that are affected by climate change and to provide information about their social, economic, and environmental attributes. The Chesapeake Bay Program's water quality and aquatic ecosystem management decisions are the primary means of restoring the health of the Bay. The scope of the pilot was limited to these management decisions to maintain a reasonably sized subset of decisions and because they align with the GCRP's mission. Other issues such as safe and adequate water supply are also important decisions to consider but are not a part of this pilot.

The intent of this report is two-fold: provide insights on the general approach to inventorying and evaluating decisions and its applicability to other national programs, and provide specific information on the Chesapeake Bay Program decisions and their relative sensitivity to climatic changes. The next phase of this project will be to test this approach using data on larger, national-scale programs and their decisions.

Susan Julius
Britta Bierwagen
Global Change Research Program, NCEA/ORD/EPA

AUTHORS AND REVIEWERS

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AUTHORS

Susan Julius, EPA
Britta Bierwagen, EPA
Chris Pyke, U.S. Green Building Council
J. Randall Freed, ICF
Susan Asam, ICF

REVIEWERS

<u>Internal Review and Peer Consultation</u>

Lewis Linker, EPA
John Thomas, EPA
Chris Weaver, EPA
Karen Metchis, EPA
Carl Hershner, Virginia Institute of Marine Sciences
Marc Landy, Boston College
Arnold Vedlitz, Texas A&M University

External Panel Review

TBD

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- Kirk Havens, Virginia Institute of Marine Sciences
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- John Hom, US Forest Service, Northern Global Change Program
- Ron Korcak, USDA
- Venkatram Mahendraker, GE Water & Process Technologies
- R. P. Morgan II, University of Maryland Center for Environmental Science, Appalachian Laboratory
- Fredrika C. Moser, Maryland Sea Grant
- Mike Naylor, Maryland Department of Natural Resources

- Vikram M Pattarkine, At-Large Member, STAC, Chesapeake Bay Program
- Clifford W. Randall, Virginia Tech
- Dave Secor, UMCES-CBL
- Jeff Skousen, West Virginia University
- Don Weller, Smithsonian Environmental Research Center
- John Young, USGS, Leetown Science Center

1. EXECUTIVE SUMMARY: OVERALL PROJECT FINDINGS

Climate change is a global phenomenon that is affecting natural and human systems in all parts of the world. Some of the decisions and actions taken to manage these systems are likely to be affected by climate change and may likewise affect the vulnerability of the managed resource or ecosystem to climate change. Maintaining or improving the health of resources, as articulated in many management goals, means maximizing the effectiveness of existing management practices. Maximizing effectiveness of practices will not only include understanding the magnitude of potential impacts, but also understanding the effects of climate change on specific practices and their performance.

The goal of this study is to formalize an approach to inventory and analyze management decisions in order to produce useful information targeted toward effective adaptation to climate change. The approach uses as its starting point ongoing planning processes and decisions geared toward achieving environmental management goals, and then collects information on decisions and prioritizes them according to specific attributes. The pilot study described in this report applies this approach and examines its usefulness to decision makers.

We began by: (1) selecting a study area and compiling a list of key decisions; (2) developing criteria for evaluating the climate-relevance of decisions; (3) applying the criteria to select decisions that are potentially sensitive to climate change; (4) soliciting expert judgment regarding those selections (and refine the selections accordingly); and (5) testing alternative weighting schemes for prioritizing decisions most in need of decision support or additional research based on the selected attributes.

We selected the Chesapeake Bay as the subject area for the pilot study because decision making occurs at several levels (e.g., state, multi-state, EPA, other federal agencies), management is concerned with both water quality and aquatic ecosystem decisions, and decisions that affect actions implemented on the ground are readily identifiable.

We undertook a literature review to identify characteristics of decisions (attributes) that may be good candidates for decision support and guide the development and application of a broad selection approach. Categories of attributes considered include *characteristics of the decision itself* (e.g., how much of an effect does the decision have, is the decision a “one-off” or will it be revisited periodically), *of the decision process* (e.g., is the process open or closed, is it flexible or rigid, does the process use detailed analyses), and *of the constraints* (e.g., laws, regulations, budgets) influencing the decision making processes. For this study, the most effective selection criteria to identify climate-relevant decisions came from the attribute category *characteristics of the decision itself*. These criteria were *climate adaptation potential* (the sensitivity of the system to climate stressors and the capacity of the practice to ameliorate the impacts of climate change) and *dimensions of timeliness* (e.g., planning horizon, implementation period, and project lifespan).

Further information gathering was undertaken to assess additional decision attributes that would facilitate prioritization of decisions most in need of decision support or additional research to effectively adapt practices to climate change impacts. As part of the prioritization process, we used a form of expert elicitation to further refine the characterization of the decisions. Expert elicitation was used because of the relative scarcity of data on the performance of best practices for our selected attributes. Therefore our initial characterization of decisions required subsequent judgment by practitioners about their plausibility. After differences were resolved in characterization between our initial assessment and the expert elicitation process, we developed several scenarios that tested alternative weighting schemes of the selected attributes (in effect, weighting gives greater importance to some attributes over others).

The test of our theoretical approach using the Chesapeake Bay Program's environmental management decisions revealed that in practice, this approach provides useful information on adaptation measures for local decision makers and direction for fruitful research endeavors that will further improve our provision of information. Results of this study are immediately useful to decision makers by informing them on the degree to which management of ecosystems depends on practices that are sensitive to climate change and whether their environmental goals are in danger of not being met. It also gives decision makers some sense of the magnitude of effort needed to address climate change effects in their plans. Decisions that were not selected using broad criteria are generally ones that are not influenced by climate-related variables, are made more frequently, or involve projects with a limited lifespan.

Results of this project highlight areas in need of further research, including: 1) refinement of our understanding about which attributes of the decision are particularly sensitive to climate, 2) how the decision or the practice itself can be most effectively changed to address climate change effects, and 3) decision attributes that carry data most critical for prioritizing decisions. It is also important to note that the scope of this framework approach included only the scientific aspects of decision making. Additional work needs to be done on the input of non-scientific stakeholders, who also play a key role in decision making. Moving forward, a key issue will be determining whether this approach is generalizable (e.g., transferable to other places and ecosystems, scalable to other organizational levels of decision making). We applied this experimental approach specifically to the Chesapeake Bay to examine its usefulness as our first step. The next step is to test its transferability and scalability either to other estuaries or other national programs.

2. EXECUTIVE SUMMARY: Chesapeake Bay Findings

Climate change is a global phenomenon that is affecting natural and human systems in all parts of the world. Some of the decisions and actions taken to manage these systems are likely to be affected by climate change and may likewise affect the vulnerability of the managed resource or ecosystem to climate change. Maintaining or improving the health of the Chesapeake Bay means maximizing the effectiveness of existing management practices. This is usually pursued by first examining the potential impacts of climate change on the Bay resources, but another key piece of information that is necessary in order to maximize the effectiveness of management practices is to develop a greater understanding of the effects of climate change on specific practices and their performance.

A pilot study was initiated to test the usefulness of an approach we developed to inventory and analyze management decisions in order to produce useful information targeted toward effective adaptation to climate change. The first step in this approach was to inventory ongoing planning processes and decisions geared toward achieving specific environmental management goals. We selected the Chesapeake Bay as the subject area for the pilot study because decision making occurs at several levels (e.g., state, multi-state, EPA, other federal agencies), management is concerned with both water quality and aquatic ecosystem decisions, and decisions that affect actions implemented on the ground are readily identifiable.

First we compiled a list of key decisions, which in the case of the Chesapeake Bay Program, consisted of point source controls and non-point source best management practices (BMPs) to achieve water quality programmatic goals and aquatic ecosystem management decisions to achieve "living resources" programmatic goals. Then we used criteria developed from the literature to evaluate whether climatic changes were relevant to any of the decisions. To rigorously review our results, we employed experts to provide their judgment as to whether they agreed with those decisions that were selected as potentially sensitive to climate change. Finally, we tested alternative weighting schemes for prioritizing decisions most in need of decision support or additional research based on the selected attributes.

Two selection criteria--*climate adaptation potential* (the sensitivity of the system to climate stressors and the capacity of the practice to ameliorate the impacts of climate change) and *dimensions of timeliness* (e.g., planning horizon, implementation period, and project lifespan)--successfully narrowed the initial inventory of over 146 water quality and aquatic ecosystem practices down to 32. Those practices that were eliminated were ones that are either insensitive to climate change stressors and would have no effect on reducing potential climate change impacts (such as management systems for poultry waste to reduce runoff), or have short lifespans and therefore could be adjusted periodically to address changing climatic conditions (such as grass-planted riparian buffer strips). The remaining 14 water quality decisions and 18 aquatic ecosystem protection decisions represent good opportunities for developing adaptation strategies within the Chesapeake Bay. Further information gathering was undertaken to assess two additional groupings of decision attributes for the 32 decisions. These were priority (the resource is a high priority, or the expected benefit from the decision support system is high), and information availability (information on the environmental and ecological functions of the resource is extensive, or information regarding climate change's impacts on the resource/management practice is extensive). The intent of selecting additional attributes was to prioritize the remaining decisions to identify those most in need of decision support or additional research to effectively adapt practices to climate change impacts.

Experts reviewed the results of the prioritization exercise, including characterization of each practice according to the four groups of decision attributes. They agreed with the initial scores in about 50 percent of cases. Of those scores with which experts disagreed, the vast majority disagreed by only 1 point on the 5-point scale. In order to assess the sensitivity of the final prioritization outcome to differences in initial versus experts' scores, three separate scenarios were analyzed. These scenarios compared the use of: 1) all of the initial scores; 2) all of the expert reviewers' suggested scores (where they disagreed with the initial scores); and 3) a hybrid set of scores that selectively replaced the initial scores with the expert reviewers' scores where their information was likely to be more comprehensive than that used to develop the initial scores.

Two more scenarios were added to assess the sensitivity of the final scores and rankings to changes in the weights of the four attribute categories. One scenario assigned an equal 25 percent weight to each category using the hybrid scenario, and another scenario assigned 50 percent weight to climate sensitivity, 20 percent to suitability, 20 percent to priority and 10 percent to information provided using the hybrid scenario.

The water quality and ecosystem management practices that consistently ranked in the top five across several scenarios that tested alternative weighting schemes of the selected attributes (in effect, weighting gives greater importance to some attributes over others) include:

- Urban Stream Restoration
- Stormwater Management: Filtering Practices
- POTWs Standards for Discharge Permits
- Living shorelines

Of the ecosystem management practices, the following two -- *managing fishery harvest levels* and *rebuilding oyster habitats using alternative substances* -- consistently ranked in the top ten. Of the water quality management practices, *urban stream restoration, stormwater management—infiltration,* and *mixed open wetlands* consistently ranked in the top ten.

Results of this study are immediately useful to decision makers by informing them on the degree to which management of ecosystems depends on practices that are sensitive to climate change and whether their environmental goals are in danger of not being met. It also gives decision makers some sense of the magnitude of effort needed to address climate change effects in their plans. An understanding of those water quality and aquatic ecosystem practices that are the highest priority in terms of their sensitivity to climate change and their ability to be modified to address climate effects gives managers in the Chesapeake Bay watershed a set of robust tools for responding to climate change. Decision makers can review their management plans with the purpose of targeting high priority practices to adjust them – spatially, temporally, and in terms of the level and degree of the practice itself – to address the range of potential impacts anticipated from climatic changes. Managers may also find useful to know those decisions that were eliminated based on using broad criteria. Those practices were generally ones that are not influenced by climate-related variables, are made more frequently, or involve projects with a limited lifespan. Therefore, those practices are not necessary to review in management plans to adjust for climate change, since they exhibit no properties that make their effectiveness dependent on climatic changes.

3. BACKGROUND AND STUDY OBJECTIVES

Decision makers can take actions that ameliorate or exacerbate resource and ecosystem vulnerability to climate change. Because current climate and ecosystem conditions are not necessarily a reliable guide to future conditions, failing to consider climate change factors may lead to management actions that compound climate impacts ("maladaptive" actions). Alternatively, decision makers who act strategically to adapt their management actions to anticipated climate change impacts may reduce the associated risks and increase their odds of achieving long-term management goals. Therefore, it is essential that climate change scientists provide the appropriate information to decision makers across the breadth of organizations, levels of government, and public and private actors.

There has been a growing recognition that the usefulness and communication of climate change science information to the decision making community needs to improve. One such call was made in the Strategic Plan of the Climate Change Science Program (CCSP 2003). The CCSP described the critical role of decision support in climate science and built into their Plan a research area devoted to developing decision support resources. In addition to these decision resources, the National Academy of Sciences (NAS) called for the CCSP to "further develop its decision support activities, making sure to meet the needs of local, regional, national, and international decision makers" in their review of the CCSP Strategic Plan (NAS 2004). The NAS repeated their recommendation for further decision support research in their 2005 report, calling for federal agencies to support research focused on improving the tools and processes by which environmental decisions are supported (NAS 2005). This general call recognized the need for developing useful criteria to evaluate decisions and for developing and testing methods for structuring decision processes. The IPCC (2007) further endorsed the need for useful decision support, recommending research on decision processes and responses at various scales of decision making.

In response to the growing need for decision support to address the impacts of climate change, the Global Change Research Program within the U.S. Environmental Protection Agency has been working in partnership with stakeholders to provide information and tools to programs, managers, and other decision-makers to help them assess and respond to global change impacts on water quality and aquatic ecosystems. Research and assessment activities are focused on four areas: water infrastructure; ambient water quality; drinking water quality; and aquatic ecosystems. A major goal is the development of adaptation strategies to increase the resilience of water and watershed systems. Adaptation is defined by the Intergovernmental Panel on Climate Change (IPCC) as an "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC 2007). In the context of our program, adaptation refers to deliberate management actions taken to achieve and sustain water quality and ecosystem protection goals under present and future climatic conditions.

As part of the GCRP's research plan, the program developed an experimental approach to systematically and quantitatively identify and evaluate management activities that need to address climate change. The underlying tenets of this approach are that many (or most) of the adaptation measures that can be taken will be associated with ongoing decision-making processes made in the context of existing institutions and environmental issues; that development of information and tools are prerequisites for incorporating adaptation into existing decision frameworks; and that it is essential to set priorities for identifying where such decision support would be most useful. The approach in this study is targeted toward those decisions that equate to actual adaptation actions on the ground rather than those decisions affecting higher-level policies.

Focusing on that limited subset of decisions was necessary to successfully achieve the objective of this pilot project with the Chesapeake Bay Program--to test our experimental approach for its technical merit and usefulness as well as its ability to be applied to other programs. First, we conduct an inventory of a set of decisions that may be affected by climate change ("climate-relevant" decisions) and then we develop a quantitative ranking of those decisions based on criteria designed to measure their comparative need to address climate change. The inventory of climate-relevant decisions includes those for which (1) the decision itself is dependent on climate factors, such as design standards that are linked to weather or hydrologic extremes (e.g., the 2-year 24-hour rainfall event or the 100-year flood), or (2) the resource or system being managed is affected by weather or climate extremes, such as submerged aquatic vegetation that may be affected by changes in salinity, temperature, light penetration, water depth, water wave and current actions, and bottom sediment.

At the outset of the project, a number of EPA programs were considered as candidates for the pilot study. The Chesapeake Bay Program (CBP) was ultimately selected primarily for two reasons:

1. The CBP is concerned with both water quality and aquatic ecosystem management decisions in restoring the health of the Bay, which align with the mission of the GCRP. Other issues such as safe and adequate water supply are also important, and this approach is expected to be applicable to such issues.

2. Clearly identifiable implementation-level decisions (i.e., decisions implemented "on the ground" with outcomes that have a direct impact on water quality and aquatic ecosystems) are available. States have developed (1) lists of point source controls and non-point source best management practices (BMPs) to achieve water quality programmatic goals and (2) aquatic ecosystem management decisions in consultation with CBP to achieve "living resources" programmatic goals. Both implementation-level decisions and the regulatory or programmatic decisions that drive them could be affected by climate change stressors. The effectiveness of implementation-level decisions may be more influenced by climate change stressors than the higher-level regulatory or programmatic decisions because implementation-level decisions are often tied directly to weather variables such as precipitation, temperature, and storm patterns. Basing such decisions on historic climatic patterns could have direct consequences for their effectiveness. Thus, these decisions could greatly benefit from decision support regarding future changes in climate.

This draft report describes the framework for setting priorities for decision support and summarizes the methodology and results of the pilot-study (section 4), and provides a summary of the lessons learned relevant to decision support (section 5). A key part of the lessons learned will be the determination of whether this approach has merit, whether it is generalizable to other places and programs, and how this work should proceed if the approach shows promise. Appendices provide the list of decisions that were addressed, as well as the templates used to characterize key sources of information.

4. DESCRIPTION OF ASSESSMENT METHOD AND RESULTS FOR CHESAPEAKE BAY

Climate is an intrinsic driver of environmental processes and therefore a component of decision-making relevant to managing ecosystems and natural resources. Climate variability and change have the potential to alter the outcome of key decisions. Decision makers however may not be aware of the assumptions they make with respect to climate change. For example, water managers often rely on historical precipitation data, implicitly assuming stationarity or an unchanging climate. Since decision makers can act to ameliorate or exacerbate their vulnerability to climate change, it is critical that they have practical, yet systematic information and tools for identifying and understanding risks and opportunities posed by a dynamic climate.

For many organizations, the first step toward adaptation begins with understanding the implications of climate variability and change for key decisions. A systematic approach to assessing their vulnerability requires a method for identifying key climate change stressors and selecting decisions that may be affected by these climate change stressors, understanding the context and characteristics of important decisions, and prioritizing the allocation of resources for a more intensive effort to gather information to support decisions. These elements provide the foundation for the design and development of decision support resources. Yet, in many cases, decisions are made without adequate attention to these issues. The result is that many decision support resources fail to provide demonstrable benefits for decision makers.

In this section, we summarize information needed to provide useful support of decisions that may be affected by climate. We then illustrate how this information is used in the pilot study of the CBP to identify decisions likely to benefit from decision support resources. Our approach is based on the hypothesis that the provision of effective decision support for climate adaptation requires understanding the relevant local climate change stressors and linking them to the context and characteristics of relevant decisions and their associated organizations. We therefore: 1) identify key climate change stressors; 2) establish system vulnerabilities; and 3) link stressors and vulnerabilities to key decision centers. Major questions include:

- who needs help and information and might benefit from decision support;
- what kinds of help and information are needed, and what specific data needs are relevant (i.e., types of climate information or analytical tools that are needed);
- why this information is better than other, alternative information;

- where the decision support is to be applied, both geographically and in which specific policy domain; and
- how to generate this information and disseminate it to users to provide support (i.e., the format and means by which information or tools should be provided).

4.1 KEY DECISION ATTRIBUTES

For the purposes of this report, a "decision" is an action taken as part of efforts to manage ecosystems and resources relevant to EPA's focus areas of water resources and aquatic ecosystems. Attributes of a decision are characteristics of the natural or other resource managed, the environmental conditions that affect the resource, or the actions associated with the decision that make climate a potentially important factor in the decision making. For example, water quality and quantity are highly valued resources and are increasingly being threatened in the United States by population pressures and point and non-point source pollution from development, industry and agriculture. If climate change is projected to put additional pressure on this resource in the time frame within which water resource planning occurs, water managers should seriously consider adopting short- and long-term adaptation strategies.

Many decisions that are made routinely by resource planners in state and local government offices use information on weather variables such as precipitation, temperature, and storm patterns, or take into account other variables, such as sea level, that will be affected by future climate. It has long been recognized that short-term weather forecasting has positive value, depending on the quality of the forecast and its accuracy (Katz and Murphy, 1997; Rayner et al., 2005). For longer-term climate change, the question is under what circumstances decision support can assist decision makers in identifying and evaluating possible adaptation responses to climate change.

The purpose of decision support is to help decision makers identify and, when appropriate, encourage adaptive outcomes through decision making. Decision support can take on a variety of forms, ranging from systematic information provision, to capacity building, to software development or the provision of other tools. In determining an appropriate form of support for environmental decision making, key themes include information processes (sources and trust) as well as available resources and political, historical and cultural contexts (see Appendix A). These various forms illustrate that there is not a precise, universally accepted definition for the term "decision support." Moreover, the design of decision support systems must take into account not only the type of information used and any information gaps, but also the potential for decision makers to use decision support, given characteristics of the decision (e.g., how sensitive to long-term climate the decision) and of the decision process (e.g., the types of decision tools that are used).

In the current context, decision support could, for example, take the form of providing decision makers with general climate change scenarios or with scenarios of specific climate change variables that are tailored to local needs, or finding ways to make climate data more accessible, useful, and timely. Alternatively, decision support could involve providing education or assistance in understanding the nature and magnitude of potential climate impacts, including possible thresholds, and available adaptation measures to decision makers and constituencies they represent. Decision support could also involve interpreting and presenting uncertainty data in a manner that is useful to decision makers, or developing decision tools that incorporate information on projected future climate and the uncertainty of that information or other analytical software (Gamble et al. 2004).

The majority of academic literature on decision support is associated with mathematical decision analysis, operations research, and computer science (Pyke et al., 2007). However, these are only a subset of the perspectives required to design, develop, and deploy effective decision support resources. In addition to the disciplinary areas above, a number of other perspectives were reviewed to capture a broader set of attributes that may be applicable to providing effective decision support. These areas included: (1) Economics and policy literature on decision analysis to inform on the type of factors taken into account by decision makers and on tools that different organizations can choose to use to make decisions; (2) Public administration and policy literature to understand how policy is actually made, including how stakeholders participate in decisions and where information comes from; (3) Organizational behavior and management science to learn about the external factors that influence organizational behavior and about the constraints that organizations impose on the flow of information, authority, and resources; (4) Knowledge management to gain perspective on how information is validated and transmitted within organizations; (5) Climate impacts and adaptation research to learn about the magnitude of impacts and the types of adaptation strategies that may be relevant to different sectors and types of decisions; (6) Environmental decision-making processes and tools to understand how decisions are made in the environmental arena and attributes of organizations that relate to their use or acceptance of decision support tools; and (7) Existing frameworks for thinking about decision support for adaptation to see how and to whom other entities and organizations have provided decision support in the context of climate change.

Information from the review above was synthesized to develop a candidate list of attributes, or characteristics, of a decision that make it a better or worse candidate for decision support. The attributes and supporting literature are summarized in Appendix A. These attributes include *characteristics of the decision itself* (e.g., how much of an effect does the decision have, is the decision a "one-off" or will it be revisited periodically), *of the decision process* (e.g., is the process open or closed, is it flexible or rigid, does the process use detailed analyses), and *of the constraints* (e.g., laws, regulations, budgets) influencing the decision making processes. The types of characteristics included in this project are listed in Table 4-1. Not all characteristics will be equally relevant to all decisions or all types of decision makers. Decisions that are sensitive to climate change may be made not only by federal, state, and government resource managers, but also by members of Non-Governmental Organizations (NGOs), business, and the general public. Developing decision support for the variety of decision makers requires understanding the process of developing policies or actions to adapt to climate change in order to predict which problems areas will be seen as problems worthy of decisions by various policy makers.

Table 4-1. Key decision attributes

Characteristics of Decisions, Decision Processes, and Decision Constraints
Timing and time horizon (planning horizon, implementation period, and project lifespan)
Extent of reversibility
Magnitude of the projected impacts of climate change
Availability of adaptation responses
Degree to which current trends are maladaptive
Relative priority of threatened resource
Objectives and purpose of the decision
Decision rules and tools
Organizational resources and expertise
Decision linkages
Information or data currently used in decision making
Internal constraints
External constraints

Projected changes in climate and climate variability will not be critical determinants in all national, state and local decisions related to management of water resources and aquatic ecosystems. Further, only a subset of decisions where climate is a critical determinant will benefit from decision support. Different types of characteristics or attributes will be important in determining whether a particular organization and decision represents, potentially, a "good" candidate for decision support of some type. Appendix A provides a more detailed discussion of each attribute deemed important to consider based on the literature review, including a description of the attribute itself and an explanation of the reasoning behind the determination that the attribute is important. [1] Each of these decision attributes informed the subsequent steps in

[1] A number of characteristics of the decision making organization and the decision should be collected for the completeness of the inventory, although the attributes are not directly relevant to the question of whether decision

this pilot study and, accordingly, shaped the information collection and selection of decisions that are the focus of the pilot study detailed in the next sections.

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support is likely to be *successful*. These include general information on decision type, instance, organization, or institution.

4.2 DECISION INVENTORY

As discussed in Section 3, the availability of implementation-level decisions (i.e., decisions implemented “on the ground” with outcomes that have a direct impact on water quality and aquatic ecosystems) was one of the reasons that the CBP was selected as the pilot study (see Figure 4-1 for map of the Chesapeake Bay Watershed). These implementation-level decisions (rather than the regulatory or programmatic decisions that drive them) provide a good point of entry for determining whether climate change is relevant by analyzing specific decision attributes such as sensitivity to climate change, time horizon of the decision, and so on. For example, both implementation-level decisions and the regulatory or programmatic decisions that drive them could be affected by climate change stressors, but it is more likely to detect the direct effects of climate change on implementation-level decisions. Similarly, the time horizons (including planning, implementation, and lifespan) of implementation-level decisions can be clearly identified in many cases based on assumptions about investment lifetimes. One caveat to this approach, however, is that although it will provide the array of existing management decisions available to address climate change, it will not uncover the potential need for new management practices that are not currently employed. Similarly, focusing on implementation-level water quality decisions places an emphasis on non-point sources, since many point source measures are largely driven by regulatory or programmatic decisions.

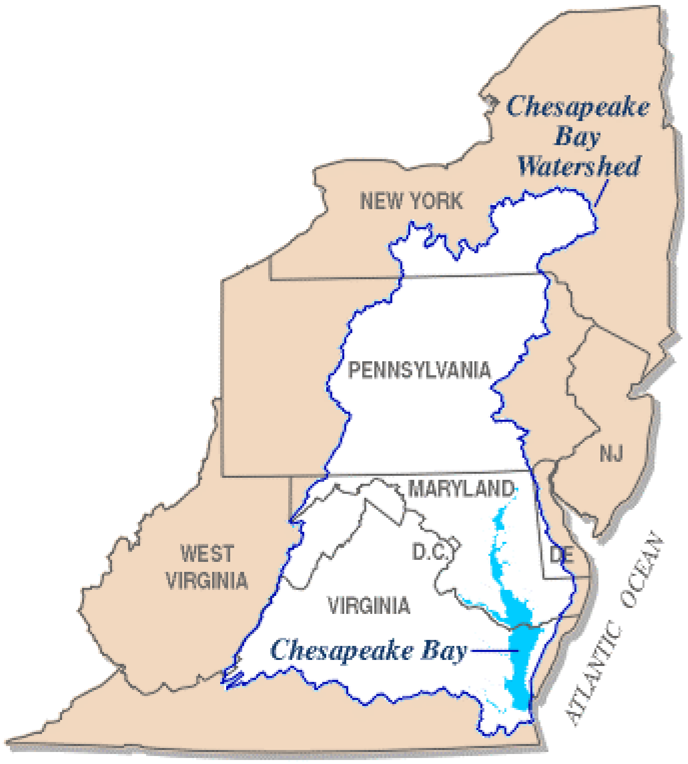


Figure 4-1. Map of Chesapeake Bay Watershed.

The initial inventory of decisions was developed based on (1) lists of point source controls and non-point source BMPs to achieve water quality programmatic goals and (2) aquatic ecosystem management decisions to achieve "living resources" programmatic goals. A variety of sources were consulted, including the Chesapeake Bay Watershed's state tributary plans for Virginia, Maryland, Pennsylvania, and Washington, D.C. For the full list of the initial set of decisions compiled, see Appendix B and C. For an example of a tributary strategy, see Pennsylvania's 2004 Strategy at http://www.depweb.state.pa.us/chesapeake/lib/chesapeake/pdfs/tribstrategy.pdf.

4.2.1 Water Quality Decisions

A list of 123 water quality-related decisions (also referred to as practices throughout the rest of this report) was compiled, primarily based on the Pennsylvania, Virginia, and Maryland tributary strategies. Each water quality practice was classified as one of four types:

- urban non-point source;

- agricultural non-point source;
- forest non-point source; or
- point source.

Each practice was then sub-classified as one of the following:

- forestry;
- water resources;
- stormwater;
- nutrient management;
- septic; or
- land use/land management

This categorization scheme enabled comparison across practice types at later stages in the selection process described below. Some examples of water quality practices and this classification scheme are shown in Table 4-2.

Table 4-2. Examples of Water Quality-Related Practices and Classification Scheme

Category	Sub-Category	Specific Practice
Agricultural NPS	Land Use/Land Management	Riparian forest buffers
Agricultural NPS	Land Use/Land Management	Acres conservation plans (farm plans)
Agricultural NPS	Land Use/Land Management	Retirement of highly erodible land-trees
Urban NPS	Stormwater	Stormwater management – wet ponds & wetlands
Urban NPS	Stormwater	Stormwater management filtering practices

Many of the practices were similar across the state tributary strategies. We grouped similar practices, which condensed the list from 123 down to 67 decisions (Appendix B and C).

4.3.2 Aquatic Ecosystem Decisions

The list of 23 aquatic ecosystem decisions focused on natural resource management activities that fell within the scope of the CBP Living Resources Subcommittee. The list was primarily derived from the Chesapeake 2000 Bay Agreement, the CBP, and NOAA Fisheries Ecosystem Plan. The ecosystem management practices were classified into one of the following three categories:

- habitat protection and/or restoration;
- biological population management; or
- non-native species management.

Some examples of aquatic ecosystem practices and this classification scheme are shown in Table 4-3.

Table 4-3. Examples of Aquatic Ecosystem Practices and Classification Scheme

Category	General Practice	Specific Practice
Habitat protection and/or restoration	Restore submerged aquatic vegetation (SAV)	Establish SAV beds that can serve as a source of plant material
Non-native species management	Invasive species management	Manage occurrence of *Phragmites australis* (common reed)
Habitat protection and/or restoration	Fishery restoration	Build fish passageways

4.3 Selection Process for Decisions

After compiling the initial list of water quality and aquatic ecosystem decisions, three qualitative selection criteria were developed and applied to the list. The purpose of the selection criteria were to efficiently assess a large list of decisions to identify which would likely be affected by changes in climate and of those decisions, which would be good candidates for decision support. The selection criteria offer a systematic approach to narrow down the initial list of decisions to a manageable subset that can be further analyzed for their relative benefit from decision support tools.

The literature review conducted at the outset of the project informed the development of the criteria. Each criterion addresses one or more of the characteristics of the decision that play a key role in determining the usefulness of decision support for adapting to climate change.

4.3.1 Criterion 1: Climate Change Adaptation Potential

The first criterion evaluated the sensitivity of the system to climate stressors and the capacity of the practice to ameliorate the impacts of climate change ("adaptation potential"). This criterion considered a few key climate change impacts that would be likely to affect the success of a management decision or practice intended to protect water quality or aquatic ecosystems. The climate change impacts considered under this first criterion were based on their relevance to the different sets of water quality and aquatic ecosystem decisions but are not exhaustive of all key impacts. Rather, they capture enough of the major impacts to allow for selection of those practices in greatest need of decision support.

The following climate change drivers expected to lead to impacts on water quality were considered in the first screening of water quality decisions:

- Lower low-flow events;
- Higher high-flow events; and
- Increased water temperatures.

The following climate change drivers expected to lead to impacts on aquatic ecosystems were considered in the first screening of aquatic ecosystem decisions:

- Increased water temperature;
- More intense or total precipitation resulting in increased runoff loads of nutrients and sediments;
- Altered flow regimes; and
- Sea level rise.

The effectiveness of each practice in the face of these climate change impacts was qualitatively assessed. For a practice to be selected as having climate change adaptation potential, the practice and resource being protected must be sensitive to at least one of the three or four climate change impacts considered for water quality or aquatic ecosystem practices, respectively. The management practice must also provide potential protection against or reduction in at least one of the climate change impacts evaluated. For example, the aquatic ecosystem practice of restoring submerged aquatic vegetation (SAV) protects shorelines and reduces shoreline erosion regardless of the presence or absence of climate change stressors. Increased sediment input due to climate change (e.g., more frequent and intense precipitation events) is expected to lead to decreased water clarity and, thus, declines in SAV. Restoring SAV will reduce the effects of increased sedimentation and protect shorelines, since it will counteract SAV losses resulting from climate change impacts. Because the practice is sensitive to several of the evaluated climate change impacts and an adaptation potential exists, it is selected for further consideration for decision support.

As a second example, a forested buffer strip protects the adjacent river or stream from other existing stressors (e.g., increases in impervious surfaces from changes in land use) regardless of the presence or absence of climate change stressors. Larger storm events due to climate change are expected to lead to an increased intensity of precipitation in some regions, and thus to an increase in amount of runoff traveling to rivers and streams. Restoring forested buffer strips will be effective at reducing the effects of larger storm events, since it will aid in the infiltration of stormwater and retention of sediment, thus counteracting the effects of increased runoff. In addition to aiding with infiltration, forested buffer strips also increase evapotranspiration and help moderate temperatures due to the increased forest cover. Since this practice is sensitive to several of the evaluated climate change impacts and an adaptation potential exists, it is selected for further consideration.

After applying the first criterion to the 90 decisions (67 water quality, 23 aquatic ecosystem), 69 (48 water quality, 21 aquatic ecosystem) remained (Appendix B and C).

4.3.2 Criterion 2: Dimensions of Timeliness

The second criterion addresses the timing and time horizon of the decisions, by analyzing the sum of years associated with:

- Planning horizon (i.e., how far in advance does planning begin for future action?),

- Implementation period (i.e., how much time is required once a decision is made to complete the project or fully implement the decision?), and
- Project lifespan (i.e., how long will the project be in place, once completed?).

After examining a frequency histogram of the timeliness criterion (Figure 4-2), it was determined that there were a number of water quality practices that had a total length of time of 20 years or less and a number that clustered from 27 or more years. Therefore, it was determined that 25 years would serve as a good cutoff point for practices considered to be "long term," since it seems to comport with the planning horizons for water quality decision making. The timeliness criterion was less useful for determining which aquatic ecosystem practices should be selected since most of them have an indefinite lifetime and remained in the set after this criterion was applied. Since the criterion was more effective in selecting some of the water quality practices, Figure 4-2 omits the aquatic ecosystem practices and only shows the timeliness of the water quality practices.

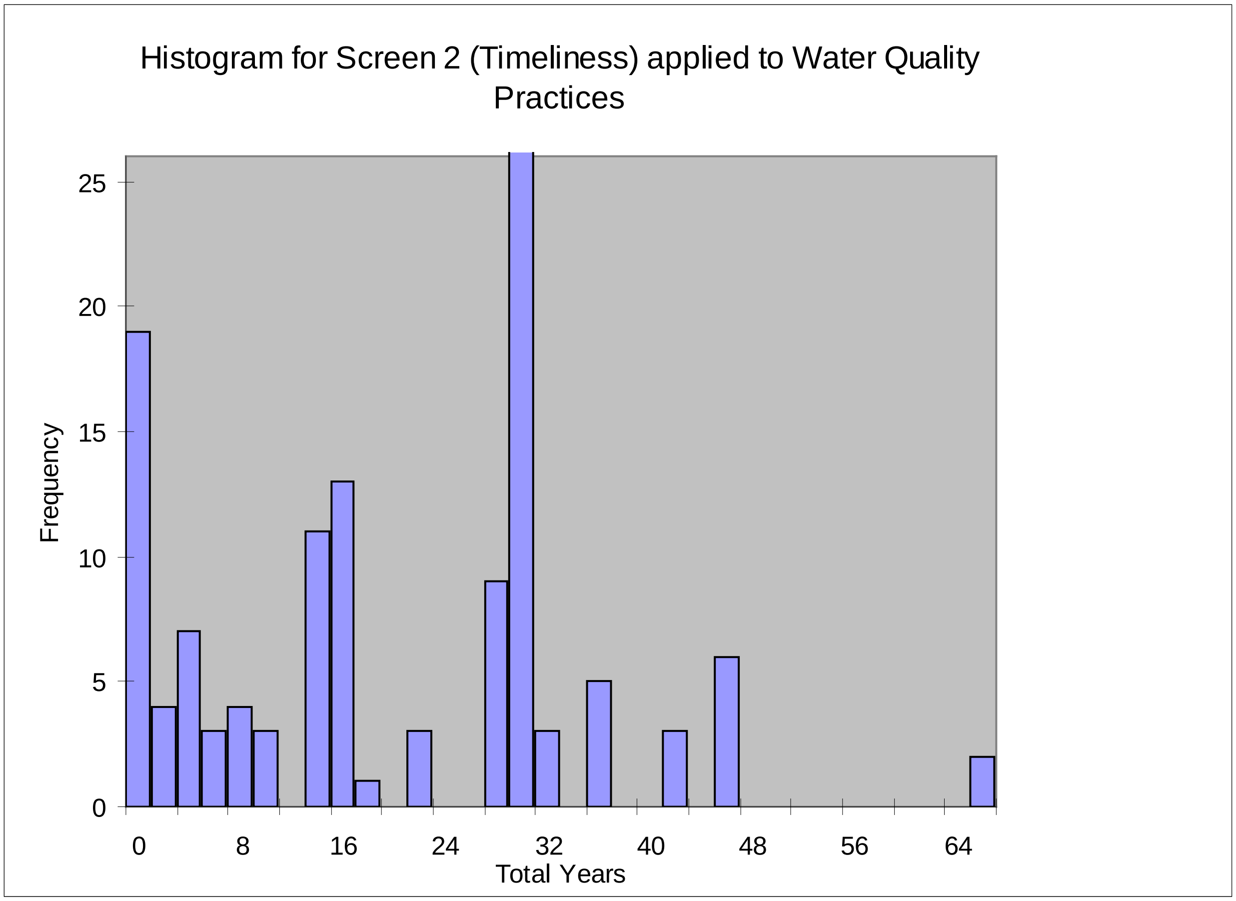


Figure 4-2. Water Quality Practices: histogram displaying the frequency (gray bars, right y-axis) of "timeliness".

As described in Section 4.1, long term decisions (defined in this study as those that are expected to perform for a total of at least 25 years) are better candidates for support than decisions that are made yearly. This is because the consequences of decisions would need to be in place long enough for climate change to be relevant to design and performance. After applying criterion 2, 42 decisions remained (21 water quality, 21 aquatic ecosystem).

4.3.3 Criterion 3: Reversibility

The third criterion attempted to address the reversibility of the decisions[2]. For each practice, this criterion looked at:

- Environmental reversibility (i.e., does the decision result in irreversible, or difficult-to-reverse, environmental changes and therefore a loss of future options?),
- Financial reversibility (i.e., does the practice represent a costs that cannot be recovered?),
- Long-term commitment (i.e., will the decision have long-term consequences or be made infrequently?), and
- Foreclosure of other options (i.e., by implementing this practice, are you limiting the availability of other practices in the future?).

Continuing from the examples above, establishing SAV beds does not foreclose other environmental options as the beds can easily be destroyed or replanted. In addition, the decision does not require a large financial investment or a long-term commitment, since it is an ongoing effort that could be interrupted at any point. An example of a potentially irreversible ecological decision is introducing diploid Asian Suminoe oysters. Unlike the triploid oysters, which are assumed to have no potential for multiplying in the Bay, the diploid oysters would reproduce and potentially have irreversible effects on ecological community structure once the oysters become established.

Decisions that were classified as irreversible according to any of these factors listed above (environmental or financial reversibility, long-term commitment, or foreclosure of other options) would pass through this third screen. Characterizing these factors proved difficult and

[2] Reversibility can refer to both environmental effects and the decision itself. Irreversible environmental effects are important for decisions; for example, if action (or failure to act) results in the loss of a natural resource that cannot be recovered, or requires many years (or significant investment) to rebuild, then the effects are somewhat irreversible, and decision makers may place a high priority on avoiding those irreversibilities. The practice may also have an element of irreversibility, if, for example, the decision involves investment in physical or natural capital. Physical capital irreversibility tends to be synonymous with large, long-term investments, and so is captured by other criteria here. In the current context, the avoidance of irreversible environmental effects is implicit in the choice of the CB as the focus of the study, since the Bay is considered to be a resource under stress and therefore vulnerable to irreversible, or difficult to reverse, changes. Thus, the primary use of this characteristic in the screening presented subsequently is to capture irreversibilities in environmental components of the decision.

highly subjective, however, because most practices can be reversed at some (potentially very high) financial cost, and therefore this criterion was ultimately regarded as having little utility. Thus, it did not further select from the set that remained after criterion 2 was applied.

4.3.4 Selection Results

Forty-two of the initial 146 decisions were selected after applying the first two criteria, including 21 water quality decisions and 21 aquatic ecosystem decisions (Appendix B and C). We determined that there still remained minimal distinctions among some of the remaining decisions and decided to further consolidate several of them. This consolidation reduced the total by 10 decisions, leaving 32 decisions (or management practices that they dictate)—14 of which were water quality and 18 of which were aquatic ecosystem practices (see Table 4-4).

Table 4-4. List of practices selected after Criteria 1 and 2 were applied to decisions database

WATER QUALITY	
Category	**Practice**
Forestry	Forest Conservation (Forest Conservation Act)
Forestry	Riparian Forest Buffers - Urban
Forestry	Tree Planting
Land Use/ Land Mgmt	Abandoned Mined Land Reclamation
Land Use/ Land Mgmt	CREP Wetland Restoration
Land Use/ Land Mgmt	Reduction in Urban Growth
Land Use/ Land Mgmt	Riparian Forest/Woodland Buffers – Agriculture
Land Use/ Land Mgmt	Wetlands - Mixed Open Land
Nutrient Management	POTW Standards for Discharge Permits
Stormwater	Stormwater Management - Dry Extended Retention/Detention Ponds
Stormwater	Stormwater Management - Filtering Practices
Stormwater	Stormwater Management - Infiltration Practices
Stormwater	Stormwater Management - Wet Ponds & Wetlands
Water resources	Urban Stream Restoration
AQUATIC ECOSYSTEMS/LIVING RESOURCES	
Practice	**Specific Practice**
Build living shorelines	Construct shallow water rock sills and employ organic materials
Fishery Restoration	Build fish passageways
Fishery Restoration	Remove physical and chemical blockages
Fishery Restoration	Maintain/protect upstream spawning habitats
Fishery Restoration	Manage fishery harvest levels
Increase Oyster populations	Breed triploid Asian Suminoe Oysters
Increase Oyster populations	Introduce diploid Asian Suminoe Oysters
Invasive Species Management	*Phragmites australis* (common reed)
Invasive Species Management	*Lythrum salicaria* (purple loosestrife)
Invasive Species Management	*Trapa natans* (water chestnut)
Invasive Species Management	*Myocastor coypus* (Nutria)
Invasive Species Management	*Dreissena polymorpha* (zebra mussels)
Restore Native Oyster Populations	Rebuild oyster habitats using alternative substances
Restore Native Oyster Populations	Rebuild oyster habitats using old oyster shells

Restore Native Oyster Populations	Create sanctuaries
Restore Native Oyster Populations	Aquaculture
Restore Native Oyster Populations	Employ disease-resistant management techniques
Restore Submerged Aquatic Vegetation	Including establish SAV beds that can serve as a source of plant material; Propagate SAV in laboratories and nurseries; and Harvest SAV from existing wild areas

4.4 DETAILED SELECTION ON DECISION ATTRIBUTES

Further information gathering was undertaken to assess additional decision attributes for the 32 decisions. The information gathered was based on the literature findings (see Appendix A), and was intended to populate the list of key decision attributes (see Section 4.1). Decision templates (see Appendix D) were completed for each of the 32 decisions to summarize the information collected during the selection criteria stage (e.g., time horizon, reversibility). Additional information was gathered primarily from readily available sources, including the Pennsylvania, Maryland, and Virginia Tributary Strategy documents, EPA documents on total maximum daily load (TMDL) compliance, CBP literature, and publicly available information on the Internet. This information helped to fill in gaps in understanding the decisions.

3.4.1 Scoring and Prioritizing Decisions

Once information was gathered from readily available sources, the next step was to develop a methodology to prioritize the 32 decisions. The method used for this study employs a form of expert judgement. In general, judgments are used throughout studies of any complex technical problems, such as when making the determination of whether a study should be done and what elements should be included, or in the selection of models and analysis forms for a particular study (Keeney and von Winterfeldt, 1991). Examples of situations in which expert judgment or elicitation is useful include when significant gaps in data exist, when data require careful interpretation, when data may seem conflicting or inconsistent, or in the choice and construction of models. According to NRC (2002), the rigorous use of expert elicitation for the analyses of risks is considered to be quality science. Expert judgment was used in this pilot study because of the relative scarcity of data on the performance of best practices for our selected attributes. Thus we had to make educated assumptions on their performance based on published literature and our own experience. These assumptions then required subsequent judgment by practitioners about their plausibility. Our use of expert judgment is consistent with EPA's general support for such an approach when conducting risk or uncertainty analysis.[3] Several examples of EPA's approach include application to components of risk assessment such as hazard assessment and dose-response evaluation (e.g., U.S. EPA 2004), and risk characterization (e.g., U.S. EPA 2005).

Similar to our decision assessment approach, the general steps in the process of elicitation may include determination of the quantities to be assessed, review of the literature, preliminary analysis of values (or uncertainty bounds/probabilities for estimates or model parameters), development of an elicitation protocol, selection of experts and elicitation of values, and finally, analysis of the results, aggregation, and resolution of disagreements (adapted from Walker, et al. 2001). Often, there are also trainings held for experts on elicitation techniques. For this study, our process was first to review the literature, use the findings to conduct our own preliminary assessment of values for each decision attribute, and then use experts selected primarily from the Chesapeake Bay Program Science and Technical Advisory Board (STAC) to review our values and provide their own judgment about those values. The specifics of our approach are described below.

First, decision attributes were grouped into 14 categories using descriptive affirmative statements that served to characterize the practices and the systems in which they are typically used. For example, the decision attributes describing the planning period, implementation period, and project lifetime fell under the affirmative statement "*Planning, implementation, and performance associated with this management action will occur over a long period of time*." Similarly, the decision attributes describing the total investment over the lifetime of a project and the estimated cost of annual payments for the project were grouped under the statement "*This management action involves a capital intensive investment.*"

The affirmative statements used to describe the 14 categories (Box 4-1) made it possible to score the "truth" of each statement. We assessed the "truth" of each of the 14 statements and assigned a score on a scale of 1 to 5 (where 1 = not true and 5 = true) based on literature and

[3] While experts play a critical role in the decision-making process, the involvement of non-scientific stakeholders can be equally critical in the decision making process. As noted later in the lessons learned and conclusions, future work in this area should ensure greater involvement of these stakeholders.

reference documents gathered on each of the decision attributes during and after the selection phase. Assigning a score to each statement made it possible to test further prioritization of decisions using a systematic approach that allowed for comparing and ranking based on their relative "truth". These values have no specific quantitative meaning except to order decisions, and should therefore be viewed as qualitative in nature. For example, the difference between a "truth" score of "1" versus "2" does not mean that an attribute receiving a "2" is twice as true as an attribute receiving a "1". Likewise, an attribute receiving a "4" is not necessarily twice as true as an attribute receiving a "2", and so forth.

Some of the statements addressed similar climate change decision support factors, so the 14 statements were further grouped into four broad categorical criteria:

1. climate sensitivity;
2. suitability;
3. priority; and
4. information availability.

This grouping was performed in an effort to minimize correlation between statements. For example, statements 1 and 2 in Box 4-1 address the vulnerability of the resource and management practice to climate change, and statements 3 and 4 address time sensitivity with respect to climate change. Both vulnerability and time sensitivity deal with climate sensitivity of the management practice (category 1 above). Similarly, statements addressing factors such as cost, time horizon, and the adaptive capacity of institutions in charge of implementing management practices help determine the suitability of the management practice to decision support (category 2 above). Two more statements address priority of the resource and management practice (category 3 above), and three statements relate to availability of information regarding the resource, climate change impacts on the resource, and the management practice (category 4 above). The diagram in Box 4-2 displays how the statements were categorized.

Box 4-1. Decision Attribute Template Statements

1. *Restoration or protection goals for this system are highly vulnerable to climate change.*
2. *The performance of this management practice is highly vulnerable to climate change.*
3. *Planning, implementation, and performance associated with this management action will occur over a long period of time.*
4. *The management action involves a near-term decision with important, long-term consequences.*
5. *The resource addressed by this management action is a very high priority issue for water quality or living resource restoration or protection efforts in the Chesapeake Bay watershed.*
6. *This management action involves a capital intensive investment.*
7. *Decision-makers have a high degree of flexibility in how they design or use this management practice.*
8. *The institutions that carry out this management action have high levels of adaptive capacity.*
9. *Adaptive changes in this management practice are likely to be limited by internal constraints within the implementing organizations.*
10. *Adaptive changes in this management practice are likely to be limited by external constraints outside of the implementing organizations.*
11. *Relative to other systems and practices in the Chesapeake Bay, a great deal is known about ecological and environmental processes relevant to this management action.*
12. *Enough information is available to anticipate the consequences of climate change for the condition of the system associated with this management action.*
13. *Enough information is available to anticipate the consequences of climate change for the performance of this management action.*
14. *This system and associated management practice are most likely to benefit from immediate investments in research to support the development of new decision support resources to facilitate adaptation to climate change.*

The logical "If-and/or" statements shown in Box 4-2 attempted to address the issue of dependence among the statements. These logical "If-and/or" statements were used to aggregate the 14 scores into four scores, one for each categorical criterion (climate sensitivity, suitability, priority, information availability). In the case of an "OR" statement, an "If" statement was used to compare the scores and then return the highest score (letting the highest score "pass through"). For example, statements 1 and 2 each address the issue of climate vulnerability, and an "OR" statement was applied based on the following logic: if either the resource itself or the performance of the management practice was considered vulnerable to climate change, then the management practice would be vulnerable to climate change. If statement 1 was assigned a score of 3 and statement 2 was assigned a score of 4, a 4 would be assigned for the sub-category of vulnerability to climate change. In essence, the score of 4 would "pass through" for this "OR" statement.

In the case of an "AND" statement, scores were multiplied. EPA determined that a management practice had to be both vulnerable to climate change and time sensitive to the impacts of climate change to be considered climate-sensitive. Therefore, the scores from the *vulnerable to climate change* sub-category and the *time sensitivity* sub-category were multiplied to produce a final subtotal score for the climate sensitivity category.

The four scores were normalized by dividing the score that resulted for each categorical criterion by the maximum of the range of scores falling within that category, and then multiplied again to produce an overall final score for each of the 32 decisions. All final scores then fell between 0 and 1. For example, if all statements for a given practice were true (on a scale of 0 = inaccurate or false and 5 = true or accurate), the process of normalizing the scores for this practice would result in a final single score of 1. Using this scoring scheme, the decisions were then ordered based on these final scores.

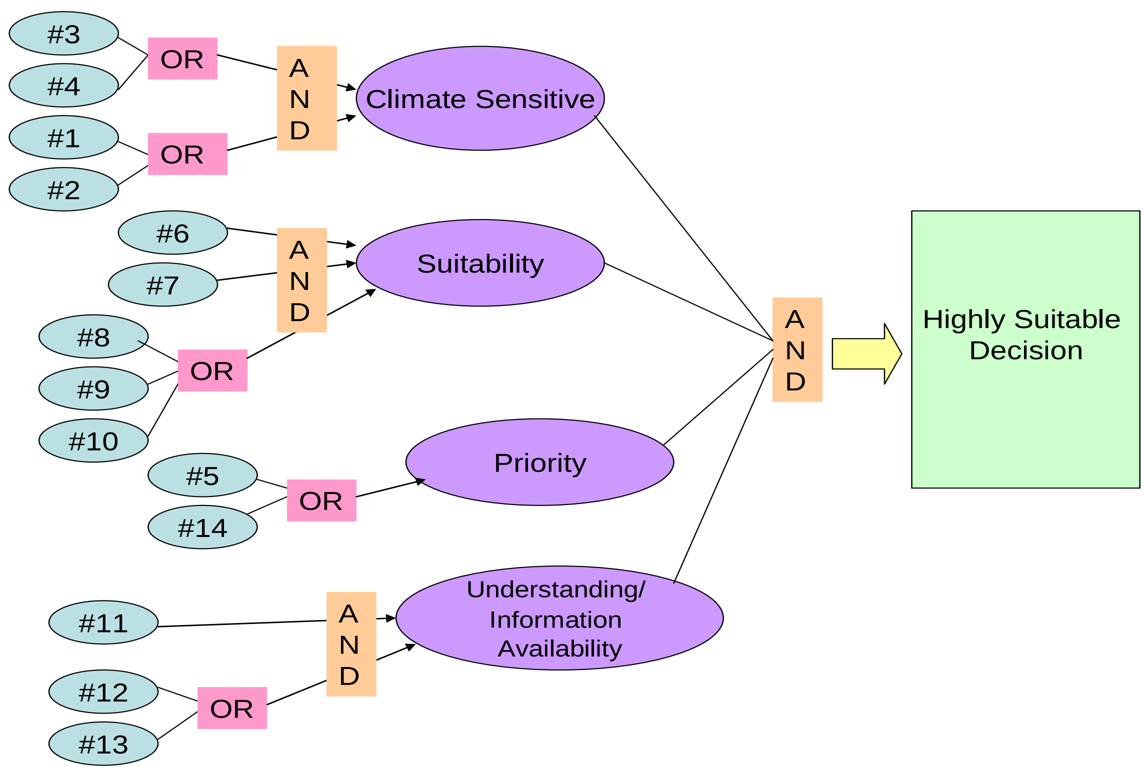
3.4.2 Developing a Prioritization Tool

A Microsoft® Excel-based tool was developed to assist in quickly comparing and ranking decisions according to the methodology described in the preceding section. The tool enabled quick quantitative comparison of scores by utilizing spreadsheet functions to automate the use of logical "If-and/or" statements. An Excel-based format was used because it is transparent, reproducible, and facilitates sensitivity analyses.

The tool allows users to select and weight the four categorical criteria (e.g., climate sensitivity, information availability) according to their individual priorities. This option provides flexibility to the user by allowing the user to evaluate decisions based on their priorities with respect to climate change impacts on resources and management practices. Adjusting the selection of the categorical criteria and the weights of each of the selected categorical criteria has an impact on the final rankings, which is discussed in more detail in Section 4.4.4.

Box 4-2. Logical "If-and/or" Statements

1. Climate Sensitivity: If the decision is highly **time sensitive** (question #3 OR #4) AND the resource/management practice is highly **vulnerable to climate change** (question #1 OR #2), then the resource/management practice is highly climate sensitive.
2. Suitability: If **capital investment** is high(est) (question #6) AND **design flexibility** of the management practice is high(est) (question #7) AND the managing institution's **adaptive capacity** is high(est) (question #8 OR #9 OR #10) then suitability/adaptability is high(est).
3. Priority: If the resource is a high **priority** (question #5) OR the expected **benefit from decision support system** is high (question #14), then the resource/management practice is a high(est) priority.
4. Information Availability: If **information on the environmental and ecological functions of the resource** is most extensive (question #11) AND **information regarding climate change's impacts on the resource/management practice** is most extensive (question #12 OR #13), then knowledge-base concerning the resource/management practice is broad(est).



4.4.3 Expert Elicitation and Revision of Scores

The initial scoring of the 14 statements for each of the management practices was followed by an expert elicitation to: (1) confirm the categorization of the decision attributes; (2) collect information that was not readily available through literature and Internet searches (e.g., internal and external constraints within the implementing organizations); (3) confirm that the sources consulted provided the best available information on the decision attributes, and (4) review and provide their own determination of the "truth" of each of the 14 statements for the 32 decisions. Experts were selected based on their scientific and technical expertise in Chesapeake Bay resource management, which was assessed based on their involvement in the CBP Science and Technical Advisory Committee (STAC) or from citations in literature reviewed for this project.

Eighteen experts were selected to participate in this exercise, with at least one expert reviewing each of the 14 water quality decision templates and 14 of the 18 ecosystem decision templates. The ecosystem management practices not reviewed included: *invasive species management - zebra mussels*; *rebuild oyster habitats using alternative substances*; *rebuild oyster habitats using old oyster shells*; and *create sanctuaries*. Experts supplied their own scores where they differed from our initial scores and provided the rationale for doing so along with recommendations about specific additional resources to consult (see Appendix D for templates, our initial scores, and expert reviewer scores).

Experts agreed with the initial scores in about 50 percent of cases. Of those scores with which experts disagreed, the vast majority disagreed by only 1 point on the 5-point scale. In order to assess the sensitivity of the final prioritization outcome to the individual scores on decision attribute statements, three separate scenarios were analyzed. The three scenarios compared the use of: 1) all of the initial scores; 2) all of the expert reviewers' suggested scores (where they disagreed with the initial scores); and 3) a hybrid set of scores that selectively replaced the initial scores with the expert reviewers' suggested scores based on the following rules:

- Statements 1, 2, 3, and 4: Adopted the experts' suggested score when an explanation was provided for why they chose to change the score. Where experts' scores varied, an average of the experts' scores was adopted. When the average was a midpoint between two whole numbers, the score was rounded up.

- Statements 6, 11, 14: Retained initial score, because the initial scoring had the advantage of internal consistency (i.e., EPA had data on cost of all management practices and could compare the costs relative to other management practices).

- Statements 5, 7: Adopted experts' suggested score. Experts' explanations tended to include additional information EPA may have not considered.

- Statements 8, 9, 10: Adopted experts' suggested score. Since several of the reviewers work in or with institutions dealing with management practices and policies, EPA assumed that they would have a better idea as to the adaptive capacity and internal and external constraints within those institutions.

- Statements 11, 12: Adopted experts' suggested score. Made an assumption that experts have been doing research on these ecosystems and management practices affecting these ecosystems for an extensive period of time and therefore know what information exists.

This approach to deriving the hybrid scenario was an informal means of handling differences in scoring between EPA and the experts and among the experts themselves. In formal expert elicitation, resolution is generally achieved through continued dialogue with participating experts. However, the transparent description above of what was done and the logic behind those choices provides the means for others to understand how we resolved disagreements. (See Appendix D for initial, expert, and hybrid scores with accompanying descriptions of how differences were resolved on an attribute-by-attribute basis.)

The sensitivity analysis conducted of these scenarios shows that the final prioritization rankings were sensitive to changes in scores of statements. The final ordering of the management practices differed according to whether scores under scenario 1, 2, or 3 were used, as can be seen in Table 4-5 and Table 4-6.

In general, a change in score affected the final prioritization when a statement was one of two statements in an "OR" branch and the change in score caused the "OR" function to choose the changed score. For example, if both scores for statements 1 and 2 had originally been 3, then the "OR" function passed that score through as a 3. However, if the set of scores based on expert review changed one of those statements to a score of 4, then the "OR" function would pass the 4 as the score for that branch, thereby changing the overall score for that management practice.

Table 4-5. Top five ecosystem management decisions resulting under the three scenarios

[1] Initial scores	[2] Expert reviewer scores	[3] Hybrid scores
Breed triploid Asian Suminoe Oysters	Invasive species management - *Phragmites australis* (common reed)	Aquaculture
Aquaculture	Build fish passageways	Breed triploid Asian Suminoe Oysters
Manage fishery harvest levels	Create sanctuaries	Create sanctuaries
Rebuild oyster habitats using alternative substances	Rebuild oyster habitats using old oyster shells	Rebuild oyster habitats using old oyster shells
Create sanctuaries	Aquaculture	Rebuild oyster habitats using alternative substances

Table 4-6. Top five water quality management decisions resulting under the three scenarios

[1] Initial scores	[2] Expert reviewer scores	[3] Hybrid scores
Stormwater Management – Filtering Practices	POTW Standards for Discharge Permits	POTW Standards for Discharge Permits
Stormwater Management – Infiltration Practices	Riparian Forest Buffers - Urban	Stormwater Management – Filtering Practices
POTWs Standards for Discharge Permits	Forest Conservation (Forest Conservation Act)	Stormwater Management – Infiltration Practices
Wetlands – Mixed Open Land	Urban Stream Restoration	Urban Stream Restoration
Riparian Forest Buffers - Urban	Stormwater Management – Filtering Practices	Riparian Forest Buffers - Urban

4.4.4 Results of Prioritization Tool Testing

Three different scenarios were tested using the methodological approach and the prioritization tool described above in an attempt to prioritize climate-sensitive decisions that afford the best opportunities for decision support within the CBP. The results of changing the scores on the 14 statements characterizing decision attributes have already been discussed in

Section 4.4.3. Additional scenarios were created to assess the sensitivity of the final scores and rankings to changes in the weights of the four categorical criteria. For example, a scenario assigning an equal 25 percent weight to each category resulted in the rankings shown in Table 4-7, using the hybrid scenario discussed in Section 4.4.3.

Table 4-7. Water quality and ecosystem management practices ranked based on equal weighting (25%) to the four categories. The top five ranked practices shown here.

Water Quality		Aquatic Ecosystems	
POTWs Standards for Discharge Permits	1	Aquaculture	1
Stormwater Management – Filtering Practices	2	Breed triploid Asian Suminoe Oysters	2
Stormwater Management – Infiltration Practices	3	Create sanctuaries	3
Urban Stream Restoration	4	Rebuild oyster habitats using oyster shells	3
Riparian Forest Buffers - Urban	5	Rebuild oyster habitats using alternative substances	5

An alternative weighting scheme, where 50 percent weight was assigned to climate sensitivity, 20 percent to suitability, 20 percent to priority and 10 percent to information provided different results. As Table 4-8 shows, for water quality, two management practices that were not in the top five in Table 4-7, (1) *urban stream restoration* and (2) *stormwater management-- wet ponds and wetlands*, are in the top five as a result of the change in the weighting scheme. The changes for aquatic ecosystem practices are more subtle, as four of the five practices that were in the top five in Table 4-7 appear in Table 4-8, although in a slightly different order, e.g. using the equal weighting, *create sanctuaries* is ranked fifth whereas with the alternative weighting scheme it ranks first.

Table 4-8. Water quality and ecosystem management practices ranked based on the following weighting scheme: climate sensitivity 50%, suitability 20%, priority 20%, information 10%. The top five ranked shown here.

Water Quality		Aquatic Ecosystems	
POTWs Standards for Discharge Permits	1	Aquaculture	1

s			
Urban Stream Restoration	2	Create sanctuaries	2
Stormwater Management - Filtering Practices	3	Living shorelines	3
Stormwater Management - Wet Ponds & Wetlands	3	Breed triploid Asian Suminoe Oysters	4
Stormwater Management – Infiltration Practices	3	Rebuild oyster habitats using alternative substances	4

Nine different scenarios were tested in total. The following water quality management practices consistently ranked in the top five for all of the scenarios:

- Urban Stream Restoration
- Stormwater Management: Filtering Practices
- POTWs Standards for Discharge Permits

Similarly, the following ecosystem management practice is consistently ranked in the top five:

- Living shorelines

Of the ecosystem management practices, the following two -- *managing fishery harvest levels* and *rebuilding oyster habitats using alternative substances* -- consistently ranked in the top ten. Of the water quality management practices, *urban stream restoration, stormwater management—infiltration, and mixed open wetlands* consistently ranked in the top ten.

The results of these different scenarios demonstrated that the prioritization approach was sensitive to changes in scores and different criteria weighting schemes. The detailed analysis and selection process showed that there were many ways to further narrow the list of candidate decisions. However, the additional step to order decisions for prioritization took much longer than the initial qualitative selection process (criteria 1 and 2) and required much more information. It may be more efficient to engage experts earlier (and more systematically) in the process, and to seek feedback on the characteristics of ongoing decisions made in climate-sensitive water quality and ecosystem management topics.

On balance, as conducted in the pilot study, the utility of the detailed prioritization step was difficult to discern. The rankings do not seem to provide a better basis for focusing decision support efforts than qualitative selection criteria 1 and 2. All of the decisions that made it through the initial selection exercise are good candidates for decision support, and as discussed further below, it may have been more informative to prioritize among the 32 decisions by engaging stakeholders from the CBP in the effort, rather than applying a complex semi-quantitative system of prioritization.

5. FINDINGS AND CONCLUSIONS

5.1 OVERALL PROJECT FINDINGS AND LESSONS LEARNED

The goal for this pilot study was to formalize our philosophy of how to effectively support adaptation to climate change, which is to use as our starting point ongoing planning processes and decisions geared toward achieving environmental management goals, and developing a systematic approach for collecting and prioritizing decisions according to specific attributes in order to provide adaptation information and research to those in greatest need and with greatest potential to address climate change impacts. This study represents one approach to testing the applicability of our philosophy. In this study we assessed the climate relevance of a specific set of decisions in a specific location -- the Chesapeake Bay watershed. The scalability of this approach to assess the climate relevance of other types of decisions or similar decisions in different locations remains to be tested.

Overall, the approach described in this report demonstrates the value of employing broad criteria to select the appropriate subset of the universe of water quality and aquatic ecosystem decisions for more detailed analysis and prioritization. Such a selection process already begins to provide information on the degree to which management of the Bay depends on practices that are sensitive to climate change, and gives states and the Bay some sense of the level of effort needed to address climate change effects in their plans. The criteria used to select decisions in this study are (1) *climate change adaptation potential* and (2) *dimensions of timeliness*.

Decisions that were not selected for further analysis are generally ones that are not influenced by climate-related variables, are made more frequently, or involve projects with a limited lifespan. Projects or future restoration plans that rely heavily on these types of practices should be less vulnerable to climate change than those relying predominantly on practices identified as climate relevant. For example, barnyard runoff controls (e.g., diversion of clean water from entering the barnyard, control of runoff from barnyard areas) may be helpful in mitigating the impacts from climate changes such as more intense storm events. However, the practice requires very little planning and implementation time. It can be undertaken on short notice as storm events are observed or expected to increase (and, thus, does not require action immediately to gain the longer-term adaptive benefits).

The findings from this project are relevant for decision makers at both the state and Chesapeake Bay watershed level as they develop, review and approve restoration plans in the future. The decisions that were selected as climate relevant also present an opportunity for further refinement through research into which attributes of the decision are particularly sensitive and how the decision or the practice itself can be most effectively changed to accommodate effects due to climate change.

The subsequent step to prioritize the remaining set of decisions based on specific attributes provides additional information on their relative vulnerabilities. The results may further aid the review of current or future restoration plans and focus more local-level research efforts based on site-specific characteristics and geography. Because prioritization is sensitive to the specific criteria and weighting approach selected, caution must be used when interpreting the results of any single weighting scheme without further analysis and input from experts as well as non-scientists (e.g., key stakeholders).

Most of the lessons learned from this project concern decisions made throughout the pilot study regarding the methodology. The discussion below addresses some of the pros and cons associated with each of these methodological decisions, with the intention of applying the methodology in this study to higher-level decision making entities in the future.

5.1.1 Engaging both technical experts and stakeholders

The variability in the results using the prioritization tool suggests two courses of action that may improve its usefulness: the first is to engage experts to a greater degree in refining the attribute scoring for each of the practices (i.e., using the expert elicitation process to come to a consensus), and the second is to apply the tool at finer geographic scales and solicit further input from appropriate decision makers who implement these specific practices. At this level decision makers can narrow the list of practices to those under consideration for a specific tributary and can provide input into which practices are reasonable to consider at that location. The results from the prioritization would then inform these decision makers about which of the practices under consideration may require modifications in order to continue to perform as climate changes.

Recommendations for the future.

As part of a preliminary assessment, and prior to soliciting expert judgment, it may be desirable to involve key stakeholders who can offer insight into the decision making process that surrounds specific decisions as well as constraints on the decisions that may shape efforts to incorporate climate change into decision making. This involvement may provide greater accuracy in the preliminary assessment to prioritize decisions and result in a meaningful, legitimate and implementable set of adaptation policy priorities.

While prioritization may still be difficult without having specific applications of practices in mind to address particular climate-related impacts, a variety of approaches could be used to test the robustness of results. One approach might be to use scenario planning to test whether specific decisions are assigned appropriate priority given their suitability and their likelihood of enhancing the resilience of systems under a range of plausible future climate impact scenarios. Scenario planning in this context is the use of a limited set of contrasting scenarios to explore both the uncertainty surrounding the future consequences of a decision and how that uncertainty may affect its likely success (Duinker and Greig, 2007; Peterson et al., 2003; CCSP, 2007).

Additionally, the approach used in this study to first review available information on specific practices and then to elicit experts' judgments provides another mechanism for prioritizing decisions in terms of additional research needs. The practices for which there was high disagreement, either among experts or among our scores and those of experts, suggests that additional research on the effects of climate change on these practices would be useful. High-scoring practices for which expert agreement was unanimous should also be examined more closely, since this combination suggests that these practices are highly sensitive to climate-change effects and information on how to modify them in light of climate change impacts is urgently needed so that they remain effective.

5.1.2 Information gathering approach

Reviewing readily available literature as an initial step in gathering information on key decision attributes made it possible to pull in enough information on which to base the initial scoring exercise. This step reduced the burden on experts who were later consulted during the expert elicitation phase of the project. Reviewers were able to react to the existing information, either corroborating the findings of the literature review or offering suggested revisions where they disagreed.

The downside was that gathering information on all of the decision attributes for 32 decisions based on literature reviewed was laborious. It would take a significant investment of resources to replicate this approach on a nationwide scale.

Further, some decision attributes such as decision constraints (both internal and external), adaptive capacity of the organization, and decision making flexibility were difficult to characterize based on reviewing readily available literature, and, thus, difficult to impossible to score within the pilot scoring system. Decision attributes that require politically-sensitive assessments of institutional resources or locally-specific barriers may be better addressed via qualitative descriptions or discussions with resource managers and decision makers, or even examined as to whether it is appropriate to collect information on, or consider these attributes.

Recommendations for the future. To fully understand the context and attributes of climate-relevant decisions, a next step in this study could involve roundtable discussions with decision makers and other stakeholders who are best positioned to comment on these factors. Workshops or another form of interactive dialogue might improve a preliminary assessment prior to engaging in the process of expert elicitation to evaluate scores independently.

5.1.3 Criteria for Prioritization

The usefulness of criteria selected for prioritization may depend on the specific decision being considered or on the context of the decision itself. If criteria vary significantly in terms of their usefulness in the prioritization process, then this may indicate the need for greater input into the prioritization process from the decision makers themselves. Or if the usefulness of criteria vary greatly based on decision-specific considerations, and this is systemic across types of decisions or for a specific scale of decisions (e.g., tributary-level decisions), it may mean that the prioritization process is not feasible – helpful decision support cannot be provided beyond identifying climate relevant decisions. To go beyond identifying climate relevant decisions would mean that the specific context needs to be considered. This may point to one of two possible courses of action: either we hand off this decision assessment process to the decision makers to prioritize the selected decisions or we engage the decision makers in further refining the tool. Further work needs to be done to test which of these two paths is appropriate to pursue.

Recommendations for the future. In future studies, one goal should be to determine whether there are a robust set of criteria that apply across decisions irrespective of the scale of the decision or other aspects of the decision context. Expert elicitation may be one way to identify such robust criteria. As a complement to information on robustness, research on decision attributes to identify those that carry data most critical for prioritizing decisions would be helpful. Put another way, if perfect information were available about each decision characteristic, knowing which characteristics would substantively affect a decision's priority ranking would be helpful. Finally, exploring disagreements among experts and stakeholders that arise during the elicitation process could provide important information on whether their basis of uncertainty is due to the relevance of climate change to the decision itself or to the actual attributes of the decision.

5.1.4 Expert Elicitation

When data are scarce but the need for information to support decisions currently being made precludes further research and data collection, expert judgment can be used in the interim to inform policy analysis and choice (Morgan and Henrion, 1990; Morgan and Keith, 1995). The approach taken in this study to prioritize decisions was an experimental application of expert elicitation using qualitative metrics. This approach does not fit neatly into a single type of expert elicitation that past studies have employed, but shares some characteristics with previous studies. The features of this approach that make it similar to other studies are its application to prioritization for risk assessment and management -- to focus the provision of climate information and establishment of research priorities -- and its application to climate change. However, the unique and experimental aspects of this approach are its specific application to climate adaptation decisions, which has not yet been done (except for the CCSP 2008 publication, SAP 4.4, that provides confidence estimates for adaptation approaches), and to decisions rather than impacts assessments (e.g., IPCC 2001, 2007) and associated modeling parameters (e.g., Morgan et al. 2001), or representations of the climate system itself (e.g., Morgan and Keith, 1995).

Our prioritization approach provided insights into a set of practices that were good candidates for decision support across a range of assumptions about performance, but also gave us insight into the relative dearth of information on attributes of adaptation decisions and therefore the degree of uncertainty about their performance with respect to anticipated climate change impacts. For example, the fundamental step of characterizing decisions according to their vulnerability to climate change (including the natural systems being targeted by decisions and the specific management practices that would be used) was difficult because these impacts have not been thoroughly studied. With respect to the broader array of decision characteristics, some experts commented that they made educated guesses in responding to the initial scoring of the truth of statements about those characteristics. While it is expected that there are varying degrees of uncertainty surrounding the judgments made in characterizing decision attributes, the pilot project did not attempt to resolve disagreements in expert judgment or to estimate uncertainty bounds for each characterization.

Recommendations for the future. Use of expert elicitation techniques in future assessments should include formal techniques for resolving disagreements in expert judgment and for estimating uncertainty or confidence in experts' qualitative or quantitative characterizations of decisions. Whether qualitative or quantitative, terms for characterizing decisions need to be clearly defined. Additionally, future assessments will have to develop formal means for factoring the uncertainty or confidence estimates into the prioritization approach.

5.1.5 Prioritization Tool

The Excel-based prioritization tool developed during this pilot project proved useful for meeting the immediate needs of sorting and prioritizing the decisions that emerged from the selection criteria. Through the process of developing and modifying it, however, it became apparent that expanded functionality could make the tool much more valuable to a wider user group.

The prioritization tool that emerged is user friendly and has the capacity to quickly sort management practices and prioritize those practices according to user-defined criteria. It allows users to modify criteria and potentially compare different outcomes.

The current tool is designed to specifically evaluate decisions made in the Chesapeake Bay watershed and is not yet transferable to other systems. The tool is not configured to include additional management practices; it only allows users to sort and prioritize decisions that are already included in the tool. The framework of the tool could be transferable to other systems, however, so that it could be utilized for other locations and to analyze different sets of management practices.

A limitation of the current tool is the quantitative methodology underlying it. Since it is applied to a qualitative assessment, the method may convey the impression of producing results that are more quantitative and accurate than they really are, given the uncertainties in the underlying data.

Recommendations for the future. If the tool were to be used on a national scale, it would need to be modified to make it more user-friendly, transparent, and offer expanded functionality (e.g., the ability of the user to add new decisions and score them). A tool may not be necessary, however. It may be preferable to simply provide decision makers with guidance on how to apply a proven framework approach to their own set of decisions.

5.1.6 Decisions not Currently Being Made

Issues that seemed important to address inevitably arose during the process of developing the approach used in the pilot study, but were not addressed either due to the timing (i.e., the stage of the study at the point when the issue was seriously considered) or resources (e.g., how much additional time and cost inclusion would incur). One issue discussed briefly below that should be considered in future decision assessment efforts are those decisions that are not currently being made.

Climate change may pose risks that are not already addressed by existing decisions because it may directly or indirectly affect a resource or ecosystem service through pathways that are different from any existing stressors. For example, coastal wetlands could be lost if they are unable to migrate inland rapidly enough or far enough to keep pace with sea level rise; CO_2 increases will increase ocean acidification, which could reduce carbonate deposition, increase coral reef mortality rates, etc.; and earlier snowmelt runoff will affect the timing and magnitude of streamflow, in turn affecting fish spawning timing and behavior, and the availability of food sources. Since these effects are not already considered in existing decision making processes, limiting the initial decision inventory to existing decisions may result in gaps in the analysis of where to focus decision support for adaptation.

Recommendations for the future. Consider identifying these gaps in current decision making when the initial inventory of decisions is developed and then conducting a preliminary assessment- of needs and possible responses to fill the gaps.

5.1.7 Framework for Assessing Climate Relevant Decisions

The framework we applied in this study worked well as an initial approach to providing information to support decisions at (1) the local scale through specific results for management practices to address climate change and (2) the national scale to provide focus for further research on management practices and on methods for prioritizing decision support information for adaptation. However, some changes in the specific steps of our framework will improve its application and results in future studies. With the changes incorporated into the initial framework, those steps are now: (1) inventory decisions through examination of existing literature, both peer-reviewed and gray literature; (2) engage stakeholders in refining the inventory by reviewing results and selecting the final set of decisions and their attributes (this may include specifying the format of the inventory itself -- such as the appropriate geographic or organizational scale of decisions to consider, how specific or general those decisions should be, whether decisions should be aggregated and how -- as well as the types of attributes that most influence the effectiveness of those decisions); (3) conduct a preliminary assessment to evaluate, select and order (prioritize) decisions according to qualitative measures of effectiveness based on decision attributes; (4) develop a protocol for the expert elicitation process using qualitative metrics; (5) select experts, focusing on the total number needed to provide credible representation in addition to obtaining the necessary backgrounds and balance; (6) conduct expert elicitation to characterize decision attributes for prioritization and to estimate confidence in, or uncertainty bounds for those characterizations; (7) resolve any differences in characterizations among experts and between experts and the preliminary assessment results; and (8) conduct prioritization analysis using final characterization results and uncertainty bounds, if elicited.

5.2 CHESAPEAKE BAY FINDINGS

The results for this single location provide information relevant for different levels of decision makers and stakeholders. Some results of this study are relevant for decision makers at the state level while other results inform decision makers operating at the scale of the whole Chesapeake Bay watershed.

Applying two criteria--(1) *climate change adaptation potential* and (2) *dimensions of timeliness*--results in the selection of 14 water quality decisions and 18 aquatic ecosystem protection decisions. Each one is sensitive to at least one or more of the projected impacts of climate change within the lifetime of the decision. Therefore, each would benefit from incorporation of climate-change considerations into the decision-making process. Most of the water quality decisions selected are related to forestry, land use/ land management, or stormwater management practices. These three categories involve situations where climate change can have a strong influence on the effectiveness of the practices in meeting their goals, and they also involve long time commitments. Nutrient management (viz., POTW effluent standards under TMDLs) and urban stream restoration are the other water quality practices that offer opportunities for adaptation, and may benefit from decision support.

For aquatic ecosystem protection, management intrinsically involves long-term commitments, and many of the targeted resources are sensitive to climate-related impacts, so most of the decisions in this arena are viable candidates for adaptation decision support. Several types of fishery restoration activities, oyster population management, invasive species management, SAV restoration, and "living shoreline" approaches are likely to not only provide near-term benefits, but may also provide resilience to the Bay in the face of long-term climate-related changes.

The subsequent step to prioritize the remaining set of decisions based on specific attributes provides additional information on their relative vulnerabilities. Because prioritization is sensitive to the specific criteria and weighting approach selected, caution must be used when interpreting the results of any single weighting scheme without further analysis and input from experts as well as non-scientists (e.g., key stakeholders). However, the prioritization tool does provide some insight into which decisions are good candidates for decision support because of consistently ranking in the highest tier across the weighting schemes. In this study, examples of good candidates for decision support include *POTW Standards for Discharge Permits, Stormwater Management – Filtering Practices, Riparian Forest Buffers – Urban, Aquaculture,* and *Create Sanctuaries*. These practices that rank highly as good candidates for decision support can inform managers as to which plans should carefully consider climate-change effects during the near-term planning processes.

5.3 CONCLUSIONS

The test of our theoretical approach using the Chesapeake Bay Program's environmental management decisions revealed that in practice, this approach provides useful information on adaptation measures for local decision makers and direction for fruitful research endeavors that will further improve our provision of information. Beginning with environmental goals and decisions embodied in existing and future restoration plans, and using broad criteria to select the appropriate subset of decisions for more detailed analysis and prioritization provides immediately useful information on the degree to which management of an ecosystem depends on practices that are sensitive to climate change. Put another way, it gives decision makers information on whether their environmental goals for which they currently manage are in danger of not being met. It also gives decision makers some sense of the magnitude of effort needed to address climate change effects in their plans. Those practices would benefit from incorporation of climate-change considerations into the decision-making process. Decisions that were not selected using broad criteria are generally ones that are not influenced by climate-related variables, are made more frequently, or involve projects with a limited lifespan. Projects or future restoration plans that rely heavily on these types of practices should be less vulnerable to climate change than those relying predominantly on practices identified as climate relevant.

Fruitful research areas highlighted by this project include: 1) further refinement of our understanding about which attributes of the decision are particularly sensitive to climate, 2) how the decision or the practice itself can be most effectively changed to accommodate climate change effects, and 3) decision attributes that carry data most critical for prioritizing decisions. It is also important to note that the scope of this framework approach included only the scientific aspects of decision making. Additional work needs to be done on the input of non-scientific stakeholders, which also plays a key role in decision making. Moving forward, a key issue will be determining whether this approach is generalizable (e.g., transferable to other places and ecosystems, scalable to other organizational levels of decision making). We applied this experimental approach specifically to the Chesapeake Bay to examine its usefulness as our first step. The next step is to test its transferability and scalability either to other estuaries or other national programs.

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APPENDIX A

A.1 Key Decision Attributes

Attributes deemed important to consider based on a review of the literature were used in two ways in this study. First, two decision attributes were used as selection criteria: climate change adaptation potential and dimensions of timeliness. These were selected because they have been identified as important in the climate change literature (see for example, IPCC, 2007). The second way decision attributes were used in this study was in developing priorities. This appendix provides additional information on attribute selection, including a description of the attribute itself and an explanation of the reasoning behind the determination that each attribute is important. [4]

A.2 Selection Criteria

A.2.1 Adaptation potential: Is it possible to reduce negative impacts of climate change?

In some cases, it may not be possible to adapt, i.e., there may not be measures and strategies to reduce the projected consequence of climate change that come within the scope of a particular decision. In these cases, there is little reason to pursue decision support, since adverse effects cannot be ameliorated. Alternatively, adaptation may be possible by adjusting existing strategies. For example, ongoing work in this project to evaluate best management practices in the Chesapeake Bay indicates that with adjustments, many of the practices that address non-point source runoff associated with land use change and agriculture would also address increases in storm intensity related to climate change. In some cases, new adaptation strategies may be needed; a key role for decision support may be to identify alternative plans and strategies that address the projected consequences of climate change. In the case of water resource

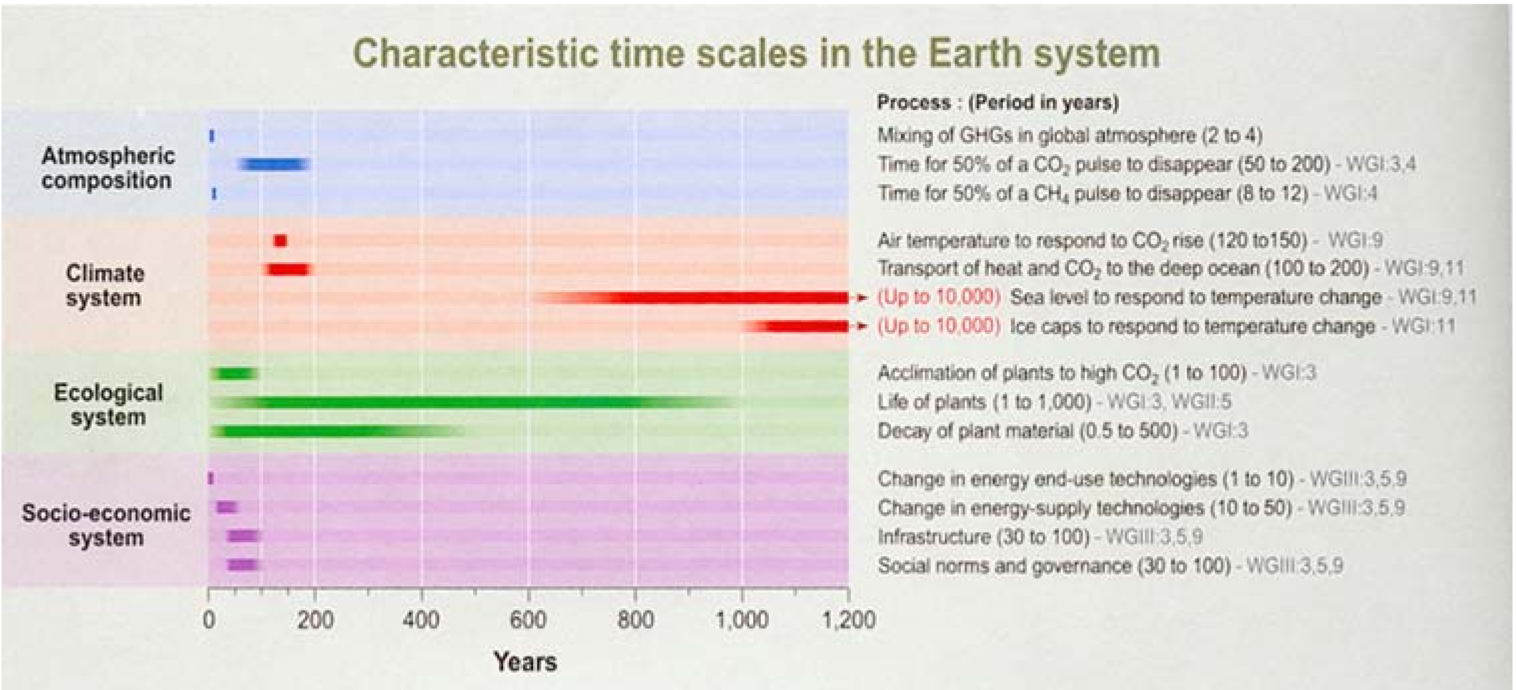
[4] A number of characteristics of the decision making organization and the decision should be collected for the completeness of the inventory, although the attributes are not directly relevant to the question of whether decision support is likely to be *successful*. These include general information on decision type, instance, organization, or institution.

management, such plans and strategies might include both structural changes and investments, but also “modifications in public policy, management practice, regulatory policy, and pricing policy” (Frederick, 1998).

A.2.2 Dimensions of Timeliness: Is climate is likely to change during the time period governed by the decision?

The time horizon of the decision is critical to determining the usefulness of decision support for adapting to climate change. If, for example, the decision affects the allocation of resources for only a short time, then it will not be critical to provide decision support. “Short,” in this context, means a time period during which climate is not expected to change dramatically (Frederick 1998, Purkey, et al. 2007). Essentially, the issue is whether ignoring information on future climate when making the decision will result in a potentially “worse” decision, i.e., in neglecting to take adaptation actions that would improve the outcome.

The IPCC Third Assessment Report (IPCC 2001) describes characteristic time scales in the earth system (see graph below). While it appears the socio-economic systems operate on shorter time scales than other components of the system, it is important to keep in mind that changes in the earth system have been occurring for some time as well as the inertia inherent in the interacting climate, ecological and socio-economic systems. The IPCC concluded that there is typically a delay of years to decades between perceiving a need to respond to climate challenges; planning, research and developing a solution; and implementing the solution. However, these time scales are not fixed and could be changed because of policies, individual choices, and information (i.e., decision support).



Aspects of timeliness include:

● ***How often the decision is made.*** This attribute is in some sense a proxy for several aspects of timing, because decisions made frequently likely have shorter planning horizons, implementation periods, and project lifespans. Decisions that are made for the long term—i.e., a combined planning horizon and implementation period that goes beyond a few decades—will be most relevant for adaptation strategies (Allen, 2005). For example, decisions that are being made that drive large and long-lived investment—such as irrigation systems or slow growing tree cultivars — will be most at risk from climate change, and so may be good candidates for decision support (Allen, 2005).

● ***Planning horizon***. How far in advance does planning begin for future action? Put differently: what is the lag between when decisions are made and when operations or actions occur? The longer this period of time is, the more likely it is that future climate will have changed and its effects should be included in present decision calculi. Hence, there is a greater likelihood that decision support, particularly support that provides usable information on projected future climatic conditions, will be of more use.

● ***Implementation period.*** Once a decision is made, how long is the time period before an action or project is completed? As in planning horizon, the longer this time period, the more likely it is that climate will have changed before the project is completed, necessitating the inclusion of long-term climate considerations in decision making. As in planning horizon, there is a greater likelihood that decision support, particularly support that provides usable information on projected future climate conditions, will be of more use.

● ***Project lifetime.*** How long will the project be in place, once completed? For physical capital, this might be interpreted as the useful lifetime of the investment. Alternatively, it could be interpreted as the duration of costs and benefits of the project, which might extend or persist beyond the lifetime of the project. Again, the longer the project is in place, the more important it is to include long-term climate considerations in the decision, and the greater the likelihood that appropriately designed decision support will provide useful information to the decision process

A.3 Prioritization Criteria

A.3.1 Potential benefits of accounting for climate change: How high are the stakes?

The potential benefit of including information on projected climate change in a decision is that the decision maker will be able to plan for future climate change and make adaptation decisions that reduce the negative impacts of climate change in a cost-effective manner. Without detailed analysis of a particular issue, however, it is difficult to determine whether an adaptation response to climate change is warranted, i.e. whether the costs of failing to adapt make it imperative to include climate change in the decision calculus.

The magnitude of benefits and costs of the problem, and of the potential solutions, are important, but so is the lifetime—how long-lived—these benefits and costs are. As Frederick (1998) writes, “In contrast to investments involving incremental capacity increases, climate expectations are likely to be very important for decisions involving long-lived benefits and costs [and] irreversibilities.” Fundamentally, we want to avoid regret (loss of future net benefits) that will occur if we make the erroneous assumption that climate is not changing..

Certain aspects of the decision are indicators of how important it *might be* to include climate, from the perspective of the stream of benefits and costs associated with the decision. These include:

● ***The reversibility of the decision.*** Decisions can have effects that are irreversible. Some paths will result in irreversible environmental changes and therefore a loss of future options

(Arrow and Fisher, 1974). "Intrinsic irreversibility" results from crossing a threshold so that the system cannot return to its previous state (IPCC 2001). Species extinction is an example of an intrinsically irreversible change. There is considerable concern about these types of changes (e.g., loss of biodiversity), in part because of the permanent loss of services that flow from these resources (e.g., genetic material that could have been of value in medicine or other applications). Even if species are not at risk, biological impacts—such as clear-cutting a forest or damage to coral reefs—may be "effectively irreversible" because they can't return to their previous state in any relevant time span (IPCC 2001; Narain et al., 2004). In the current context, irreversibilities tend to make a decision a better candidate for decision support.

● ***The magnitude of projected impacts of climate change.*** In cases where resources are vulnerable and the adverse impacts of climate change have been projected to be high, decision support may yield substantial benefits, i.e., if decision support helps reduce impacts by encouraging adaptation as an outcome of management decisions.[5] Some autonomous adaptation will occur, which will be important when evaluating the benefits of providing decision support. Essentially one needs to determine what impacts will look like in the presence of autonomous human responses to climate change, but in the absence of overt adaptation projects, plans, or strategies (Frederick 1998). Situations where adverse impacts are projected to be higher are more likely to need decision support that synthesizes prevailing knowledge and clarifies decision options.

● ***The magnitude of costs.*** The higher the costs of investment or other resource costs that will be obligated by the decision, the more important it is to take climate into account in order to ensure an adaptive decision. Certain fixed investments can be considered irreversible over relevant time horizons (e.g., a sewer system, a wastewater treatment plant, an electric power plant, a road). Typically, these decisions are made infrequently and the cost of

[5] Not all effects of climate change will be negative, especially given the benefits of adaptation. Assuming uniform change across climate divisions, Mendelsohn (2001) finds that the costs of climate change to market sectors in agriculture, forestry, energy, and water are highest in the Southeast, South Plains, and Southwest, with relative gains to the Midwest and Northeast regions of the country. At the North American scale, the Intergovernmental Panel on Climate Change reports that some areas may benefit from climate change (IPCC 2007). Because climate models show an amplification of warming at the poles, Northern Canada may benefit economically from warming trends with increased shipping activity due to deeper ports and longer navigational seasons (Watson, Zinyowera, and Moss 1997).

reversing or repairing a decision can be quite high. In contrast, the more often a decision is made, the more opportunity there is for reacting to changing climate, potentially reversing a previous decision at a relatively modest cost. In general, it is likely that decisions that are made more frequently rely more on information on current rather than future climate conditions since there are many opportunities to update the data (i.e., it is possible to "wait and see"). Hence, decisions that are made frequently may not be good candidates for decision support whereas those decisions that involve higher costs (i.e., infrequent, hard to reverse) are likely to be good candidates for decision support.

A.3.2 The specific focus of the decision: What are the objectives and purpose of the decision?

This attribute refers to the specific nature of the problem and policy issue being evaluated. For example, flood control issues will be approached very differently from water quality issues. A key step will be to determine whether climate affects problems already being addressed by decision makers (Frederick, 1998). For example, consider a resource that is threatened and is in danger of experiencing substantial losses – in areal extent, population, quality of life, etc. -- under existing stresses. These resources typically receive higher priority and garner more attention from a management perspective. If such resources are likely to face increases in stress levels or additional sources of stress, the stakes only become higher. In cases where climate change is an additional stressor on critical resources, the decision will be a better candidate for decision support.

In some cases, the objective of a decision is such that it may override any attempt to include climate change in the decision. For example, transportation infrastructure decisions may have military or homeland defense implications that override climate change concerns. In the water sector, flood protection often takes on an air of urgency that can overwhelm what should be an area where climate considerations are relevant. For example, when a levee protecting an island in California's Sacramento-San Joaquin Delta failed during the summer of 2005, the decision was made to quickly mobilize resources to restore the levee to its original configuration rather than to assess the appropriateness of this levee in the face of potential climate change. In a similar fashion, the levee failures associated with Hurricane Katrina have created an urgency to reinforce California's levees in their present alignment and configuration.

These types of situations, where non-climate factors are the main considerations and/or there is a heightened sense of urgency, may lead to decisions that are maladaptive from a climate change perspective. For example, sea-level rise associated with climate change increases the potential harm to coastal areas caused by the practice of developing low-lying coastal areas (Easterling et al., 2004). If current trends in the decision are maladaptive, exacerbating known or projected risks, then the decision represents a better candidate for decision support.

A.3.3 What other decisions are being made that are linked or interdependent?

A decision is not always made in isolation, but frequently may be part of a broader decision making process. These interdependent decisions may or may not be climate-related but nonetheless may affect whether or not the decision—or set of decisions—is a good candidate for decision support. For example, a decision about impounding a stream to make a pond may be one part of a set of decisions being made for a housing development. In this case, the decision is linked to other decisions, because the decision on the pond depends on other decisions of size and design being made for the development. In this case, also, decisions about the housing development are likely to be guided by various government regulations and standards. Thus, while the decision on the pond's placement and design is *linked* to other decisions being made by the housing developer, it is analytically—from a climate perspective—independent. Government standards governing the pond and other features of the housing development can be set independent of each other, although climate may factor into these standards to a greater or lesser extent.

In the case in which decisions are linked and interdependent, multiple decisions may be climate-related. For example, standards governing water quality and pollutant emissions into water bodies will reflect a host of considerations, including decisions made regarding reservoir and dam management, water uses, and of course expected average precipitation, droughts, storms, and other factors. In this example, the decisions are interdependent and depend on climate.

Clearly, there is no simple answer to the question of how interdependence affects whether or not a specific decision is a good candidate for decision support. However, information about the characteristics of interdependent decisions may help in making a determination, such as:

- Do all the related decisions depend on climate variables?
- Are the same decision makers involved in all the decisions, and how many are there?
- Are the decisions made as part of the same process, so that it is possible to include climate considerations into multiple decisions at once?
- How much control do decision makers have over the outcomes in each case?

A.3.4 What are the decision rules and tools used to make decisions?

To be effective, adaptation strategies must be incorporated into normal decision making and should not be separate from other dimensions of risk management and decision making (Allen, 2005). However, in some cases, individuals use simplified decision rules (such as historical precedent) to make decisions. In other cases, detailed decision analytic models, or tools such as benefit-cost analysis, may be used (Pyke et al., 2007; Gamble et al. 2004). In cases where analytical models are used that explicitly incorporate climate information to support the decisions process, the decision will be a better candidate for decision support, particularly if the data or models are in a form that are consistent with existing (or readily available) climate data. Conversely, in situations where simplified decision rules guide the decision making process, or decisions are not data-driven, it may be more difficult to provide decision support to encourage adaptation.

A.3.5 What organizational resources and expertise are available?

It may be difficult for decision makers to get climate change on the agenda because they are often juggling multiple issues of immediate importance, or because they face financial or human resource constraints that limit their ability to address climate change impacts (CIG, 2006). If the organization is willing to (and typically does) expend resources on planning and analysis, it will be a better candidate for decision support. Similarly, if the organization already has a fair amount of expertise in climate analysis and routinely deals with quantitative information and uncertainty of the type that climate change involves, the decision will be a better candidate for decision support. Alternatively, however, an organization that does not have a high level of resources available or existing experience, but that is highly motivated to include climate in its decision making, may be a good candidate for decision support that includes training, education, and tool development.

A.3.6 What scientific information or other data are currently used in the decision?

Many resource agencies, such as water resource management agencies, are accustomed to responding to seasonal or inter-annual variations in climate (CIG, 2006). Expectations of future climate are frequently implicitly or (more rarely) explicitly based on a continuation of past patterns (Allen, 2005). If the decision process routinely uses climate variables, uncertainty data, and other scientific information in making the decision, it may be a better candidate for decision support.

Thus, it might be natural to assume that forecast climate change data could be more easily incorporated into these decision making processes. However institutional and other constraints may prevent a manager from assimilating forecasted climate data in the decision. Moreover, many decision makers indicate that planning for future climate change requires data specific to the decision maker's area of interest, for example a particular river reach (CIG, 2006). Thus, while a decision which already explicitly incorporates climate data may be a better candidate for decision support than a decision that does not use climate data, other considerations may be more important.

A.3.7 What are the potential constraints in using scientific information?

Institutional constraints. Even in cases where climate change information is available, institutional constraints may prevent decision makers from using that information. For example, a recent study of water managers and planners found that, in general, managers did not use probabilistic forecast information about seasonal and interannual climate variability in their planning (Rayner et al., 2005). While managers cited concern about the limited accuracy of scientific forecasts as one reason why the information was not used, institutional factors also appeared to play a role. Key institutional factors identified by the study as affecting the use of new information were complexity and conservatism. Complexity—in the built system and in the institutions and decision making process—can present a challenge to the use of climate change information, because it tends to obscure managers' understanding of the sensitivity of different types of decisions to improved information (Rayner et al., 2005). A conservative approach to risk and decision making can also reduce the extent to which decision makers are willing to adopt new approaches or incorporate new information (Rayner et al., 2005).

Regulatory, operational, or legal constraints. The inclusion of climate change in decision making processes is not always feasible. For example, the legal frameworks for project planning in California—namely the National Environmental Protection Act (NEPA) and California Environmental Quality Act (CEQA)—have made it difficult to include climate change in water resource planning, despite the prudence of factoring these changes into supporting analyses (Purkey et al., 2007). The problem arose because the perception was that significant changes in hydrology would not occur within the typical 20 to 30 year planning horizon of most NEPA and CEQA studies (Purkey et al., 2007). Such difficulties do not mean that climate change should not be incorporated into decisions or that decision support is not warranted, only that it will be more difficult to accomplish and may require legal or other changes. The California legislature did act to ease this constraint with legislation such as Senate Bill 97, which requires that CEQA actions address greenhouse gas emissions and effects from proposed projects[6]. Several other states, such as Massachusetts and Washington, have taken similar efforts to modify their environmental policy acts in order to include climate change effects in decision making. However, the constraint remains for the majority of states and federal projects subject to NEPA.

Institutional inertia, misperceptions, and other factors that make it difficult to get climate change on the agenda. For many decisions—particularly those in the water resources arena—it may make sense to incorporate climate change data into decision making. Yet, for the most part, this has not occurred. Further, many decision makers are resistant to including climate change in decision-making processes (CIG, 2006, Morss et al., 2005). For many decision makers, climate change will be viewed as a "new" issue, competing with a host of other issues that are already monopolizing their attention. Climate change will often be perceived as an issue

[6] http://info.sen.ca.gov/pub/07-08/bill/sen/sb_0051-0100/sb_97_bill_20070824_chaptered.html

to address later, “when we see that change is occurring”[7], or when magnitudes and thresholds of effects are more clearly understood. Uncertainty over how to plan for climate change will also retard action (CIG, 2006). Moreover, decision makers may be hesitant to pursue climate change as an issue because they expect that it will require developing substantially different policies and planning approaches, even where that is not necessarily the case (CIG, 2006).

External stakeholder groups. The extent to which agency actors are responsive to, or insulated from, constituent pressures will be an important consideration in selection of decisions that may benefit from decision support. In fact, it is often stakeholders who move climate change considerations into the center of resource management decision making. In the area of re-licensing hydropower facilities, for example, stakeholders have begun to insist that analysis of future operating conditions include an analysis of how these operations would perform under alternative climate futures. Absent this insistence on the part of stakeholders, many utilities acknowledge that they would not pursue this line of investigation.

Stakeholders are an important component and, in some cases, determinant of the decision. As another example, permit decisions on where to locate commercial treatment, storage, and disposal facilities of hazardous waste require public and stakeholder input. As part of this process, open forums are held to discuss facility design, commercial benefits, and environmental and public health concerns. (For example, the EPA advises against the location of such operations in sensitive environments such as hurricane alleys, flood plains, and areas of high seismological activity).

Decision support will be less effective if it does not recognize the role that these groups play in the decision process, perhaps to the extent of providing them with information. For example, because climate change may increase the intensity and frequency of hydro-meteorological disasters, relevant risk data could benefit stakeholder forums on long-term, high-risk land use planning.

The range of stakeholder groups that participate actively, as well as associations, political groups, or other entities that indirectly influence a given decision have implications for the effectiveness of decision support. For example, a decision with lengthy, extensive, and inclusive

[7] As evident from our earlier discussion of timelines, for many decisions it will indeed be the most appropriate to address climate change later, rather than sooner, because better information will become available. The challenge is to identify which decisions should address climate change in the near term.

stakeholder processes will have more diffuse, unidentified, and numerous influences on the decision. Because decision makers may have less control over the actual decision, a support system that focuses narrowly on the decision maker may not contribute much to the decision. This also suggests that decision support, to be effective, may need to be focused beyond direct decision makers, and on the broader group influencing decisions.

Where decision makers get their information—whom do they trust? Information on climate change is generally transmitted by different intermediaries—scientific organizations, advocacy organizations, and government—via a variety of different media, such as scientific reports, memos, newsletters, directives and journal articles, as well as through mass media such as newspapers and television. (Nelkin, 1987; Bell, 1994; Trumbo, 1996; Jacob and Hellstrom, 2000; Plein, 1991; Kingdon, 1995). A variety of strands of research provide some suggestions about organizational attributes that affect the sources and flows of information and, thus, provide insights into the potential usefulness of decision support.

One helpful strand of research comes from *social network analysis,* which is a set of tools for mapping important knowledge relationships between people or departments, usually within an organization. This process has led to a number of important lessons about how organizations work, including the sources of information and data, ways to include collaboration, and means of transferring knowledge in an organizational setting (Cross et al., 2002). There is a tendency to rely on data sources and individuals or associations that are known personally, rather than on databases, articles, or other impersonal sources of data. Decision makers are known to form "cozy relationships" with information providers they trust and clientele groups they serve directly. Thus, *who* you know will to some extent determine *what* you know (Cross et al., 2002).

In the current context, the sources of information that decision makers typically use may influence both whether the decision/organization is a good candidate for decision support, as well as the best means of providing that support. Organizations that are highly insular (i.e., rely entirely on information sources within the organizations) may be more difficult candidates for decision support. In contrast, non-governmental organizations that obtain information through centralized sources, such as trade associations, may be easier to access through those organizations. If organizations—including state and local government officials—rely on Federal government data sources, these sources will be familiar and may offer a good conduit for improving adaptation decision making.

Similarly, the literature on "communities of practice" suggests that information is not held only individually within and among organizations, but collectively. A community of practice is a group across which know-how is shared; the community need not be formal, but may be implicit in the relationships that develop (Brown and Duguid, 1998). A community of practice develops a shared view of what it does, how to do it, how it relates to other practices, and cultivates a network for information flows (Brown and Duguid, 1998; Brown and Duguid, 2001) This shared view, and how the community interfaces with other communities, may have an influence not only on information flows within the community, but on how decisions are made (an influence that is distinct from the organization making the decision). Thus, it may be important to understand how information is shared, and the "community" decision makers belong to, in deciding whether and how to provide decision support. Communities of practice, if isolated, can become rigid in their views, which will also have implications for decision support (Brown and Duguid, 1998).

It is also important to understand how information is used, in order to set priorities for action. The literature on agenda setting provides information on how information is used in politics: why do policymakers focus on some information while ignoring other information that is "deemed" to be less relevant (Jones and Baumgarten 2005). Issues that are defined as being important may also depend on the filters that individuals use in processing information (Wood and Vedlitz 2007). Moreover, for some stakeholders, there may be a disconnect in how the information that is received is applied. The literature on social amplification of risk provides insight into the gap between technical assessments of environmental risk and lay perceptions of those risks—perceptions that may guide, or at least influence, stakeholder decision making (see for example, Pidgeon, Kasperson, and Slovic 2003).

APPENDIX B

Water Quality BMP Screens

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Urban NPS	Forestry	Forest Conservation	Infrastructure planning	N	Y	Y	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration. Higher Temperature: More forest cover	Yes, CC may increase intensity of storm events which would reduce the infiltration provided by this measure. It is unlikely that either temperature or evapotranspiration benefits will be affected.	5	5	25	35	Planning and implementation are highly variable. Dependant on project size.	3	1	Y	E: It would be difficult to reforest land after it has been developed.
Urban NPS	Forestry	Forest Conservation	Narrower Residential Streets	N	Y	Y	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration. Higher Temperature: More forest cover	Yes, CC may increase intensity of storm events which would reduce the infiltration provided by this measure. It is unlikely that either temperature or evapotranspiration benefits will be affected.	5	5	25	35	Planning and implementation are highly variable. Dependant on project size.	3	1	Y	E: It would be difficult to reforest land after it has been developed.
Urban NPS	Forestry	Forest Conservation	Open Space Design & Set Asides	N	Y	Y	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration. Higher Temperature: More forest cover	Yes, CC may increase intensity of storm events which would reduce the infiltration provided by this measure. It is unlikely that either temperature or evapotranspiration benefits will be affected.	5	5	25	35	Planning and implementation are highly variable. Dependant on project size.	3	1	Y	E: It would be difficult to reforest land after it has been developed.
Urban NPS	Water resources	Marine Pump outs (installation)		N	N	N	N	N/A	N/A				0				N	

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Urban NPS	Forestry	Tree Planting	any tree plantings not along rivers and streams	N	Y	Y	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration. Higher Temperature: More forest cover	Yes, CC may increase intensity of storm events which would reduce the infiltration provided by this measure. It is unlikely that either temperature or evapotranspiration benefits will be affected.	1	1	25	27	Planning and implementing tree planting should be relatively simple (minimal time constraints). 25-year lifetime of project estimate is for establishment of urban "forest."	3	2	Y	E: Trees can be planted at any time or removed fairly easily. Their ability to act as a buffer, however, will likely increase as they grow in size; F: Capital costs should be moderate.
Urban NPS	Stormwater	Enhanced Stormwater Management	Ponds	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC will increase higher high flows which may be harder to control through stormwater management.	2	2	25	29	Planning and implementation are highly variable. Dependant on regulatory process.	2	3	Y	F: Not putting controls in place would be moderately irreversible, given the cost to retrofit.
Urban NPS	Stormwater	Enhanced Stormwater Management	Porous Pavement	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC will increase higher high flows which may be harder to control through stormwater management.	2	2	25	29	Planning and implementation are highly variable. Dependant on regulatory process.	2	3	Y	F: Not putting controls in place would be moderately irreversible, given the cost to retrofit.
Urban NPS	Stormwater	Enhanced Stormwater Management	Buffer Zones	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC will increase higher high flows which may be harder to control through stormwater management.	2	2	25	29	Planning and implementation are highly variable. Dependant on regulatory process.	2	3	Y	F: Not putting controls in place would be moderately irreversible, given the cost to retrofit.

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Urban NPS	Stormwater	Enhanced Stormwater Management	Infiltration trench/basin	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC will increase higher high flows which may be harder to control through stormwater management.	2	2	25	29	Planning and implementation are highly variable. Dependant on regulatory process.	2	3	Y	F: Not putting controls in place would be moderately irreversible, given the cost to retrofit.
Urban NPS	Nutrient Management	Erosion and Sediment Control (During Construction)	Geotextiles	N	Y	N	Y	Higher High Flows: Encourages Infiltration through natural ground cover	Yes, CC may increase intensity of storm events which would result in greater rates of soil erosion.	1	1	1	3	This BMP should be easy to plan & implement b/c of its short lifespan and limited application.	1	1	N	This BMP controls erosion during construction only, so does not involve anything irreversible.
Urban NPS	Nutrient Management	Erosion and Sediment Control (During Construction)	Sediment Traps	N	Y	N	Y	Higher High Flows: Encourages Infiltration through natural ground cover	Yes, CC may increase intensity of storm events which would result in greater rates of soil erosion.	1	1	1	3	This BMP should be easy to plan & implement b/c of its short lifespan and limited application.	1	1	N	This BMP controls erosion during construction only, so does not involve anything irreversible.
Urban NPS	Nutrient Management	Erosion and Sediment Control (During Construction)	Filter Berms	N	Y	N	Y	Higher High Flows: Encourages Infiltration through natural ground cover	Yes, CC may increase intensity of storm events which would result in greater rates of soil erosion.	1	1	1	3	This BMP should be easy to plan & implement b/c of its short lifespan and limited application.	1	1	N	This BMP controls erosion during construction only, so does not involve anything irreversible.
Urban NPS	Nutrient Management	Erosion and Sediment Control (During Construction)	Mulching	N	Y	N	Y	Higher High Flows: Encourages Infiltration through natural ground cover	Yes, CC may increase intensity of storm events which would result in greater rates of soil erosion.	1	1	1	3	This BMP should be easy to plan & implement b/c of its short lifespan and limited application.	1	1	N	This BMP controls erosion during construction only, so does not involve anything irreversible.
Urban NPS	Septic	Septic Connections		N	N	N	N	N/A	N/A				0				N	

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Urban NPS	Septic	Septic Denitrification		N	N	N	N	Note: Eutrophication does cause lower DO and so does higher temperature. However this was considered a secondary effect.	N/A				0				N	
Urban NPS	Septic	Septic Pumping		N	N	N	N	Note: Eutrophication does cause lower DO and so does higher temperature. However this was considered a secondary effect.	N/A				0				N	
Urban NPS	Stormwater	Stormwater Management Conversion	wet extended detention ponds	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC may increase intensity of storm events which would be harder to control through traditional stormwater management.	1	1	25	27	Retrofit of existing ponds has shorter planning-implementation phase than establishing new ponds.	2	3	Y	E: Will alter landscape, but probably not irreversibly; F: large upfront capital costs
Urban NPS	Stormwater	Stormwater Management Conversion	dry extended detention ponds	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC may increase intensity of storm events which would be harder to control through traditional stormwater management.	1	1	25	27	Retrofit of existing ponds has shorter planning-implementation phase than establishing new ponds.	2	3	Y	E: Will alter landscape, but probably not irreversibly; F: large upfront capital costs

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Urban NPS	Stormwater	Stormwater Management Conversion	retention facilities	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC may increase intensity of storm events which would be harder to control through traditional stormwater management.	1	1	25	27	Retrofit of existing ponds has shorter planning-implementation phase than establishing new ponds.	2	3	Y	E: Will alter landscape, but probably not irreversibly; F: large upfront capital costs
Urban NPS	Stormwater	Stormwater Management Retrofits	detention pond	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC will increase higher high flows which may be harder to control through traditional stormwater management.	1	1	25	27	Planning may be shorter due to existing development, but will be more constrained.	2	3	Y	E: Will alter landscape, but probably not irreversibly; F: large upfront capital costs
Urban NPS	Stormwater	Stormwater Management Retrofits	wetland	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC will increase higher high flows which may be harder to control through traditional stormwater management.	1	1	25	27	Planning may be shorter due to existing development, but will be more constrained.	2	3	Y	E: Will alter landscape, but probably not irreversibly; F: large upfront capital costs
Urban NPS	Stormwater	Stormwater Management Retrofits	underground sand filtering system	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC will increase higher high flows which may be harder to control through traditional stormwater management.	1	1	25	27	Planning may be shorter due to existing development, but will be more constrained.	2	3	Y	E: Will alter landscape, but probably not irreversibly; F: large upfront capital costs
Urban NPS	Stormwater	Stormwater Management Retrofits	infiltration trench	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC will increase higher high flows which may be harder to control through traditional stormwater management.	1	1	25	27	Planning may be shorter due to existing development, but will be more constrained.	2	3	Y	E: Will alter landscape, but probably not irreversibly; F: large upfront capital costs

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Urban NPS	Nutrient Management	Urban Nutrient Management	chemical fertilizers	N	N	N	N	Note: Eutrophication does cause lower DO and so does higher temperature. However this was considered secondary effect.	N/A				0				N	
Urban NPS	Stormwater	Impervious Surface Reduction – Non-structural Practices	Urban Forestry	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC may increase intensity of storm events which would mean that more impervious surfaces may be needed to reach the desired decrease in runoff.	1	1	10	12	May include grass pavers for driveway/sidewalk, grass lot parking. Planning and implementation time variable.	1	1	N	E: Should improve environment rather than degrade; F: Not likely to require large upfront investment
Urban NPS	Land Use/ Land Mgmt	Reduction in Urban Growth	Urban Forestry	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	N/A	5	10	25	40	Taking urban land and returning it to forest, mixed open, and ag land could be a time consuming and incremental process	3	1	Y	E: Not pursuing this BMP (curbing development) could further degrade environment
Urban NPS	Land Use/ Land Mgmt	Reduction in Urban Growth	Narrower Residential Streets	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	N/A	5	10	25	40	Taking urban land and returning it to forest, mixed open, and ag land could be a time consuming and incremental process	3	1	Y	E: Not pursuing this BMP (curbing development) could further degrade environment

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Urban NPS	Land Use/ Land Mgmt	Reduction in Urban Growth	Open Space Design	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	N/A	5	10	25	40	Taking urban land and returning it to forest, mixed open, and ag land could be a time consuming and incremental process	3	1	Y	E: Not pursuing this BMP (curbing development) could further degrade environment
Urban NPS	Forestry	Riparian Forest Buffers - Urban	riparian buffers	N	Y	Y	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration. Higher Temperature: More forest cover	Yes, CC may require larger forest buffers because of more intense storm events.	2	2	25	29	Implementation (planting trees) should be quick. Planning may take longer in developed areas. Dependent on project size.	3	2	Y	E: Should improve environment rather than degrade; F: Does not require a large capital investment.
Urban NPS	Land Use/ Land Mgmt	Riparian Grass Buffers-Developed Land	grassed buffers	N	Y	N	Y	Higher High Flows: Encourages Infiltration	Yes, CC may require larger buffers because of more intense storm events.	2	5	10	17	Implementation may take several years if impervious land has to be converted to grasses. Dependent on project size.	1	2	N	E: Should improve environment rather than degrade; F: Capital costs should be moderate
Urban NPS	Stormwater	Stormwater Management - Wet Ponds & Wetlands	wet pond	N	Y	N	Y	Higher High Flows: Encourages Infiltration, slows runoff	Yes, CC may require more wetland areas because of more intense storm events.	2	2	25	29	Planning and implementation period dependent on larger development process (e.g., for a housing tract).	3	3	Y	E: Should improve environment rather than degrade; Not pursuing this BMP, however, could lead to further destruction of wetlands; F: High capital costs

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Urban NPS	Stormwater	Stormwater Management - Wet Ponds & Wetlands	wet extended detention ponds	N	Y	N	Y	Higher High Flows: Encourages Infiltration, slows runoff	Yes, CC may require more wetland areas because of more intense storm events.	2	2	25	29	Planning and implementation period dependent on larger development process (e.g., for a housing tract).	3	3	Y	E: Should improve environment rather than degrade; Not pursuing this BMP, however, could lead to further destruction of wetlands; F: High capital costs
Urban NPS	Stormwater	Stormwater Management - Wet Ponds & Wetlands	retention ponds	N	Y	N	Y	Higher High Flows: Encourages Infiltration, slows runoff	Yes, CC may require more wetland areas because of more intense storm events.	2	2	25	29	Planning and implementation period dependent on larger development process (e.g., for a housing tract).	3	3	Y	E: Should improve environment rather than degrade; Not pursuing this BMP, however, could lead to further destruction of wetlands; F: High capital costs
Urban NPS	Stormwater	Stormwater Management - Wet Ponds & Wetlands	shallow wetlands	N	Y	N	Y	Higher High Flows: Encourages Infiltration, slows runoff	Yes, CC may require more wetland areas because of more intense storm events.	2	2	25	29	Planning and implementation period dependent on larger development process (e.g., for a housing tract).	3	3	Y	E: Should improve environment rather than degrade; Not pursuing this BMP, however, could lead to further destruction of wetlands; F: High capital costs

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Urban NPS	Stormwater	Stormwater Management - Wet Ponds & Wetlands	pond/ wetlands	N	Y	N	Y	Higher High Flows: Encourages Infiltration, slows runoff	Yes, CC may require more wetland areas because of more intense storm events.	2	2	25	29	Planning and implementation period dependent on larger development process (e.g., for a housing tract).	3	3	Y	E: Should improve environment rather than degrade; Not pursuing this BMP, however, could lead to further destruction of wetlands; F: High capital costs
Urban NPS	Stormwater	Stormwater Management - Wet Ponds & Wetlands	constructed wetlands	N	Y	N	Y	Higher High Flows: Encourages Infiltration, slows runoff	Yes, CC may require more wetland areas because of more intense storm events.	2	2	25	29	Planning and implementation period dependent on larger development process (e.g., for a housing tract).	3	3	Y	E: Should improve environment rather than degrade; Not pursuing this BMP, however, could lead to further destruction of wetlands; F: High capital costs
Urban NPS	Stormwater	Stormwater Management - Dry Detention & Hydrodynamic Structures	dry detention basins	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC may increase intensity of storm events which would be harder to control through traditional stormwater management.	2	2	25	29	Planning and implementation period dependent on larger development process (e.g., for a housing tract).	1	3	Y	F: High capital costs
Urban NPS	Stormwater	Stormwater Management - Dry Detention & Hydrodynamic Structures	swirl separators, or hydrodynamic structures	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC may increase intensity of storm events which would be harder to control through traditional stormwater management.	2	2	25	29	Planning and implementation period dependent on larger development process (e.g., for a housing tract).	1	3	Y	F: High capital costs

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Urban NPS	Stormwater	Stormwater Management - Dry Detention & Hydrodynamic Structures	catch basins	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC may increase intensity of storm events which would be harder to control through traditional stormwater management.	2	2	25	29	Planning and implementation period dependent on larger development process (e.g., for a housing tract).	1	3	Y	F: High capital costs
Urban NPS	Stormwater	Stormwater Management - Dry Detention & Hydrodynamic Structures	In line storage	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC may increase intensity of storm events which would be harder to control through traditional stormwater management.	2	2	25	29	Planning and implementation period dependent on larger development process (e.g., for a housing tract).	1	3	Y	F: High capital costs
Urban NPS	Stormwater	Stormwater Management - Dry Extended Retention Ponds	Dry Extended Retention Ponds	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC may increase intensity of storm events which would be harder to control through traditional stormwater management.	2	2	25	29	Planning and implementation period dependent on larger development process (e.g., for a housing tract).	1	3	Y	F: High capital costs
Urban NPS	Stormwater	Stormwater Management - Dry Extended Retention Ponds	extended detention basins	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC may increase intensity of storm events which would be harder to control through traditional stormwater management.	2	2	25	29	Planning and implementation period dependent on larger development process (e.g., for a housing tract).	1	3	Y	F: High capital costs

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Urban NPS	Stormwater	Stormwater Management - Infiltration Practices	Infiltration trenches	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC may increase intensity of storm events which would be harder to control through traditional stormwater management.	2	2	25	29	Planning and implementation period dependent on larger development process (e.g., for a housing tract).	1	3	Y	E: Impact on environment?; F: High capital costs
Urban NPS	Stormwater	Stormwater Management - Infiltration Practices	Infiltration basins	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC may increase intensity of storm events which would be harder to control through traditional stormwater management.	2	2	25	29	Planning and implementation period dependent on larger development process (e.g., for a housing tract).	1	3	Y	E: Impact on environment?; F: High capital costs
Urban NPS	Stormwater	Stormwater Management - Infiltration Practices	porous pavement	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC may increase intensity of storm events which would be harder to control through traditional stormwater management.	2	2	25	29	Planning and implementation period dependent on larger development process (e.g., for a housing tract).	1	3	Y	E: Impact on environment?; F: High capital costs
Urban NPS	Stormwater	Stormwater Management - Filtering Practices	dry swales	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC may increase intensity of storm events which would be harder to control through traditional stormwater management.	2	2	25	29	Planning and implementation period dependent on larger development process (e.g., for a housing tract).	1	4	Y	F: One of highest capital costs of all BMPs, according to PA Trib Strategy

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Urban NPS	Stormwater	Stormwater Management - Filtering Practices	wet swales	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC may increase intensity of storm events which would be harder to control through traditional stormwater management.	2	2	25	29	Planning and implementation period dependent on larger development process (e.g., for a housing tract).	1	4	Y	F: One of highest capital costs of all BMPs, according to PA Trib Strategy
Urban NPS	Stormwater	Stormwater Management - Filtering Practices	bioretention	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC may increase intensity of storm events which would be harder to control through traditional stormwater management.	2	2	25	29	Planning and implementation period dependent on larger development process (e.g., for a housing tract).	1	4	Y	F: One of highest capital costs of all BMPs, according to PA Trib Strategy
Urban NPS	Stormwater	Stormwater Management - Filtering Practices	grassed channels	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC may increase intensity of storm events which would be harder to control through traditional stormwater management.	2	2	25	29	Planning and implementation period dependent on larger development process (e.g., for a housing tract).	1	4	Y	F: One of highest capital costs of all BMPs, according to PA Trib Strategy
Urban NPS	Stormwater	Stormwater Management - Filtering Practices	sand filters	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC may increase intensity of storm events which would be harder to control through traditional stormwater management.	2	2	25	29	Planning and implementation period dependent on larger development process (e.g., for a housing tract).	1	4	Y	F: One of highest capital costs of all BMPs, according to PA Trib Strategy
Urban NPS	Water resources	Urban Stream Restoration	Forested Buffers	N	Y	N	Y	Higher High Flows: Encourages Infiltration and reduces rate of flow	Yes, CC will increase higher high flows which may make stream restoration less effective at nutrient and sediment reductions.	5	10	50	65	Highly variable. Dependent upon restoration objectives.	3	1	Y	E: Not pursuing this BMP could further degrade environment; F: Capital costs should be low

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Urban NPS	Water resources	Urban Stream Restoration	Grassed buffers	N	Y	N	Y	Higher High Flows: Encourages Infiltration and reduces rate of flow	Yes, CC will increase higher high flows which may make stream restoration less effective at nutrient and sediment reductions.	5	10	50	65	Highly variable. Dependent upon restoration objectives.	3	1	Y	E: Not pursuing this BMP could further degrade environment; F: Capital costs should be low
Urban NPS	Land Use/ Land Mgmt	Wetlands - Mixed Open Land	constructed wetlands	Y	Y	Y	Y	Lower Low Flows: Non-tidal wetlands can act as a source of groundwater discharge during low flow periods, evening the hydrograph. Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC will increase higher high flows which may make wetlands less effective at nutrient and sediment reductions.	5	10	30	45	Planning and implementation highly variable, depending upon restoration objectives.	3	2	Y	E: Not pursuing this BMP could further degrade environment; F: Capital costs should be moderate
Urban NPS	Land Use/ Land Mgmt	Wetlands - Mixed Open Land	shallow wetlands	Y	Y	Y	Y	Lower Low Flows: Non-tidal wetlands can act as a source of groundwater discharge during low flow periods, evening the hydrograph. Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC will increase higher high flows which may make wetlands less effective at nutrient and sediment reductions.	5	10	30	45	Planning and implementation highly variable, depending upon restoration objectives.	3	2	Y	E: Not pursuing this BMP could further degrade environment; F: Capital costs should be moderate

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	**Category**	**Practice**	**Specific Practice**	**Lower low flow**	**Higher high flow**	**Higher temperatures**	**Does an adaptive benefit exist?**	**Rationale**		**Years for planning**	**Years for implementation**	**Lifetime of project**	**Total**	**Comments**	**Irreversibility: Environmental**	**Irreversibility: Financial**	**Irreversibility: Y or N**	**Comments**
Urban NPS	Land Use/ Land Mgmt	Wetlands - Mixed Open Land	Extended Detention Wetland	Y	Y	Y	Y	Lower Low Flows: Non-tidal wetlands can act as a source of groundwater discharge during low flow periods, evening the hydrograph. Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC will increase higher high flows which may make wetlands less effective at nutrient and sediment reductions.	5	10	30	45	Planning and implementation highly variable, depending upon restoration objectives.	3	2	Y	E: Not pursuing this BMP could further degrade environment; F: Capital costs should be moderate
Urban NPS	Land Use/ Land Mgmt	Abandoned Mined Land Reclamation	tree planting	N	Y	N	Y	Higher high flows: Will reduce sediment uptake and increase infiltration	N/A	5	10	20	35	Planning and implementation highly variable, depending upon restoration objectives.	1	3	Y	E: Should enhance environment; F: Large capital investment
Urban NPS	Land Use/ Land Mgmt	Abandoned Mined Land Reclamation	grass/shrub planting	N	Y	N	Y	Higher high flows: Will reduce sediment uptake and increase infiltration	N/A	5	10	20	35	Planning and implementation highly variable, depending upon restoration objectives.	1	3	Y	E: Should enhance environment; F: Large capital investment
Urban NPS	Forestry	Forest Harvesting Practices	Minimize the number of skid trail stream crossings	N	Y	Y	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration. Higher Temperature: More forest cover	No CC does not affect the effectiveness.	1	0	1	2	Implemented at time of harvesting; little planning required	1	1	N	E: Should enhance environment if implemented, but not cause irreversible damage if not implemented; F: Minimal capital investment

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Urban NPS	Forestry	Forest Harvesting Practices	Carefully Locate, Design and Build All Roads and Skid Trails	N	Y	Y	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration. Higher Temperature: More forest cover	No CC does not affect the effectiveness.	1	0	1	2	Implemented at time of harvesting; little planning required	1	1	N	E: Should enhance environment if implemented, but not cause irreversible damage if not implemented; F: Minimal capital investment
Urban NPS	Forestry	Forest Harvesting Practices	Keep landings out of low spots and poorly drained places	N	Y	Y	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration. Higher Temperature: More forest cover	No CC does not affect the effectiveness.	1	0	1	2	Implemented at time of harvesting; little planning required	1	1	N	E: Should enhance environment if implemented, but not cause irreversible damage if not implemented; F: Minimal capital investment
Urban NPS	Nutrient Management	Street Sweeping in Urban Areas		N	N	N	N	N/A	N/A				0				N	
Urban NPS	Nutrient Management	Dirt and Gravel Road Erosion and Sediment Controls	Keep the road surface tight and impervious	N	Y	N	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration	Yes, CC may increase intensity of storm events which would be harder to control through dirt and gravel road erosion/sediment control.	2	2	10	14	Planning and implementation highly variable, depending upon project size.	2	1	N	E: Not pursuing this BMP could damage the environment, but probably not irreversibly; F: Low capital investment per foot of road

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Urban NPS	Nutrient Management	Dirt and Gravel Road Erosion and Sediment Controls	Road grading	N	Y	N	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration	Yes, CC may increase intensity of storm events which would be harder to control through dirt and gravel road erosion/sediment control.	2	2	10	14	Planning and implementation highly variable, depending upon project size.	2	1	N	E: Not pursuing this BMP could damage the environment, but probably not irreversibly; F: Low capital investment per foot of road
Urban NPS	Nutrient Management	Dirt and Gravel Road Erosion and Sediment Controls	maintain a proper road crown for good drainage	N	Y	N	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration	Yes, CC may increase intensity of storm events which would be harder to control through dirt and gravel road erosion/sediment control.	2	2	10	14	Planning and implementation highly variable, depending upon project size.	2	1	N	E: Not pursuing this BMP could damage the environment, but probably not irreversibly; F: Low capital investment per foot of road
Agricultural NPS	Nutrient Management	Animal Waste Management System– Livestock		N	N	N	N	N/A	N/A				0				N	
Agricultural NPS	Nutrient Management	Animal Waste Management System – Poultry		N	N	N	N	N/A	N/A				0				N	

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Agricultural NPS	Nutrient Management	Barnyard Runoff Controls - With Storage & Without Storage	roof runoff control	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC may increase intensity of storm events which would be harder to control through traditional runoff controls.	1	1	3	5	Planning and implementation should be relatively simple for these types of controls. Retrofits to existing farms.	1	1	N	E: Changes to the environment will not be major and should be reversible; F: Low capital costs
Agricultural NPS	Nutrient Management	Barnyard Runoff Controls - With Storage & Without Storage	diversion of clean water from entering the barnyard	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC may increase intensity of storm events which would be harder to control through traditional runoff controls.	1	1	3	5	Planning and implementation should be relatively simple for these types of controls. Retrofits to existing farms.	1	1	N	E: Changes to the environment will not be major and should be reversible; F: Low capital costs
Agricultural NPS	Nutrient Management	Barnyard Runoff Controls - With Storage & Without Storage	control of runoff from barnyard areas	N	Y	Y	Y	Higher High Flows: Encourages Infiltration Higher Temperature: Reduces runoff	Yes, CC may increase intensity of storm events which would be harder to control through traditional runoff controls.	1	1	3	5	Planning and implementation should be relatively simple for these types of controls. Retrofits to existing farms.	1	1	N	E: Changes to the environment will not be major and should be reversible; F: Low capital costs
Agricultural NPS	Land Use/ Land Mgmt	Carbon Sequestration		N	N	N	N	N/A	N/A				0				N	

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Agricultural NPS	Land Use/ Land Mgmt	Acres Cereal Cover Crops	Acres Cereal Cover Crops	N	Y	N	Y	Higher High Flows: Encourages Infiltration	Yes, CC may increase intensity of storm events which would be harder to control through traditional cover crops.	0	0	1	1	Planning and implementation occurs within a year of planting.	1	1	N	E: Changes to the environment will not be major and should be reversible; F: Low capital costs
Agricultural NPS	Land Use/ Land Mgmt	Commodity Cereal Cover Crops	Commodity Cereal Cover Crops	N	Y	N	Y	Higher High Flows: Encourages Infiltration (lower magnitude than non-harvested cover crops)	Yes, CC will increase higher high flows which may be harder to control through traditional cover crops.	0	0	1	1	Planning and implementation occurs within a year of planting.	1	1	N	E: Changes to the environment will not be major and should be reversible; F: Low capital costs
Agricultural NPS	Land Use/ Land Mgmt	Acres Conservation Plans (Farm Plans)	conservation tillage	N	Y	N	Y	Higher High Flows: Encourages Infiltration	Yes, CC may increase intensity of storm events which would be harder to control with farm plans.	2	2	10	14	Planning and implementation should not take more than a couple years, but probably highly variable.	1	1	N	E: Changes to the environment will not be major and should be reversible; F: Low capital costs
Agricultural NPS	Land Use/ Land Mgmt	Acres Conservation Plans (Farm Plans)	crop rotations	N	Y	N	Y	Higher High Flows: Encourages Infiltration	Yes, CC may increase intensity of storm events which would be harder to control with farm plans.	2	2	10	14	Planning and implementation should not take more than a couple years, but probably highly variable.	1	1	N	E: Changes to the environment will not be major and should be reversible; F: Low capital costs
Agricultural NPS	Land Use/ Land Mgmt	Acres Conservation Plans (Farm Plans)	grassed waterways	N	Y	N	Y	Higher High Flows: Encourages Infiltration	Yes, CC may increase intensity of storm events which would be harder to control with farm plans.	2	2	10	14	Planning and implementation should not take more than a couple years, but probably highly variable.	1	1	N	E: Changes to the environment will not be major and should be reversible; F: Low capital costs

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Agricultural NPS	Land Use/ Land Mgmt	Acres Conservation Plans (Farm Plans)	sediment basins	N	Y	N	Y	Higher High Flows: Encourages Infiltration	Yes, CC may increase intensity of storm events which would be harder to control with farm plans.	2	2	10	14	Planning and implementation should not take more than a couple years, but probably highly variable.	1	1	N	E: Changes to the environment will not be major and should be reversible; F: Low capital costs
Agricultural NPS	Land Use/ Land Mgmt	Acres Conservation Plans (Farm Plans)	grade stabilization structures	N	Y	N	Y	Higher High Flows: Encourages Infiltration	Yes, CC may increase intensity of storm events which would be harder to control with farm plans.	2	2	10	14	Planning and implementation should not take more than a couple years, but probably highly variable.	1	1	N	E: Changes to the environment will not be major and should be reversible; F: Low capital costs
Agricultural NPS	Land Use/ Land Mgmt	Acres Conservation Till		N	N	N	N	N/A	N/A				0				N	
Agricultural NPS	Nutrient Management	Nutrient Management-Agriculture		N	N	N	N	N/A	N/A				0				N	
Agricultural NPS	Nutrient Management	Phytase Feed Additives – Poultry		N	N	N	N	Note: Does this decrease enteric fermentation? Is this given to cows?	N/A				0				N	

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Agricultural NPS	Land Use/ Land Mgmt	Retirement of Highly Erodible Land-Trees	tree planting	N	Y	Y	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration. Higher Temperature: More forest cover	Yes, CC may increase intensity of storm events which would be harder to control through riparian buffer controls.	1	2	10	13	Planning and implementation are highly variable, depending on project size.	2	1	N	E: Not implementing this BMP could cause further environmental degradation of already vulnerable lands; F: Low capital costs
Agricultural NPS	Land Use/ Land Mgmt	Retirement of Highly Erodible Land-Trees	shrub/grasses planting	N	Y	Y	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration. Higher Temperature: More forest cover	Yes, CC may increase intensity of storm events which would be harder to control through riparian buffer controls.	1	2	10	13	Planning and implementation are highly variable, depending on project size.	2	1	N	E: Not implementing this BMP could cause further environmental degradation of already vulnerable lands; F: Low capital costs
Agricultural NPS	Land Use/ Land Mgmt	Riparian Forest Buffers – Agriculture	riparian buffers (planted along rivers and streams)	N	Y	Y	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration. Higher Temperature: More forest cover	Yes, CC may increase higher high flows which may be harder to control through riparian buffer controls.	1	2	25	28	Planning and implementation are highly variable, depending on project size.	3	2	Y	E: Should improve environment rather than degrade; F: Does not require a large capital investment.
Agricultural NPS	Land Use/ Land Mgmt	Rotational Grazing/Grazing Land Protection with Stream Fencing	rotational grazing and stream fencing	N	Y	N	Y	Higher High Flows: Encourages Infiltration	Yes, CC may increase intensity of storm events which would be harder to control through rotational grazing.	1	2	10	13	Planning and implementation are highly variable, depending on project size.	1	1	N	E: Changes to the environment will not be major and should be reversible; F: Low capital costs

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Agricultural NPS	Water resources	Stream Protection with Fencing	fencing along streams	N	Y	N	Y	Higher High Flows: Encourages Infiltration	Yes, CC may increase higher high flows which may be harder to control through streambank fencing and riparian controls.	1	2	10	13	Planning and implementation should not take more than a couple years.	1	1	N	E: Changes to the environment will not be major and should be reversible; F: Low capital costs
Agricultural NPS	Water resources	Stream Protection without Fencing with Off Stream Watering and Tree Planting	watering holes with tree planting	N	Y	N	Y	Higher High Flows: Encourages Infiltration	Yes, CC may increase higher high flows which may be harder to control through fencing and riparian controls.	1	2	10	13	Planning and implementation should not take more than a couple years.	1	1	N	E: Changes to the environment will not be major and should be reversible; F: Low capital costs
Agricultural NPS	Nutrient Management	Off-Stream Watering		N	N	N	N	N/A	N/A				0				N	
Agricultural NPS	Land Use/ Land Mgmt	Conservation Tillage	Conservation tillage	N	Y	N	Y	Higher High Flows: Encourages Infiltration	Yes, CC may increase intensity of storm events which would be harder to control with conservation tillage.	0	0	1	1	Planning and implementation occurs within a year of planting.	1	1	N	E: Changes to the environment will not be major and should be reversible; F: Low capital costs
Agricultural NPS	Land Use/ Land Mgmt	Cover Crops, Early	Cover Crops	N	Y	N	Y	Higher High Flows: Encourages Infiltration	Yes, CC may increase intensity of storm events which would be harder to control with cover crops.	0	0	1	1	Planning and implementation occurs within a year of planting.	1	1	N	E: Changes to the environment will not be major and should be reversible; F: Low capital costs

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Agricultural NPS	Nutrient Management	Runoff Control	Ponds	N	Y	N	Y	Higher High Flows: Encourages Infiltration	Yes, CC may increase intensity of storm events which would be harder to control with traditional runoff controls.	1	3	10	14	Planning and implementation are highly variable, depending on project size.	2	1	N	E:Not implementing this BMP could lead to environmental degradation from animal waste; F: Low capital costs
Agricultural NPS	Nutrient Management	Runoff Control	Lagoons	N	Y	N	Y	Higher High Flows: Encourages Infiltration	Yes, CC may increase intensity of storm events which would be harder to control with traditional runoff controls.	1	3	10	14	Planning and implementation are highly variable, depending on project size.	2	1	N	E:Not implementing this BMP could lead to environmental degradation from animal waste; F: Low capital costs
Agricultural NPS	Nutrient Management	Runoff Control	Tanks for Liquid Waste	N	Y	N	Y	Higher High Flows: Encourages Infiltration	Yes, CC may increase intensity of storm events which would be harder to control with traditional runoff controls.	1	3	10	14	Planning and implementation are highly variable, depending on project size.	2	1	N	E:Not implementing this BMP could lead to environmental degradation from animal waste; F: Low capital costs
Agricultural NPS	Nutrient Management	SCWQP Implementation and Treatment of Highly Erodible Land	crop rotations	N	Y	N	Y	Higher High Flows: Encourages Infiltration	Yes, CC may increase intensity of storm events which would be harder to control effectively with traditional erosion controls.	1	1	10	12	Planning and implementation should not take more than a couple years.	2	1	N	E: Not implementing this BMP could cause further environmental degradation of already vulnerable lands; F: Low capital costs

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Agricultural NPS	Nutrient Management	SCWQP Implementation and Treatment of Highly Erodible Land	sediment basins	N	Y	N	Y	Higher High Flows: Encourages Infiltration	Yes, CC may increase intensity of storm events which would be harder to control effectively with traditional erosion controls.	1	1	10	12	Planning and implementation should not take more than a couple years.	2	1	N	E: Not implementing this BMP could cause further environmental degradation of already vulnerable lands; F: Low capital costs
Agricultural NPS	Nutrient Management	SCWQP Implementation and Treatment of Highly Erodible Land	grade stabilization structures	N	Y	N	Y	Higher High Flows: Encourages Infiltration	Yes, CC may increase intensity of storm events which would be harder to control effectively with traditional erosion controls.	1	1	10	12	Planning and implementation should not take more than a couple years.	2	1	N	E: Not implementing this BMP could cause further environmental degradation of already vulnerable lands; F: Low capital costs
Ag/ Forest NPS	Land Use/ Land Mgmt	Forest Conservation (Forest Conservation Act)	Open Space Set Aside (Conservation reserve)	N	Y	Y	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration. Higher Temperature: More forest cover	No, CC does not affect the effectiveness.	5	1	25	31	This will require planning but minimal implementation	3	1	Y	E: It would be difficult to reforest land after it has been developed.
Ag/ Forest NPS	Land Use/ Land Mgmt	Forest Conservation (Forest Conservation Act)	tree planting	N	Y	Y	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration. Higher Temperature: More forest cover	No, CC does not affect the effectiveness.	5	1	25	31	This will require planning but minimal implementation	3	1	Y	E: It would be difficult to reforest land after it has been developed.

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Ag/ Forest NPS	Land Use/ Land Mgmt	Forest Harvesting Practices- Preventing clearcut	Minimize the number of skid trail stream crossings	N	Y	Y	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration. Higher Temperature: Conservation of forest cover	No, CC does not affect the effectiveness.	1	2	5	8	Implemented at time of harvesting. Dependant on project size.	1	1	N	E: Should enhance environment if implemented, but not cause irreversible damage if not implemented; F: Minimal capital investment
Ag/ Forest NPS	Land Use/ Land Mgmt	Forest Harvesting Practices- Preventing clearcut	Carefully Locate, Design and Build All Roads and Skid Trails	N	Y	Y	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration. Higher Temperature: Conservation of forest cover	No, CC does not affect the effectiveness.	1	2	5	8	Implemented at time of harvesting. Dependant on project size.	1	1	N	E: Should enhance environment if implemented, but not cause irreversible damage if not implemented; F: Minimal capital investment
Ag/ Forest NPS	Land Use/ Land Mgmt	Forest Harvesting Practices- Preventing clearcut	Keep landings out of low spots and poorly drained places	N	Y	Y	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration. Higher Temperature: Conservation of forest cover	No, CC does not affect the effectiveness.	1	2	5	8	Implemented at time of harvesting. Dependant on project size.	1	1	N	E: Should enhance environment if implemented, but not cause irreversible damage if not implemented; F: Minimal capital investment
Ag/ Forest NPS	Land Use/ Land Mgmt	Forest Buffer Strip	Forested Buffers	N	Y	Y	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration. Higher Temperature: More forest cover	Yes, CC may make the current buffer less effective and a larger buffer necessary.	1	2	25	28	Planning and implementation are highly variable, depending on project size.	3	2	Y	E: Should improve environment rather than degrade; F: Does not require a large capital investment.

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Ag/ Forest NPS	Land Use/ Land Mgmt	Grassed Buffer Strip	grassed buffers	N	Y	N	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration.	Yes, CC may make the current buffer less effective and a larger buffer necessary.	1	1	10	12	Planning and implementation are highly variable, depending on project size.	1	2	N	E: Should improve environment rather than degrade; F: Capital costs should be moderate
Ag/ Forest NPS	Land Use/ Land Mgmt	CREP Wetland Restoration	shallow wetlands	N	Y	Y	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration.	Yes, CC may cause higher high flows that could reduce the effectiveness of wetlands as sediment/nutrient control measures.	5	10	30	45	Planning may take several years and implementation could last for even longer, depending on restoration needs.	3	3	Y	E: Should improve environment rather than degrade; Not pursuing this BMP, however, could lead to further destruction of wetlands; F: High capital costs
Ag/ Forest NPS	Land Use/ Land Mgmt	CREP Wetland Restoration	Extended Detention Wetland	N	Y	Y	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration.	Yes, CC may cause higher high flows that could reduce the effectiveness of wetlands as sediment/nutrient control measures.	5	10	30	45	Planning may take several years and implementation could last for even longer, depending on restoration needs.	3	3	Y	E: Should improve environment rather than degrade; Not pursuing this BMP, however, could lead to further destruction of wetlands; F: High capital costs
Ag/ Forest NPS	Land Use/ Land Mgmt	CREP Wetland Restoration	pond/ wetlands	N	Y	Y	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration.	Yes, CC may cause higher high flows that could reduce the effectiveness of wetlands as sediment/nutrient control measures.	5	10	30	45	Planning may take several years and implementation could last for even longer, depending on restoration needs.	3	3	Y	E: Should improve environment rather than degrade; Not pursuing this BMP, however, could lead to further destruction of wetlands; F: High capital costs

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Ag/ Forest NPS	Land Use/ Land Mgmt	Woodland Buffer Filter Area	Buffer Zones	N	Y	N	Y	Higher High Flows: Encourages Infiltration and Evapotranspiration. Higher Temperature: More forest cover	Yes, CC may make the current buffer less effective and a larger buffer necessary.	1	1	25	27	Planning and implementation are highly variable, depending on project size.	3	2	Y	E: Should improve environment rather than degrade; F: Does not require a large capital investment.
Ag/ Forest NPS	Land Use/ Land Mgmt	Woodland Erosion Stabilization	Land shaping and planting permanent vegetation	N	Y	N	Y	Higher high flows: Will reduce sediment uptake and increase infiltration	Yes, CC may increase intensity of storm events, which would reduce the effectiveness of woodlands as sediment control.	2	2	10	14	Planning and implementation are highly variable, depending on project size.	1	2	N	E: Should improve environment rather than degrade; F: Does not require a large capital investment.
Agricultural NPS	Nutrient Management	Sidedress Application of Nitrogen on Corn		N	N	N	N	N/A	N/A				0				N	
Agricultural NPS	Nutrient Management	Manure Application to Corn using Pre-Sidedress		N	N	N	N	N/A	N/A				0				N	
Agricultural NPS	Nutrient Management	Nitrate Test to Determine Need for Sidedress Nitrogen		N	N	N	N	N/A	N/A				0				N	
Agricultural NPS	Nutrient Management	Late Winter Split Application of Nitrogen on Small Grain		N	N	N	N	N/A	N/A				0				N	

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Agricultural NPS	Land Use/ Land Mgmt	Vegetative Stabilization of Marsh Fringe Areas	Land shaping and planting permanent vegetation	N	Y	N	Y	Higher high flows: Will reduce sediment uptake and increase infiltration	Yes, higher high flows will decrease effectiveness of vegetation stabilization	1	1	10	12	Planning and implementation are highly variable, depending on project size.	1	2	N	E: Should improve environment rather than degrade; F: Capital costs should be moderate
Agricultural NPS	Land Use/ Land Mgmt	Permanent Vegetative Cover on Cropland		N	N	N	N	Duplicative of cover crops	N/A				0				N	
Agricultural NPS	Land Use/ Land Mgmt	Permanent Vegetative Cover on Cropland for Wildlife	Permanent Vegetative Cover on Cropland for Wildlife	N	Y	N	Y	Higher high flows: Will reduce sediment uptake and increase infiltration	Yes, CC may increase intensity of storm events which would decrease effectiveness of vegetative cover.	1	1	5	7	Planning and implementation are highly variable, depending on project size.	2	1	N	E:Not implementing this BMP could lead to declines in wildlife populations and ecosystem health; F: Low capital costs
Agricultural NPS	Land Use/ Land Mgmt	Stripcropping Systems	Stripcropping Systems	N	Y	N	Y	Higher high flows: Will reduce sediment uptake and increase infiltration	Yes, CC may increase intensity of storm events which would decrease effectiveness of stripcropping systems	1	1	5	7	Planning and implementation are highly variable, depending on project size.	1	1	N	E: Changes to the environment will not be major and should be reversible; F: Low capital costs
Agricultural NPS	Land Use/ Land Mgmt	Buffer Stripcropping	Buffer Strip-cropping	N	Y	N	Y	Higher high flows: Will reduce sediment uptake and increase infiltration	Yes, CC may increase intensity of storm events which would decrease effectiveness of buffer stripcropping	1	1	5	7	Planning and implementation are highly variable, depending on project size.	1	1	N	E: Changes to the environment will not be major and should be reversible; F: Low capital costs

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Agricultural NPS	Land Use/ Land Mgmt	Buffer Stripcropping /Wildlife Option	Buffer Strip-cropping	N	Y	N	Y	Higher high flows: Will reduce sediment uptake and increase infiltration	Yes, CC may increase intensity of storm events which would decrease effectiveness of buffer stripcropping.	1	1	5	7	Planning and implementation are highly variable, depending on project size.	1	1	N	E: Changes to the environment will not be major and should be reversible; F: Low capital costs
Agricultural NPS	Land Use/ Land Mgmt	Terrace System	Terrace System	N	Y	N	Y	Higher high flows: Will reduce sediment uptake and increase infiltration	Yes, CC may increase intensity of storm events which would decrease effectiveness of terrace systems.	2	2	10	14	A terrace system may require years of planning and implementation. Dependant on project size.	2	2	N	E: Terraced systems alter the landscape and remain in place unless actively removed; F: moderate capital investment (?)
Agricultural NPS	Land Use/ Land Mgmt	Small Acreage Grazing System		N	N	N	N	Duplicative of Fenced alternating grazing areas	N/A				0				N	
Agricultural NPS	Land Use/ Land Mgmt	Farm Road or Heavy Traffic animal Travel lane Stabilization	Keep the road surface tight and impervious	N	Y	N	Y	Higher high flows: will reduce sediment uptake	Yes, CC may increase intensity of storm events which would decrease effectiveness of road stabilization	5	5	10	20	Planning and implementation are highly variable, depending on project size.	2	1	N	
Agricultural NPS	Land Use/ Land Mgmt	Farm Road or Heavy Traffic animal Travel lane Stabilization	Road grading	N	Y	N	Y	Higher high flows: will reduce sediment uptake	Yes, CC may increase intensity of storm events which would decrease effectiveness of road stabilization	5	5	10	20	Planning and implementation are highly variable, depending on project size.	2	1	N	

BMP				SCREEN 1: CC Adaptive benefit					Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility			
BMP Type	Category	Practice	Specific Practice	Lower low flow	Higher high flow	Higher temperatures	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Environmental	Irreversibility: Financial	Irreversibility: Y or N	Comments
Agricultural NPS	Land Use/ Land Mgmt	Farm Road or Heavy Traffic animal Travel lane Stabilization	maintain a proper road crown for good drainage	N	Y	N	Y	Higher high flows: will reduce sediment uptake	Yes, CC may increase intensity of storm events which would decrease effectiveness of road stabilization	5	5	10	20	Planning and implementation are highly variable, depending on project size.	2	1	N	
Point Source	Nutrient Management	POTWs Standards for Discharge Permits	POTWs Standards for Discharge Permits	Y	N	N	Y	Lower low flows: Stricter effluent standards will reduce pollution impact under low flow conditions	Yes, CC could reduce the effectiveness of planned TMDLs in meeting design water quality criteria (e.g., if future 7Q10 is lower than current 7Q10).	5	5	20	30	Planning and implementation are highly variable, depending on project size.	1	4	Y	

Ecosystem BMP Screens

Ecosystem ("living resources") BMPs			SCREEN 1: CC Adaptive benefit						Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility (evaluated at the Specific Practice Level)					Source(s)
Category	Practice	Specific Practice	Increased Water Temp	Sedimentation	Altered Flow Regimes	Sea Level Rise	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Financial	Irreversibility: Long Term Commitment	Irreversibility: Forcloses Other Options?	Irreversibility: Y or N	Comments	
Habitat protection and/or restoration	Build living shorelines	Construct shallow water rock sills to absorb wave energy with wetland vegetation planted behind	N	Y	Y	Y	Y	Living shorelines will allow wetland migration and other adaptive changes to take place as climate changes.	Yes--sea level rise will lead to shoreline migration.			indefinite	0		2	3	2	Y	Construction of living shorelines represents a long-term commitment, but does not completely foreclose other options	
Habitat protection and/or restoration	Build living shorelines	Employ organic materials such as fiber logs	N	Y	Y	Y	Y	Living shorelines will allow wetland migration and other adaptive changes to take place as climate changes.	Yes--sea level rise will lead to shoreline migration.			indefinite	0		2	3	2	Y	Construction of living shorelines represents a long-term commitment, but does not completely foreclose other options	
Habitat protection and/or restoration	Fishery Restoration	Build fish passageways	Y	N	Y	N	Y	Fish passageways will increase the chance of fish survival generally as well as in the face of climate impacts such as increased water temps and altered flow regimes	Yes--altered flow regimes could impact the effectiveness of the passageways.			indefinite	0		2	3	2	Y	Building fish passageways involves construction of structures that are intended to survive years into the future. Other options could still be employed, however, as long as the fish passageways do not interfere.	

Ecosystem ("living resources") BMPs			SCREEN 1: CC Adaptive benefit						Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility (evaluated at the Specific Practice Level)					Source(s)
Category	Practice	Specific Practice	Increased Water Temp	Sedimentation	Altered Flow Regimes	Sea Level Rise	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Financial	Irreversibility: Long Term Commitment	Irreversibility: Forcloses Other Options?	Irreversibility: Y or N	Comments	
Habitat protection and/or restoration	Fishery Restoration	Remove physical and chemical blockages for Bay species such as sturgeon, sea turtles, manatees	Y	N	Y	N	Y	Fish passageways will increase the chance of fish survival generally as well as in the face of climate impacts such as increased water temps and altered flow regimes.	Yes--altered flow regimes could impact the effectiveness of the passageways.			indefinite	0		2	3	1	Y	Removal of physical or chemical blockages is intended to be permanent. Removing blockages does not foreclose any other options.	Chesapeake 2000 Bay Agreement, http://www.chesapeakebay.net/agreement.htm; NOAA Chesapeake Bay Office Strategic Plan, http://noaa.chesapeakebay.net/docs/ReadingRoom/NCBOStrategicPlanFINAL.pdf
Biological population management	Fishery Restoration	Maintain/protect upstream spawning habitats	Y	N	Y	N	Y	Protecting upstream spawning habitats will increase the chance of fish survival generally as well as in the face of climate impacts such as increased water temps and altered flow regimes	Yes--upstream spawning habitats may shift as water temperature and flow regimes change.			indefinite	0		2	2	1	N	Maintenance and protection of upstream habitats will require ongoing effort, which could be interrupted at any time. It does not foreclose other options later.	

Ecosystem ("living resources") BMPs			SCREEN 1: CC Adaptive benefit						Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility (evaluated at the Specific Practice Level)					Source(s)
Category	Practice	Specific Practice	Increased Water Temp	Sedimentation	Altered Flow Regimes	Sea Level Rise	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Financial	Irreversibility: Long Term Commitment	Irreversibility: Forcloses Other Options?	Irreversibility: Y or N	Comments	
Biological population management	Fishery Restoration	Manage fishery harvest levels - important fisheries include: American eel, Shad, Atlantic menhaden, Black sea bass, Bluefish, Tautog, Blue Crab etc.	Y	N	Y	N	Y	More abundant and robust fisheries will have more likelihood of being resilient to climate change impacts.	Yes--spawning is temperature dependent for some species and altered flow regimes could interfere with migration and natural spawning cycles.			indefinite	0		2	1	1	N	Managing harvest levels requires ongoing effort, which could be interrupted at any time. Harvest levels may also be revised every year. It does not foreclose other options.	NOAA Fisheries Ecosystem Plan, http://noaa.chesapeakebay.net/docs/FEP_DRAFT.pdf
Biological population management	Increase Oyster populations	Breed triploid Asian Suminoe Oysters	Y	Y	Y	N	Y	Can withstand large temperature and salinity ranges, unlike native oyster population.	Yes--even though this species can withstand more adverse conditions, there are limits to its resilience.			indefinite	0		2	3	3	Y	It will be difficult to remove introduced oysters, so it is a long term commitment. This practice forecloses other options, since there is a chance of non-sterile oysters being introduced and causing irreversible ecosystem changes	Chesapeake Bay Program

Ecosystem ("living resources") BMPs			SCREEN 1: CC Adaptive benefit						Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility (evaluated at the Specific Practice Level)					Source(s)
Category	Practice	Specific Practice	Increased Water Temp	Sedimentation	Altered Flow Regimes	Sea Level Rise	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Financial	Irreversibility: Long Term Commitment	Irreversibility: Forcloses Other Options?	Irreversibility: Y or N	Comments	
Biological population management	Increase Oyster populations	Introduce diploid Asian Suminoe Oysters	Y	Y	Y	N	Y	Can withstand large temperature and salinity ranges, unlike native oyster population.	Yes--even though this species can withstand more adverse conditions, there are limits to its resilience.			indefinite	0		2	3	3	Y	It will be difficult to remove introduced oysters, so it is a long term commitment. This practice forecloses other options, since there is a chance of extinction of native oysters and hybridization.	Chesapeake Bay Program
Non-native species management	Invasive Species Management	*Phragmites australis* (common reed)	N	Y	Y	N	Y	Invasive species such as *Phragmites australis* can survive in adverse conditions unsuitable for native species; controlling invasives will give native species a better chance of adapting and surviving in the face of climate change.	Yes--altered conditions could alter where and when invasive species thrive and, thus, impact the management plans to control them.			indefinite	0		2	2	1	N	Controlling invasive will require ongoing effort, which could be interrupted at any point. Does not foreclose other options.	Common Reed (*Phragmites australis*) in the Chesapeake Bay: A Draft Bay-wide Management Plan. October 2003.

Ecosystem ("living resources") BMPs			SCREEN 1: CC Adaptive benefit						Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility (evaluated at the Specific Practice Level)					Source(s)
Category	**Practice**	**Specific Practice**	**Increased Water Temp**	**Sedimentation**	**Altered Flow Regimes**	**Sea Level Rise**	**Does an adaptive benefit exist?**	**Rationale**		**Years for planning**	**Years for implementation**	**Lifetime of project**	**Total**	**Comments**	**Irreversibility: Financial**	**Irreversibility: Long Term Commitment**	**Irreversibility: Forcloses Other Options?**	**Irreversibility: Y or N**	**Comments**	
Non-native species management	Invasive Species Management	*Lythrum salicaria* (purple loosestrife)	N	N	Y	N	Y	Primarily invades disturbed wetlands, but large colonies can develop in any moist or marshy site; controlling invasives will give native species a better chance of adapting and surviving in the face of climate change.	Yes--altered conditions could alter where and when invasive species thrive and, thus, impact the management plans to control them.			indefinite	0		2	2	1	N	Controlling invasive will require ongoing effort, which could be interrupted at any point. Does not foreclose other options.	Purple Loosestrife (*Lythrum salicaria*) in the Chesapeake Bay Watershed: A Regional Management Plan. May 2004.
Non-native species management	Invasive Species Management	*Trapa natans* (water chestnut)	N	Y	N	N	Y	Floating rosette of leaves around a central stem that is rooted in the sediment; controlling invasives will give native species (e.g., SAV) a better chance of adapting and surviving in the face of climate change.	Yes--altered conditions could alter where and when invasive species thrive and, thus, impact the management plans to control them.			indefinite	0		2	2	1	N	Controlling invasive will require ongoing effort, which could be interrupted at any point. Does not foreclose other options.	Water Chestnut (*Trapa natans*) in the Chesapeake Bay Watershed: A Regional Management Plan. December 2003.
Non-native species management	Invasive Species Management	*Cygnus olor* (mute swan)	N	N	N	N	N	Sea level rise can flood nests.	Yes--altered conditions could alter where and when invasive species thrive and, thus, impact the management plans to control them.			indefinite	0					N		Mute Swan (*Cygnus olor*) in the Chesapeake Bay: A Draft Bay-wide Management Plan. November 2003.

Ecosystem ("living resources") BMPs			SCREEN 1: CC Adaptive benefit						Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility (evaluated at the Specific Practice Level)					Source(s)
Category	**Practice**	**Specific Practice**	**Increased Water Temp**	**Sedimentation**	**Altered Flow Regimes**	**Sea Level Rise**	**Does an adaptive benefit exist?**	**Rationale**		**Years for planning**	**Years for implementation**	**Lifetime of project**	**Total**	**Comments**	**Irreversibility: Financial**	**Irreversibility: Long Term Commitment**	**Irreversibility: Forcloses Other Options?**	**Irreversibility: Y or N**	**Comments**	
Non-native species management	Invasive Species Management	*Myocastor coypus* (Nutria)	N	Y	N	Y	Y	Sea level rise exacerbates the effects of Nutria feeding, which destroys marsh and eventually becomes open water.	Yes--altered conditions could alter where and when invasive species thrive and, thus, impact the management plans to control them.			indefinite	0		2	2	1	N	Controlling invasive will require ongoing effort, which could be interrupted at any point. Does not foreclose other options.	Nutria (*Myocastor coypus*) in the Chesapeake Bay: A Draft Bay-Wide Management Plan. November 2003.
Non-native species management	Invasive Species Management	*Dreissena polymorpha* (zebra mussels)	Y	Y	N	N	Y	Optimal conditions for spawning occur when water temp is greater than 12C. Larvae are free-swimming and live in the water colimn for up to 3 months as long as the water temp remains between 10 and 25C.	Yes--altered conditions could alter where and when invasive species thrive and, thus, impact the management plans to control them.			indefinite	0		2	2	1	N	Controlling invasive will require ongoing effort, which could be interrupted at any point. Does not foreclose other options.	Zebra Mussels (*Dreissena polymorpha*) in the Chesapeake Bay Watershed: A Regional Management Plan. Final Draft. May 2004.
Non-native species management	Invasive Species Prevention	Voluntary ballast water management program	N	N	N	N	N	The ballast water management program does not have an adaptive benefit.	No				0					N		Chesapeake 2000 Bay Agreement

Ecosystem ("living resources") BMPs			SCREEN 1: CC Adaptive benefit						Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility (evaluated at the Specific Practice Level)					Source(s)
Category	Practice	Specific Practice	Increased Water Temp	Sedimentation	Altered Flow Regimes	Sea Level Rise	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Financial	Irreversibility: Long Term Commitment	Irreversibility: Forcloses Other Options?	Irreversibility: Y or N	Comments	
Biological population management	Restore Native Oyster Populations	Rebuild oyster habitats using alternative substances	N	Y	Y	N	Y	Oyster reef development and protection can control and enhance water flow, which could improve the quality of the oyster's own habitat (in the face of altered flow regimes and increased sedimentation and salinity).	Yes--flourishing oyster populations require proper salinity, decreased sediment concentrations, and extended warm water growing and breeding season.			indefinite	0		2	3	1	Y	Intent of practice is to restore long-term habitat	Chesapeake Bay Program
Biological population management	Restore Native Oyster Populations	Rebuild oyster habitats using old oyster shells	N	Y	Y	N	Y	Oyster reef development and protection can control and enhance water flow, which could improve the quality of the oyster's own habitat (in the face of altered flow regimes and increased sedimentation and salinity).	Yes--flourishing oyster populations require proper salinity, decreased sediment concentrations, and extended warm water growing and breeding season.			indefinite	0		2	3	1	Y	Intent of practice is to restore long-term habitat. Does not foreclose other options, since oyster shell reefs are naturally occurring and could be deconstructed.	Chesapeake Bay Program

Ecosystem ("living resources") BMPs			SCREEN 1: CC Adaptive benefit						Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility (evaluated at the Specific Practice Level)					Source(s)
Category	Practice	Specific Practice	Increased Water Temp	Sedimentation	Altered Flow Regimes	Sea Level Rise	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Financial	Irreversibility: Long Term Commitment	Irreversibility: Forcloses Other Options?	Irreversibility: Y or N	Comments	
Biological population management	Restore Native Oyster Populations	Create sanctuaries	N	Y	Y	N	Y	Oyster reef development and protection can control and enhance water flow, which could improve the quality of the oyster's own habitat (in the face of altered flow regimes and increased sedimentation and salinity).	Yes--flourishing oyster populations require proper salinity, decreased sediment concentrations, and extended warm water growing and breeding season.			indefinite	0		2	3	1	Y	Intent of practice is to restore long-term habitat, but sanctuary designation could technically be removed at any point.	Chesapeake 2000 Bay Agreement
Biological population management	Restore Native Oyster Populations	Aquaculture	N	Y	Y	N	Y	Oyster reef development and protection can control and enhance water flow, which could improve the quality of the oyster's own habitat (in the face of altered flow regimes and increased sedimentation and salinity).	Yes--flourishing oyster populations require proper salinity, decreased sediment concentrations, and extended warm water growing and breeding season.			indefinite	0		2	3	1	Y	Intent of practice is to restore long-term habitat and would require an upfront resource investment and significant planning.	Chesapeake 2000 Bay Agreement

Ecosystem ("living resources") BMPs			SCREEN 1: CC Adaptive benefit						Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility (evaluated at the Specific Practice Level)					Source(s)
Category	**Practice**	**Specific Practice**	**Increased Water Temp**	**Sedimentation**	**Altered Flow Regimes**	**Sea Level Rise**	**Does an adaptive benefit exist?**	**Rationale**		**Years for planning**	**Years for implementation**	**Lifetime of project**	**Total**	**Comments**	**Irreversibility: Financial**	**Irreversibility: Long Term Commitment**	**Irreversibility: Forcloses Other Options?**	**Irreversibility: Y or N**	**Comments**	
Biological population management	Restore Native Oyster Populations	Employ disease-resistant management techniques (e.g., breed disease-resistant oysters, clean bars of infected oysters before planting, limit distribution of infected seed)	N	Y	Y	N	Y	Oyster reef development and protection can control and enhance water flow, which could improve the quality of the oyster's own habitat (in the face of altered flow regimes and increased sedimentation and salinity).	Yes--flourishing oyster populations require proper salinity, decreased sediment concentrations, and extended warm water growing and breeding season.			indefinite	0		2	3	1	Y	Intent of practice is to restore long-term habitat. Does not foreclose other options.	Chesapeake 2000 Bay Agreement
Habitat protection and/or restoration	Restore Submerged Aquatic Vegetation	Establish SAV beds that can serve as a source of plant material	N	Y	Y	Y	Y	Submerged aquatic vegetation reduces shoreline erosion.	Yes--Increased sediment input is expected to lead to decreased water clarity and, thus, declines in SAV.			indefinite	0		2	2	1	N	Restoring SAV will require ongoing effort that could be interrupted at any point.	
Habitat protection and/or restoration	Restore Submerged Aquatic Vegetation	Propagate SAV in laboratories and nurseries	N	Y	Y	Y	Y	Submerged aquatic vegetation reduces shoreline erosion.	Yes--Increased sediment input is expected to lead to decreased water clarity and, thus, declines in SAV.			indefinite	0		2	2	1	N	Restoring SAV will require ongoing effort that could be interrupted at any point.	

Ecosystem ("living resources") BMPs			SCREEN 1: CC Adaptive benefit						Does climate change affect the effectiveness of the BMP?	SCREEN 2: Dimensions of Timeliness					SCREEN 3a: Irreversibility (evaluated at the Specific Practice Level)					Source(s)
Category	Practice	Specific Practice	Increased Water Temp	Sedimentation	Altered Flow Regimes	Sea Level Rise	Does an adaptive benefit exist?	Rationale		Years for planning	Years for implementation	Lifetime of project	Total	Comments	Irreversibility: Financial	Irreversibility: Long Term Commitment	Irreversibility: Forcloses Other Options?	Irreversibility: Y or N	Comments	
Habitat protection and/or restoration	Restore Submerged Aquatic Vegetation	Harvest SAV from existing wild areas (when it will not harm donor population or area is being claimed for development anyway)	N	Y	Y	Y	Y	Submerged aquatic vegetation reduces shoreline erosion.	Yes--Increased sediment input is expected to lead to decreased water clarity and, thus, declines in SAV.			indefinite	0		2	2	1	N	Restoring SAV will require ongoing effort that could be interrupted at any point.	

APPENDIX C

Tables C-1 and C-2 list all of the water quality and aquatic ecosystem decisions examined in this pilot project for the Chesapeake Bay and shows which decisions remained for further analysis and which were eliminated.

Table C-1. All water quality decisions considered for this pilot project and labeled according to whether the decision was eliminated and when, or whether the decision remained in the analysis and was aggregated into a broader practice or renamed.[8]

Water Quality Decisions (not aggregated)	Brief Description of Decision	Eliminated after Application of Criterion 1[a] or 2[b], or Remained	Final Aggregated Decision Nomenclature
Abandoned Mined Land Reclamation: Grass/Shrub Planting	Reclamation of abandoned mined land through planting of grass, shrubs, or trees.[9]	Remained	Abandoned Mined Land Reclamation
Abandoned Mined Land Reclamation: Tree Planting	See above description of abandoned mined land reclamation.	Remained	
Acres Cereal Cover Crops: Acres Cereal Cover Crops	Cover crops (harvested or non-harvested) grown to provide winter cover of cropland.[10]	2	
Acres Conservation Plans (Farm Plans): Conservation Tillage	Conservation plans are comprehensive plans that address natural resource management on agricultural lands and utilize best management practices to control erosion and sediment loss and manage runoff. Conservation tillage involves planting and growing crops with minimal disturbance of the surface soil. No-till farming is a form of	2	

[8] Only one point source water quality decision was evaluated in this project: "POTWs Standards for TMDLs". All other decisions deal with non-point sources.

[9] Pennsylvania Department of Environmental Protection. 2004. Pennsylvania's Chesapeake Bay Tributary Strategy. Accessed online at: http://www.depweb.state.pa.us/chesapeake/lib/chesapeake/pdfs/tribstrategy.pdf (Accessed 9/29/08).

[10] Maryland Department of Natural Resources, Chesapeake & Coastal Watershed Service. 1999. Maryland's Tributary Strategies: Best Management Practices Progress Report. Accessed online at: http://www.dnr.state.md.us/bay/tribstrat/bmp_report_1998.pdf (Accessed 9/29/08).

Water Quality Decisions (not aggregated)	Brief Description of Decision	Eliminated after Application of Criterion 1[a] or 2[b], or Remained	Final Aggregated Decision Nomenclature
	conservation tillage in which the crop is seeded directly into vegetative cover or crop residue with no disturbance of the surface soil. Minimum tillage farming involves some disturbance of the soil, but uses tillage equipment that leaves much of the vegetative cover or crop residue on the surface.[11]		
Acres Conservation Plans (Farm Plans): Crop Rotations	See above description of conservation plans.	2	
Acres Conservation Plans (Farm Plans): Grade Stabilization Structures	Grade stabilization structures are installed to stabilize the channel grade and control erosion to prevent the formation or advance of gullies and headcuts. The practice is used in areas where structures are necessary to stabilize the site.[12]	2	
Acres Conservation Plans (Farm Plans): Grassed Waterways	See above description of conservation plans.	2	
Acres Conservation Plans (Farm Plans): Sediment Basins	See above description of conservation plans.	2	
Acres Conservation Till	A process that uses tillage equipment to seed the crop directly into the vegetative cover or crop residue on the surface, with minimal soil disturbance.[13]	1	
Animal Waste Management System – Livestock	Management system for livestock waste to reduce runoff.	1	

[11] Pennsylvania Department of Environmental Protection. 2004. Pennsylvania's Chesapeake Bay Tributary Strategy. Accessed online at: http://www.depweb.state.pa.us/chesapeake/lib/chesapeake/pdfs/tribstrategy.pdf (Accessed 9/29/08).

[12] United States Department of Agriculture, Natural Resources Conservation Service. 2008. National Conservation Practice Standards. Accessed online at: http://www.nrcs.usda.gov/TECHNICAL/standards/nhcp.html (Accessed 9/29/08).

[13] Maryland Department of Natural Resources, Chesapeake & Coastal Watershed Service. 1999. Maryland's Tributary Strategies: Best Management Practices Progress Report. Accessed online at: http://www.dnr.state.md.us/bay/tribstrat/bmp_report_1998.pdf (Accessed 9/29/08).

Water Quality Decisions (not aggregated)	Brief Description of Decision	Eliminated after Application of Criterion 1[a] or 2[b], or Remained	Final Aggregated Decision Nomenclature
Animal Waste Management System – Poultry	Management system for poultry waste to reduce runoff.	1	
Barnyard Runoff Controls – With & Without Storage: Control of Runoff from Barnyard Areas	The installation of practices to control runoff from barnyard areas. Examples include practices such as roof runoff control, diversion of clean water from entering the barnyard and control of runoff from barnyard areas.[14]	2	
Barnyard Runoff Controls – With & Without Storage: Diversion of Clean Water from Entering the Barnyard	See above description of barnyard runoff controls.	2	
Barnyard Runoff Controls – With & Without Storage: Roof Runoff Control	See above description of barnyard runoff controls.	2	
Buffer Stripcropping	Growing crops in a systematic arrangement of strips across the field to reduce soil erosion by wind and water. This practice is used on cropland and wildlife areas where field crops are grown. The crops are arranged so that a strip of grass or close-growing crop is alternated with a clean tilled strip or a strip with less protective cover.[15]	2	
Buffer Stripcropping: Wildlife Option	See explanation above of buffer stripcropping.	2	
Carbon Sequestration	Carbon sequestration refers to the conversion of cropland to hayland (warm season grasses). The hayland is managed as permanent hayland, providing a mechanism	1	

[14] Pennsylvania Department of Environmental Protection. 2004. Pennsylvania's Chesapeake Bay Tributary Strategy. Accessed online at: http://www.depweb.state.pa.us/chesapeake/lib/chesapeake/pdfs/tribstrategy.pdf (Accessed 9/29/08).

[15] United States Department of Agriculture, Natural Resources Conservation Service. 2008. National Conservation Practice Standards. Accessed online at: http://www.nrcs.usda.gov/TECHNICAL/standards/nhcp.html (Accessed 9/29/08).

Water Quality Decisions (not aggregated)	Brief Description of Decision	Eliminated after Application of Criterion 1[a] or 2[b], or Remained	Final Aggregated Decision Nomenclature
	for sequestering carbon within the soil.[16]		
Commodity Cereal Cover Crops: Commodity Cereal Cover Crops	Commodity cover crops grown to provide winter cover of cropland to prevent erosion.[17]	2	
Conservation Tillage: Conservation tillage	A process that uses tillage equipment to seed the crop with minimal soil disturbance.[18]	2	
Cover Crops, Early: Cover Crops	See general cover crop description. Efficiency varies by when planted.[19]	2	
CREP Wetland Restoration: Extended Detention Wetland	Wetland restoration is the reestablishment of wetlands on mixed open land where they used to exist. Extended detention wetlands provide a greater degree of downstream channel protection.[20]	Remained	CREP Wetland Restoration
CREP Wetland Restoration: Pond/Wetlands	See above description of CREP Wetland Restoration.	Remained	
CREP Wetland Restoration: Shallow Wetlands	See above description of CREP Wetland Restoration.	Remained	
Dirt and Gravel Road Erosion and Sediment Controls: Keep the Road Surface Tight and Impervious	Implementation of practices to stabilize dirt and gravel roads adjacent to streams. The purpose of this BMP is to significantly	2	

[16] Pennsylvania Department of Environmental Protection.

[17] Maryland Department of Natural Resources, Chesapeake & Coastal Watershed Service. 1999. Maryland's Tributary Strategies: Best Management Practices Progress Report. Accessed online at: http://www.dnr.state.md.us/bay/tribstrat/bmp_report_1998.pdf (Accessed 9/29/08).

[18] Maryland Department of Natural Resources, Chesapeake & Coastal Watershed Service. 1999. Maryland's Tributary Strategies: Best Management Practices Progress Report. Accessed online at: http://www.dnr.state.md.us/bay/tribstrat/bmp_report_1998.pdf (Accessed 9/29/08).

[19] Pennsylvania Department of Environmental Protection. 2004. Pennsylvania's Chesapeake Bay Tributary Strategy. Accessed online at: http://www.depweb.state.pa.us/chesapeake/lib/chesapeake/pdfs/tribstrategy.pdf (Accessed 9/29/08).

[20] Metropolitan Council and Barr Engineering Co. 2001. Constructed Wetlands: Stormwater Wetlands. Minnesota Urban Small Sites BMP Manual. Prepared for the Metropolitan Council by Barr Engineering Corps. Accessed online at: http://www.metrocouncil.org/environment/Watershed/bmp/CH3_STConstWLSwWetland.pdf (Accessed 9/29/08).

Water Quality Decisions (not aggregated)	Brief Description of Decision	Eliminated after Application of Criterion 1[a] or 2[b], or Remained	Final Aggregated Decision Nomenclature
	reduce the erosion of sediment and the nutrients within the sediment from the road and adjacent areas into the stream.[21]		
Dirt and Gravel Road Erosion and Sediment Controls: Maintain a Proper Road Crown for Good Drainage	Proper crowning and compacting of the road surface quickens the removal of runoff, thus protecting the road surface from degradation.[22]	2	
Dirt and Gravel Road Erosion and Sediment Controls: Road Grading	Grading consists of cutting through, redistributing, and re-compacting the road surface crust, and/or adding new road fill material to obtain the desired roadway shape and profile.[23]	2	
Enhanced Stormwater Management: Buffer Zones	Vegetative filter strips, or buffer zones, are densely vegetated sections of land designed to convey runoff in the form of sheet flow from adjacent developed sites.[24]	Remained	Stormwater Management - Filtering Practices
Stormwater Management – Filtering Practices: Bioretention	Bioretention utilizes soils and both woody and herbaceous plants to remove pollutants from storm water runoff. In bioretention systems, runoff is conveyed as sheet flow to the treatment area, which consists of a grass buffer strip, sand bed, ponding area, organic layer or	Remained	

[21] Pennsylvania Department of Environmental Protection.

[22] Environmental Protection Agency. 2000. Chapter 1: Road Surface. Recommended Practices Manual: A Guideline for Maintenance and Service of Unpaved Roads. Choctawhatchee, Pea and Yellow Rivers Watershed Management Authority. Accessed online at: http://www.epa.gov/owow/nps/unpavedroads/ch1.pdf (Accessed 9/29/08).

[23] Ibid.

[24] Environmental Protection Agency, Office of Water. 1996. Environmental Protection Agency, Office of Water. 1996. Protecting Natural Wetlands: A Guide to Stormwater Best Management Practices. Accessed online at: http://www.epa.gov/owow/wetlands/pdf/protecti.pdf (Accessed 9/29/08).

Water Quality Decisions (not aggregated)	Brief Description of Decision	Eliminated after Application of Criterion 1[a] or 2[b], or Remained	Final Aggregated Decision Nomenclature
	mulch layer, planting soil and plans.[25]		
Stormwater Management – Filtering Practices: Dry Swales	Dry swales are vegetated, open-channel areas designed specifically to treat and attenuate stormwater runoff for a specified water quality volume. As stormwater runoff flows along these channels, it passes through vegetation that slows the water to allow filtering through a subsoil matrix, and/or infiltration into the underlying soils.[26]	Remained	
Stormwater Management – Filtering Practices: Grassed Channels	Grassed channels are channels lined with grass or erosion-resistant plant species that are constructed for the stable conveyance of stormwater runoff. They use the ability of vegetation to reduce the flow velocities associated with concentrated runoff.[27]	Remained	
Stormwater Management – Filtering Practices: Sand Filters	Sand filters are systems of underground pipes beneath a self-contained bed of sand designed to treat urban stormwater.[28]	Remained	
Stormwater Management – Filtering Practices: Wet Swales	Wet swales consist of a broad open channels capable of temporarily storing water. Unlike the dry swale, the wet swale does not have an underlying filtering bed. The wet swale is	Remained	

[25] Environmental Protection Agency, Office of Water. 1999. Storm Water Technology Fact Sheet: Bioretention. Accessed online at: http://www.epa.gov/owm/mtb/biortn.pdf (Accessed 9/29/08).

[26] Environmental Protection Agency. Grassed Swales. National Pollutant Discharge Elimination System (NPDES). Accessed online at: http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=75 (Accessed 9/29/08).

[27] Environmental Protection Agency, Office of Water. 1996. Environmental Protection Agency, Office of Water. 1996. Protecting Natural Wetlands: A Guide to Stormwater Best Management Practices. Accessed online at: http://www.epa.gov/owow/wetlands/pdf/protecti.pdf (Accessed 9/29/08).

[28] Ibid.

Water Quality Decisions (not aggregated)	Brief Description of Decision	Eliminated after Application of Criterion 1[a] or 2[b], or Remained	Final Aggregated Decision Nomenclature
	constructed directly within existing soils and may or may not intersect the water table.[29]		
Stormwater Management Retrofits: Underground Sand Filtering System	Construction of stormwater facilities on lands previously developed without such facilities.[30]	Remained	
Enhanced Stormwater Management: Infiltration trench/basin	Enhancements emphasize water quality controls in addition to water quantity controls.[31]	Remained	Stormwater Management - Infiltration Practices
Enhanced Stormwater Management: Porous Pavement	Porous pavement is an alternative to conventional pavement and is designed to minimize surface runoff.[32]	Remained	
Stormwater Management – Infiltration Practices: Infiltration Basins	Infiltration basins are stormwater impoundments that detain stormwater runoff and return it to the ground by allowing runoff to infiltrate gradually through the soils of the bed and sides of the basin.[33]	Remained	
Stormwater Management – Infiltration Practices: Infiltration Trenches	An infiltration trench is an excavated trench backfilled with clean, coarse aggregate to allow for the temporary storage of runoff. Infiltration trenches remove fine particulates and	Remained	

[29] Metropolitan Council and Barr Engineering Co. 2001. Wet Swales. Minnesota Urban Small Sites BMP Manual. Prepared for the Metropolitan Council by Barr Engineering Corps. Accessed online at: http://www.metrocouncil.org/environment/Watershed/bmp/CH3_STConstWLWetSwale.pdf (Accessed 9/29/08).

[30] Maryland Department of Natural Resources, Chesapeake & Coastal Watershed Service. 1999. Maryland's Tributary Strategies: Best Management Practices Progress Report. Accessed online at: http://www.dnr.state.md.us/bay/tribstrat/bmp_report_1998.pdf (Accessed 9/29/08).

[31] Ibid.

[32] Environmental Protection Agency, Office of Water. 1996. Environmental Protection Agency, Office of Water. 1996. Protecting Natural Wetlands: A Guide to Stormwater Best Management Practices. Accessed online at: http://www.epa.gov/owow/wetlands/pdf/protecti.pdf (Accessed 9/29/08).

[33] Ibid.

Water Quality Decisions (not aggregated)	Brief Description of Decision	Eliminated after Application of Criterion 1[a] or 2[b], or Remained	Final Aggregated Decision Nomenclature
	soluble pollutants from runoff by temporary storage and infiltration into the underlying soil.[34]		
Stormwater Management – Infiltration Practices: Porous Pavement	Porous pavement is an alternative to conventional pavement designed to minimize surface runoff.[35]	Remained	
Stormwater Management Retrofits: Infiltration Trench	An infiltration trench is an excavated trench backfilled with clean, coarse aggregate to allow for the temporary storage of runoff. Infiltration trenches remove fine particulates and soluble pollutants from runoff by temporary storage and infiltration into the underlying soil.[36]	Remained	
Enhanced Stormwater Management: Ponds	See above description of stormwater management.	Remained	Stormwater Management - Wet Ponds & Wetlands
Stormwater Management – Wet Ponds & Wetlands: Constructed Wetlands	Constructed wetlands are shallow pools constructed on non-wetland sites as part of the stormwater collection and treatment system. Constructed wetlands are designed to maximize removal of pollutants from stormwater through physical, chemical, and biological mechanisms.[37]	Remained	
Stormwater Management – Wet Ponds & Wetlands: Pond/Wetlands	Wet ponds are depressions constructed by excavation and embankment procedures to store excess runoff temporarily on a site. Wet ponds regulate stormwater runoff from a given rainfall event by the temporary	Remained	

[34] Ibid.

[35] Environmental Protection Agency, Office of Water. 1996. Protecting Natural Wetlands: A Guide to Stormwater Best Management Practices. Accessed online at: http://www.epa.gov/owow/wetlands/pdf/protecti.pdf (Accessed 9/29/08).

[36] Ibid.

[37] Ibid..

Water Quality Decisions (not aggregated)	Brief Description of Decision	Eliminated after Application of Criterion 1[a] or 2[b], or Remained	Final Aggregated Decision Nomenclature
	storage of peak flows in order to mitigate quantity and quality impacts to downstream systems.[38]		
Stormwater Management – Wet Ponds & Wetlands: Retention Ponds	See above description of wet ponds.	Remained	
Stormwater Management – Wet Ponds & Wetlands: Shallow Wetlands	See above description of wet ponds.	Remained	
Stormwater Management – Wet Ponds & Wetlands: Wet Extended Detention Ponds	See above description of wet ponds.	Remained	
Stormwater Management – Wet Ponds & Wetlands: Wet Pond	See above description of wet ponds.	Remained	
Stormwater Management Retrofits: Wetland	Construction of stormwater facilities on lands previously developed without such facilities.[39]	Remained	
Erosion and Sediment Control (During Construction): Filter Berms	A gravel or stone filter berm is a temporary ridge made up of loose gravel, stone, or crushed rock that slows, filters, and diverts flow from an open traffic area and acts as an efficient form of sediment control.[40]	2	
Erosion and Sediment Control (During Construction): Geotextiles	Filtering the stormwater through a fine mesh geotextile material will remove sediments and prevent premature clogging.[41]	2	
Erosion and Sediment Control	Mulching is the application of a	2	

[38] Environmental Protection Agency, Office of Water. 1996. Protecting Natural Wetlands: A Guide to Stormwater Best Management Practices. Accessed online at: http://www.epa.gov/owow/wetlands/pdf/protecti.pdf (Accessed 9/29/08).

[39] Maryland Department of Natural Resources, Chesapeake & Coastal Watershed Service. 1999. Maryland's Tributary Strategies: Best Management Practices Progress Report. Accessed online at: http://www.dnr.state.md.us/bay/tribstrat/bmp_report_1998.pdf (Accessed 9/29/08).

[40] Stormwater Authority. Filter Berms. Stormwater Best Management Practices. Accessed online at: http://www.stormwaterauthority.org/assets/Filter%20Berms.pdf (Accessed 9/29/08).

[41] Environmental Protection Agency, Office of Water.

Water Quality Decisions (not aggregated)	Brief Description of Decision	Eliminated after Application of Criterion 1[a] or 2[b], or Remained	Final Aggregated Decision Nomenclature
(During Construction): Mulching	protective cover of plant residue or other suitable material not produced on the site to the soil surface. This practice is used to help control erosion, protect crops, conserve moisture, prevent compaction, reduce runoff and control weeds.[42]		
Erosion and Sediment Control (During Construction): Sediment Traps		2	
Farm Road or Heavy Traffic Animal Travel Lane Stabilization: Keep Road Surface Tight and Impervious	See previous description of lane stabilization.	2	
Farm Road or Heavy Traffic Animal Travel Lane Stabilization: Maintain a Proper Road Crown for Good Drainage	See previous description of road crown maintenance.	2	
Farm Road or Heavy Traffic Animal Travel Lane Stabilization: Road grading	See previous description of road grading.	2	
Forest Buffer Strip: Forested Buffers	A linear strip of forest along rivers and streams that filters nutrients and sediment and enhances stream habitat.[43]	Remained	Riparian Forest/Woodland Buffers – Agriculture
Riparian Forest Buffers – Agriculture: Riparian Buffers	Riparian Forest Buffers are linear wooded areas planted along rivers and streams.[44]	Remained	
Woodland Buffer Filter Area: Buffer Zones	Wooded or other buffer areas planted along woodlands.[45]	Remained	

[42] United States Department of Agriculture, Natural Resources Conservation Service. 2008. National Conservation Practice Standards. Accessed online at: http://www.nrcs.usda.gov/TECHNICAL/standards/nhcp.html (Accessed 9/29/08).

[43] Maryland Department of Natural Resources, Chesapeake & Coastal Watershed Service. 1999. Maryland's Tributary Strategies: Best Management Practices Progress Report. Accessed online at: http://www.dnr.state.md.us/bay/tribstrat/bmp_report_1998.pdf (Accessed 9/29/08).

[44] Pennsylvania Department of Environmental Protection. 2004. Pennsylvania's Chesapeake Bay Tributary Strategy. Accessed online at: http://www.depweb.state.pa.us/chesapeake/lib/chesapeake/pdfs/tribstrategy.pdf (Accessed 9/29/08).

Water Quality Decisions (not aggregated)	Brief Description of Decision	Eliminated after Application of Criterion 1[a] or 2[b], or Remained	Final Aggregated Decision Nomenclature
Forest Conservation (Forest Conservation Act): Open Space Set Aside (Conservation Reserve)	Open spaces are grassed or wooded areas located within development sites to increase pervious area. Open areas reduce the velocity of surface runoff, resulting in an increased contact time of sheet flow with the soil and vegetative surfaces.[46]	Remained	Forest Conservation (Forest Conservation Act)
Forest Conservation (Forest Conservation Act): Tree Planting	Implementation of the Forest Conservation Act, which requires the retention of a portion of forested lands on any newly developed site.[47]	Remained	
Forest Conservation: Infrastructure Planning	See above description of forest conservation.	Remained	
Forest Conservation: Narrower Residential Streets	See above description of forest conservation.	Remained	
Forest Conservation: Open Space Design & Set Asides	See above description of forest conservation.	Remained	
Forest Harvesting Practices: Carefully Locate, Design and Build All Roads and Skid Trails	Application of regulatory and voluntary best management practices applied to timber harvests, including erosion and sediment control and streamside management zones.[48] Soil uncovered by vehicles and skid trails is vulnerable to erosion. Keep roads and skid trails out of wet and poorly drained spots to minimize soil erosion.	2	

[45] Connecticut River Joint Commissions of New Hampshire and Vermont. 2001. Guidance for Communities in the Connecticut River Watershed. Riparian Buffers for the Connecticut River Watershed. Accessed online at: www.crjc.org/buffers/Guidance%20for%20Communities.pdf (Accessed 9/29/08).

[46] Environmental Protection Agency, Office of Water. 1996. Environmental Protection Agency, Office of Water. 1996. Protecting Natural Wetlands: A Guide to Stormwater Best Management Practices. Accessed online at: http://www.epa.gov/owow/wetlands/pdf/protecti.pdf (Accessed 9/29/08).

[47] Maryland Department of Natural Resources, Chesapeake & Coastal Watershed Service. 1999. Maryland's Tributary Strategies: Best Management Practices Progress Report. Accessed online at: http://www.dnr.state.md.us/bay/tribstrat/bmp_report_1998.pdf (Accessed 9/29/08).

[48] Ibid.

Water Quality Decisions (not aggregated)	Brief Description of Decision	Eliminated after Application of Criterion 1[a] or 2[b], or Remained	Final Aggregated Decision Nomenclature
Forest Harvesting Practices: Keep Landings out of Low Spots and Poorly Drained Places	See above description of forest harvesting practices.	2	
Forest Harvesting Practices: Minimize the Number of Skid Trail Stream Crossings	See above description of forest harvesting practices.	2	
Forest Harvesting Practices- Preventing Clearcut: Carefully Locate, Design and Build All Roads and Skid Trails	See above description of forest harvesting practices.	2	
Forest Harvesting Practices- Preventing Clearcut: Keep Landings out of Low Spots and Poorly Drained Places	See above description of forest harvesting practices.	2	
Forest Harvesting Practices- Preventing Clearcut: Minimize the Number of Skid Trail Stream Crossings	See above description of forest harvesting practices.	2	
Grassed Buffer Strip: Grassed Buffers	A linear strip of grass along rivers and streams that filters nutrients and sediment and enhances stream habitat.[49]	2	
Impervious Surface Reduction – Non-structural Practices: Urban Forestry	Planting trees to reduce impervious surface area.	2	
Late Winter Split Application of Nitrogen on Small Grain	Split application is the process of matching nitrogen supply for a pre-established target yield and a given level of soil moisture, and then supplying the remaining nitrogen as moisture conditions improve.[50]	1	
Manure Application to Corn using Pre-Sidedress	Side-dressing corn with Nitrogen at time that is most beneficial to	1	

[49] Maryland Department of Natural Resources, Chesapeake & Coastal Watershed Service. 1999. Maryland's Tributary Strategies: Best Management Practices Progress Report. Accessed online at: http://www.dnr.state.md.us/bay/tribstrat/bmp_report_1998.pdf (Accessed 9/29/08).

[50] Saskatchewan Soil Conservation Association. 2003. Soil Facts: Nitrogen – Split Application. The Newsletter of the Saskatchewan Soil Conservation Association, Issue 37. Accessed online at: www.ssca.ca/newsletters/issue37/Rich1.html (Accessed 9/29/08).

Water Quality Decisions (not aggregated)	Brief Description of Decision	Eliminated after Application of Criterion 1[a] or 2[b], or Remained	Final Aggregated Decision Nomenclature
	the crop.		
Marine Pump Outs: Installation	A facility sited at marinas for pumping sewage from boat holding tanks to a dockside storage facility.[51]	1	
Nitrate Test to Determine Need for Sidedress Nitrogen	See above description of manure application to crops using pre-sidedress.	1	
Nutrient Management: Agriculture	A comprehensive plan to manage the amount, placement, timing and application of animal waste, fertilizer, sludge, or other plant nutrients.[52]	1	
Off-Stream Watering	Providing troughs or other watering devices in remote locations away from the stream to discourage animals from entering the stream, and the provision of some fencing adjacent to stream crossings to limit access points.[53]	1	
Permanent Vegetative Cover on Cropland		1	
Permanent Vegetative Cover on Cropland for Wildlife: Permanent Vegetative Cover on Cropland for Wildlife		2	
Phytase Feed Additives: Poultry	Use of Phytase as a poultry feed additive to reduce phosphorus concentrations in swine manure.[54]	1	
POTWs Standards for Discharge Permits: POTWs	Increased occurrence of low flows in receiving streams may	Remained	POTWs Standards for Discharge

[51] Maryland Department of Natural Resources, Chesapeake & Coastal Watershed Service.

[52] Maryland Department of Natural Resources, Chesapeake & Coastal Watershed Service. 1999. Maryland's Tributary Strategies: Best Management Practices Progress Report. Accessed online at: http://www.dnr.state.md.us/bay/tribstrat/bmp_report_1998.pdf (Accessed 9/29/08).

[53] Ibid.

[54] Pennsylvania Department of Environmental Protection. 2004. Pennsylvania's Chesapeake Bay Tributary Strategy. Accessed online at: http://www.depweb.state.pa.us/chesapeake/lib/chesapeake/pdfs/tribstrategy.pdf (Accessed 9/29/08).

Water Quality Decisions (not aggregated)	Brief Description of Decision	Eliminated after Application of Criterion 1[a] or 2[b], or Remained	Final Aggregated Decision Nomenclature
Standards for Discharge Permits[55]	lead to decreased contaminant dilution capacity, requiring changes to discharge permits.		Permits
Reduction in Urban Growth: Narrower Residential Streets	Reduction in projections for the conversion of urban land. This results in "returning" urban land to forest, mixed open and agricultural land.[56]	Remained	Reduction in Urban Growth
Reduction in Urban Growth: Open Space Design	See above description for reduction in urban growth.	Remained	
Reduction in Urban Growth: Urban Forestry	See above description for reduction in urban growth.	Remained	
Retirement of Highly Erodible Land-Trees: Shrub/Grasses Planting	Retirement takes marginal and highly erosive agricultural cropland out of production by planting permanent vegetative cover such as shrubs, grasses, and/or trees.[57]	2	
Retirement of Highly Erodible Land-Trees: Tree Planting	See above description for retirement of highly erodible land.	2	
Riparian Forest Buffers – Urban: Riparian Buffers	Riparian Forest Buffers are linear wooded areas planted along rivers and streams.[58]	Remained	Riparian Forest Buffers – Urban
Riparian Grass Buffers – Developed Land: Grassed Buffers	Grassed Buffers are linear strips of maintained grass or other non-woody vegetation between the edge of fields and streams, rivers or tidal waters.[59]	2	
Rotational Grazing/Grazing Land Protection with Stream Fencing: Rotational Grazing	This practice involves dividing pasture areas into cells or paddocks. Each paddock is	2	

[55] This is the only point source water quality decision that was evaluated. All other decisions deal with non-point sources.

[56] Ibid.

[57] Pennsylvania Department of Environmental Protection. 2004. Pennsylvania's Chesapeake Bay Tributary Strategy. Accessed online at: http://www.depweb.state.pa.us/chesapeake/lib/chesapeake/pdfs/tribstrategy.pdf (Accessed 9/29/08).

[58] Ibid.

[59] Ibid.

Water Quality Decisions (not aggregated)	Brief Description of Decision	Eliminated after Application of Criterion 1[a] or 2[b], or Remained	Final Aggregated Decision Nomenclature
and Stream Fencing	intensively grazed for a short period, and then allowed to rest and recover before being grazed again. The amount of time each cell is grazed and then rested relates to the time of year, quality of the forage and the growth stage of the forage.[60]		
Runoff Control: Lagoons	Methods for control of livestock waste runoff.	2	
Runoff Control: Ponds	See above description for runoff control.	2	
Runoff Control: Tanks for Liquid Waste	See above description for runoff control.	2	
SCWQP Implementation and Treatment of Highly Erodible Land: Crop Rotations	A comprehensive plan addressing natural resource management of farmland directed toward the control of erosion and sediment loss, and management of animal waste or agricultural chemicals.[61]	2	
SCWQP Implementation and Treatment of Highly Erodible Land: Grade Stabilization Structures	See above description of SCWQP implementation.	2	
SCWQP Implementation and Treatment of Highly Erodible Land: Sediment Basins	See above description of SCWQP implementation.	2	
Septic Connections	The connection of failing septic systems to sewer lines.[62]	1	
Septic Denitrification	The installation of new systems or retrofitting of existing systems with technology to remove nitrogen from individual systems.[63]	1	

[60] Ibid.

[61] Maryland Department of Natural Resources, Chesapeake & Coastal Watershed Service. 1999. Maryland's Tributary Strategies: Best Management Practices Progress Report. Accessed online at: http://www.dnr.state.md.us/bay/tribstrat/bmp_report_1998.pdf (Accessed 9/29/08).

[62] Ibid.

[63] Ibid.

Water Quality Decisions (not aggregated)	Brief Description of Decision	Eliminated after Application of Criterion 1[a] or 2[b], or Remained	Final Aggregated Decision Nomenclature
Septic Pumping	Pumping individual septic systems once every three years, the average routine maintenance of these systems.[64]	1	
Sidedress Application of Nitrogen on Corn	Use of sidedress application system for nitrogen on corn to reduce runoff.	1	
Small Acreage Grazing System	The purpose of this BMP is to increase the level of forage and livestock implementation, increase forage nutrient removal, density and average height resulting in improved infiltration and decreased runoff.[65]	1	
Stormwater Management – Dry Detention & Hydrodynamic Structures: Dry Detention Basins	This stormwater management category includes practices such as dry detention basins and hydrodynamic structures designed to moderate flows. Dry detention basins are structures for detaining runoff water which remain dry between storm events.[66]	Remained	Stormwater Management - Dry Extended Retention/Detention Ponds
Stormwater Management – Dry Detention & Hydrodynamic Structures: Swirl Separators, or Hydrodynamic Structures	This stormwater management category includes practices such as dry detention basins and hydrodynamic structures designed to moderate flows.[67] Swirl separators and hydrodynamic structures are often used to separate out solid waste, suspended sediments, oils and debris from stormwater.	Remained	

[64] Ibid.

[65] Pennsylvania Department of Environmental Protection. 2004. Pennsylvania's Chesapeake Bay Tributary Strategy. Accessed online at: http://www.depweb.state.pa.us/chesapeake/lib/chesapeake/pdfs/tribstrategy.pdf (Accessed 9/29/08).

[66] Pennsylvania Department of Environmental Protection. 2004. Pennsylvania's Chesapeake Bay Tributary Strategy. Accessed online at: http://www.depweb.state.pa.us/chesapeake/lib/chesapeake/pdfs/tribstrategy.pdf (Accessed 9/29/08).

[67] Ibid.

Water Quality Decisions (not aggregated)	Brief Description of Decision	Eliminated after Application of Criterion 1[a] or 2[b], or Remained	Final Aggregated Decision Nomenclature
Stormwater Management – Dry Detention & Hydrodynamic Structures: Catch Basins	Catch basins prevent materials such as sand, silt, leaves and debris from washing away with the stormwater by catching them in a filtered drainage structure.	Remained	
Stormwater Management – Dry Detention & Hydrodynamic Structures: In line storage	Placing devices in the storm drain system to restrict the rate of flow.	Remained	
Stormwater Management – Dry Extended Retention Ponds: Dry Extended Retention Ponds	This stormwater management category includes practices such as dry extended detention ponds and extended detention basins.[68]	Remained	
Stormwater Management – Dry Extended Retention Ponds: Extended Detention Basins	See above descriptions of stormwater management practices.	Remained	
Stormwater Management Conversion: Dry Extended Detention Ponds	See above descriptions of stormwater management practices.	Remained	
Stormwater Management Conversion: Retention Facilities	See above descriptions of stormwater management practices.	Remained	
Stormwater Management Conversion: Wet Extended Detention Ponds	See above descriptions of stormwater management practices.	Remained	
Stormwater Management Retrofits: Detention Pond	See above descriptions of stormwater management practices.	Remained	
Stream Protection with Fencing: Fencing Along Streams	Stream protection with fencing involves the fencing of narrow strips of land along streams to completely exclude livestock.[69]	2	
Stream Protection without Fencing with Off Stream Watering and Tree Planting: Watering Holes with Tree Planting	This option involves the use of troughs or "watering holes" in remote locations away from streams, as well as the placement of stream crossings.[70]	2	

[68] Ibid.

[69] Ibid.

[70] Ibid.

Water Quality Decisions (not aggregated)	Brief Description of Decision	Eliminated after Application of Criterion 1[a] or 2[b], or Remained	Final Aggregated Decision Nomenclature
Street Sweeping in Urban Areas	This practice reduces the wash off of detritus and air deposited compounds from urban areas by regular sweeping of impervious streets.[71]	1	
Stripcropping Systems	Stripcropping is growing crops in a systematic arrangement of strips across the field to reduce soil erosion by water and wind. This practice is used on cropland and certain recreation and wildlife lands where field crops are grown. The crops are arranged so that a strip of grass or close-growing crop is alternated with a clean tilled strip or a strip with less protective cover.[72]	2	
Terrace System	Terraces break up a slope by providing areas of low slope in the reverse direction, keeping water from proceeding down slope at increasing volume and velocity. Terraces generally direct flow across a vegetated, steep slope to a stable outlet.[73]	2	
Tree Planting: Not Along Rivers and Streams		Remained	Tree Planting
Urban Nutrient Management: Chemical Fertilizers	Management of nutrient inputs in urban areas.	1	
Urban Stream Restoration: Forested Buffers	Use of forested buffers to protect streams in urban areas.	Remained	Urban Stream Restoration
Urban Stream Restoration:	Use of grassed buffers to protect	Remained	

[71] Ibid.

[72] United States Department of Agriculture, Natural Resources Conservation Service. 2008. National Conservation Practice Standards. Accessed online at: http://www.nrcs.usda.gov/TECHNICAL/standards/nhcp.html (Accessed 9/29/08).

[73] Point and Nonpoint Source Programs, Water Quality Division, Wyoming Department of Environmental Quality. 1999. Urban Best Management Practices for Nonpoint Source Pollution. Accessed online at: http://deq.state.wy.us/wqd/watershed/Downloads/NPS%20Program/92171.pdf (Accessed 9/29/08).

Water Quality Decisions (not aggregated)	**Brief Description of Decision**	**Eliminated after Application of Criterion 1[a] or 2[b], or Remained**	**Final Aggregated Decision Nomenclature**
Grassed Buffers	streams in urban areas.		
Vegetative Stabilization of Marsh Fringe Areas: Land Shaping and Planting Permanent Vegetation		2	
Wetlands – Mixed Open Land: Constructed Wetlands	See above descriptions of wetlands.	Remained	Wetlands – Mixed Open Land
Wetlands – Mixed Open Land: Extended Detention Wetlands	See above descriptions of wetlands.	Remained	
Wetlands – Mixed Open Land: Shallow Wetlands	See above descriptions of wetlands.	Remained	
Woodland Erosion Stabilization: Land Shaping and Planting Permanent Vegetation		2	

[a] Screen 1: Climate change adaptation potential

[b] Screen 2: Dimensions of timeliness

Table C-2: All aquatic ecosystem decisions considered for this pilot project and labeled according to whether the decision remained in the analysis and was aggregated into a broader practice or was eliminated and when.

Aquatic Ecosystem Decisions (not aggregated)	Brief Description of Decision	Remained after Application of Criterion 1[a] or 2[b], or Eliminated	Final Aggregated Decision Nomenclature
Build Living Shorelines: Construct Shallow Water Rock Sills to Absorb Wave Energy with Wetland Vegetation Planted Behind	Living shorelines employ natural habitat elements to protect shorelines from erosion while also providing critical habitat for wildlife and water quality benefits. Living shorelines can use rock sills or other approaches to absorb wave energy and protect vegetation.[74]	Remained	Living Shorelines
Build Living Shorelines: Employ Organic Materials such as Fiber Logs	See above description of living shorelines.	Remained	
Fishery Restoration: Build Fish Passageways		Remained	Build Fish Passageways
Fishery Restoration: Maintain/Protect Upstream Spawning Habitats		Remained	Maintain/Protect Upstream Spawning Habitats
Fishery Restoration: Manage Fishery Harvest Levels	Fishery management strategies attempt to keep fish populations within sustainable population ranges.	Remained	Manage Fishery Harvest Levels
Fishery Restoration: Remove Physical and Chemical Blockages for Bay Species	Removal of physical barriers or chemical gradients that restrict or impede movement or migration of fish or other aquatic organisms.[75]	Remained	Remove Physical and Chemical Blockages
Increase Oyster Populations: Breed Triploid Asian Suminoe Oysters	Introduction of non-native Suminoe oysters in order to offset declining populations of native	Remained	Breed Triploid Asian Suminoe Oysters

[74] Virginia Coastal Zone Management Program. 2007. Living Shorelines: The Natural Approach to Controlling Shoreline Erosion. VA CZM Issue Fact Sheet Series. Accessed online at: http://www.deq.virginia.gov/coastal/documents/lsfactsheet.pdf (Accessed 9/29/08).

[75] United States Department of Agriculture, Natural Resources Conservation Service. 2008. National Conservation Practice Standards. Accessed online at: http://www.nrcs.usda.gov/TECHNICAL/standards/nhcp.html (Accessed 9/29/08).

Aquatic Ecosystem Decisions (not aggregated)	Brief Description of Decision	Remained after Application of Criterion 1[a] or 2[b], or Eliminated	Final Aggregated Decision Nomenclature
	oysters. Oysters are triploid in order to ensure infertility.[76]		
Increase Oyster Populations: Introduce Diploid Asian Suminoe Oysters	Introduction of non-native Suminoe oysters in order to offset declining populations of native oysters in Chesapeake Bay.[77] Diploid oysters are fertile.	Remained	Introduce Diploid Asian Suminoe Oysters
Invasive Species Management: *Cygnus olor* (Mute Swan)		1	
Invasive Species Management: *Dreissena polymorpha* (Zebra Mussels)		Remained	*Dreissena polymorpha* (Zebra Mussels)
Invasive Species Management: *Lythrum salicaria* (Purple Loosestrife)		Remained	*Lythrum salicaria* (Purple Loosestrife)
Invasive Species Management: *Myocastor coypus* (Nutria)		Remained	*Myocastor coypus* (Nutria)
Invasive Species Management: *Phragmites australis* (Common Reed)		Remained	*Phragmites australis* (Common Reed)
Invasive Species Management: *Trapa natans* (Water Chestnut)		Remained	*Trapa natans* (Water Chestnut)
Invasive Species Prevention: Voluntary Ballast Water Management Program	Ballast water discharged from ships is one of the largest pathways for the introduction and spread of invasive species. This management practice involves ships monitoring and reporting ballast water discharge.[78]	1	
Restore Native Oyster	Use of old oyster shells to	Remained	Rebuild Oyster

[76] Powledge, F. 2005. Chesapeake Bay Restoration: A Model of What? BioScience 55(12):1032-1038.

[77] Ibid.

[78] United States Coast Guard, U.S. Department of Homeland Security. Ballast Water Management: Overview. Accessed online at: http://www.uscg.mil/hq/cg5/cg522/cg5224/bwm.asp (Accessed 9/29/08).

Aquatic Ecosystem Decisions (not aggregated)	Brief Description of Decision	Remained after Application of Criterion 1[a] or 2[b], or Eliminated	Final Aggregated Decision Nomenclature
Populations: Rebuild Oyster Habitats Using Old Oyster Shells	assist in rebuilding oyster habitats.		Habitats Using Old Oyster Shells
Restore Native Oyster Populations: Aquaculture	Use of aquaculture to rebuild oyster populations.	Remained	Aquaculture
Restore Native Oyster Populations: Create Sanctuaries	Sanctuaries are areas where shellfish harvest is prohibited. The purpose of this practice is to protect oysters from harvest and increase population numbers.[79]	Remained	Create Sanctuaries
Restore Native Oyster Populations: Employ Disease-Resistant Management Techniques	Oyster populations are severely threatened by disease. These management techniques would attempt to encourage the long-term development of disease-resistance in oysters.[80]	Remained	Employ Disease-Resistant Management Techniques
Restore Native Oyster Populations: Rebuild Oyster Habitats Using Alternative Substances	Use of alternative substances to assist in rebuilding oyster habitats.	Remained	Rebuild Oyster Habitats Using Alternative Substances
Restore Submerged Aquatic Vegetation (SAV): Establish SAV Beds		Remained	SAV
Restore Submerged Aquatic Vegetation: Harvest SAV from Existing Wild Areas		Remained	
Restore Submerged Aquatic Vegetation: Propagate SAV in Laboratories and Nurseries		Remained	

[a] Screen 1: Climate change adaptation potential

[b] Screen 2: Dimensions of timeliness

[79] Chesapeake Bay Program. 2004. Chesapeake Bay Oyster Management Plan. Report accessed online at: http://www.chesapeakebay.net/content/publications/cbp_12889.pdf (Accessed 9/29/08).

[80] Ibid.

APPENDIX D

Decision Attribute Template

Instructions: This information will be used to score and rank the suitability of management decisions for research and development investments to help facilitate adaptation to climate change. The analysis will be conducted with a fuzzy logic-based model that evaluates the "truth" of a series of statements with respect to a set of logical rules. This document contains a set of logical statements and scores based the information described below each statement. We are asking for your critical peer-review of our estimates.

Best Management Practice

1. Restoration or protection goals for this <u>system</u> are highly vulnerable to climate change.

1	**2**	**3**	**4**	**5**	**Score**
Not true	…	Maybe	…	True	

Definitions: Where Vulnerability = f(management goal, sensitivity of *system* to climate change, capacity for autonomous adaptation). Autonomous adaptation refers to changes that are likely to take place without specific interventions (i.e., the development of new adaptive strategies, specific incentives, or specialized decision support resources)

2. The performance of this management practice is highly vulnerable to climate change.

1	**2**	**3**	**4**	**5**	**Score**
Not true	…	Maybe	…	True	

Definitions: Where Vulnerability = f(management goal, sensitivity of *management practice* to climate change, capacity for autonomous adaptation). Sensitivity of the management practice refers to potentially negative changes in performance with respect to expected cost, efficiency, or effectiveness. Autonomous adaptation refers to changes that are likely to take place without specific interventions (i.e., the development of new adaptive strategies, specific incentives, or specialized decision support resources).

Best Management Practice	
ATTRIBUTE	**DESCRIPTION/RATIONALE**
Brief Description	
Focus of the decision in terms of geographic area	
Focus area	
Overall (strategic) goal of the decision	
Objective and purpose of decision [decision endpoint]	
Climate is relevant to issues of concern [Does climate change affect the effectiveness of the decision?] (Y/N)	
The potential for adaptive responses (viz., those that could be incorporated in this decision) to mitigate impacts	
How frequently the decision is made [for a given site or focus area]	

Best Management Practice	
3. Planning, implementation, and performance associated with this management action will occur over a long period of time.	

1	2	3	4	5	Score
Not true	…	Maybe	…	True	

Definitions: Long-term decisions have overall project planning, implementation, and performance periods equal to or greater than 25 years

Planning period	
Implementation period	
Project lifetime	

4. The management action involves a near-term decision with important, long-term consequences.

1	2	3	4	5	Score
Not true	…	Maybe	…	True	

Definitions: Important consequences may include irreversible actions (e.g., grade and fill, infrastructure development, habitat loss/creation) or long-term commitments (e.g., expectations for continued funding, maintenance).

Irreversible decision [Does decision preclude future options or require a strong commitment to the post-decision status quo?] (Y/N)	
Current trends are maladaptive (Y/N)	

Best Management Practice	
5. The resource addressed by this management action is a very high priority issue for water quality or living resource restoration or protection efforts in the Chesapeake Bay watershed.	

1	2	3	4	5	Score
Not true	…	Maybe	…	True	

Definitions: Priority reflects relative importance among resources associated with the Chesapeake Bay Program.

Priority of threatened resources (ranked on a scale of 1-4, where 4 is a high priority resource)	

6. This management action involves a capital intensive investment.

1	2	3	4	5	Score
Not true	…	Maybe	…	True	

Definitions: Capital intensive means that implementing the management action requires more than normal operating funds, such as a supplemental appropriation, bond issue, loan).

Total investment over lifetime of project	
Estimated cost of annual payments [including operation and maintenance and land rentals, where applicable]	

Best Management Practice
Characteristics of the decision process
7. Decision-makers have a <u>high degree of flexibility</u> in how they design or use this management practice.

1	2	3	4	5	Score
Not true	…	Maybe	…	True	

Definitions: Flexibility means discretion with regard to the design and geographic placement of this management practice (as opposed to instances where the decision maker is highly constrained).

Statutory (or other) authority for the decision	
Voluntary or Regulatory?	
Incentives for the decision [Why are you doing this program?]	
Organization with primary decision-making responsibility	
Other organizations with decision-making responsibility	
Decision rules and tools used to make decisions	
Climate-related data (e.g., precipitation, stream flow, sea level, temperature) currently used in the decision	
Decisions interlinked	

Best Management Practice	
8. The institutions that carry out this management action have high levels of adaptive capacity.	

1	2	3	4	5	Score
Not true	…	Maybe	…	True	

Definitions: Adaptive capacity refers to the ability to respond to or accommodate change. Organizations with high-levels of adaptive capacity can manage changing conditions, because they have substantial levels of technical expertise, financial and operational resources, and flexibility in how they carry out their missions.

Organizational resources for climate change	
Organizational expertise in climate change	

9. Adaptive changes in this management practice are likely to be limited by internal constraints within the implementing organizations.

1	2	3	4	5	Score
Not true	…	Maybe	…	True	

Definitions: Internal constraints are barriers to implementing adaptive change, such as rigid operational rules, inflexible organizational culture, legal constraints, or unresponsive funding arrangement.

Institutional constraints	
Operational constraints	
Relative priority of this decision within the primary decision-making organization	

Best Management Practice	
Decision maker receptivity/ recognition that climate change is a factor that should be considered in this decision	
Flexibility to incorporate climate change as a decision factor	

10. Adaptive changes in this management practice are likely to be limited by <u>external</u> constraints outside of the implementing organizations.

1	2	3	4	5	Score
Not true	…	Maybe	…	True	

Definitions: External constraints are barriers to implementing adaptive change, such as limitations of funding or resources, legal requirements, or competition with other groups.

Legal constraints	
Regulatory constraints	
Involvement of stakeholder groups	
Where do stakeholders get their information	
Whom do stakeholders trust?	

11. Relative to other systems and practices in the Chesapeake Bay, a great deal is known about ecological and environmental processes relevant to this management action.

1	2	3	4	5	Score
Not true	…	Maybe	…	True	

Definitions: Are this system and practice relatively well-understood with respect to others in the Chesapeake Bay watershed (i.e., relatively speaking, is this something we know very well)?

Best Management Practice

12. Enough information is available to anticipate the consequences of climate change for the <u>condition of the system</u> associated with this management action.

1	2	3	4	5	Score
Not true	…	Maybe	…	True	

Definitions: Can we anticipate the consequences of climate change (in general terms) on the condition of the ecological or environmental system addressed by this management practice? In other words, do we know enough to say what increases in temperature, changes in precipitation, or rising sea levels may do to the resource?

13. Enough information is available to anticipate the consequences of climate change for the <u>performance of this management action</u>.

1	2	3	4	5	Score
Not true	…	Maybe	…	True	

Definitions: Can we anticipate the consequences of climate change (in general terms) on the performance management practice (i.e., cost, effectiveness)?

Google Scholar search results	
Web of Science results	

Best Management Practice
14. This system and associated management practice are most likely to benefit from immediate investments in research to support the development of new decision support resources to facilitate adaptation to climate change.

1	2	3	4	5	Score
Not true	…	Maybe	…	True	

Definitions: This is a synthetic question. Based on the preceding statements and information, is it likely that: (1) this system is likely to experience significant climate impacts; (2) adaptive measures are available; (3) implementing organizations are capable of making adaptive changes, and (4) the system and associated practices are sufficiently well-understood scientifically to provide the basis for the development of new decision support resources.

Ecosystem Management (Tables D-1 - D-14)

Table D-1. Statement 1: Restoration or protection goals for this system are highly vulnerable to climate change

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Living Shorelines	5	5	5	
Build fish passageways	4	4	4	Unclear what "system" refers to – passageway? Stream? Fish population?
Remove physical and chemical blockages	4	4	4	
Maintain/protect upstream spawning habitats	4	4	4	
Manage fishery harvest levels	4	4	4	**Reviewer 1**: Climate modifies effectiveness but does not completely undo management of harvest levels. **Reviewer 2**: Under "definitions" I'm not clear on what you mean by vulnerability = f ? Is this referring to frequency? Function? Since fishery managers commonly use the term F = fishing mortality, I suggest changing it to some other variable so there is no confusion.
Breed triploid Asian Suminoe Oysters	4	4	4	If system means Chesapeake Bay.
Introduce diploid Asian Suminoe Oysters	4	3	3	Unknown--maybe--3.
Phragmites australis (common reed)	3	4-5	4	4 or 5, goals are definitely vulnerable because coastal flooding will increase area at threat to invasion by *Phragmites australis*.
Lythrum salicaria (purple loosestrife)	3	3	3	In general, the successes and failures of Nutria eradication efforts in Louisiana should be considered when developing restoration or protection goals for the CB. The Louisiana wetlands system may become an important model for wetlands further north as climate change alters northern wetlands.
Trapa natans (water chestnut)	3	3	3	I think the supporting evidence suggests there is a better understanding of *Trapa natans* occurrence than perhaps is

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
				warranted. The most recent infestation's origins I think were unclear, so understanding how this species will respond to climate change is highly uncertain. "Altered conditions" might increase or decrease the invasiveness of this species. I disagree with the awkwardly phrased non-sequitur in the section responding to "The potential for adaptive responses….mitigate impacts."
Myocastor coypus (Nutria)	3	3	3	
Dreissena polymorpha (zebra mussels)	3	3	3	
Rebuild oyster habitats using alternative substances	4	4	4	
Rebuild oyster habitats using old oyster shells	4	4	4	
Create sanctuaries	4	4	4	
Aquaculture	4	4	4	
Employ disease-resistant management techniques	4	2-3	2	I do not agree that the long term goal of restoration is "highly" vulnerable to climate change. The very nature of the activity allows adaptive management to accommodate this change. Furthermore, selective breeding for disease resistance is iterative and dynamic. My rating 2-3.
SAV	4	1	1	The goals are an historic acreage, so future warming will in no way affect the goals themselves. Seems to be off-question. The question is about the goals, the rationale is describing performance.

Table D-2. Statement 2: The performance of this management practice is highly vulnerable to climate change

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Living Shorelines	4	4	4	

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Build fish passageways	3	4	4	Increased flashiness seems likely and this will affect performance.
Remove physical and chemical blockages	3	3	3	Upstream habitat shift with temperature and flow regime are likely to affect the timing of spawning and to change the geography of spawning particularly for cold water species such as yellow and white perch.
Maintain/protect upstream spawning habitats	5	5	5	Upstream habitat shift with temperature and flow regime are likely to affect the timing of spawning and to change the geography of spawning particularly for cold water species such as yellow and white perch.
Manage fishery harvest levels	4	4	4	"Game" term in justification is anachronistic and implies angling only. Suggest word change to harvest or fishery. Climate can differentially affect recruitments of differing components of fish community upon which harvesters depend, permitting some degree of switching or flexibility by fishers and regulators.
Breed triploid Asian Suminoe Oysters	4	3	3	The process of hatchery production of this type of seed for aquaculture also embraced selective breeding and domestication, which is adaptive and responsive to gradual changed in climate change.
Introduce diploid Asian Suminoe Oysters	4	3	3	Since introduction of *ariakensis* is essentially the equivalent process of restoration of native oysters (hatchery, planting, reefs, recruitment, etc), the same comments apply regarding the fact that a long time span is needed and adaptive management can be practiced during introduction. Therefore that makes the management practice less vulnerable to climate change.
Phragmites australis (common reed)	3	4-5	4	4 or 5, management of *Phragmites australis* under climate change will be one of "moving goal posts" as suitability of environment changes.

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Lythrum salicaria (purple loosestrife)	3	3	3	
Trapa natans (water chestnut)	3	4	4	*T. natans* is intolerant of salinity. Climate change sea level rise and salt intrusion will limit its ability to colonize the Chesapeake Bay.
Myocastor coypus (Nutria)	3	3	3	**Reviewer 1**: The information identified is accurate, but in the Chesapeake Bay system Nutria is not really competing with any native species, therefore competitive advantage is not likely to be the impact of climate change. Range extension is more likely the issue, with climate change bringing more moderate winter temps, thus enabling the spread of Nutria. **Reviewer 2**: As wetlands form the habitat for nutria it is possible that responses by wetlands to climate change will affect nutria. Understanding this relationship should drive adaptive management. Rates of loss of wetlands due to climate change versus nutria damage may change under different climate scenarios. It may not be appropriate to *a priori* assume that any climate change scenario will result in an increase in marsh loss due to nutria. Climate change driven wetland loss rates may become so significant as to render the nutria contribution insignificant. That said, current management strategies to eradicate nutria and reduce their contribution to wetland loss now are sound.
Dreissena polymorpha (zebra mussels)	3	3	3	
Rebuild oyster habitats using alternative substances	4	4	4	
Rebuild oyster habitats using old oyster shells	4	4	4	
Create sanctuaries	5	5	5	
Aquaculture	4	2	2	The process of hatchery production of this type of seed for aquaculture also embraced selective breeding and domestication, which is adaptive and responsive to gradual

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
				changed in climate change.
Employ disease-resistant management techniques	3	2-3	3	I do not agree that the long term goal of restoration is "highly" vulnerable to climate change. The very nature of the activity allows adaptive management to accommodate this change. Furthermore, selective breeding for disease resistance is iterative and dynamic. My rating 2-3.
SAV	4	4	4	Yes for mesohaline Chesapeake, unknown for freshwater Chesapeake. The table on page 2 needs substantial corrections (e.g. there are no restoration projects in Tangier Sound).

Table D-3. Statement 3: Planning, implementation, and performance associated with this management action will occur over a long period of time

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Living Shorelines	5	5	5	
Build fish passageways	5	5	5	Should be made clearer whether performance includes post-implementation monitoring against bench marks.
Remove physical and chemical blockages	5	5	5	
Maintain/protect upstream spawning habitats	4	4	4	
Manage fishery harvest levels	5	5	5	Planning period may take longer than 6 months and up to 2 years. Implementation = on-going
Breed triploid Asian Suminoe Oysters	5	1	5	Absolutely disagree.
Introduce diploid Asian Suminoe Oysters	5	5	5	Agree, but not as long as native restoration since results will be clearer sooner. In fact, it will be very difficult to decide whether the oyster is failing or the introduction is failing.
Phragmites australis (common reed)	5	5	5	

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Lythrum salicaria (purple loosestrife)	5	5	5	Reviewer 1: Likely to be much longer than CBP 5 year, actually a continuing issue as biogeographic provinces shift north. Reviewer 2: However, weather extremes especially cold can cause high mortalities and limit expansion. If climate change results in severe seasonally extremes, i.e. colder winters and hotter summers, nutria expansion into Bay could be limited or reduced.
Trapa natans (water chestnut)	5	3	5	Is this not somewhat dependent on state agencies continuing to be committed to the management of this species?
Myocastor coypus (Nutria)	5	5	5	
Dreissena polymorpha (zebra mussels)	5	5	5	
Rebuild oyster habitats using alternative substances	5	5	5	
Rebuild oyster habitats using old oyster shells	5	5	5	
Create sanctuaries	5	5	5	
Aquaculture	5	1	5	Absolutely not true. If anything, aquaculture will be the fastest response to depletion of oyster stocks, because it is not dependent upon Federal or State programs. Rather it is driven by private enterprise and business investment.
Employ disease-resistant management techniques	5	5	5	
SAV	5	5	5	No, the planning period and implementation period is rarely less than one year. Most projects take place for at least 3 years.

Table D-4. Statement 4: The management action involves a near-term decision with important, long-term consequences

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Living Shorelines	4	4	4	
Build fish passageways	4	4	4	
Remove physical and chemical blockages	4	4	4	Concur although there are long-term consequences in going from lacustrine to fluvial habitats that have not been adequately studied.
Maintain/protect upstream spawning habitats	2	2	2	Concur although there are long-term consequences in going from lacustrine to fluvial habitats that have not been adequately studied.
Manage fishery harvest levels	2	2,3	3	Reviewer 1: (Agrees with score of 2) Often fishing effects are reversible; oysters are a notable exception. Reviewer 2: I think it should be a 3. Fishing can affect ecosystem structure & function and may be irreversible.
Breed triploid Asian Suminoe Oysters	2	2.5	3	Depending on whether you release these or keep them contained in aquaculture, this is NOT an irreversible decision, that is the premise of using triploids in the first place. At the least, it has far less "irreversibility" than diploid introduction and shouldn't even be in the same category. The explanations in your rational boxes do not parallel the concerns of this question, e.g., "intent of the practice is to restore long-term habitat" and "availability of a consistent supply of disease-resistant seed oysters is the main constraint on the growth of the industry", the latter of which is a comment that pertains to native seed, not non-native seed. My rating: 2.5.
Introduce diploid Asian Suminoe Oysters	5	5	5	
Phragmites australis (common reed)	3	1-2	2	I would say 1 or 2. This will be an "adaptive management" process, no near term actions are likely to forestall future management actions.

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Lythrum salicaria (purple loosestrife)	3	3	3	
Trapa natans (water chestnut)	3	4	4	If the near term decision is to stop management of the species, *Trapa natans* will spread and become more costly and possibly more difficult to eradicate.
Myocastor coypus (Nutria)	3	3	3	
Dreissena polymorpha (zebra mussels)	3	3	3	
Rebuild oyster habitats using alternative substances	2	2	2	
Rebuild oyster habitats using old oyster shells	2	2	2	
Create sanctuaries	4	4	4	
Aquaculture	4	3	3	Depends whether this is a public or private activity. Your boxes listing rationale are not consonant with the premise of doing private aquaculture, they are addressing restoration factors.
Employ disease-resistant management techniques	4	4	4	
SAV	3	5	5	Once a site is selected, a commitment must be made if anything is to be learned from the action.

Table D-5. Statement 5: The resource addressed by this management action is a very high priority issue for water quality or living resource restoration or protection efforts in the Chesapeake Bay watershed

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Living Shorelines	3	4	4	Seems inconsistent – top priority given in explanation (Lutz ref) with which I concur.
Build fish passageways	3	4	4	While Alosa seems to be focus, recent evidence indicates that eels are strongly curtailed by existing passageways and impoundments. Freshwater fish will also benefit by increased

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
				connectivity among habitats that passageways can afford.
Remove physical and chemical blockages	3	4	4	Re-establishing connectivity is important for non-Alosa species such as eels, which are strongly curtailed by impoundments. Important also to freshwater fishes such as perches which can migrate widely within non-tidal rivers and streams.
Maintain/protect upstream spawning habitats	3	4	4	Re-establishing connectivity is important for non-Alosa species such as eels, which are strongly curtailed by impoundments. Important also to freshwater fishes such as perches which can migrate widely within non-tidal rivers and streams.
Manage fishery harvest levels	3	4	4	Reviewer 1: Concur. Managing harvest levels is a needed ingredient in Ecosystem management, but higher priority is needed on habitat and climate issues that affect living resources. Reviewer 2: This should be a 4. Water quality criteria were set in the CB for fish species and fish are one of the prime concerns of the general public.
Breed triploid Asian Suminoe Oysters	3	2	2	Again assuming that your meaning is to use triploids for aquaculture, there is practically no Bay wide, only very local, benefit to even extensive aquaculture farms. The real benefit of enabling aquaculture in a water quality sense is to have industry interest in the health of the Bay.
Introduce diploid Asian Suminoe Oysters	3	3	3	
Phragmites australis (common reed)	4	4	4	
Lythrum salicaria (purple loosestrife)	4	4	4	
Trapa natans (water chestnut)	4	4	4	Unclear which ecosystem resources might be affected by a large *Trapa natans* infestation. Beyond ecosystem disturbance this species has the potential to disrupt navigation in a waterway that might be more significant than the ecological consequences.

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Myocastor coypus (Nutria)	4	3	3	Nutria represent a significant problem in localized areas, not a wide spread threat at this time.
Dreissena polymorpha (zebra mussels)	4	4	4	
Rebuild oyster habitats using alternative substances	3	3	3	
Rebuild oyster habitats using old oyster shells	3	3	3	
Create sanctuaries	3	3	3	
Aquaculture	3	3	3	Given the limited ecological services likely to be provided by aquaculture
Employ disease-resistant management techniques	3	3	3	
SAV	4	4	4	

Table D-6. Statement 6: This management action involves a capital intensive investment

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Living Shorelines	2	2	2	
Build fish passageways	2	4	2	Problem is that evaluation of passageways is under-funded. Annual costs should be incurred to cover long-term evaluation of some passage-ways.
Remove physical and chemical blockages	4	4	4	Concur, but inadequate funding given to monitoring the effectiveness of opening up new spawning habitats.
Maintain/protect upstream spawning habitats	2	2	2	Concur, but inadequate funding given to monitoring the effectiveness of opening up new spawning habitats.
Manage fishery harvest levels	3	3	3	Reviewer 1: Concur, but insufficient investments and coordination exist in monitoring programs. Also, most DNR costs go towards enforcement that is unrelated to fisheries

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
				management (boating, water safety, etc). **Reviewer 2:** Probably an underestimate for monitoring especially with the new demands for ecosystem-based management.
Breed triploid Asian Suminoe Oysters	3	3	3	The so called cost of this option is one that is borne by private investment and industry growth rather than Federal programs. Therefore the answer depends on the context of whose cost you mean. Public cost? No. Private cost = private investment. This question illustrates why it is important to better define the issue, rather than the vague "Breed triploid oysters."
Introduce diploid Asian Suminoe Oysters	3	4-5	3	Same investment as needed for native restoration, or higher. My rating 4-5.
Phragmites australis (common reed)	2	4	2	Aerial spraying for eradication very costly.
Lythrum salicaria (purple loosestrife)	2	4	2	Capital intensive to eradicate
Trapa natans (water chestnut)	2	4	2	**Reviewer 1:** Capital intensive to remove. **Reviewer 2:** It does seem to be true that the most recent infestations were controlled using existing funds at MD DNR. However, that wasn't true for the Potomac River. So, the justification actually sets up conditions that show high uncertainty in the cost. The current management effort is managed within existing funds (how much should be included here), however, a massive infestation would require a capital investment.
Myocastor coypus (Nutria)	2	4	2	Capital intensive to eradicate.
Dreissena polymorpha (zebra mussels)	2	2	2	
Rebuild oyster habitats using alternative substances	3	3	3	
Rebuild oyster habitats using old oyster shells	4	4	4	

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Create sanctuaries	2	2	2	
Aquaculture	3	3	3	Not much public investment if its mostly private investment.
Employ disease-resistant management techniques	3	4-5	3	The capital investment is huge, much higher than anyone has yet envisaged realistically. In essence, oyster restoration is minimally vested in Maryland and grossly underinvested in Virginia. My rating 4-5.
SAV	2	1	2	Very low cost compare to other restoration (e.g. wetland, oyster). the costs are far higher than $100/acre. That may be the seeding cost, but water quality and follow-up monitoring will make the costs approximately $2K to $10K/acre.

Table D-7. Statement 7: Decision-makers have a high degree of flexibility in how they design or use this management practice

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Living Shorelines	4	4	4	
Build fish passageways	5	5	5	Concur - flexibility is important to make progress.
Remove physical and chemical blockages	3	3	3	Concur but too much flexibility could be a problem in linear systems where priority should be on downstream impoundments.
Maintain/protect upstream spawning habitats	5	5	5	Concur but too much flexibility could be a problem in linear systems where priority should be on downstream impoundments.
Manage fishery harvest levels	4	4,1	2	Reviewer 1: Agree with score of 4. Reviewer 2: Rate as 1, due to failure to effectively regulate oyster harvests. BBCAC effort on blue crabs points way towards integrated and effective management but this effort has been disbanded due to lack of funding. Currently there exists little way to effectively management living resources

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
				between bay states (here I am not considering ASMFC – which is a compact of coastal states, which typically encompasses living resources at larger scale than the Bay Ecosystem).
Breed triploid Asian Suminoe Oysters	4	4	4	WHAT management practice? Again, if you mean aquaculture, then we have to define what the actual management practice is for that. If you mean extensive planting of triploids as a public resource, that is entirely different.
Introduce diploid Asian Suminoe Oysters	4	3	3	The fact of the matter is that the science of introduction is similar to that of restoration and has only recently been formulated and insufficiently tested – largely owing to insufficient SCALE. Assuming that the science will be improved, it may be that the techniques are very precise and relatively inflexible.
Phragmites australis (common reed)	5	4	4	In Virginia *P. australis* is a protected marsh type under the Virginia Tidal Wetlands Act. It is considered of low value however permits for displacing it are still required.
Lythrum salicaria (purple loosestrife)	4	4	4	
Trapa natans (water chestnut)	4	4	4	
Myocastor coypus (Nutria)	4	4	4	Don't know how flexible the stated rules really are with regards to management decisions. However, I am assuming this is a valid score because the eradication effort is underway and permitted so it must be operating under fairly flexible rules and regulations. However, if eradication is unsuccessful, it may be necessary to further evaluate the "flexibility" of existing regulations.
Dreissena polymorpha (zebra mussels)	4	4	4	
Rebuild oyster habitats using alternative substances	3	3	3	

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Rebuild oyster habitats using old oyster shells	2	2	2	
Create sanctuaries	2	2	2	
Aquaculture	2	4	4	Presumably there is a great degree of flexibility in implementing oyster culture regulations and policy.
Employ disease-resistant management techniques	4	3	3	The fact of the matter is that the science of restoration using disease-resistance management techniques has only recently been formulated and insufficiently tested – largely owing to insufficient SCALE. Assuming that the science will be improved, it may be that the techniques are very precise and relatively inflexible.
SAV	2	3	3	I think we do have a lot of flexibility relative to other kinds of restoration. However, there are substantial geographic constraints. I disagree that this is a regulatory activity. There has only been one regulatory SAV restoration project in the history of the Chesapeake Bay.

Table D-8. Statement 8: The institutions that carry out this management action have high levels of adaptive capacity

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Living Shorelines	NR	NR	NR	
Build fish passageways	NR	NR	NR	
Remove physical and chemical blockages	NR	NR	NR	
Maintain/protect upstream spawning habitats	NR	NR	NR	
Manage fishery harvest levels	NR	NR	NR	
Breed triploid Asian Suminoe Oysters	NR	NR	NR	
Introduce diploid Asian Suminoe Oysters	NR	3	3	The institutions have high adaptive capacity IF they are

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
				appropriately funded and IF they achieve a level of interagency cooperation (including flexibility in expenditure of funds) that allows it. Now, formalities in ACE procedure severely limit flexibility in VA. In MD I think things are in better shape, largely because of the overarching organizational structure of ORP.
Phragmites australis (common reed)	NR	NR	NR	
Lythrum salicaria (purple loosestrife)	NR	NR	NR	
Trapa natans (water chestnut)	NR	NR	NR	
Myocastor coypus (Nutria)	NR	2	2	The agencies involved are generally focused on other issues and not well funded. There is flexibility in defining strategy, but not great latitude in assigning resources.
Dreissena polymorpha (zebra mussels)	NR	NR	NR	
Rebuild oyster habitats using alternative substances	NR	NR	NR	
Rebuild oyster habitats using old oyster shells	NR	NR	NR	
Create sanctuaries	NR	NR	NR	
Aquaculture	NR	NR	NR	Regulations are adaptive. There really isn't a "policy" here.
Employ disease-resistant management techniques	NR	NR	NR	The institutions have high adaptive capacity IF they are appropriately funded and IF they achieve a level of interagency cooperation (including flexibility in expenditure of funds) that allows it. Now, formalities in ACE procedure severely limit flexibility in VA. In MD I think things are in better shape, largely because of the overarching organizational structure of ORP.
SAV	NR	1	1	The work to date has been 100% grant driven, and as such there is little to no adaptive capability.

Table D-9. Statement 9: Adaptive changes in this management practice are likely to be limited by internal constraints within the implementing organizations

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Living Shorelines	3	3	3	
Build fish passageways	2	2	2	
Remove physical and chemical blockages	NR	NR	NR	Unclear what EFI refers to. Never heard of this term.
Maintain/protect upstream spawning habitats	3	3	3	Unclear what EFI refers to. Never heard of this term.
Manage fishery harvest levels	3	4	4	**Reviewer 1:** Uprate to 4. Lack of climate considerations in current management of living resources at Bay Program or state levels. **Reviewer 2**: 4 because collecting fishery independent data is and will continue to be limited by funding. There are also political constraints because of the economic considerations.
Breed triploid Asian Suminoe Oysters	2	2	2	WHAT management practice? Again, if you mean aquaculture, then we have to define what the actual management practice is for that. If you mean extensive planting of triploids as a public resource, that is entirely different.
Introduce diploid Asian Suminoe Oysters	2	2	2	
Phragmites australis (common reed)	2	2	2	
Lythrum salicaria (purple loosestrife)	2	2	2	
Trapa natans (water chestnut)	2	3	3	How do you know that there won't be internal constraints? I would think that without a justification you would need to rank this as 3.
Myocastor coypus (Nutria)	2	3	3	Game control agencies in MD and VA have limited options for control – basically they only regulate voluntary hunting pressure.

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Dreissena polymorpha (zebra mussels)	2	2	2	
Rebuild oyster habitats using alternative substances	NR	NR	NR	
Rebuild oyster habitats using old oyster shells	NR	NR	NR	
Create sanctuaries	NR	NR	NR	
Aquaculture	NR	2	2	
Employ disease-resistant management techniques	NR	NR	NR	The institutions have high adaptive capacity IF they are appropriately funded and IF they achieve a level of interagency cooperation (including flexibility in expenditure of funds) that allows it. Now, formalities in ACE procedure severely limit flexibility in VA. In MD I think things are in better shape, largely because of the overarching organizational structure of ORP.
SAV	4	4	4	Would de-emphasize operational constraints.

Table D-10. Statement 10: Adaptive changes in this management practice are likely to be limited by external constraints outside of the implementing organizations

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Living Shorelines	4	4	4	
Build fish passageways	4	3	3	Would tend to down-rate this to 3. Seems to be growing momentum by stakeholders to build passageways and remove impoundments.
Remove physical and chemical blockages	4	4	4	No opinion. No justification is given for external constraints, although external constraints on this activity can be substantial.
Maintain/protect upstream spawning habitats	NR	NR		No opinion. No justification is given for external constraints.
Manage fishery harvest levels	4	4,3	3	Reviewer 1: Agrees with score of 4.

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
				Reviewer 2: Downrate to 3. ASMFC, NOAA have taken lead at looking at climate issues, but no way currently for this science or related regulatory tools to filter down to state level.
Breed triploid Asian Suminoe Oysters	5	5	5	WHAT management practice? Again, if you mean aquaculture, then we have to define what the actual management practice is for that. If you mean extensive planting of triploids as a public resource, that is entirely different.
Introduce diploid Asian Suminoe Oysters	5	5	5	
Phragmites australis (common reed)	3	4	4	In Virginia *P. australis* is a protected marsh type under the Virginia Tidal Wetlands Act. It is considered of low value however permits for displacing it are still required.
Lythrum salicaria (purple loosestrife)	3	3	3	
Trapa natans (water chestnut)	3	3	3	
Myocastor coypus (Nutria)	3	1 or 5	1	If eradication is completed under the given management plan and funding, then external constraints would not be barriers. OR, 5, – if eradication isn't completed under the given management plan and funding, then external constraints would be barriers. I'm not sure I see a middle road here, unless the stakeholders have long-term funding they would put toward this problem.
Dreissena polymorpha (zebra mussels)	3	3	3	
Rebuild oyster habitats using alternative substances	2	2	2	
Rebuild oyster habitats using old oyster shells	3	3	3	
Create sanctuaries	2	2	2	
Aquaculture	2	2	2	I agree.
Employ disease-resistant management techniques	3	3	3	

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
SAV	NR	4	4	Only real limitations are logistics.

Table D-11. Statement 11: Relative to other systems and practices in the Chesapeake Bay, a great deal is known about ecological and environmental processes relevant to this management action

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Living Shorelines	3	3	3	There is an increasing knowledge base, but much more work is needed on evaluation or restored living shorelines.
Build fish passageways	3	2	3	Down-rate to 2, Efficacy of passageway inadequately known.
Remove physical and chemical blockages	3	2	3	Knowledge base is inadequate and this should be recognized.
Maintain/protect upstream spawning habitats	3	2	3	Knowledge base is inadequate and this should be recognized.
Manage fishery harvest levels	4	4	4	
Breed triploid Asian Suminoe Oysters	4	4	4	If you mean aquaculture, I agree with your score.
Introduce diploid Asian Suminoe Oysters	2	2	2	If not lower.
Phragmites australis (common reed)	4	4	4	
Lythrum salicaria (purple loosestrife)	4	3	4	There are a couple of compelling articles (Fransworth and Ellis, 2001; Hager and McCoy, 1998) on the uncertainties about the detrimental effects of *L. salicaria* on ecological and environmental processes.
Trapa natans (water chestnut)	4	4	4	
Myocastor coypus (Nutria)	4	4	4	
Dreissena polymorpha (zebra mussels)	4	4	4	
Rebuild oyster habitats using alternative substances	3	3	3	
Rebuild oyster habitats using old oyster shells	4	4	4	

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Create sanctuaries	4	4	4	
Aquaculture	4	4	4	
Employ disease-resistant management techniques	3	3	3	I think we know more than we think and that the application of the sciences to oyster restoration has been constrained by the lack of an overarching "czar" of restoration.
SAV	4	3	4	Far more is known about wetlands, forests, and fisheries than SAV.

Table D-12. Statement 12: Enough information is available to anticipate the consequences of climate change for the condition of the system associated with this management action

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Living Shorelines	3	2	2	Not adequately supported. Some literature on sea ingress on marsh grasses and erosion should be acknowledged as relevant.
Build fish passageways	3	2	2	Down-rate to 2, long term performance of passageways not well known to enable predictions on how climate will affect passageway performance.
Remove physical and chemical blockages	3	2	2	Knowledge base is inadequate and this should be recognized.
Maintain/protect upstream spawning habitats	3	2	2	Knowledge base is inadequate and this should be recognized.
Manage fishery harvest levels	3	3	3	Concur – substantial information accruing but needs to be further developed in precautionary framework for managing harvest levels given expected climate change.
Breed triploid Asian Suminoe Oysters	4	4	4	
Introduce diploid Asian Suminoe Oysters	4	4	4	
Phragmites australis (common reed)	2	3-4	3	I would say 3 or 4. Information could be gleaned from studies

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
				of other similar species (e.g. Spartina) in uptake of carbon, influence of temp, etc. See work of Drake et al.
Lythrum salicaria (purple loosestrife)	2	2	2	
Trapa natans (water chestnut)	2	2	2	
Myocastor coypus (Nutria)	2	2	2	
Dreissena polymorpha (zebra mussels)	2	2	2	
Rebuild oyster habitats using alternative substances	4	4	4	
Rebuild oyster habitats using old oyster shells	4	4	4	
Create sanctuaries	4	4	4	
Aquaculture	4	4	4	
Employ disease-resistant management techniques	4	4	4	
SAV	4	2	2	Given the extremely small margin of the sedimentary environment in which SAV live, and the dramatic ways in which sea level rise might change this, I don't think we know much about how the system itself might change.

Table D-13. Statement 13: Enough information is available to anticipate the consequences of climate change for the performance of this management action

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Living Shorelines	1	1	1	Searches are perfunctory and give little real sense of quality or quantity of relevant work conducted. I understand that such review would require increased scholarship, but I do not think the program should stand by these sorts of searches of indicative of quantity of pertinent information.
Build fish passageways	1	1	1	

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Remove physical and chemical blockages	1	1	1	Concur, but search procedure is inadequate without expert scholarship to filter down relevant scientific information.
Maintain/protect upstream spawning habitats	2	2	2	Concur, but search procedure is inadequate without expert scholarship to filter down relevant scientific information.
Manage fishery harvest levels	1	1,2	2	**Reviewer 1:** Agrees with score of 1. **Reviewer 2:** Uprate to 2. There is growing research and information specific to the Chesapeake.
Breed triploid Asian Suminoe Oysters	1	1	1	
Introduce diploid Asian Suminoe Oysters	2	1	1	
Phragmites australis (common reed)	3	3	3	
Lythrum salicaria (purple loosestrife)	3	3	3	
Trapa natans (water chestnut)	2	2	2	
Myocastor coypus (Nutria)	2	2	2	
Dreissena polymorpha (zebra mussels)	3	3	3	
Rebuild oyster habitats using alternative substances	1	1	1	
Rebuild oyster habitats using old oyster shells	2	2	2	
Create sanctuaries	3	3	3	
Aquaculture	5	5	5	
Employ disease-resistant management techniques	2	2	2	There is as much information now to speculate on the consequence of climate change on this management option as there will ever be. The rest of the information is measuring the climate change as it occurs, not anticipating it.
SAV	2	2	2	Though a Current Contents search would make a lot more sense than a Google search.

Table D-14. Statement 14: This system and associated management practice are most likely to benefit from immediate investments in research to support the development of new decision support resources to facilitate adaptation to climate change

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Living Shorelines	4	4	4	
Build fish passageways	3	4	3	Rate to 4 to reflect that current deficiency in evaluating performance over long term will be aided the sooner we give priority to evaluating performance.
Remove physical and chemical blockages	3	3	3	Inadequacies of research and monitoring have been long recognized. Impoundment removal for the sake of improving spawning habitat is currently more engineering than one that is justified scientifically.
Maintain/protect upstream spawning habitats	4	4	4	Inadequacies of research and monitoring have been long recognized. Impoundment removal for the sake of improving spawning habitat is currently more engineering than one that is justified scientifically.
Manage fishery harvest levels	4	4	4	
Breed triploid Asian Suminoe Oysters	3	3	3	Enabling legislation and tech transfer is likely the most effective means of implementation if you mean aquaculture.
Introduce diploid Asian Suminoe Oysters	3	4	3	If introduction decision is made, then more research money will have to follow the decision, similar or of greater scope to that put in to MAKE the decision.
Phragmites australis (common reed)	3	4	3	I would give this a 4. Development of decision support tools for this species taking into account climate model projections could be very useful for management. alternative development of this and similar species.
Lythrum salicaria (purple loosestrife)	3	2	3	The occurrence of *L. salicaria* in the watershed is significant and there is considerable uncertainty as to the role this species plays in the ecosystem. Its ecological significance (monoculture, pollinator shifts, biological control) needs to be

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
				much better understood before reasonable restoration efforts in a changing climate regime can be developed.
Trapa natans (water chestnut)	3	3	3	
Myocastor coypus (Nutria)	3	2	3	I might rank it as 2 right now, however, after the 5 year project is complete you will have a better sense of how to rank this system and the management practices for immediate investment in research. In a truly adaptive approach you may find at the end of the nutria eradication effort that this ranking becomes 4 or 5.
Dreissena polymorpha (zebra mussels)	3	3	3	
Rebuild oyster habitats using alternative substances	4	4	4	
Rebuild oyster habitats using old oyster shells	4	4	4	
Create sanctuaries	4	4	4	
Aquaculture	4	3	4	This question is also poorly defined. The juxtaposition of "restore" and "aquaculture" is strange. Restoration is a public activity and aquaculture – private. Perhaps you mean, use aquaculture for extensive plantings for the public fishery.
Employ disease-resistant management techniques	3	3	3	
SAV	4	4	4	Some very basic research needs to be done, and this would greatly benefit our understanding of how adaptive SAV might be to temperature changes.

Water Quality (Tables D-15 – D-28)

Table D-15. Statement 1: Restoration or protection goals for this system are highly vulnerable to climate change

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Forest Conservation (Forest Conservation Act)	4	4	4	
Riparian Forest Buffers - Urban	4	4	4	
Tree Planting	2	3	3	Since this is the CB/Mid-Atlantic, urban conditions have higher CO2, other greenhouse gases, heat island effects. Tree planting for the urban areas may be competing with successful invasive trees like tree of heaven.
Abandoned Mined Land Reclamation	3	2,4-5	2	Reviewer 1: I would probably rate it slightly lower, perhaps a "2." AML reclamation will go until the worst offenders that impact the environment are reclaimed. Reviewer 2: I disagree with this score, especially since there is a strong possibility that increasing temperature throughout coal-mining regions will accelerate microbial processes in AMLR. Would rate as 4-5 in score.
CREP Wetland Restoration	4	3	3	Most of the wetlands in the CB watershed are non-tidal (10x the number of tidal wetlands). CREP wetland restoration is primarily a non-tidal wetland program, salt water intrusion is only a minor issue for this at present, and will become significant only under long term changes in sea level. Changes in rainfall are more likely to be important.
Reduction in Urban Growth	3	4	4	Climate change indicates sea level and temperature rise and a shift in aquatic and terrestrial biota.
Riparian Forest/Woodland Buffers – Agriculture	4	3	3	I think the ability to identify the best sites for restoration/preservation and to convince (or pay) landowners to do so would be relatively independent of climate change.

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
				However, the effects of climate change on performance in meeting water quality goals are very uncertain.
Wetlands - Mixed Open Land	4	3	3	Most wetlands are non-tidal, salt water intrusion is not that big an issue.
POTWs Standards for Discharge Permits	4	3,3,5	4	Reviewer 1: 3. Ideally POTWs should not be affected by increased runoff, because they should be treating municipal sewage which would depend upon population rather than climate change. Reviewer 2: 3. TMDLs are based on limiting nutrient concentrations, which won't change significantly with temperature increases. Reviewer 3: 5.
Stormwater Management - Dry Extended Retention/Detention Ponds	4	4	4	
Stormwater Management - Filtering Practices	4	4	4	
Stormwater Management - Infiltration Practices	4	4	4	This comment applies more generally: I'd have been inclined to look at Maryland and perhaps Center for watershed Protection references in addition to a PA ref.
Stormwater Management - Wet Ponds & Wetlands	4	4	4	
Urban Stream Restoration	4	4	4	

Table D-16. Statement 2: The performance of this management practice is highly vulnerable to climate change

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Forest Conservation (Forest Conservation Act)	2	4	4	Not only does climate change affect survival rates of planted trees, but also influences incidence of pests and pathogens, which can affect our ability to conserve forests.

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Riparian Forest Buffers - Urban	4	3	3	**Reviewer 1:** I would rank this a 3 rather than a 4 – I think it is more similar to tree planting than suggested here. **Reviewer 2:** if this is the restoration of the riparian buffer.
Tree Planting	2	2	2	
Abandoned Mined Land Reclamation	4	4	4	
CREP Wetland Restoration	4	3	3	Increased precipitation may diminish WQ services of restored wetlands, but is more likely to make wetland restoration more successful.
Reduction in Urban Growth	2	1	1	I might be inclined to give it a 1.
Riparian Forest/Woodland Buffers – Agriculture	4	3	3	I would assign a 3 to reflect uncertainty about how climate change would affect buffer responses.
Wetlands - Mixed Open Land	4	3	3	Maybe due to altered precipitation.
POTWs Standards for Discharge Permits	3	2	2	**Reviewer 1**: Increased temperature will improve process performance and increased precipitation will decrease point source significance. **Reviewer 2**: Reduce score for "True" to 2.
Stormwater Management - Dry Extended Retention/Detention Ponds	4	4	4	
Stormwater Management - Filtering Practices	4	4	4	Agree, but the write up refers to "infiltration." To me, "filtration" refers to the manufactured filtering units; Infiltration is like grassy swales, rain-gardens & porous pavements. Looking over the two write-ups, perhaps the two should be combined or more clearly differentiated.
Stormwater Management - Infiltration Practices	4	4	4	This is somewhat speculative, but I agree.
Stormwater Management - Wet Ponds & Wetlands	4	4	4	
Urban Stream Restoration	4	4	4	

Table D-17. Statement 3: Planning, implementation, and performance associated with this management action will occur over a long period of time

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Forest Conservation (Forest Conservation Act)	4	4	4	
Riparian Forest Buffers - Urban	4	4	4	
Tree Planting	4	4	4	
Abandoned Mined Land Reclamation	3	3	3	
CREP Wetland Restoration	3	3	3	Program implementation is falling well short of goals.
Reduction in Urban Growth	5	5	5	
Riparian Forest/Woodland Buffers – Agriculture	3	4	3	The higher score is based on an assumption that there might be greater demands on forest buffers as sources of cellulose or biomass for bioenergy. If so, the 20+ year timeframes for 'projected lifetimes' will be substantially reduced, maybe more like a 5-6 year rotation.
Wetlands - Mixed Open Land	5	5	5	
POTWs Standards for Discharge Permits	3	5	3	I would give a score of 5 for "true". The time frame for implementation has significant impact on the outcome.
Stormwater Management - Dry Extended Retention/Detention Ponds	4	5	4	Might even rate a 5. Other state (e.g. MD & VA) guidelines and information from Center for Watershed protection would be of value.
Stormwater Management - Filtering Practices	4	4	4	
Stormwater Management - Infiltration Practices	4	4	4	.
Stormwater Management - Wet Ponds & Wetlands	4	4	4	
Urban Stream Restoration	5	5	5	The Baltimore County study is a good reference.

Table D-18. Statement 4: The management action involves a near-term decision with important, long-term consequences

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Forest Conservation (Forest Conservation Act)	4	5	5	This is pretty much a certainty.
Riparian Forest Buffers - Urban	3	4	4	Supporting evidence seems to add that it is difficult to reverse initial decision/action.
Tree Planting	2	3-4,4	4	**Reviewer 1**: I would give this a score of 3 or 4 – there are important, long-term consequences – it is not irreversible, but practically so, and is important habitat creation. **Reviewer 2**: Agree if this is for an existing green and open space management action, I would disagree, give score of 4, if this is a street tree urban tree planting, and the required maintenance.
Abandoned Mined Land Reclamation	4	4	4	
CREP Wetland Restoration	3	3	3	
Reduction in Urban Growth	5	5	5	In fact, once it's developed, redevelopment at an even higher density is quite possible.
Riparian Forest/Woodland Buffers – Agriculture	4	5	5	I believe the 10 and 25 year project lifetimes are gross underestimates. It takes many years for a forest to develop. Some mechanisms of nutrient retention (e.g., denitrification could continue indefinitely and have no set "lifetime."
Wetlands - Mixed Open Land	3	4-5	4	I would score higher – 4/5. There is a nationwide federal law for wetland protection under the Clean Water Act – administered through the Corps. Several court cases, including recent Supreme Court case outlines jurisdictions. Regulatory actions have and will continue to have cumulative impacts over time.
POTWs Standards for Discharge Permits	4	5	5	**Reviewer 1:** Recommend a score of 5 since the action results in long-term consequences, particularly with respect to irreversible actions and funding.

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
				Reviewer 2: Using Caps for existing plants will have major impacts on effluent requirements and future development. That's good, not bad.
Stormwater Management - Dry Extended Retention/Detention Ponds	3	4	4	I think this rates a 4, as once implemented the typical pond is in for the duration.
Stormwater Management - Filtering Practices	4	4	4	
Stormwater Management - Infiltration Practices	4	4	4	.
Stormwater Management - Wet Ponds & Wetlands	5	5	5	The connection between wetlands and water quality is well established.
Urban Stream Restoration	3	4	4	This seems more like a 4.

Table D-19. Statement 5: The resource addressed by this management action is a very high priority issue for water quality or living resource restoration or protection efforts in the Chesapeake Bay watershed

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Forest Conservation (Forest Conservation Act)	4	5	5	Highest retention of water/nutrients/habitats is by forests compared to other land uses.
Riparian Forest Buffers - Urban	5	5	5	
Tree Planting	4	4	4	
Abandoned Mined Land Reclamation	4	4	4	
CREP Wetland Restoration	5	5	5	
Reduction in Urban Growth	4	3	3	Depending on the interpretation of the question, I may be inclined to give it a 3. While land use is a significant focus of the C2K agreement, my sense is that there have been very little changes in land use planning that have been driven by Program goals.

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Riparian Forest/Woodland Buffers – Agriculture	5	4	4	Riparian buffers have indeed been selected as a high priority restoration by CBP, but we don't know that we will actually achieve the estimated nutrient reductions with these practices. Perhaps other nutrient management actions should be elevated in priority?
Wetlands - Mixed Open Land	5	5	5	
POTWs Standards for Discharge Permits	5	5	5	
Stormwater Management - Dry Extended Retention/Detention Ponds	5	5	5	
Stormwater Management - Filtering Practices	5	5	5	
Stormwater Management - Infiltration Practices	5	5	5	.
Stormwater Management - Wet Ponds & Wetlands	5	5	5	
Urban Stream Restoration	5	5	5	Agree, but the supporting information is pretty thin.

Table D-20. Statement 6: This management action involves a capital intensive investment

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Forest Conservation (Forest Conservation Act)	1	3	1	I would agree with a score of 1 if management action is by developer, however question does not distinguish who pays until you read statement 7 supporting evidence. Lifetime of project is not the same as establishment/afforestation/reforestation.
Riparian Forest Buffers - Urban	2	4	2	I am assuming that the management action is restoration of riparian forested buffer. At 13.3 million/acre lifetime, 170K/acre annual cost is not spare change compared to quoted cost of nutrient removal. The cost of nutrient removal, is this on existing or new buffers? Supporting evidence contradictory on

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
				cost benefits.
Tree Planting	2	3	2	Continuing and maintenance cost in supporting evidence re high. No implementation costs given.
Abandoned Mined Land Reclamation	4	4	4	
CREP Wetland Restoration	3	3	3	
Reduction in Urban Growth	1	NR	1	
Riparian Forest/Woodland Buffers – Agriculture	2	2	2	
Wetlands - Mixed Open Land	3	4	3	Restoration programs lag behind implementation goals, largely for lack of funding.
POTWs Standards for Discharge Permits	3	4	3	**Reviewer 1:** When we go to tighter (lower) nutrient limits in the treated effluent from POTWs, the processes are usually capital intensive. **Reviewer 2**: Disagree with 3. There is little doubt this will involve high capital investment.
Stormwater Management - Dry Extended Retention/Detention Ponds	4	4	4	Agree. Individually, these ponds are not as capital intensive as, say, a wastewater plant and are often folded into the cost of development.
Stormwater Management - Filtering Practices	4	4	4	
Stormwater Management - Infiltration Practices	4	4	4	
Stormwater Management - Wet Ponds & Wetlands	3	3	3	
Urban Stream Restoration	3	4	3	I think this is a 4 and that the $240/foot seems low to me.

Table D-21. Statement 7: Decision-makers have a high degree of flexibility in how they design or use this management practice

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Forest Conservation (Forest Conservation Act)	2	2	2	
Riparian Forest Buffers - Urban	4	3	3	I might rank this as 3 – I suspect the statutory and other authorities are conflicting and thus somewhat restrictive.
Tree Planting	4	4	4	Maybe even bump it up to a 5.
Abandoned Mined Land Reclamation	2	3	3	There is flexibility especially in terms of water treatment options under AML projects.
CREP Wetland Restoration	2	2	2	Participation by landowners is voluntary, in addition to the land condition requirements.
Reduction in Urban Growth	5	4	4	Efforts to severely restrict sprawl often run afoul of court decisions or "grandfather" effects of prior planning & zoning decisions.
Riparian Forest/Woodland Buffers – Agriculture	4	2	2	I believe that decision makers are highly constrained in the placement of buffers. They go mainly to sites on the properties of willing landowners who meet the constraints to be eligible to receive financial incentives. Restorations are opportunistic rather than precisely targeted to give the maximum nutrient benefit.
Wetlands - Mixed Open Land	4	3	3	
POTWs Standards for Discharge Permits	3	4-5,2	3	Reviewer 1: True = 4 or 5. The degree of flexibility and a thorough evaluation of various options and selection of key routes for implementation is a crucial part of mitigating the climate change effects. Reviewer 2: No, 2. Even with nutrient trading options, effluent caps will limit technologies that can be used and TMDLs will limit the locations for trading.
Stormwater Management - Dry Extended Retention/Detention Ponds	4	4	4	Agree. Not a 5 because and site planners tend not to incorporate SWM into the site design, but assume that the

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
				downstream pond will take care of things.
Stormwater Management - Filtering Practices	4	4	4	Agree with score, but don't agree with the statement that "this BMP is highly regulated by the Feds…" "Locals" should be listed as those with decision-making responsibility.
Stormwater Management - Infiltration Practices	4	4	4	Not sure that I agree with the statement that "this BMP is highly regulated by the Feds…" It's really more of a state & local issue.
Stormwater Management - Wet Ponds & Wetlands	4	4	4	
Urban Stream Restoration	4	4	4	Agree with score, but question the omission of any MD references. Balt. Co,. & Mont. Co have been leaders.

Table D-22. Statement 8: The institutions that carry out this management action have high levels of adaptive capacity

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Forest Conservation (Forest Conservation Act)	NR	3,2	3	Reviewer 1: I would give it a 3, depending on the level of government (local, state, Fed), and regional resources. Reviewer 2: Not scored, but I would rate this as a 2.
Riparian Forest Buffers - Urban	NR	3	3	This was not rated, but I would score it as a 3
Tree Planting	NR	3	3	Reviewer 1: This was not rated, but I would rate it as a 3. Reviewer 2: No score given, no documentation so I give it a 3, maybe.
Abandoned Mined Land Reclamation	NR	3,1		Agencies implementing the program are generally resource limited (both funding and staffing).
CREP Wetland Restoration	NR	2	2	Reviewer 1: In relation to climate change, the 3 (maybe) score is based on that fact that the institutions may have adaptive capacity but they may lack the necessary research or trend data to react, in a timely fashion, to climate change impacts.

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
				Also, since climatic changes impacts would occur in a slow progression over time there is a need to identify organizations that are looking at trend data and also identify what possible impacts will be before they occur on-the-ground. **Reviewer 2**: I would assign a 2.The organizations are limited by the factors that you cited for item 9.
Reduction in Urban Growth	NR	3	3	There are few effective monitoring programs in place to inform effective adaptive management.
Riparian Forest/Woodland Buffers – Agriculture	NR	2	3	**Reviewer 1**: The organizations are limited by the factors that you cited for item 9. **Reviewer 2**: In relation to climate change, the 3 (maybe) score is based on that fact that the institutions may have adaptive capacity but they may lack the necessary research or trend data to react, in a timely fashion, to climate change impacts. Also, since climatic changes impacts would occur in a slow progression over time there is a need to identify organizations that are looking at trend data and also identify what possible impacts will be before they occur on-the-ground.
Wetlands - Mixed Open Land	NR	2	2	**Reviewer 1:** there are few effective monitoring programs in place to inform effective adaptive management
POTWs Standards for Discharge Permits	NR	3,2,3		**Reviewer 1**: Score of 3 (none given). The adaptive capacity depends upon management setup and financial resources. **Reviewer 2**: 2, POTWs follow NPDES permits and do not have much flexibility after permits are issued by state agencies. **Reviewer 3**: Recommend a score of 3 since institutions may have some degree of adaptive capability.
Stormwater Management - Dry Extended Retention/Detention Ponds	NR	3	3	No score assigned. I'd assign a 3 as such organizations can adapt, but it occurs slowly.

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Stormwater Management - Filtering Practices	NR	4	4	
Stormwater Management - Infiltration Practices	NR	3	3	
Stormwater Management - Wet Ponds & Wetlands	NR	3	3	
Urban Stream Restoration	NR	3	3	No score assigned. I'd go with a 3.

Table D-23. Statement 9: Adaptive changes in this management practice are likely to be limited by internal constraints within the implementing organizations

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Forest Conservation (Forest Conservation Act)	2	3,4	3	Reviewer 1: I would rate this as a 3. Reviewer 2: 4. Definition and Rationale tend to say there are internal limits.
Riparian Forest Buffers - Urban	NR	4	4	This was not scored, but I would score it as a 4.
Tree Planting	NR	4,3	4	Reviewer 1: This was not rated, but I would rate it as a 4. Reviewer 2: No score given. So I give it a maybe for lack of information, 3.
Abandoned Mined Land Reclamation	3	4	4	There may be severe future budget limitations at the state and federal level that will affect the ability to attack AMLR problems.
CREP Wetland Restoration	4	4	4	
Reduction in Urban Growth	3	3	3	3 is OK, but in fact state agencies are often pretty limited in the control they exert over "sprawl-reduction" activities.
Riparian Forest/Woodland Buffers – Agriculture	4	5	5	Agree with all the cited barriers but add to it the unknown impacts of potential climate change and the implementing organizations will be overwhelmed.
Wetlands - Mixed Open Land	3	3	3	

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
POTWs Standards for Discharge Permits	3	3	3	Agree. However, legislatures can enact restrictions that severely increase restraints.
Stormwater Management - Dry Extended Retention/Detention Ponds	3	4	4	I think this one rates a 4. Change can come, but it tends to come slowly and only after an accumulation of evidence that such a change is warranted. The one sentence is true, but somewhat simplistic. It took MD quite a while to institute its new SW rules, with lots of stakeholder involvement, a few years ago.
Stormwater Management - Filtering Practices	NR	2	2	
Stormwater Management - Infiltration Practices	NR	3	3	
Stormwater Management - Wet Ponds & Wetlands	NR	3	3	
Urban Stream Restoration	4	4	4	Agree. Add cost to this, especially without a permitting driver.

Table D-24. Statement 10: Adaptive changes in this management practice are likely to be limited by external constraints outside of the implementing organizations

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Forest Conservation (Forest Conservation Act)	4	4	4	
Riparian Forest Buffers - Urban	3	3	3	
Tree Planting	3	3	3	
Abandoned Mined Land Reclamation	5	5	5	
CREP Wetland Restoration	2	4	4	The program depends on landowner willingness to participate.
Reduction in Urban Growth	4	4	4	I agree with 4, but it's not entirely clear what is "internal" and what is "external." i.e., if the focus is on state agencies, local agencies would be external and can be very independent.
Riparian Forest/Woodland Buffers – Agriculture	NR	4	4	Reviewer 1: Without specific data or research on global change impacts the external constraints on adaptive change

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
				will become messy. **Reviewer 2**: Constraints on the funding for restorations and the opportunistic nature of restoration placement will limit adaptive capacity.
Wetlands - Mixed Open Land	NR	NR	NR	**Reviewer 1**: Virginia major competition with mitigation banking industry. High returns for mitigation banks reduce interest in restoration activities. **Reviewer 2**: Land use control is the nexus of the issue and management agencies generally have no purview in that matter.
POTWs Standards for Discharge Permits	3	4-5,4	4	**Reviewer 1**: True = 4 or 5. Since external constraints exert a greater level of influence on outcome. **Reviewer 2**: 4, POTWs typically face funding constraints to implement permit requirements and do not have control over permitting process itself.
Stormwater Management - Dry Extended Retention/Detention Ponds	4	4	4	At this point, the Tributary Strategies have had minimal impact on what localities elect to do.
Stormwater Management - Filtering Practices	3	3	3	
Stormwater Management - Infiltration Practices	3	3	3	A 3 is probably right, but no rationale is provided.
Stormwater Management - Wet Ponds & Wetlands	3	3	3	
Urban Stream Restoration	4	4	4	

Table D-25. Statement 11: Relative to other systems and practices in the Chesapeake Bay, a great deal is known about ecological and environmental processes relevant to this management action

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Forest Conservation (Forest Conservation Act)	5	5	5	
Riparian Forest Buffers - Urban	5	5	5	
Tree Planting	5	5	5	
Abandoned Mined Land Reclamation	3	3	3	
CREP Wetland Restoration	3	3	3	
Reduction in Urban Growth	5	4	5	We don't do a "5-level" job of predicting the nutrient and sediment runoff from various land uses, nor do we have as a good a handle on the BMP efficiencies of control practices as we should.
Riparian Forest/Woodland Buffers – Agriculture	5	4	5	**Reviewer 1**: Not convinced that we understand subsurface water movement in these systems. **Reviewer 2**: I would assign a 3. We don't know enough about the balance among different retention mechanisms (tree uptake, denitrification, storage in soil) in riparian zones, nor about how that balance varies spatially and temporally. The balance could strongly affect responses to climate change. We also don't know enough about how knowledge of nutrient retention along individual transects through riparian buffers "scales up" to give effect reductions in nutrient discharges from complex landscapes.
Wetlands - Mixed Open Land	3	3	3	
POTWs Standards for Discharge Permits	5	5	5	
Stormwater Management - Dry Extended Retention/Detention Ponds	4	4	4	
Stormwater Management - Filtering Practices	4	3	4	This is probably a 3.

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Stormwater Management - Infiltration Practices	4	3	4	Agree, though no citations are given.
Stormwater Management - Wet Ponds & Wetlands	4	4	4	
Urban Stream Restoration	4	4	4	

Table D-26. Statement 12: Enough information is available to anticipate the consequences of climate change for the condition of the system associated with this management action

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Forest Conservation (Forest Conservation Act)	4	4	4	
Riparian Forest Buffers - Urban	4	4	4	
Tree Planting	4	4	4	
Abandoned Mined Land Reclamation	4	3	3	There is enough uncertainty in climate change models that I would be hesitant to score this as a 4. This would certainly be the case with effects of climate change on the biochemical and soil processes AMLR projects.
CREP Wetland Restoration	4	4	4	
Reduction in Urban Growth	4	4	4	
Riparian Forest/Woodland Buffers – Agriculture	4	3	3	There is a lot of uncertainty here. Changing climate could promote forest growth (a positive) or kill off some species (a negative). Changing climate could reduce buffer effectiveness by modifying delivery mechanisms or enhance effectiveness by promoting retention mechanisms (e.g., denitrification).
Wetlands - Mixed Open Land	4	4	4	
POTWs Standards for Discharge Permits	4	4	4	
Stormwater Management - Dry Extended	2	2	2	

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Retention/Detention Ponds				
Stormwater Management - Filtering Practices	2	2	2	
Stormwater Management - Infiltration Practices	2	2	2	
Stormwater Management - Wet Ponds & Wetlands	2	2	2	
Urban Stream Restoration	4	3	3	A 3 might be better; qualitatively, I agree, but I'm not sure the state of the science is prepared to give definitive answers.

Table D-27. Statement 13: Enough information is available to anticipate the consequences of climate change for the performance of this management action

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Forest Conservation (Forest Conservation Act)	3	3	3	
Riparian Forest Buffers - Urban	2	3	3	I think we know more about the functions of the riparian buffers than indicated.
Tree Planting	2	3	3	Reviewer 1: although could bump it up to a 3 – I think we know a little bit more than what is found only by Google. Reviewer 2: We look at urban areas as future conditions of climate change and GHG interactions. We don't study urban trees as much as natural forested ecosystems.
Abandoned Mined Land Reclamation	1	2	2	Just because there are few connections between climate change and AML reclamation on the web doesn't mean that we don't know anything.
CREP Wetland Restoration	3	3	3	Information is not specific, and implications for CREP have not been analyzed.
Reduction in Urban Growth	4	3	3	I'd be inclined to go with a 3. It seems to me there's a lot we don't know.

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Riparian Forest/Woodland Buffers – Agriculture	2	1	1	**Reviewer 1**: Score = 1. Not sure that we even have enough data on the long term performance of the practice at current conditions no less with changes added. **Reviewer 2**: I would assign a 1.We need more basic science on the balances between different retention mechanisms and how that balance varies. We also need more knowledge about applying transect studies of riparian buffers to whole watersheds.
Wetlands - Mixed Open Land	3	3	3	
POTWs Standards for Discharge Permits	1	3	3	Current knowledge is sufficient to anticipate many of the consequences of climate change on point source management.
Stormwater Management - Dry Extended Retention/Detention Ponds	2	2	2	
Stormwater Management - Filtering Practices	3	2	2	Might be a 2.
Stormwater Management - Infiltration Practices	3	3	3	
Stormwater Management - Wet Ponds & Wetlands	2	2	2	
Urban Stream Restoration	2	2	2	

Table D-28. Statement 14: This system and associated management practice are most likely to benefit from immediate investments in research to support the development of new decision support resources to facilitate adaptation to climate change

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
Forest Conservation (Forest Conservation Act)	4	4	4	
Riparian Forest Buffers - Urban	4	4	4	
Tree Planting	3	4	3	Mid-Atlantic urban areas are competing with invasives and are subject to interaction of multiple stresses: elevated CO2,

Management Practice	Initial Score	Reviewer Score	Final Score	Reviewer Comments
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Abandoned Mined Land Reclamation	3	4	3	It would not be perfect but there is a strong potential that funding for looking at climate change and AMLR treatment would at least identify the critical parameters needed to develop new decision matrices. At the very least, these could be potentially used to assist agencies that are charged with reclamation.
CREP Wetland Restoration	3	3	3	Agree with rationale
Reduction in Urban Growth	4	5	4	I could support a 5 on this.
Riparian Forest/Woodland Buffers – Agriculture	4	5	4	Reviewer 1: We need more basic science on the balances between different retention mechanisms and how that balance varies. We also need more knowledge about applying transect studies of riparian buffers to whole watersheds. Reviewer 2: Score = 5.
Wetlands - Mixed Open Land	4	3	4	There is always room for more research, but it is not clear that it could make significant changes in adaptive management capacity in the short term.
POTWs Standards for Discharge Permits	4	4	4	Disagree. I believe there is adequate information to make informative decisions regarding this issue. What is lacking is acceptance by much of the regulated community and policy makers.
Stormwater Management - Dry Extended Retention/Detention Ponds	3	3	3	
Stormwater Management - Filtering Practices	3	3	3	
Stormwater Management - Infiltration Practices	3	3	3	
Stormwater Management - Wet Ponds & Wetlands	3	3	3	
Urban Stream Restoration	4	4	4	