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**REVIEW OF THE OFFICE OF
RESEARCH AND DEVELOPMENT'S
GLOBAL CHANGE RESEARCH PROGRAM
AT THE
U.S. ENVIRONMENTAL PROTECTION AGENCY**

Final Report

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I. SUMMARY

I.1 Introduction

The objective of this review of the Global Change Research Program was to evaluate the relevance, quality, performance, scientific leadership, and resources of the Program. It was conducted by a subcommittee established by the Board of Scientific Counselors (BOSC) of the U.S. Environmental Protection Agency's (EPA) Office of Research and Development (ORD). The Global Change Subcommittee responded to a series of questions organized around two fundamental questions:

1. Is the Program engaged in the “right work”?
2. Does the Program conduct its research and assessment activities “well”?

Two structural elements informed the Subcommittee's review. First, the Subcommittee was charged to review EPA's Global Change Research Program on its own merits, taking as given its role in the national Climate Change Science Program (CCSP), of which it is but one small component. This role shifted from (early in the period under review) assessing the consequences of global change within three geographic regions to (at present and for the future) the conduct of research and other activities designed to inform potentially beneficial adaptive decisions by those who may be affected by possible global change. In short, the present purpose of the Program is to serve the national interest by providing decision support (within its area of responsibility) to public and private sector decision makers (mostly outside EPA or even the Federal Government) so that they might act in ways that will increase the expected national welfare given the challenges and opportunities associated with global change. Thus, the Program is in ORD, but its outputs are designed to be used primarily outside its organizational home. Second, the emphasis of the Program is on the consequences of global change for air and water quality, human health, and ecosystems, not on the effects of human activities or other factors on global change. The review process and goals of the review are described in Section II.2.

The Subcommittee organized the review around the four focus areas of the Program—air quality, water quality, ecosystems, and human health—and the Program's place-based framework for regional assessments. Chapter II introduces the review and explains the charge to the Subcommittee and the organization of the report. Chapter III, Program Performance and Future Direction, provides the Subcommittee's overall assessment of Program performance, strategy, priorities, leadership, and future directions. Chapters IV through VIII provide detailed assessments of the Program's four focus areas—health, ecosystems, water, and air quality—and of the Program's place-based framework for regional assessments, respectively. The Subcommittee's charge is provided in Appendix A.

I.2 Overarching Conclusions

The Subcommittee concludes that the Program has provided substantial benefits to the nation and that it is on course to make significant further contributions to societal outcomes by informing and facilitating decisions by the public and private sector actors who must consider the prospects of global change. The Program's earlier emphases on regional assessment of the consequences of global change and involvement of stakeholders were pioneering. They led to substantial social learning about how large-scale changes might be brought down to the local level and involve citizens and local organizations in effective adjustment and adaptation. The Program produced significant findings that have been appropriately disseminated both in the peer-reviewed scientific literature and more generally, and have led to better understanding of, and potential adaptation to, global change. The Program has been well received in the global change community and has strong working relationships with other bodies in the national interagency team. The Program has attracted a dedicated and skilled set of internal and external participants who evidence a high level of enthusiasm and energy.

Two underlying themes have surfaced in the Program's approach to its work. The first is that its emphasis now and for the future should be on decision support—improving the ability of those who control action to make wiser choices in the face of global change through provision of useful research and other activities. The Subcommittee concludes that this is the right emphasis and that it should be a guiding star for the efforts of this Program. The second emphasis is on stakeholder involvement—being “demand driven” and participatory. The Subcommittee again agrees that this is the right emphasis as a means of doing business and applauds the Program for its successes in this regard. It cautions, however, that for the future the Program should consider expanding the definition of stakeholders from site-specific interests to include venues for involvement of persons concerned about longer term adaptation challenges and for those concerned about localized but dispersed potentially affected resources and interests such as habitat preservation.

The overall conclusion of the Subcommittee is that the Program on the whole has done the “right work” and that it has done it “well.” The Subcommittee also, however, identified a number of areas in which future performance can be improved to meet the Program's evolving mission and responsibilities, as detailed in the body of the report. These include: (1) a more rigorous approach to priority setting; (2) a redirection of its place-based activities toward those that will have broader national applicability; (3) increased attention to threshold and episode-driven—in contrast to incremental—changes; (4) an expansion of its consultation with external advisors who can identify emerging opportunities for productive work, help the Program avoid projects with minimal payoffs, and increase interaction with complementary U.S. CCSP efforts; and (5) specific recommendations in each research focus area.

I.3 Findings

Program-wide findings are summarized in this section; additional findings related specifically to the Program's focus areas are presented in Chapters IV through VIII.

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1. The Program has been directed toward important problems as seen at its initiation and has performed well in pursuing their resolution.
2. The Program leadership and staff (both internal and external collaborators) have demonstrated skill, creativity, energy, and poise in conducting the Program and have achieved success.
3. The results of the research and operations of the Program have been well received by the user communities and have garnered leadership status for the Program in the global change scientific and decision communities and elsewhere.
4. The evolving national understanding of, and approach to, global change and the shifting requirements for research that have followed mean that the direction of the Program also must evolve if it is to provide maximum benefit to the nation.
5. The Program leadership is aware of the need for change in direction and has taken measured steps toward formulating and implementing the needed shifts.
6. There are opportunities to increase the effectiveness and benefits from the Program that should be explored.

The results from the Program and the national benefits from current and planned activities justify its continued support.

I.4 Recommendations

Program-wide recommendations are summarized in this section; additional recommendations related specifically to the Program's focus areas are presented in Chapters IV through VIII.

1. The Program should affirm its current emphasis on decision support for adaptation to global change and direct its resources accordingly. It should, however, assure that sufficient resources are devoted to the "harvest" of the results of the Program's previous assessment of global change impacts by preparing and making available generally applicable "lessons learned" and other assessment results.
2. The Program should consider developing an explicit framework for priority setting and project selection to guide future Program activities; when articulated, such a framework would aid communication with its publics by making explicit those types of activities that were and were not candidates for action.
3. The Program should engage diverse and multidisciplinary ("wise" as well as expert) external advisors to assist in formulating future Program direction and focus area projects. Given the very long-term nature of potential global change impacts (including consequences that occur across decades) such advisors should be tasked to address intergenerational concerns.

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4. The Program should take a more integrated and comprehensive systems approach when designing and implementing its activities across focus areas. In particular, it should consider integrating the Program's water quality and ecosystems focus areas to a greater extent. Further, it should consider and take into account ancillary benefits and costs in evaluating its past and proposed activities.
5. The Program should explicitly take account of intra-Program and external synergies in research and in project evaluation, selection, design, and implementation.
6. The Program should expand its efforts on non-steady-state (nonlinear-response) issues such as thresholds and episode-driven changes.
7. The Program should explore cooperation with other efforts to provide decision support tools and information.
8. The Program should develop a new strategy for place-based adaptation decision support activities that recognizes the importance of engagement of local stakeholders while assuring that the results of the investment have extended applicability of national significance and verifiable traction with decision makers

II. REVIEW OF THE GLOBAL CHANGE RESEARCH PROGRAM

II.1 Introduction

The purpose of this Report is to provide an external review of the performance of the U.S. Environmental Protection Agency's (EPA) Global Change Research Program and of its plans for and progress toward meeting its responsibilities in the future.

This report has been prepared by the Global Change Subcommittee of the Board of Scientific Counselors (BOSC) of EPA's Office of Research and Development (ORD), and it responds to a charge issued by EPA. In performing this review, the BOSC Global Change Subcommittee relied on materials supplied by the Program and on presentations made during conference calls and a subsequent fact-to-face meeting. Necessarily, however, the Subcommittee also called upon its experience and expertise and on other materials in conducting this review. In the course of the review, emphasis was placed on responding directly to the charge issued by the BOSC. In some particulars, the Subcommittee found that it could not address the charge completely because of limited information availability or of limited time to review available information. In other instances, the Subcommittee found it necessary to go beyond the charge to bring to the review matters it considered worthy of attention. The charge to the Subcommittee is provided in Appendix A.

The BOSC's Global Change Subcommittee conducted this review (see Appendix B for a list of the Subcommittee members). Prior to the review, the Subcommittee met twice via conference call (August 4 and September 13, 2005) for orientation to the Federal Advisory Committee Act (FACA) requirements, to discuss the review procedures, and to hear an overview of the Global Change Research Program and its relationship to the organization of EPA's ORD. The face-to-face review meeting was conducted September 26-28, 2005, in Alexandria, Virginia. Subsequent to the Alexandria meeting, a teleconference was held on December 6, 2005, to finalize the draft report. The review meeting and the three teleconferences were conducted as open meetings under the guidelines of FACA.

II.2 Overall Goals, Charge, and Structure of the Review

The National Academies (formerly known as the National Academy of Sciences) has recommended independent expert review for evaluating federal research programs. EPA's ORD is committed to independent expert review of its environmental research programs for objective evaluation of research at the program level to establish "best practices" in federal research program design, management, and evaluation, and to assist the Agency in preparing performance and accountability reports to Congress under the Government Performance and Results Act (GPRA) of 1993. In May 2004, the BOSC Executive Committee agreed to undertake a review of

the Global Change Research Program and formed the Global Change Subcommittee to perform this task and to provide a report to the BOSC Executive Committee.

This review differs from previous Multi-Year Plan (MYP) reviews in that it includes a prospective as well as retrospective evaluation, examining the future direction of the EPA research in this Program as well as progress to date. Both perspectives were required because the Program experienced a significant change in its proximate goals and purpose during the period covered by the review. The review is intended to provide guidance that will help ORD: (1) assess the progress and direction of the Program; (2) plan, implement, and strengthen the Program; (3) make research investment decisions over the next 5 years; (4) compare the Program with programs designed to achieve similar outcomes in other parts of EPA and in other federal agencies; and (5) prepare EPA's performance and accountability reports to Congress under GPRA.

The objective of the review was to evaluate the relevance, quality, performance, scientific leadership, and resources of the Program. The Subcommittee responded to a series of questions (the verbatim Subcommittee charge is provided in Appendix A) organized around two fundamental questions:

1. Is the Global Change Research Program engaged in the "right work"?
2. Does the Program conduct its research and assessment activities "well"?

The Subcommittee chose to organize the review around the four focus areas of the Program—air quality, water quality, ecosystems, and human health—and the Program's place-based framework for regional assessments. Chapter III, Program Performance and Future Direction, provides the Subcommittee's overall assessment of Program performance, strategy, priorities, leadership, and future directions, focusing on two fundamental questions and a series of sub-questions as follows:

Question 1: Is the Global Program engaged in the "right work"?

- ✧ Does the Program have, and is its direction guided by, a clearly defined and articulated mission with an undergirding rationale?
- ✧ Do its strategic goals flow from and support this mission? If so, are these goals structured to be consistent with the goals of ORD?
- ✧ If achieved, will these goals optimally serve the Agency and the interagency CCSP, as well as the larger public interest they both serve?
- ✧ Are the four focus areas of the Program—air quality, water quality, ecosystems, and human health—and the emphasis on place-based assessments consistent with EPA's mission, the Agency's role in the CCSP, identified scientific needs, and stakeholder interests?

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- ✧ Is the enhanced role of decision support as a guiding principle for Program activities consistent with and appropriate to the overall mission of the Program?
- ✧ Is the emphasis on stakeholder engagement in the planning and prioritization of the research appropriate for meeting Program goals?
- ✧ What insights or suggestions might the Subcommittee offer with respect to changes in priority or in the structure and content of the work of the Program?

Question 2: Does the Program conduct its research and assessment activities “well”?

- ✧ Does the Program further promote high quality research through competitive, merit-based funding? When funds are not competitively awarded, does the alternative process for allocating funds also help to ensure quality?
- ✧ Does the Program use peer review properly and effectively to improve, and to ensure the quality of, its products?
- ✧ Does the Program utilize performance measures effectively for evaluating progress towards its long-term goals (LTGs)?

Each subsequent focus area chapter and the concluding regional assessment chapter addresses sub-questions of Questions 1 and 2 as follows:

For Question 1:

- ✧ Are the Program activities that target these focus areas of the highest priority and consistent with resource availability and likelihood of success?
- ✧ Is the enhanced role of decision support as a guiding principle for Program activities consistent with and appropriate to the overall mission of the Program? If so, do the Program’s planned activities support an increased emphasis on decision support?
- ✧ Is the emphasis on stakeholder engagement in the planning and prioritization of the research appropriate for meeting Program goals? If so, are the regional or place-based assessments useful test beds for learning how to do stakeholder-relevant assessments and decision support?
- ✧ What insights or suggestions might the Subcommittee offer with respect to changes in priority or in the structure and content of the work of the Program?

For Question 2:

- ✧ Has the Program demonstrated consistent, superior scientific quality in its research and assessment products?

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- ✧ Has the Program effectively integrated intramural and extramural research and assessment activities to attain its goals?
- ✧ Has the Program used the results of assessments together with stakeholder feedback to identify key research gaps and to update the Program's research agenda?
- ✧ Has the Program provided useful information and tools to stakeholders in a timely manner, and has it communicated its results effectively to its clients and to the broader scientific community?
- ✧ Has the Program evolved over time to provide decision support more effectively to its clients?
- ✧ Has the Program made significant progress toward each of its LTGs?
- ✧ Has the Program achieved important environmental outcomes?
- ✧ Have the Program and its scientists played leadership roles in the global change research community and in furthering global change science?
- ✧ What insights or suggestions might the Subcommittee offer to improve the effectiveness of the operation of the Program?

II.3 Background for the Global Change Research Program and for This Program Review

A key aspect of the Program, which is distinct from other EPA research programs, is that it operates within the context of the multi-agency CCSP, a melding of the Bush Administration's Climate Change Research Initiative and the U.S. Global Change Research Program (USGCRP) (EPA 2003, Multi-Year Plan, Goal 6). The USGCRP, established in 1989 and authorized by Congress in the Global Change Research Act of 1990, includes 11 member agencies. USGCRP activities are coordinated by the Subcommittee on Global Change Research within the National Science and Technology Council's Committee on Environment and Natural Resources. The activities of EPA's Program are closely coordinated with this interagency effort.

The CCSP Strategic Plan provides an overall framework for agency planning within which EPA's Program must function. The Strategic Plan defines EPA's unique niche as an assessment-oriented program with a primary focus on understanding the regional consequences of global change for human health and ecosystems. EPA has in turn elaborated its vision of program goals, within the context of the Strategic Plan, in its own Research Strategy. The Research Strategy details the organization of the Program around the focus areas of air quality, water quality, ecosystems, human health, and the place-based framework for regional assessments.

Two organizational elements thus informed the Subcommittee's review. First, ORD's Global Change Research Program is but one, relatively modest, portion of a total national program, and

the Subcommittee was charged to review the Program on its own merits, with the Program's role in the national program as a given. Second, the emphasis of the Program is on the consequences of global change for air and water quality, human health, and ecosystems, not the effects of human activities or other factors on global change.

Although the original vision of the Program was to assess the consequences of global change across four focus areas and within three regions of the United States, doing so allowed the Program to identify opportunities for improved societal outcomes in the face of global change through development of adaptive strategies. In turn, the identification of such opportunities led to the task of conducting research and other activities to support and inform decisions that might be taken by the responsible parties—private or government—to adapt to such change in an optimal way. This logical progression of tasks is reflected in Program activities, with the earlier emphasis on assessment giving way to the current emphasis on decision support.

The “research to inform decisions” emphasis of the Program as found in its current Research Strategy surfaced after much of the work reviewed here was commissioned and completed. The review, therefore, was faced with evaluating some work that was designed to meet the earlier but now partially preempted programmatic emphasis rather than on the evolved emphasis of decision support. Although this presented no difficulties in fulfilling the portion of the charge related to whether the work was done “well,” it did require special treatment of the portion of the charge related to whether it was the “right work.” The Subcommittee resolved this latter difficulty by considering past, and in some cases still continuing, work in the context in which it was conceived.

With reference to more recent and future work, the Subcommittee adopted the current Program premise as to its “right work.” In this regard, the Subcommittee concluded that it would be useful to those using this Report to outline our understanding of the appropriate role of the Program in the current national global change effort as a basis for interpreting the report's conclusions, especially with respect to priorities. That understanding and the framework principles for priority setting that are implied are presented in a section of the next chapter.

With respect to the “done well” question, fewer problems arose in pursuing the Subcommittee's task. It adopted generally recognized scientific criteria for peer reviews of this sort.

One aspect of this review and evaluation of the Program deserves special attention and recognition. A criterion for program effectiveness that has received broad currency throughout the government is its delivery of beneficial *outcomes*, not outputs. Outcomes are defined as results that in a measurable way can be shown to improve national welfare—measured perhaps in economic resources saved, lives extended, illnesses prevented, and so forth. While applauding the emphasis on results rather than on outputs, the Subcommittee concluded that it was inappropriate to use this approach broadly in evaluating the Program. There are two reasons for this conclusion. First, especially with respect to the newer focus on decision support, the benefits, for the most part, will be garnered in the long term and with substantial lags. Although today's decisions with regard to challenges posed by climate variability are an entirely appropriate testing ground for the ability of science to engage practitioners and address their needs, adaptation by its nature is to deal with future global changes and/or requires time. It is

investment expended today that is designed to benefit those in the future. Thus, measurable outcomes should be seen in terms of the *expected* value of the improved decisions that occur—and cannot, in most cases, be observed today. Second, the Program outputs are in the nature of intermediate goods. That is, they are in the nature of improved information, tools, and processes that can be used by decision makers to increase the resilience of the nation in the face of prospective global change. The Program is responsible for providing useful outputs and it is tasked to assure that decision makers are informed of their availability, but it cannot mandate or require their use—and only in use will measurable outcomes result.

The purpose of the Program, however, is to improve outcomes—to yield national benefits. Therefore, it is incumbent on the Program to produce outputs that will maximize those outcomes. A continuing challenge for the Program is to assess whether its outputs are useful and used, and to incorporate observed and expected benefits from its activities into its evolving program plans. The Subcommittee addresses this issue in its discussion of priority setting in the next chapter.

III. OVERALL PROGRAM PERFORMANCE AND FUTURE DIRECTION

The purpose of this chapter is to present the Subcommittee’s view of the performance, operation, priorities, direction, and planned future course of the Program taken as a whole. It draws upon the focus area chapters that follow but also integrates observations and conclusions reached in examining documents provided, participating in discussions and presentations by Program staff, and the Subcommittee’s own deliberations based on those sources of information. This chapter seeks to serve those readers who need to understand how and to what extent the Program provides overall benefits to the nation in exchange for the resources expended and how those benefits might be increased. The chapter begins with a concise statement of the Subcommittee’s conclusions about the Program and then takes up the two major charge questions in turn.

III.1 General Conclusions

The Subcommittee concluded that the Program had provided substantial benefits to the nation and that it was on course to make significant further contributions to improving outcomes in the face of potential global change. The Program’s earlier emphases on regional assessment of the consequences of global change and involvement of stakeholders in defining both matters of interest and possible paths to improvement were pioneering. They led to substantial social learning about how large-scale changes might be brought down to a local level and involve citizens and local organizations in effective adjustment and adaptation. The Program produced significant findings that were appropriately disseminated both in the peer-reviewed scientific literature and more generally, and have led to better understanding of, and potential welfare-enhancing adaptation to, global change. The Program has been well received in the global change community and has strong working relationships with other bodies in the national interagency team. The Program has attracted a dedicated and skilled set of internal and external participants who evidence a high level of enthusiasm and energy. All of this has been accomplished in the face of the fact that the Program operates in the context of an interagency effort—the CCSP—but within ORD, which has a complementary but distinct mission and culture. The success of the Program speaks well for both its leadership and the leadership of ORD.

The Subcommittee observed that the national understanding of and approach to global change has evolved from the earlier issue of determining the consequences of possible global change to the now more-pressing one of optimal adaptation to it, even given all the uncertainties that remain. The Program has responded to these shifting priorities—from assessment of potential impacts of global change to incorporation of global change in decision support for adaptation strategies—and is on track to continue to do so. It is clear, however, that work remains in completing the earlier efforts, especially by “harvesting and bringing to market” the lessons learned from the work that was initiated earlier.

The Subcommittee found that substantial synergies existed among different elements of the Program and between the Program and other efforts, and that the nation had benefited through their recognition and exploitation—focus area and place-based efforts benefited from research results and learning from each other, Program and core ORD regulatory support activities were mutually supportive, and partner federal and non-federal agency activities were enriched by and in turn enriched Program efforts. The Subcommittee suggests that the Program take appropriate credit for the synergistic benefits that have flowed from its activities and that it continue to be aggressive in searching out opportunities to exploit such synergies as it plans and prioritizes its future activities.

The remaining chapters of this report document some of the promising Program activities that can be expected to yield improved national outcomes. They also identify some directions that the Program might go to increase the benefits it will yield. Later in this chapter, the Subcommittee suggests a framework for priority setting that could guide future Program activities and that, perhaps more importantly, when articulated would aid communication with its publics by making explicit those types of activities that were and were not candidates for action.

Two underlying themes have surfaced in the Program’s approach to its work. The first is that its emphasis now and for the future should be on decision support—improving the ability of those who control action to make wiser choices in the face of global change through provision of useful research and other activities. The Subcommittee concludes that this is the right emphasis and that it should be a guiding star for the efforts of this Program. In essence, it is designed and supported for its contribution to improved outcomes coming primarily from the actions of others, not for its contributions to EPA’s regulatory agenda or for its contributions to scientific progress, per se. The second emphasis is on stakeholder involvement—being “demand driven” and participatory. The Subcommittee again agrees that this was the right emphasis as a means of doing business and applauds the Program for its successes in this regard in its earlier activities. It cautions, however, that for the future the definition of stakeholders should be expanded to include those representing longer term adaptation challenges and localized but dispersed potentially affected resources and interests. In this light, the Subcommittee suggests the possible advantage of establishing formal or informal advisory groups, as noted in more detail below. The point is that the Program needs to ensure that it includes the stakeholders “not at the table”—including provision for the interests of future generations.

In short, the past results from the Program and the national benefits from current and planned activities justify its continued support. The Subcommittee’s observations and recommendations are provided in the spirit of seeking to further improve on a successful effort.

III.2 Is the Program Engaged in the “Right” Work?

III.2.1 Introduction

The Subcommittee found that the mission of the Program has evolved over recent years in response to both a new context and shifting national priorities and that the direction of the Program has appropriately adapted to meet that new mission. The previous mission was to

collaborate in a national effort of assessment of the implications of global change; this mission was clearly articulated and its rationale understood by EPA. The chosen strategic goals that flowed from that mission directed the selection of activities to be commissioned and carried out, for the most part successfully. The new mission is to build on the initial mission to support and inform decisions that will lead to successful adaptation to global change, and the rationale for this mission also is clearly understood. Although the goals to be pursued in accomplishing this mission are manifest, the criteria and process for selecting activities to be commissioned and carried out are ongoing and success cannot yet be determined.

The Subcommittee noted that the previous—and current—missions for the Program arose outside of the normal processes of ORD and were grafted upon (and competed for resources with) established missions and research programs. In brief, the basic mission and reason for being of ORD is to provide scientific support for EPA in its environmental (largely) regulatory agenda. Its laboratory/center organization, its programmatic foci, and its staff are appropriately structured and motivated by the set of goals and topic areas inherent in this mission. The assessment (and now adaptation facilitation) activities of the Program are arguably tangential to this regulatory support thrust of ORD, and in that sense are somewhat removed from ORD's major goals, yet consistent with them. The Program, in fulfilling its mandates from the CCSP, necessarily tends to be more top-down in setting its agenda than is otherwise the case in ORD. The agenda is properly determined by both its mission and by the combination of external needs and available opportunities that are presented, not by internal EPA needs or scientific opportunities. Yet, the Program must depend on the resources and talents of constituent parts of ORD to conduct much of its work. The Subcommittee observed that this divergence in missions, clients, and functions has created organizational and administrative difficulties for the Program in the past. This was recognized in fall 2004 when then-Assistant Administrator Paul Gilman and then-Deputy Administrator (now Administrator) Stephen Johnson announced that the leadership of the Program would be a National Program Director (NPD) with enhanced budgetary and other authority to conduct the Program.¹ The Program now has authority and influence more closely in keeping with its responsibility.

In contrast to the partial divergence of the Program from ORD's core regulatory *programmatic* goals, the Subcommittee concluded that the Program was well structured to meet ORD's *operational* goals and conducted itself accordingly. These latter include such matters as a commitment to good science, appropriate reliance on external expertise, rigorous peer review, and so forth.

As previously noted, the mission and overarching goals of the Program, both current and previous, were assigned as part of a government-wide effort by the CCSP. They were made an EPA ORD responsibility because of the judgment that EPA ORD was the most appropriate group within the Federal Government to undertake these responsibilities. The Subcommittee concluded that it was not appropriate or possible for it to evaluate the decision to place these responsibilities with the Program. It did observe, however, that the goals of the Program, if achieved, would make an important contribution to the public interest. Indeed, the earlier assessment activities have had a demonstrable effect in increasing public understanding of the

¹ Paul Gilman, "Budget Authority for ORD's New National Program Directors," Memorandum to Deputy Administrator Stephen Johnson, concurrence noted: September 21, 2004.

potential for various elements of global change to have significant effects on environmental, health, and economic outcomes that people value. They also have led to a greater understanding of the issues associated with future adaptation to global change, which is the focus of the current and future Program activities. Thus, the scientific work conducted and planned by the Program has served and can be expected to serve the larger public interest.

III.2.2 Focus Areas and Place-Based Emphasis

In pursuing its assigned goals, the Program has focused on four areas and has given emphasis to their place-based components. The selected areas are air quality, water quality, ecosystems, and human health. These areas reflect EPA's historical regulatory mission, legislative mandates, and research strengths, as well as meet the needs of the overall CCSP. In addition, of course, they represent central issues associated with the potential impacts of global change and therefore, fulfill the larger public interest in global change research. Consequently, they offer opportunities for synergistic benefits in producing useful outcomes and in efficient use of overall resources while fulfilling the Program's more narrow goals. The Subcommittee concluded that the four focus areas were appropriate.

In emphasizing the place-based component of global change the Program recognizes the obvious—most impacts and potential impacts are local, as are most actions to adapt to global change. Further, organized and/or identified stakeholders necessarily represent and are concerned with, and are most likely to act upon, impacts that affect them most directly, and typically such matters are defined by place. Therefore, the selection of a place-based emphasis was commendable by the Program. Nonetheless, the Subcommittee had concerns about how particular elements of the place-based component begun in a pilot phase have evolved. In brief, the Program has limited resources to affect a national purpose. One such purpose is to improve the ability of localities to adapt, and in pursuit of this goal, it is important for the Program to understand how such actions might be taken and what decision support would be most effective. In doing so, it needs to involve localities for the purpose of learning and developing broadly applicable lessons that may be applied widely; any specific benefit to the locality itself is welcome but tangential. The Subcommittee observed that substantial effort had been expended in some instances in serving local interests directly, without an obvious payoff in terms of broadly applicable processes or learning. Noting this, the Subcommittee is fully aware that involvement with stakeholders and external researchers requires a sharing of decision-making power and that the Program faces tensions in determining the course of a project once begun. This argues for, as the Program fully understands, a very careful articulation of the goals of a project before it commences. It also suggests the possible advantage to the articulation of principles for selecting activities as noted in a later section of this chapter. These comments should not imply that the Subcommittee is negative toward further local projects that are appropriately designed for their potential large-scale benefits by means of possible replication and/or of applicable lessons learned.

The Subcommittee made an important distinction in its deliberations regarding the place-based emphasis of the Program, a distinction that it concluded had not always been recognized in the Program's activities, but certainly could be. That distinction is between "place" defined by geographic or political boundaries (site-specific) and "place" defined by the locus of potential

impacts from global change (problem-specific.) Place defined by geographic or political boundaries is unique; place defined by potential impacts need not be unique. Instead, it is defined by the set of conditions that are affected by a possible global change, and although these may be present within only one geographic or political locality, they typically will be found more widely.

The Subcommittee concluded that, by its nature, a *national* program that maximizes the public interest will be directed toward developing scientific information that can be applied wherever the conditions warrant, not with addressing one locality after another to solve its problems by allocating whatever resources are necessary for the task.² By analogy, the private physician's focus is on the individual patient; the public health practitioner, in contrast, is focused on the health of the population as a whole. The private physician is obligated to apply all resources necessary to benefit his/her patient notwithstanding the possibility that other patients might be benefited more. In contrast, in pursuing improved public health, resources should be allocated to maximize the health of the community at large. This suggests the Program's appropriate focus for problem-defined, place-based efforts: activities that *use* a local problem and those affected as a test bed and research venue to build tools and increase knowledge that potentially could be used by others in all localities with similar conditions—and that would likely benefit the specific site as well.

III.2.3 Priority Setting Framework to Determine the “Right Work”

The previous section notes that the Subcommittee concluded that the Program was engaged in the “right work” in pursuing its four focus areas and conducting its work in a place-based context. The further question is whether the *activities selected* in each of these areas represented choices consistent with yielding the greatest national benefit. To answer this question, it is necessary to have a principled decision framework that provides priority-setting criteria for selecting activities to pursue. As noted below, the Subcommittee recommends that the Program devise, implement, and disseminate such a set of principles as information and guidance to persons interested in and involved with its operation. That is, the Subcommittee suggests that the added transparency that such a process change would yield would serve the Program, its clients, and those on whom it relies for resources well by increasing the confidence in, and the predictability of, its selection of activities. For its own purposes, the Subcommittee inferred and structured such a set of principles to use in its review, and applied these principles in the succeeding chapters. These provide examples of what the Subcommittee members have in mind and may be useful to the Program as it proceeds in its planning for future work. Here, the Subcommittee presents its basis for evaluating the priorities incorporated in the past and especially the planned activities of the Program, and as a basis for this, its understanding of the premises on which the Program is based.

The Program, as part of the national CCSP, starts with the premise that multiple changes may be in the offing that will affect the optimal behavior of individuals, businesses, and government at

² The Subcommittee noted that some site-specific issues were of such broad, large, or charismatic significance that they, for that reason, rose to “national” status. One example noted was the Florida Everglades. Further, some site-specific work might be used to inform conditions under which practitioners are motivated to fully engage in the design and implementation of applied research.

all levels. These changes include those associated with: global climate change, increased ultraviolet (UV) radiation reaching the earth, rising and shifting population and associated demographic changes, altered land use, and so forth. Each of these could present stresses, some reinforcing those imposed by others. These stresses may present themselves incrementally over time, episodically, or relatively suddenly—either because “tilt points” are reached or because a threshold may be crossed.

The strategic goal of the Program is to foster the development of those scientific results that will inform potentially adaptive behavior so that responses by decision makers will lead to the highest value outcome possible—given the uncertainties, the costs of adaptation, the sometimes long lead times involved, and the institutional and other constraints on action. In short, the purpose of the Program is to make it possible for decision makers to choose courses of action that will enhance the *expected* value of outcomes, given potential changes. The presumption is that those who are making the decisions are motivated by and responsive to the principals (local, state, or national residents, economic interests, social groups, or themselves) for which they, as agents, will be acting based on increased knowledge and understanding gleaned from the Program. The further presumption is that the Program is serving the national interest by making this possible. In defining the national interest, the presumption is that under applicable laws and regulations, the Program has the overriding mission of improving the national welfare, as that welfare is judged by those living now, who also serve as spokespersons for those who follow them. The latter point is particularly important because many of the potential actions the Program could inform will have effects in the future—perhaps far in the future. (See more on this in Section III.2.5 on stakeholders.)

Three overriding tasks follow from this strategic goal. The first is to illuminate those choices where action can take place—opportunities for adaptation—that could increase the expected value of outcomes given the potential changes that may occur. The second is to produce the information required by decision makers so that they might choose what, to them, is the optimal behavior with respect to those choices. The third is to assure that the information and understanding created in partnership or consultation with those for whom it could be useful is disseminated widely and evaluated regularly.

This concept of the goal and tasks of the Program presents a striking challenge for a scientific research program. In short, the research initiatives must be demand driven. Given the suite of potential global changes that may affect decisions, first, the possibility and potential value of adaptive action must be determined; second, the information required to structure and evaluate the action must be identified; and third, only then can a research effort be designed to provide that information and support the decision. Inherently, then, to succeed, the Program must be driven by the opportunities presented to improve future outcomes where those outcomes could be affected by global change.

The further challenge follows: from the immense suite of potential decisions for which scientific research might provide information of value, those must be chosen that offer the prospect of the highest *national* return from the limited resources available to the Program to support such research. In making these choices, one clear bright line is obvious; the Program should not support research that would otherwise be conducted by others, notably those in the private sector

for their own benefit. Further, the Program should concentrate its activities where the prospects for development of decision support tools is feasible because of the availability of data and existing knowledge of mechanisms. An additional factor is that the Program should focus its resources in areas where the development of decision support tools is feasible because of the availability of data and existing knowledge of mechanisms. It follows that the definition of the “right work” for the Program is the research that has the highest expected value in terms of the net national return—a combination of the expected success of the research and the expected value of the improvement in decisions if the research were successful and utilized.

From this definition, the Subcommittee devised a framework for evaluating Program activities in terms of doing the “right work.” That framework and the premises that guided its formulation follow. (Note: as explained above, the Program goals and role have shifted and the framework presented here is appropriate only for activities initiated after the shift and for future work.)

The starting point for determining the “right work” in improving adaptation decisions is to fence off that work for which there will not be a high national payoff, either because adaptation will occur naturally or because others will provide decision support. This category of decisions is that wherein the change is discernable and incremental and where those affected *both control the adaptation process and have an incentive to adapt*. For example, if there is, or is expected to be, a gradual decrease in annual rainfall and/or change in temperatures in a locality, farmers will alter tillage practices and crop choices to accommodate the shifts. In a rough and ready way, with some leading and others following, farmers will change their behavior to achieve the best adjustments possible—while bearing the unavoidable costs. In short, there are compelling incentives for individuals to forecast and devise appropriate responses to discernable changes and to take action when it is appropriate. There are similar compelling incentives for those who serve them (in this example, agribusiness concerns, farmers’ organizations) to conduct any adaptation research that is necessary. The Program will face strong pressures to devote its resources to such research, but to do so would simply replace that which would otherwise occur and divert scarce resources from more productive uses.

Those more productive uses could fall into several classes. The first of these is where cumulative incremental changes (including those affecting individuals who control adaptive processes) are predicted to reach a “tilt point” where the effects are different in kind and/or degree and of such a nature that optimal adaptation requires preparation that involves, for example, social decisions or long lead times. That preparation and optimal adaptation will not occur without appropriate research and external intervention, which opens an opportunity for the Program to make a meaningful contribution to future national wellbeing.

The second use to which Program resources might be directed is that where the decisions are not in the hands of private parties and/or where private parties have no incentives to act. Social (collective) decisions are required. Two subclasses can be identified. The first is with regard to social infrastructure such as hydro facilities, water supply or treatment, or land use. The second is with regard to relatively unmanaged systems, such as wildlife and habitat, estuaries, and valued ecological services. The collective decisions that are required for adaptation must be identified, proximate decision makers (local, state, or national officials or others) informed, and those who must approve the decisions—citizens, taxpayers, those directly affected—must be

consulted and approve before adaptive action is taken. For both of these subclasses of potentially welfare-enhancing adaptations, long lead times often are required for effective action. Consequently, efforts must be expended well before benefits are garnered—and those benefits are speculative because of the uncertainties of the existence, timing, magnitude, and consequences of the potential changes that might make adaptation actions appropriate. In these circumstances, the Program can provide and disseminate credible research that informs potential decisions, providing a valuable service that would not otherwise be available.

A third class of uses to which Program resources might be highly productive is in the provision of information and/or services based on research that has the character of being a “social good”—that is, when once produced, is available to all and may be of widespread benefit but that is not in the interest of any one party to produce. Examples of this class of uses include such outputs as credible “early warning” of prospective changes (particularly sudden changes) to which individuals and others might respond; development of adaptation support mechanisms that require collective investment or long lead times (such as vaccines for emerging diseases); or processes to shorten the lag in discerning and reacting to global change (such as mechanisms to disseminate “best practices” more speedily).

The practical problem of choosing a portfolio of activities for the Program from the array of opportunities remains. In doing so, the Subcommittee concluded that the formulation above would be helpful as a framework for setting priorities, and recommends that EPA consider adopting such a framework. In the first instance, it provides a principled basis for rejecting whole classes of opportunities as inappropriate, thus narrowing the field to more manageable dimensions. Of the opportunities remaining, for some there is no obvious or willing group of decision makers/stakeholders available to make use of any research provided, and if so, no matter how valuable the research to potential decisions, it would have no national benefit because it would not be used. Although in some circumstances it might be appropriate to attempt to build such a coterie of willing prospective users, the effort of doing so would divert resources from the primary task of providing decision support for adaptation. What then remains is to choose from among the possible activities those that would have the greatest expected national value in minimizing the cost of possible global change. This decision would be informed by the prospects for success of the activity on its own terms, the likelihood of improving decisions taken, and the difference between national welfare with and without the improved basis for adaptation, taking both present and future into account.

The Subcommittee was unable to “map” Program activities against this suggested framework for priority setting in a comprehensive way because of limitations of time and information, though specific comments are made with respect to past and planned activities in the chapters that follow. Consequently, the Subcommittee does not offer an overall evaluation (scorecard) of whether the Program has pursued the “right work” in its portfolio of activities based on these criteria. Moreover, the Subcommittee recognizes that the Program has multiple goals, some preceding and others supplementary to the decision support emphasis, that also represent “right work.” The Subcommittee concludes, however, that if and when the Program devises, adopts, and enunciates such a set of principles it will be better able to assure itself, the public, and future reviewers that its resources are being devoted within its mandate to those activities that promise the greatest return in national wellbeing.

III.2.4 Is Decision Support an Appropriate Guiding Principle for the Program?

As noted above, during the course of the Program's operation considered in this review its mission shifted from being part of a national assessment of the consequences of global change to being an instrument for research to enhance the ability of the nation to adapt to changes that might occur. In pursuing this new mission, the Program concluded that its resources could be used to best advantage by concentrating on informing decision makers about the consequences of alternative courses of action in the face of possible global changes. In that way, the Program would provide the tools with which those responsible for decisions could achieve the optimal outcomes, given the uncertainties, the prospective conditions they faced, and their values and concerns.

The Subcommittee concurs with this choice and the reasoning that undergirds it. Providing such decision support is likely to have the greatest potential return from the resources available to the Program. With well chosen activities, its products are in the nature of a collective good that would not otherwise be available. Further, such products can be tailored by decision makers to fit specific conditions, yielding optimal results. In short, decision support fits properly into our pluralistic and federal system and represents an efficient and effective direction of Program resources to support the national goal of enhancing welfare in the face of possible global changes.

Given that the emphasis on providing decision support is appropriate, the question remains as to whether the Program's current and planned activities are optimally effective in their fulfillment. In the Subcommittee's opinion, there are four criteria for a positive answer: the target of the decision support must be important and of national significance, the requirements of the task should be consistent with the scientific and other resources available to the Program, the potential users of the tools produced must be receptive and the tools must be disseminated to them, and, finally, the tools must be "user friendly" so that they will actually be used to enhance the quality of decisions.

Success for the Program in its future activities will require that these criteria be met in the design and operation of all of its activities. Note, then, that providing decision support must be incorporated as a "way of doing business"; it is not a standalone activity to be pursued in the abstract. In this light, the Subcommittee noted that the Program had devoted some resources, and was intending to devote more, to advancing the science of decision support. The Subcommittee concluded that such activities were appropriate if, *but only if*, they were designed to fill gaps in knowledge *essential to conducting its primary mission, which would not or could not be filled by others*. The Subcommittee urges the Program to reconsider in this light any projects designed to advance the science associated with decision support.

The succeeding chapters consider the function of decision support within each of the focus areas as evidenced by past and planned activities.

III.2.5 Is “Stakeholder Engagement,” as Implemented, an Appropriate Emphasis?

In its current mission, the success of the Program depends on actions considered or taken by decision makers who are informed by the Program’s products. As noted earlier, the Program produces intermediate products, not desired outcomes.³ Thus, to succeed, the Program needs to be intimately involved with and guided by its “customers”—those who can and may use the information provided to inform their choices regarding adaptation to global change. The term of art chosen by the Program for this involvement and guidance is “stakeholder engagement.” By whatever term, the Subcommittee agrees that an intimate connection with current and prospective adaptation decision makers is a correct, and indeed necessary, component of Program emphasis. It also agrees that place-based activities, such as some of those in which the Program has participated, can be appropriate test beds and learning experiences for this purpose.

The question remains as to *which* decision makers the Program needs to connect, and for *what* purpose. In evaluating Program activities and plans in this regard, the Subcommittee referred to the criteria outlined above and found that, *ex post*, some of the stakeholder involvement did not appear to have a priority that would justify use of Program resources. This class of involvement would be that where it turned out that the focus was on support of unique site-specific decisions rather than on problem-specific research that could be applied more broadly—even if the locus of that research was in one place in concert with one group of potential decision makers. The Subcommittee also noted, however that the Program could not (and should not) control how stakeholder-oriented projects evolved, and that useful lessons were and could be drawn even from projects that emphasized parochial concerns and actions.

The Subcommittee also observed that global change impacts may lie in the future and/or may not be discernable in a way that would compel the interest of the sort of stakeholders involved in past Program activities, much less action. Yet, the Program’s responsibility in serving the public interest includes the interest of future generations and of the broader community. For this reason, the Program has the responsibility to reach out to “stakeholders” regarding potential adaptation to changes over the horizon. Here the Subcommittee has in mind, for example, global changes that may induce stresses that lead to “tilt points” or thresholds and/or that may have significant consequences for future generations. To meet its responsibilities to stakeholders “not now at the table,” the Subcommittee recommends that the Program consider convening expert advisory groups in some of its focus areas to contemplate what work should be done now in anticipation of future stakeholder interest.

³ By analogy, if the product were clean clothes, the Program would produce the washing machines. For the washing machine manufacturer to succeed, clothes have to be expected to get dirty and clean ones be preferred. Further, the machines must: (a) be designed to do the required job that projected users perceive needs to be done; (b) work effectively; (c) be known by and accessible to potential users; and (d) be user-friendly in the hands of final operators. Unless all of these conditions are met, no beneficial outcomes will result—the washing machines will rust on the loading dock. In the case of the Program, it would produce research of no value (given its mission) because it was not used.

III.3 Is the Program Doing Its Work “Well”?

The Subcommittee sought to review and evaluate the quality of the Program’s performance on those activities in which it had been engaged both by examining the Program as a whole and by examining its separate elements and selected projects. Given the limited time and resources available for the review and the breadth and extent of the task, it was impossible to perform a rigorous and complete examination. Consequently, the Subcommittee’s observations and conclusions were based on a sampling of the work (including peer reviewed literature, focus area and programmatic overview documents, posters displaying scientific results, assessment documents from the First National Assessment and more recent assessment efforts, and materials from related Web sites) and on an examination of the quality assurance and measurement processes that were in place. The subsequent chapters provide specific review and evaluation of particular activities; the discussion that follows reports on the Subcommittee’s observations and conclusions regarding the overall performance of the Program.

The Subcommittee concluded that the Program had “demonstrated consistent, superior scientific quality in its research and assessment products” in the review formulation found in its charge. It has a commendable record of publications in quality, peer-reviewed journals as one item of evidence in this regard. The leadership of the Program has put in place generally accepted practices to promote scientific quality and has held participants accountable. The Subcommittee observed that the staff members associated with the Program and the participants in its sponsored research on the whole were highly qualified, well regarded in the research community, and appeared to be well-motivated and deeply engaged in the effort. The scientists involved have played leadership roles in the global change research community and have pioneered in some respects, especially in the earlier assessment activities. The leadership of the Program provides well-respected and recognized national and international contributions to the broader global change assessment and adaptation endeavor.

The Program uses the Science To Achieve Results (STAR) Program to fund a significant portion of its extramural research activities (in 2005, the STAR Program represented \$6.7 million in extramural grants). The STAR Program is a mechanism to assure that external funding is awarded competitively, based on merit. The Subcommittee found no evidence that the allocation of tasks between intramural and extramural researchers was anything other than appropriate, and commends the Program for its integration of the two arms of its research effort. Individual projects are peer reviewed as appropriate, as part of the ongoing evaluation process, to assure that efforts are on track, and/or before publication or release of final products. The leadership of the Program appears to be intimately familiar with, and thus able to critique and advise on, efforts as they are underway.

The Subcommittee does not have information on which to evaluate the effectiveness of interim processes to assure that projects and other efforts are on track. It did examine the externally published schedule for delivery of given projects and deliverables and found that these schedules had been met. As noted above, it is inherently difficult for the Program to measure and thus to provide evidence of progress and performance in meeting its LTGs (particularly improved adaptive outcomes) because those in part rely on the actions of others and because such results will be apparent only after substantial lags. The Subcommittee encourages the Program to work

toward providing such measures, taking as possible guidance the recent National Research Council (NRC) study.⁴

Taken on its own terms, the Program has provided useful information and tools to its stakeholder community in a timely manner. It also has communicated its results to the larger scientific community through reports and publications. The Subcommittee observed, however, that success for the Program depends on its serving the larger community of potential stakeholders, not solely those who have been involved in its activities. To succeed in this larger task, the Program needs to focus more intently on broadening its impact and increasing the range of those who may use its work. To do this, the Program needs to first, draw lessons of general applicability from its past activities (especially the regional, place-based endeavors) and communicate them more broadly. Second, the Program needs to select and design its future activities with broad applicability in mind. The section above that elaborates on the Subcommittee's views of Program priority setting details the criteria that could guide this shift in Program emphasis and direction. In the Subcommittee's opinion, this structuring of the mind-set of the Program as it selects its work would be an important means of meeting the proximate goal of providing decision support more effectively to its clients.

The past research of the Program has identified substantial opportunities for efforts to support its evolving mission of informing potential adaptation decisions. These have been used to select "targets of opportunity" for its newer and future work. At the same time, both the shift in mission emphasis and the completion of some previous activities suggest that the Program's future research agenda will be appropriately very different from that which led to its past activities. Commendably, the Program has recognized the need for transition and is in the process of putting it in place. The Subcommittee thus recommends that for the immediate future the Program should both "harvest" the results of its previous research in the form of preparing and making available generally applicable lessons for broader applicability while also devoting an increasing amount of its resources to its new direction and mission.

In summary, the Program has made progress toward each of the LTGs that guided its earlier activities, and has evolved toward a structure and configuration that will facilitate success in achieving those goals that now guide its behavior. In doing so, it has achieved some significant environmental outcomes, as noted in the chapters below. The Subcommittee notes again, however, that the utility and benefit of the Program, by its nature, cannot be evaluated by the otherwise commendable metric of observable outcomes, for reasons provided above.

⁴ National Research Council, Committee on Metrics for Global Change Research, Thinking Strategically: The Appropriate Use of Metrics for the Climate Change Science Program, 2005.

IV. HUMAN HEALTH FOCUS AREA

IV.1 Human Health Focus Area Overview

The LTG of the Human Health Focus Area is that “decision makers in the states and EPA regional and program offices will use scientific information and decision tools from EPA’s research and assessment program to protect human health by adapting to global change.” In setting out to accomplish this goal, the focus area has defined four content-based categories for research and assessment activities through 2009:

1. Weather-related morbidity.
2. Effects of global change on water and vector-borne diseases.
3. Effects of global change on morbidity associated with airborne allergens.
4. Effects of global change on ambient air pollutants.

In addition, the Program has committed to periodic (5-year) reviews of direct and indirect impacts of global change on human health.

Assessment activities in human health effects of global change are hampered by a severe lack of basic health data to serve as baselines for such assessments as well as to enable the types of epidemiologic research necessary to derive quantitative linkages between environmental parameters including climate variability and human diseases and other health outcomes. Because of the difficulties of studying health outcomes, there is limited understanding of the mechanisms by which climate variability may change incidence of human diseases, such as vector and water-borne infections. Limited understanding of mechanisms and limited data also translate into very few available models with which to conduct assessments of potential impacts of global change on health, in contrast to other focus areas that have a longer history of use of predictive modeling.

Given these knowledge and tool constraints, the Human Health Focus Area has made an exceptional contribution to the science of health effects of global change. It has narrowed its focus on the four categories of health impacts listed above, and made appropriate use of both intramural and extramural resources.

There are several different types of work products relevant to this focus area:

- ✧ Literature reviews/descriptions of “state-of-the-science.”
- ✧ Retrospective epidemiologic studies of the association between past climate variability and human health outcomes.
- ✧ Development of conceptual frameworks for models and model development.

- ✧ Selective or comprehensive health assessments.
- ✧ Workshops/training sessions.

The Human Health Focus Area has appropriately pursued projects in all of these categories over the past 5 years. It has leveraged this breadth of activity by using the assessment efforts to help define research gaps and thus inform the research agenda for the Program. In addition, the Program has used literature reviews to guide the timing and need for assessments.

IV.2 Question 1: Is the Human Health Focus Area Engaged in the “Right” Work?

Are the Program activities that target these focus areas of the highest priority and consistent with resource availability and likelihood of success?

The Program activities in the Human Health Focus Area have appropriately prioritized both public health importance and likelihood of success. This has led to starting with critical problems that have more direct connections between climate factors and health, and thus present more manageable modeling challenges, such as heat stress and weather extremes. The Program delayed more complicated activities that required development of intermediate models, such as studies of vector-borne diseases and air pollution health effects. All of the areas identified by the Program (heat and cold-related illness, waterborne illness, vector-borne illness, and air pollution related health effects) represent important public health problems and merit research activities.

Is the enhanced role of decision support as a guiding principle for program activities consistent with and appropriate to the overall mission of the Program?

The increased focus on decision support is highly consistent with the health protection inherent in the mission of the Program and EPA as a whole. By clearly focusing on decision support, the Program is better able to define its stakeholders and, in effect, clients, as well as facilitating evaluation of how well the stakeholders and clients are being served. In the context of public health protection, there are a great number of different decision makers in a wide variety of agencies (ranging from public health agencies to water and air quality management agencies, etc.) for whom reliable, scientific information on potential stressors to human health related to impending global change is critical. Explicitly using a decision support framework for planning, conducting, and evaluating the work of the Program will assure the relevance of its work products. The recent STAR Request for Applications (RFA) that directly solicits projects to develop public health decision support tools is a critical component of the health focus and should be closely monitored for efficacy of the decision support focus.

Is the emphasis on stakeholder engagement in the planning and prioritization of the research appropriate for meeting Program goals? If so, are the regional or place-based assessments useful test beds for learning how to do stakeholder-relevant assessments and decision support?

To effectively support decision makers, stakeholders must be engaged on a routine basis in the projects, available to give input, and willing to participate in the evaluation of decision support information. Usually stakeholder engagement is appropriate for meeting Program goals. For evaluation of the regional and place-based assessments, the reader is directed to Chapter VIII. The current STAR Program solicitation on decision support systems involving climate change and public health will invite stakeholders to test mechanisms for stakeholder engagement in the development of decision support tools. The Program then should consider appropriate complementary activities to promote more iterative interaction with stakeholders.

What insights or suggestions might the Subcommittee offer with respect to changes in priority or in the structure and content of the work of the Program?

See Section IV.4 Recommendations.

IV.3 Question 2: Does the Human Health Focus Area Conduct Its Research and Assessment Activities “Well”?

Has the Program demonstrated consistent, superior scientific quality in its research and assessment products?

Yes, the quality of the research and assessment products is demonstrated by the high quality of journals publishing this work. Examples include:

- ✧ Hospital admissions for heart disease: the effects of temperature and humidity, published in *Epidemiology* in 2004
- ✧ The association between extreme precipitation and waterborne disease outbreaks in the United States, 1948-1994, published in the *Journal of the American Public Health Association* in 2001.
- ✧ The potential health impacts of climate variability and change for the United States: executive summary of the report of the health sector of the U.S. National Assessment, published in *Environmental Health Perspectives* in 2000.
- ✧ Satellite imagery characterizes local animal reservoir populations of Sin Nombre virus in the southwestern United States, published in the *Proceedings of the National Academy of Sciences* in 2002.

Furthermore, the Program consistently has involved experts from a wide range of fields in the process of defining programmatic context and evaluating scientific merit.

Has the Program effectively integrated intramural and extramural research and assessment activities to attain its goals?

Yes. Because the Agency does not have significant expertise in public health and epidemiology, it has made excellent use of extramural programs, especially the STAR Program, to complete research projects of critical importance to the assessment activities. Much initial work was completed through a cooperative agreement with the Johns Hopkins School of Hygiene and Public Health (now the Bloomberg School of Public Health). Examples of recent STAR RFAs include two to assess heat- and cold-related illnesses, particularly in children, and water-borne diseases.

In the Human Health Focus Area, similar to the Program as a whole, the Agency must balance addressing the wide breadth of potential health effects of climate change with the need to conduct more in-depth analyses of specific problems to create useful tools.

Has the Program used the results of assessments together with stakeholder feedback to identify key research gaps and to update the Program's research agenda?

Yes. The National Assessment, for which the Program had the lead on the health assessment, identified 30 knowledge gaps in 5 categories of research needs within the health area. Many of the knowledge gaps were fundamental uncertainties of the relationships between environmental factors, from temperature and air pollution to infectious agents, and human health outcomes, independent of climate interactions. The regional assessments, although not specifically focused on health, identified increased heat stress and potential impairment of water quality as regional consequences of concern. The Program has begun to address some of these key knowledge gaps that pertain more closely to climate interactions through two mechanisms. The first was a joint interagency Request for Proposals (RFP) that funded a total of 12 projects including 3 related to waterborne diseases. The Program also issued two RFAs in 2005 through the STAR Program, the first on heat- and cold-related morbidity and the second on decision support for public health decision makers. A 2005 commissioned report surveyed the literature on health and climate change since 2001, and concluded that although some progress had been made in understanding the fundamental relations between environmental factors and human health (including heat-related morbidity and air pollution effects), there had not been many new published studies on climate change and human health.

The Program also has used sponsored workshops through professional societies to further elicit feedback. Stakeholder feedback is particularly challenging and complex given the nature of public health decision making and the range of types of issues related to global change that the Program is addressing. Just as the Program has adopted a sequential approach to the development of global change related health information, productive interaction with stakeholders will be advanced by iterative assessment, reflection, and adaptation within the Program itself.

Has the Program provided useful information and tools to stakeholders in a timely manner, and has it communicated its results effectively to its clients and to the broader scientific community?

By publishing study and assessment results in a variety of prominent journals in the environmental health fields, the Program has communicated its results effectively to its clients and the broader scientific community. In addition, program scientists have helped produce monographs in cooperation with other entities, including the World Health Organization and the Electric Power Research Institute, which further disseminate the information produced by the Program.

The National Assessment contained useful information and it was distributed widely. Its executive summary as well as component parts of the assessment were published in *Environmental Health Perspectives*, an appropriately high profile environmental health journal. In addition, the Program has produced two specific tools useful in public health decision support. The Philadelphia Hot Weather Health Watch/Warning System, established in conjunction with an external partner (University of Delaware), provides a model of decision support and public health adaptation that has been adopted by the National Weather Service for use throughout the country. A second useful tool that has been developed by the Program and already implemented is the early warning system for Hantavirus outbreaks in the Four Corners region based on satellite maps. These are extremely valuable tools coming out of a very small program.

Has the Program evolved over time to provide decision support more effectively to its clients?

The Program is in the midst of transition to a clearer focus on decision support in the health arena. Over the past 5 years, key tools for decision support were developed, as mentioned above, but the overarching focus on decision support is receiving greater emphasis at present. It is anticipated that the new RFA on decision support tools will further this evolution and enable more effective support.

Has the Program made significant progress toward each of its LTGs?

The Program has one defined LTG—“*Decision makers in the states and EPA regional and program offices will use scientific information and decision tools from EPA’s research and assessment program to protect human health by adapting to global change*”—with the above-mentioned subcomponents based on different health content areas. The examples listed above of decision support tools that have been developed and the publishing and dissemination of the health sector part of the National Assessment Report represent significant progress towards the LTG of having key decision makers use scientific information and tools developed by the Program. Because of the scientific complexity of assessing health impacts related to global change, some content areas have seen greater progress than others. The Program has taken a sequential approach to developing information in the content areas, such as performing assessments of ambient air impacts after other air pollution modeling activities are completed. This sequential approach is appropriate, even though it means delaying development of tools in certain areas.

Has the Program achieved important environmental outcomes?

The Human Health Focus Area has developed two tools (the Philadelphia Hot Weather Watch/Warning System and the Hantavirus tool) that are contributing to direct health benefits in cities around the country and in the Four Corners area of the Southwest. Although quantification is difficult, it is likely that numerous lives have been saved and serious illnesses avoided by these products. Improved ability to predict infectious diseases and air pollution episodes related to climate variability also will have direct benefits in terms of lives saved and illnesses avoided.

Have the Global Change Research Program and its scientists played leadership roles in the global change research community and in furthering global change science?

Yes. The EPA scientists clearly have played leadership roles in the global change and human health community, as evidenced by their editing books published with international organizations like the World Health Organization.

What insights or suggestions might the Subcommittee offer to improve the effectiveness of the operation of the Program?

See Section IV.4 Recommendations.

IV.4 Recommendations

1. No changes to structure or priorities are offered at this time.
2. Following through on ongoing air quality modeling and health impacts research is important for public health decision making. The Global Change Research Program should continue collaboration with the Office of Air and Radiation (OAR) on integrated modeling efforts, especially for ozone and fine particulates.
3. EPA is playing a critical role in addressing the lack of data and knowledge regarding health effects of climate change. The Agency does not have the resources, nor is it EPA's mission, however, to fully address the data and research needs for public health protection; data resources such as public health surveillance and disease registries are within the purview of the Department of Health and Human Services (HHS) through the Centers for Disease Control and Prevention (CDC). The Program should continue its efforts to engage HHS, particularly now that it is emphasizing decision support and many of the critical health decisions will be made by personnel within HHS.
4. Developing an interface with the world of health decision makers is a complex but critical undertaking. The first step could be the creation of an advisory group that includes representatives from local and state public health agencies, public health and medical professional organizations, key insurers, and major hospitals. EPA could break new ground by establishing an ongoing dialogue with such groups (e.g., via workshops)

to elicit types of decisions, discuss which decisions might be influenced by climate change, and explore new methods for testing the utility of the information and decision tools produced.

5. Recognizing that true impacts of climate change on health in the United States and other developed countries may be secondary effects of either primary climate drivers, like sea level rise (loss of fisheries, population dislocation) and extreme events (secondary infections, population dislocation, loss of employment, etc.) or the secondary effects of adaptation measures (pesticide use, decline in outdoor physical activity, redirection of public resources) is important. Incorporating these complex interactions into primary research and decision support is far more difficult, but offers potentially higher payoffs in terms of producing information of major significance for public policy decisions. The Subcommittee encourages EPA to pursue assessments of secondary effects and the specific needs of public health decision makers with regards to these secondary effects.

V. ECOSYSTEMS FOCUS AREA

V.1 Ecosystems Focus Area Overview

The Ecosystems Focus Area conducts analytical research and evaluations of the effects of global change on aquatic ecosystems (freshwater and coastal) and their services. Aquatic ecosystems provide key services to all of society but are vulnerable to changes in climate, land use, and other drivers of global change. Global changes are addressed in the context of other stressors with the goal of improving society's ability to respond and adapt to global changes, including climate and its variability, land use, and UV radiation. This focus area engages researchers and stakeholders in analysis, evaluation, and interpretation of information from multiple disciplines and multiple locations to formulate assessment endpoints that will inform decisions important to society. Although focused on aquatic ecosystems (an interagency decision largely based on EPA's strong background in aquatic ecosystem research and regulation such as the Clean Water Act [CWA]), relevant terrestrial ecosystems are included in the evaluations as necessary to more fully understand the impacts of global change on aquatic ecosystem functioning and services (e.g., in a watershed context).

The Ecosystems Focus Area reflects EPA's mission to protect the environment. It leverages the Agency's strengths in aquatic ecosystem research and ecological risk assessment, carried out in other EPA organizations, to advance adaptations to global changes. It also addresses EPA's need to implement regulations such as the CWA and the Clean Air Act. Each ecosystem evaluation supports multiple EPA strategic goals, including Goal 4: Healthy Communities and Ecosystems, and the mission to safeguard the natural environment and conserve ecosystems for diversity, sustainability, and economic productivity. Analyses support EPA's Office of Water in fulfilling its CWA responsibilities to restore and maintain the chemical, physical, and biological integrity of the nation's waters. The LTG of the Ecosystems Focus Area is *"that decision makers in the states and EPA regional and program offices will use scientific information and decision tools from EPA's research and assessment program to protect aquatic ecosystems by adapting to global change."*

This focus area also addresses the needs for research and analysis articulated in the evolving national and international global change programs and related environmental analyses. Previous national and international water sector reports document the importance placed by academic and stakeholder communities on aquatic ecosystems. The Global Change Research Program is engaged in addressing the mandates of the President's Ocean Action Plan. The current, multi-agency CCSP recognizes the need for ecosystems research as a high priority in its Strategic Plan, which was affirmed by the 2004 National Academies review of the plan. The work of the Ecosystems Focus Area is consistent with a major international assessment of the vulnerability of ecosystem services in Europe to global change.

With an immensely broad potential mandate and limited resources, the Ecosystems Focus Area appears to be doing appropriate work and doing it well. This Subcommittee recognizes and affirms that this focus area targets a topic of high priority consistent with the CCSP's decision to divide responsibilities across agencies and to assign to EPA the role of assessment for decision support. The Subcommittee saw clear evidence that decision support is foremost in planning the focus area. The Ecosystems Focus Area has solicited and incorporated stakeholder views and participation with the result that there are far more opportunities for useful stakeholder involvement than the Program's funding can accommodate. Stakeholder involvement often has involved leveraging multiple resources for common gain. The focus area is well conceptualized so that regional or place-based analyses fit well with more generic (but usually site-specific also) projects to develop adaptation information and tools. Nonetheless, the rationale for having both site-specific ecosystems and place-based administrative units in the Program is elusive. Considering the wide diversity of aquatic ecosystems in the United States, the multitude of local stressors (only some of which are changing globally), competing stakeholders, and the historical context of research and societal attention, the focus area has chosen appropriate subjects and locations for its activities.

The Ecosystems Focus Area seems to have conducted its selected topics well. There is an impressive consolidated reference list of peer-reviewed publications (output metric), extramural and intramural projects seem well integrated, stakeholders have been involved, decision support has been increasingly stressed, and there has been significant progress toward meeting established goals. The tracking of EPA-derived results and information to actual decisions and environmental outcomes is less clear, although laudable efforts toward this end have been initiated.

Through this program review, the Subcommittee identified several recommendations specific to the Ecosystems Focus Area, which are listed in the next two sections under the general headings of doing the "right work," and doing it "well."

V.2 Question 1: Is the Ecosystems Focus Area Engaged in the "Right Work"?

Are the Program activities that target these focus areas of the highest priority, consistent with resource availability and likelihood of success?

The Program activities chosen to target the Ecosystems Focus Area appear to be high priority consistent with resource availability and likelihood of success. A plethora of possible activities in the area of aquatic ecosystems presents a dilemma for the Program. Every definable ecosystem in the United States faces some degree of alteration from stressors associated with "global change" especially climate change. For example, coastal ecosystems face both long-term trends of sea level rise and the prospect of increased incidence of storms that rapidly alter the landscape and its aquatic ecosystems, often degrading the ecosystem services they provide (including physical protection from such storms by wetlands). Inland aquatic ecosystems face altered patterns of both base water availability for stream flows and flood or drought events. Both inland and coastal aquatic ecosystems face concurrent increases in human developments. Unique

ecosystems such as coral reefs attract attention as they show increased signs of damage and long-term stress. Certain changes in aquatic ecosystems appear to be related to increased UV radiation, concurrent with the well-publicized rise in incidence of skin cancers in humans. The goods and services provided by aquatic environments to human society are so important and diverse that stakeholders abound, often with quite specific needs (e.g., navigation, hydropower, water supply, waste transport and assimilation, fisheries, wildlife, recreation). With a small level of resources compared to the strategic mandate, the Ecosystems Focus Area has necessarily selected a limited number of representative activities, even considering its narrowed aquatic scope. The Subcommittee believes the selections have been appropriate, but certainly not comprehensive.

An early focus on UV radiation effects in aquatic systems and species appears to have successfully run its cycle of risk analysis, funding, monitoring, reports, and publication of high-quality papers in peer-reviewed journals. The UV issue is important nationwide and was a good one for EPA to select as an early target.

The Sacramento/San Joaquin River basin in California is an appropriate watershed for intense activity. Water supplies are highly subscribed, the area is growing in human population and water use, Chinook salmon are a valued yet threatened resource, and cold water temperatures and adequate flows for migrations are essential habitat features for salmon but greatly affected by both land use and climatic changes. There already are federal and state efforts (and strong stakeholder support) to understand and better manage the San Francisco Bay/Sacramento/San Joaquin watershed (e.g., CALFED Bay-Delta Program, a consortium of state and federal programs focused on the welfare of Bay and watershed ecosystems) with which the EPA efforts can be leveraged. The Yakima River basin in Washington State is likewise a useful target watershed.

Similarly, the management of South Florida wetland watersheds constituting the greater Everglades has been a good choice for EPA's activity. Everglades restoration is a national and regional priority and there are other efforts in that region with which EPA's Global Change Research Program has been aligned. There also are discrete entities making management decisions to which EPA's information can be directed (e.g., South Florida Management District).

The Subcommittee initially questioned whether attention to coral reefs was the "right work" considering the diversity of nationwide options. Coral reefs are hardly typical of most of the continental United States (or even coastal zones, for that matter), and their problems seemed very specialized. On further reflection, however, we realized that this ecosystem offered a discrete case for which important impacts, adaptation, and outcomes could be evaluated with high likelihood of identifying outcomes and impacts on decision making. Coral reefs occur in U.S. waters, e.g., Florida, Caribbean, American Samoa, and Hawaii. One hypothesis for their ecosystem-wide ills due to bleaching, disease, and tissue loss has been the interaction among UV exposure, high water temperatures, and poor water quality (all within EPA's expertise and mandate). Research and analysis in Florida and American Samoa in collaboration with others are leading to coral biocriteria, adaptive management and monitoring programs, and establishment of Marine Protected Areas.

The Subcommittee strongly concurs with the initial forays into the topic of nonlinear dynamics in ecosystem responses to climatic change (thresholds and episodic events), as evidenced by the EPA-supported papers. More attention could be given to these scenarios.

Future plans reflect appropriate directions, although a pragmatic view will be necessary for the ultimate choices. Invasive species in aquatic systems clearly are a global change that present information needs and decision opportunities, and have broad stakeholder support for prevention and adaptation. EPA's recent high reliance on biological water quality indicators for its CWA responsibilities makes it imperative that the implications of climate change on these indicators be understood and accommodated. How humans use land certainly affects aquatic ecosystems and is under study by others, but accounting for interactions with aspects of global change is challenging. Although influencing decisions with good information is the ultimate programmatic goal, the reviewers were cautious about expanding the Program into decision science.

There is a great deal of overlap between the Ecosystems Focus Area and the Water Quality Focus Area, particularly because of the Ecosystems Focus Area's focus on aquatic environments. Although a distinction is readily made for topics such as wastewater treatment and drinking water (Water Quality Focus Area), the distinction is less clear when water quality is taken to include topics such as riparian buffer strategies, watershed management, and nonpoint pollution, all of which are best viewed in an aquatic ecosystem context. Subcommittee members reviewing both focus areas noted this strong linkage and a fairly artificial distinction being made by the Program. A strong functional integration between water quality and ecosystems in the Global Change Research Program seems essential, even if the topics are viewed distinct organizationally.

There also is an inherent overlap between the "Place-Based" Focus Area and the Ecosystems Focus Area. Most of the Ecosystems Focus Area projects are conducted in a "place" such as the Sacramento/San Joaquin River basin watershed or South Florida. Even generic topics such as coral reefs or UV radiation have selected places for study. It was not clear how the Program distinguishes between overtly "place-based" and otherwise site-specific topics in other focus areas.

This said, it is not clear what decision criteria are used to select topical areas for new ecosystem initiatives. The recent STAR solicitation for the Global Change Research Program Ecosystems Focus Area sought proposals on land-water interactions. Although the Subcommittee concurred with this selection, it would be useful to know more about the basis for the decision and what alternative choices were considered.

Is the enhanced role of decision support as a guiding principle for Program activities consistent with and appropriate to the overall mission of the Program? If so, do the Program's planned activities support an increased emphasis on decision support?

Decision support as a guiding principle for Program activities is well demonstrated in the Ecosystems Focus Area. In concert with the Office of Management and Budget's Program Assessment Rating Tool (PART) for evaluating federal activities and the National Academies'

analysis of appropriate metrics for the CCSP, the Ecosystems Focus Area has selected studies that can lead to discrete decisions and resource management actions, as noted above. From the broad array of potential topics, EPA has selected activities that are explicitly tied to management entities and their potential actions to which EPA-derived information can be applied.

Is the emphasis on stakeholder engagement in the planning and prioritization of the research appropriate for meeting Program goals?

Stakeholder engagement is a mixed blessing for the Ecosystems Focus Area. Involvement of stakeholders is essential for the Program's mission, yet there can be too much of a good thing. There are so many aquatic ecosystem services affected by global changes and so many needs of stakeholders nationwide that selecting among them has been a challenge for the Program. When the Program was initiated, there was a need to solicit stakeholder support; as the Program matured, the problem became an overabundance of needs, which forced the Program to make hard choices among needs and potential participants. The Subcommittee members gained the impression from EPA staff that stakeholder involvement in the particular subject areas chosen (which also are locale specific) has been useful as test beds for learning how to do stakeholder-relevant assessments and decision support.

What insights or suggestions might the Subcommittee offer with respect to changes in priority or in the structure and content of the work of the Program?

See Section V.4 Recommendations.

V.3 Question 2: Does the Ecosystems Focus Area Conduct Its Research and Assessment Activities “Well”?

Has the Program demonstrated consistent, superior scientific quality in its research and assessment products?

Although it is difficult to thoroughly evaluate the scientific quality of work conducted in such a broad topic as ecosystems, the Subcommittee nonetheless concludes that the quality is high based on several standard metrics. The Ecosystems Focus Area has a long list of peer-reviewed publications in high-quality journals, book chapters, and reports (“output metric” per the NRC). Subcommittee members were familiar with some specific publications on the consolidated list provided by EPA, and considered the papers to be consistently of high scientific merit (e.g., numerous papers on climate effects on fish habitat in Midwest streams and lakes in collaboration with EPA's Duluth, Minnesota staff). Collaboration with the EPA STAR Program has ensured high quality contractors and proposals for use in the Program's analyses.

Has the Program effectively integrated intramural and extramural research and assessment activities to attain its goals?

The programmatic documents reviewed by the Subcommittee and the presentations heard by the members clearly lay out a strategy of using both EPA staff and outside personnel and functions to accomplish program objectives. The STAR Program provides solicitations and funding for extramural activities that are integral to the in-house evaluations. The consolidated reference list provided to the Subcommittee clearly reflects the activities of both EPA laboratories and external contractors/grantees. Papers from both inside and outside EPA are included, as well as many individual papers co-authored by both EPA staff and contractors/grantees.

Has the Program used the results of assessments together with stakeholder feedback to identify key research gaps and to update the Program's research agenda?

As indicated earlier, both a blessing and curse of the Ecosystems Focus Area is the breadth of input provided by stakeholders and the previous evaluations of potential ecosystem responses to global change. To be fully responsive to these inputs, the ecosystems research agenda could be extended well into the century and require far more resources than would ever be available. The Program managers have distilled this input into a coherent and valuable program, despite the limited resources to make it truly comprehensive.

Has the Program provided useful information and tools to stakeholders in a timely manner, and has it communicated its results effectively to its clients and to the broader scientific community?

In many respects, the more complex a research and analysis project (and the greater the number of stakeholders and collaborators), the less clearly one sees items of practical use linked to EPA's Program. The coral project is especially useful in this regard: it has straightforward information about coral damages and hypotheses for these damage, has a limited geographic extent, a defined stakeholder base of resource managers, a limited set of management options, and fairly clear mandates for actions. The Ecosystems Focus Area of the Program has clearly responded to needs, sponsored research (with other units of EPA), analyzed the available information, and clarified management options leading to biocriteria and management decisions such as creation of Marine Protected Areas ("outcome metrics" per the NRC). The outcomes were less easy to see in other areas, despite abundant output (e.g., publications). The Subcommittee was told, however, that EPA's Sacramento/San Joaquin water resources studies have led to an update of the California Department of Water Resources Water Plan, watershed rehabilitation and management planning by several public and private management entities, and contributions to a report to the Governor of California on the state's water resources. The Program staff has identified expected outcomes for all current and future projects.

Has the Program evolved over time to provide decision support more effectively to its clients?

The Ecosystems Focus Area has demonstrably evolved more toward decision support. Early focus on outputs, particularly scientific publications, has been extended to greater sensitivity to stakeholders and providing them with the tools and information needed for their responsibilities. This evolution is evidenced in the programmatic documents reviewed and the presentations heard by the Subcommittee members. A LTG of the focus area reflects decision support: *“decision makers in the states and EPA regional and program offices will use scientific information and decision tools from EPA’s research and assessment program to protect aquatic ecosystems by adapting to global change.”* Because EPA input becomes diffused with other considerations of public policy and implementation, it is a challenge to clearly identify the success of this evolution, however. It would be useful to have a feedback system whereby, by questionnaire or other means, the utility of this focus area’s decision support efforts can be evaluated.

Has the Program made significant progress toward each of its LTGs?

There appears to be significant progress toward meeting the LTG quoted above, at least in terms of output metrics. A table of Performance Goals and Measures provided to the Subcommittee tabulates Annual Performance Goals (APGs) and Annual Performance Measures (APMs). It appears that deadlines for task completions have been met, and relevant products for the CCSP have been produced. The consolidated reference list of publications reflects research and analyses toward these goals and measures. A listing of accomplishments of the Ecosystems Focus Area indicates where the products (outputs) have been (or are being) directed to relevant decision makers. This is especially evident in the watershed assessments, where there are defined organizations with responsibilities for watershed management (e.g., the South Florida Water Management District for the Everglades). The coral reef work has clearly led to products intended for decision makers, including the reference book, “A Reef Manager’s Guide to Coral Bleaching” and preparations for an International Marine Protected Areas Congress in October 2005. There has been an explicit effort to engage local resource managers in applying EPA’s assessment frameworks. A competitive solicitation provided funds to improve local capacity to manage risks of climate change, with funds going to the American River Watershed Institute (California), University of Alaska–Fairbanks, World Wildlife Fund for American Samoa coral reefs, and the Goleta Water District (California). As noted above, it is difficult to see the ultimate effects on environmental decisions without some accounting method.

Has the Program achieved important environmental outcomes?

As previously mentioned, it is difficult to pinpoint either specific public policy decisions or environmental outcomes that were derived specifically from the EPA Program. By integrating its efforts with those of stakeholders and other agencies/organizations, EPA’s research is favorably leveraged but the specific Agency contribution also is diffused. On the whole, this integration is likely beneficial to the environmental outcome, but accountability suffers. It likely rests on the focus area leaders to consciously track decision making in cases where EPA has contributed funding or information to identify outcomes that have direct EPA connections. The

Subcommittee was gratified that such a monitoring effort has been initiated. The Ecosystems and Decision Support staffs have begun a new initiative to identify and understand climate-related decisions. These initial efforts have included examination of state-level decisions and management actions to control invasive species and the decision processes used by states, counties, and municipalities to protect watersheds.

Have the Global Change Research Program and its scientists played leadership roles in the global change research community and in furthering global change science?

The Program's more senior staff in the Ecosystems Focus Area has shown important leadership in the global change community. The leader of the Ecosystems Focus Area has participated in scientific discussions at scientific society meetings and the Program has provided EPA support for technical gatherings and publications. The Program has effectively bridged the gap between scientific/technical communities and more public stakeholders in its study areas. The reorientation of missions under the interagency CCSP has somewhat complicated the leadership roles, however. The Subcommittee concludes that an approach focused on quiet implementation of clearly needed research and analysis of technical issues is as appropriate as high-profile leadership at this time.

What insights or suggestions might the Subcommittee offer to improve the effectiveness of the operation of the Program?

See Section V.4 Recommendations.

V.4 Recommendations

- 1. The Ecosystems Focus Area will be most effective nationally when activities are selected that are truly representative of the needs of U.S. aquatic ecosystems for adaptation decisions for global change.** The Program might usefully ask: "What will most Americans need to know to wisely accommodate the effects of various aspects of global change on aquatic ecosystem structure, function, and services?" Coral reef analyses, for example, may have usefully yielded rapid success for the Program, yet met the needs of a very select few. There is little transferability to the needs of Midwesterners or the East Coast metropolitan strip, for example. On the other hand, the water use and river habitat issues of the Sacramento/San Joaquin River basin are likely representative of much of the arid and rapidly developing West, and should have high transferability (assuming someone actively transfers the knowledge).
- 2. The Program could usefully address nonsteady-state (nonlinear-response) issues such as thresholds and episode-driven changes.** The existence and appearance of thresholds in ecosystem structure and function can have dramatic implications for ecosystem services. Thresholds occur when small incremental changes suddenly cause phase changes in ecosystems, such as when seasonal freeze-thaw cycles in a gradually warming environment no longer support permanent ice cover or permafrost. Episodes

(infrequent but strong habitat altering events such as hurricanes or floods) can be more effective in restructuring ecosystems than the steady-state environment or gradual environmental changes. Change in the frequency and severity of such episodes (as has been suggested for hurricanes and inland flood-drought cycles) may be of special consequence for ecosystem structure, function, and services.

3. **The Program could beneficially integrate the Water Quality Focus Area and the Ecosystems Focus Area to a greater extent.** Although the Subcommittee saw no obvious conflicts, it seemed that the two focus areas have been drawing closer together in the topics being covered, such as watersheds and nonpoint source pollution.
4. **The Program could consider further clarifying the distinction (or alternatively, the integration) between the Place-Based Focus Area and the Ecosystems Focus Area.** Most ecosystems studies and analyses are necessarily based in places, yet may not fully cover distinctive regional attributes in their selection of site-specific topics (which is the domain of the Place-Based Focus Area).
5. **An ongoing advisory committee representing ecosystem-related organizations may be useful for obtaining both broad-based stakeholder engagement and extended outreach to potential users (informal, non-FACA).** Scientific societies (e.g., American Fisheries Society, Ecological Society of America, North American Benthological Society), implementation agencies (e.g., Army Corps of Engineers, Bureau of Reclamation, regional water resource management agencies), advocacy groups (e.g., Sierra Club, Environmental Defense, Natural Resources Defense Council), and trade organizations (e.g., National Hydropower Association) could be candidates for a revolving advisory structure.

The initiative to identify and understand climate-related decisions in the Ecosystems Focus Area will help EPA's Global Change Research Program most strongly when it monitors and evaluates the specific contributions from EPA-sponsored projects. With the Ecosystems Focus Area's LTG of affecting environmental decisions, it seems critical to be able to document the Agency's contributions for use in internal evaluations of Program effectiveness and for OMB assessments of the performance of federal programs (PART). It may be useful to initiate stakeholder surveys to provide feedback on EPA's contributions to complex decision making involving numerous entities (e.g., watershed management). The excellent papers listed in the consolidated reference list might be tracked for number and place of citations, although this would cover mostly the academic uses.

The ongoing advisory committee recommended above (Question 1, Recommendation 5) would be a valuable tool for feedback on quality and usefulness of the Program's output as well as on whether it is doing the "right" research. It also would open avenues for technical leadership by EPA staff working with the organizations represented on the committee.

VI. WATER QUALITY FOCUS AREA

VI.1 Water Quality Focus Area Overview

Water is a critical area of research for EPA's Global Change Research Program. It is of importance to every sector and place in the nation. Water also is inextricably linked to the other Program focus areas (i.e., ecosystems, human health, air, and place-based or regional). Indeed, as EPA Administrator Stephen Johnson noted recently: "Water, over the next decade and further, will be the environmental issue that we as a nation, and frankly, as a world, will be facing."⁵

Water resources may be critically impacted by climate change and variability. In all areas of the United States water systems are vulnerable to impacts affecting both water quality and quantity. Impacts to critical infrastructure, including water and wastewater systems, and to "ecosystem services" provided by watersheds and wetlands, are of concern. EPA's statutory mandate to implement various laws, including the CWA and the Safe Drinking Water Act, underpin the Program's appropriate focus on water quality. As noted in the Program overview, the objective of the CWA is "to restore and maintain the chemical, physical, and biological integrity of the nation's waters."⁶ The *restoration* dimension is especially challenging in the face of both climate change and other stressors. EPA has made important progress, and further integration of its efforts will be required to meet the mandate.

The Program structured the Water Focus Area specifically "to look at the effectiveness of drinking water and wastewater treatment facilities as source and receiving water quality changes" and to investigate "... alternative approaches to accomplishing the goals of water treatment."⁷ Meeting these legal mandates and policy priorities will require additional research (and the resources to support it) related to climate impacts as discussed below, and expansion beyond the current narrow focus on water quality will be necessary.

EPA, unlike any other federal agency, has a mandate and responsibility to address water issues involving *quality* for human health and ecosystems across the United States and its trust territories. The *quantities* of water sufficient to support both ecosystem functions and people are inextricably linked to the quality issue. This is a formidable task. Other federal agencies, such as the U.S. Army Corps of Engineers, U.S. Geological Survey, and U.S. Bureau of Reclamation, are key players and partners addressing parts of these mandates in specific places. EPA, however, is the only agency with responsibilities spanning this broad range of issues. Potential impacts of climate change and variability on water resources, including timing and patterns of precipitation and runoff, affect both water quality and quantity. As such, the Program research

⁵ EPA Administrator Stephen L. Johnson, quoted in: Neuman J. "Water Safety Tops EPA Chief's List," *Los Angeles Times*, June 9, 2005, p. A-10.

⁶ EPA Global Change Research Program, "Program Overview," 2005 (August), p. 13.

⁷ EPA Global Change Research Program, "Water Quality Focus Area Overview," 2005 (August), p. 1.

should seek to provide additional critically important science-based information to inform decisions on both issues.

Water issues also are linked in important ways to the other Program focus areas—human health, ecosystems, air, and issues involved in understanding potential impacts to regions. EPA’s Global Change Research Program recognizes that the potential impacts of global change must be examined in the context of other stresses on society, the economy, and ecosystems. Engagement with a broad range of stakeholders, and an orientation to scientific research that can provide a sound basis upon which to inform decision makers, is a notable accomplishment of the Program and the Water Focus Area in particular. The evolving decision-support focus of Program is needed and appropriate.

VI.2 Question 1: Is the Water Quality Focus Area Engaged in the “Right” Work?

In general, the Program is engaged in the “right” work, though with too few resources. In the case of the Water Quality Focus Area, the impacts of climate change and variability are potentially very serious. The key points presented below are that the water area needs to be: (1) expanded beyond the narrow focus on quality, (2) integrated more fully with the other focus areas, and (3) funded at a more realistic level.

Are the Program activities that target these focus areas of the highest priority and consistent with resource availability and likelihood of success?

Water quality has been identified as the priority area of research for the Program’s water focus. This is unquestionably the “right” work to be undertaking as a key priority, but the task requires consideration of an expanded scope of work (and a considerable increase in resources) in the context of challenges regarding the potential impacts of climate change and variability on water resources.

Given the importance of water quality for both human health and ecosystem functions, the choice of priorities is appropriate. The focus on quality, however, appears too narrow to take full advantage of EPA’s opportunities, expertise, and legal mandates. As noted in the Program Overview: “To achieve this objective [*restore and maintain the chemical, physical, and biological integrity of the nation’s waters*, as called for in the CWA], watersheds and their aquatic ecosystems are being restored and protected to improve human health, enhance water quality, reduce flooding, and provide habitat for wildlife. The aim of the *Safe Drinking Water Act* and its amendments is to protect public health by regulating the nation’s public drinking water supply and by protecting that supply’s sources.”⁸ This important mandate calls for a more encompassing approach to water.

The priority of current work addressing areas such as potential impacts on drinking water infrastructure, combined sewer systems, publicly owned wastewater treatment works, and

⁸ EPA Climate Change Research Program, “Program Overview,” 2005 (August), p. 13.

nonpoint sources of pollution and TMDL (total maximum daily load) management options is highly appropriate and well targeted. In particular, the focus on “low impact development” and prevention of nonpoint source pollution, building on the work of EPA’s Office of Wetlands, Oceans and Watersheds is a promising direction.

Is the enhanced role of decision support as a guiding principle for Program activities consistent with and appropriate to the overall mission of the Program?

Decision support tools and methods are critically needed to address the challenges of climate change and variability to water systems. The Program is making important contributions in this area. Decisions involving large capital investments, long-term infrastructure development, and sometimes irreversible impacts require science-based information. Program research is focused on providing information that can be used by decision-makers in determining opportunities to invest public and private resources more effectively in the face of global change. This evolving decision-support function is needed and holds the potential to provide improved cost-effectiveness and targeting of investments of scarce resources. Of particular value is research and the development of tools and methods that assist decision makers to secure *multiple benefits* through well-designed policy strategies and investments. This will in turn require greater integration among the focus areas.

Is the emphasis on stakeholder engagement in the planning and prioritization of the research appropriate for meeting Program goals? If so, are the regional or place-based assessments useful test beds for learning how to do stakeholder-relevant assessments and decision support?

In the area of water management (both quality and quantity), effective stakeholder engagement is key to the identification of the right research questions and priorities and, in many cases, to the effective conduct of the research. Stakeholders often have essential information for the research process. They interpret information to make management decisions, and they set priorities based on a perception of past, present, and future hydrologic and other conditions. As such, it is critical that researchers engage with stakeholders. (Note that this does *not* imply that stakeholders should determine the research questions. Rather, it means that researchers should be informed by the engagement.) In turn, the Global Change Research Program notes that: “We use the results of these studies to investigate adaptation options to improve society’s ability to effectively respond to the risks and opportunities presented by global change and to increase the resilience of systems to change.”⁹ It elaborates: “The GCRP is *outcome oriented*. The ultimate goal of the GCRP is to inform policy decisions in a timely fashion. The Program provides the best available scientific and socioeconomic information to increase the likelihood that improvements in human health and the environment will occur.”¹⁰ This seems a highly appropriate approach for the Program.

Many of the specific issues addressed are necessarily place-based, and research often must examine a specific watershed or place, such as the Everglades or the Central Valley of

⁹ EPA Global Change Research Program, “Program Overview,” 2005 (August), p. 1.

¹⁰ EPA Global Change Research Program, “Program Overview,” 2005 (August), p. 3.

California, for example.¹¹ To this extent, place-based or regional assessments are appropriate and needed. The methods and lessons developed, e.g., the BASINS (Better Assessment Science Integrating Point and Non-point Sources) model applications and the GIS-based calculator developed by the American River Watershed Institute, are important and valuable contributions. In fact, in both of these examples, the stakeholder involvement was a key component of both the research and the value of the effort.

A new approach and strategy to involvement of stakeholders within regions, and in specific places, would seem to be worth exploring. Building on the experience gained by the Program, and in light of the significant developments in research, tools, and public understanding regarding the implications of climate change and variability, there may be new approaches to regional and place-based research activities that will yield greater benefits than past models.

VI.3 Question 2: Does the Water Quality Focus Area Conduct Its Research and Assessment Activities “Well”?

The Program is well designed and the researchers have produced important and useful results and products. EPA researchers and those funded through EPA’s grant programs are producing valuable and important work.

Has the Program demonstrated consistent, superior scientific quality in its research and assessment products?

The research and assessment products examined by the Subcommittee appear to be of high quality. The constraints of time and resources precluded a thorough examination of all of the products sufficient to answer this question definitively. The processes followed appear to be solid and appropriate, and the work is good.

Has the Program effectively integrated intramural and extramural research and assessment activities to attain its goals?

EPA has considerable strengths in its own experts and laboratories, as well as within its network of outside researchers, with regard to water quality. The Program has made good use of outside experts and researchers to complement this institutional expertise to address issues raised by global change. The research work examined represents a good balance of internal and external effort and results. For example, the BASINS model effort taps both internal work and extramural research by competent entities in the specific location (in this case the Central Valley of California) to develop highly useful work.

¹¹ Both of these examples are included in the Ecosystems Focus Area.

Has the Program used the results of assessments together with stakeholder feedback to identify key research gaps and to update the Program’s research agenda?

The current emphasis in the Water Quality Focus Area on capital-intensive, long-term investments to restore and maintain water quality within the context of climate change and variability indicates the use of valuable input from stakeholders who face these difficult decisions. The emphasis on water quality issues related to impacts of climate change on stormwater runoff (e.g., the focus on combined sewer systems and combined sewer overflows [CSOs] and publicly owned treatment works [POTWs]) is well placed.

Has the Program provided useful information and tools to stakeholders in a timely manner, and has it communicated its results effectively to its clients and to the broader scientific community?

The American River Watershed Institute model and calculator is a good example of a tool of considerable potential value to stakeholders. Though listed under the Ecosystems Focus Area, it actually is a tool to better understand impacts of climate change to water supply and quality, as well as to ecosystems. Investigating potential impacts under differing climate change scenarios is facilitated by the tool. It is timely, powerful, and understandable, and it builds continuously on our understanding of climate science in that it is designed to allow input of the latest understanding of climate change to understand impacts.

Another tool of a similar nature is the BASINS model. Again, this is a valuable tool for translating scientific information in ways that stakeholders can use to explore options and make real-world management decisions, and it can accommodate evolving understandings of systems based on new scientific research and information.

Has the Program evolved over time to provide decision support more effectively to its clients?

Research within the Water Quality Focus Area appears to have evolved from a focus on questions relating to issues such as sea level rise and contaminant levels in drinking water related to weather extremes to questions of water management that should be of use to various “clients” including water managers. The focus on high-cost, long-term investment decisions faced by communities and water managers is a positive one. As noted, increased integration of both focus areas and water quality and quantity issues through multiple-benefit strategies would be useful. The focus on POTWs and CSOs is directly in line with “client” needs.

The areas of future research identified, such as riparian buffers and “green” infrastructure, are promising. Research is needed on the effectiveness of these approaches to meet water quality objectives as well as improved water recharge functions. The reduction of nonpoint pollution to estuaries and other water bodies also is a critically important concern to “clients” in all sectors, and the research, tools, and methods developed by the Program are valuable inputs to meet decision support needs.

Has the Program made significant progress toward each of its LTGs?

The LTG set forth for the Water Quality Focus Area is: “By 2009, decision makers in the states and EPA regional and program offices will use scientific information and decision tools from EPA’s research and assessment program to protect water quality by adapting to global change.”¹² The Program has designed a reasonable approach to address this goal, and it appears to be making solid progress toward it. A broader goal encompassing the links between water quality and quantity, and between water systems and the other focus areas, would be superior to this narrow goal. It also is worth noting that to protect water quality (the narrower goal), it will be necessary to restore watershed and ecosystem functions in many areas, especially with anticipated changes in precipitation patterns and other factors due to climate change.

Has the Program achieved important environmental outcomes?

In the Water Quality Focus Area, the measurable environmental outcome would logically be water quality. The nature of the research on *future* impacts due to climate change and variability does not provide an immediate measurable environmental outcome (because the projected impacts are in the future). One way to assess future outcomes is to consider the approaches being discussed with regard to the focus area. As noted in the Water Quality Focus Area Overview, “New work on nonpoint source pollution management and alternatives to infrastructure-intensive treatment may enable communities to address water quality problems without making such large investments.”¹³ This kind of approach is gaining currency and, if adopted by stakeholders, could yield both important environmental outcomes and significant economic benefits. To the extent that decision makers and stakeholders are factoring in changes in snow regimes (rain versus snow at different elevations) for water supply and quality concerns, and the sea level implications for salt water intrusion to surface water and groundwater supplies, the Program’s work appears to be providing environmental and economic benefits and outcomes.

Have the Global Change Research Program and its scientists played leadership roles in the global change research community and in furthering global change science?

The Program and its scientists have been engaged in the key research programs and have played important leadership roles. It is worth noting that EPA experts in other parts of the Agency also have provided leadership in key areas such as improved practices (e.g., low impact development) that can provide important economic and environmental benefits directly related to the impacts of climate change and variability. Program scientists deserve credit for leadership not only in the global change research community, but also in the realms of intra-Agency, interagency, and stakeholder processes where science is translated into solutions.

¹² EPA Global Change Research Program, “Water Quality Focus Area Overview,” 2005 (August), p. 3.

¹³ EPA Global Change Research Program, “Water Quality Focus Area Overview,” 2005 (August), p. 2.

VI.4 Recommendations

What insights or suggestions might the Subcommittee offer with respect to changes in priority or in the structure and content of the work of the Program?

The Subcommittee offers the following recommendations:

1. **The Water Quality Focus Area needs to be explicitly integrated with the other focus areas, and it needs to encompass water quantity issues as they relate to water quality.** For instance, a number of the examples listed in the Ecosystems Focus Area are equally, if not more so, water issues involving both timing and quantities of supply as well as water quality issues.
2. **Integrate water *quality* with key aspects of related water *quantity*.** The Focus Area Overview notes that within the Global Change Research Program, the Water Quality Focus Area examines water quality and human uses; water quality as it affects the natural environment is addressed by the Ecosystems Focus Area. The Subcommittee recognizes that water quality is inextricably linked to water quantity, so information about water quantity (e.g., streamflow) from other federal agencies was used in the conduct of the water quality assessments.¹⁴
3. **The focus on water *quality* is appropriate, but it should be expanded to include related water quantity issues.** A broader approach would:
 - a. Allow improved accounting of multiple benefits through a more integrated and comprehensive systems approach to water management.
 - b. Take greater advantage of end-use efficiency opportunities, water recharge and reuse opportunities, and ecosystem and system design benefits that will be increasingly valuable under conditions of climate change and variability.
 - c. More fully incorporate excellent work taking place in other parts of EPA and other agencies that provide both water supply and quality benefits together.

The Program should seek to make greater use of internal expertise and the contributions of its stakeholder networks to tackle some of these water issues. (Leadership at the Administrator level is probably needed for this. The Administrator's public statements along these lines are very encouraging.)

4. **Increased attention should be directed to the identification and quantification of *multiple-benefits* strategies.**
 - a. Support the development and application of multiple-benefits analysis tools and methodologies.
 - b. Develop improved accounting methods to assess benefits (economic and environmental) derived from improved water management strategies in the context of potential climate change and variability.

¹⁴ EPA Global Change Research Program, "Water Quality Focus Area Overview," 2005 (August), p. 1.

What insights or suggestions might the Subcommittee offer to improve the effectiveness of the operation of the Program?

The Subcommittee offers the following recommendations:

1. **Develop a broader focus on water systems (beyond quality)** to include research strategies addressing climate change and variability and opportunities to build resilience that link:
 - a. Natural “infrastructure” options (e.g., involving watersheds, wetlands, riparian areas) that provide valuable services for water quality and quantity with drinking water quality, ecosystem water quality (e.g., temperature, “loadings”, flows), stormwater management and flood control, and wastewater processes.
 - b. Human health impacts and issues such as flood management and water quality.
 - c. Water supply reliability (for both human and ecosystem needs).
2. **Integrate the Water Quality Focus Area with other focus areas in a more deliberate way.** (Water issues are very much a part of the ecosystems focus, and they are important to human health, air, and regions.) A more explicit linking of the water issues would potentially allow for increased coordination and a potential increase in benefits from the research investments.
3. **Establish an advisory committee to increase communication with and between water managers, researchers, and policy-makers and implementers** regarding research priorities, results, and practical considerations for policy implementation.
4. **Establish a much more robust budget commitment to water.** (The Water Quality Focus Area is budgeted at a tiny fraction of the other areas—\$0.5 million/year versus \$3.6-\$7.8 million/year for the other areas.)¹⁵ Given the critical importance of water issues, this seems a serious under-investment.
5. **The ecosystem services concept is a useful one and should be used as a research and practical policy objective.**
 - a. Focus on the development of tools to better establish the quantification of benefits of integrated strategies.

¹⁵ EPA Global Change Research Program, “Program Overview,” 2005 (August), p. 12.

VII. AIR QUALITY FOCUS AREA

VII.1 Air Quality Focus Area Overview

EPA supports the statutory mandate to monitor, assess, and improve air quality within the United States to protect both human health and the environment. The Agency also is charged to participate in the CCSP as well as develop an understanding of the possible impacts of future climate changes on national air quality, a topic for which very little research has been conducted up to the present time. Because the thermodynamic variables of the climate system can have direct effects upon the constituents of the atmosphere that define air quality, the two topics are intimately connected, many times in nonlinear ways, so that only by a process that considers the impacts of both simultaneously can the effects of one upon the other be identified. They cannot be understood separately if we are to obtain scientifically consistent assessments of future changes.

To approach this complex problem, the Program has defined six main activities around which to define its air quality work:

1. Maintain an understanding of overall air quality changes within the United States.
2. Identify regional linkages between climate and air quality changes.
3. Determine how climate changes directly impact pollutant and greenhouse gas emissions.
4. Quantitatively consider relationships between changes in land cover (usually due to human activities) and emissions.
5. Study the implications of future technology scenarios on regional air quality.
6. Develop and apply decision support tools for stakeholders and policy makers to understand possible regional adaptations to global and air quality change.

The Program also has committed to development of two major assessment reports: (1) 2007 – Impacts of Climate Change on U.S. Air Quality, and (2) 2010 – The Combined Impacts of Climate, Technological, and Emission Changes on U.S. Air Quality. These two reports are to include:

- ✧ Synthesis of both intramural and extramural research, which includes regional change scenarios, gaseous emissions of pollutants and greenhouse gases, regional weather patterns, technological change analyses, and related global and regional air quality simulations.
- ✧ Evaluations of the range of uncertainties within complex air quality assessments.
- ✧ Identification of additional research needs.

The mix of future energy sources, technological developments, and driving habits around the world as well as industrial development will determine the human-induced greenhouse gas forcing of climate that needs to be considered. Modeling of air quality coupled with climate change is complicated by the broad range of model results that are obtained when different models or model versions use identical model inputs and equivalent “spin up” and boundary assumptions.¹⁶ Despite the many years of intercomparison, including a suite of versions of Goddard Institute for Space Studies (GISS) models, along with a large host of different versions of other climate models submitted by many researchers worldwide, there is an arbitrary nature in choosing which climate model and which version, including air chemistry, should be used for the study of air quality assessment under changing conditions of human-induced climate forcing. At this point, EPA air quality decision makers have exerted a great deal of effort in choosing one version of the suite of GISS models upon which to base their assessments. This choice seems entirely appropriate but must be recognized to be a limitation of using climate models. The use of one model in no way reflects on the excellent work discussed here. The arbitrary nature of climate modeling is a fact that has been known for a long time and is not likely to be resolved anytime soon. Even unexpected extreme climate events can play into the limitation of our abilities to predict future climate.

Other factors also play prominently into development of assessment scenarios. Because of the stochastic nature of the weather that goes into defining climate, there always is a range of meteorological variability in predicting climate. Seasonal weather is not identical from one year to the next. The seasonal variability is likely to always be greater than the annual change in signal from human-induced climate change so that any adaptation measures that are based on the previous few years of seasonality combined with predicted changes from human forcing will be based in large part on the range of natural seasonal variability and only in a secondary way, on the influence of the human climate forcing. This greatly complicates the researchers’ abilities to help stakeholders to adapt to what might be thought to be human-induced climate change.

Additional technical constraints have included: (1) the ability to link global forcing of climate to regional scale modeling processes, and (2) development of high resolution (e.g., 36-km grid) inputs necessary for various modeling efforts. Recognizing these factors, the Program’s air quality research has made excellent progress in developing an assessment of the influence of global climate change. It has developed its focus into the six areas mentioned previously and has made very good applications of both its extramural and intramural resources.

The strategy for the assessment has involved the following:

- ✧ Use of the STAR Program to build a scientific base to generate inputs for the modeling and assessment efforts.
- ✧ Use of the Community Multi-scale Air Quality (CMAQ) model to evaluate air quality changes from climate changes through the year 2050.

¹⁶ In 1989, the Department of Energy started the Program for Climate Model Diagnosis and Intercomparison (PCMDI) at the Lawrence Livermore National Laboratory. The mission of the program is to develop improved methods and tools for diagnosis, validation, and intercomparison of global climate models; this study is continuing to this day and has been an important effort for interagency work in climate modeling.

- ✧ Development of an overall strategy to advise the air quality science and policy community.

Collaborative efforts to develop this focus area have included four EPA laboratories and centers, 25 STAR grantees, and the Pacific Northwest National Laboratory (PNNL), funded through an Interagency Agreement. Stakeholders have included EPA's OAR and regional planning organizations such as the Northeast States for Coordinated Air Use Management (NESCAUM).

A number of different outputs have been developed:

- ✧ Support of activities related to the National Assessment.
- ✧ Literature analyses and descriptions of the state-of-the-science.
- ✧ Selective downscaling outputs for use in regional air quality and vegetative models.
- ✧ Global chemical modeling results to be used in regional air quality modeling.
- ✧ Quantification of the response of biogenic and anthropogenic emissions to increases in both atmospheric temperature and CO₂.
- ✧ Population projections to be used in emissions models.
- ✧ National databases for use in developing future transportation and energy sector technologies.
- ✧ Regional technology models to be used in partnership with NESCAUM.

VII.2 Question 1: Is the Air Quality Focus Area Engaged in the “Right” Work?

Are the Program activities that target these focus areas of the highest priority and consistent with resource availability and likelihood of success?

The Program developments in the Air Quality Focus Area have appropriately prioritized the approaches taken to assess the impact of climate change on air quality in the United States consistent with the availability of resources and the likelihood of success. This effort has led to the use of one version of the GISS climate model for determining likely climate changes forcing of air quality changes. The model results represent downscaled global climate and chemistry modeling outputs for use in regional air quality and vegetation modeling. This work is probably the highest priority activity consistent with resource availability and likelihood of success. The different outputs referred to above show excellent use of the resources furnished.

Is the enhanced role of decision support as a guiding principle for Program activities consistent with and appropriate to the overall mission of the Program?

The enhanced consideration of decision support is most consistent with the protection of the air quality in the overall mission of the Program and EPA in general. Many impacts from climate change are expected to occur at the regional and local levels; hence, to prepare for these consequences, it is essential that decision makers and stakeholders have the best tools and information available to anticipate changes and develop adaptive measures in a meaningful and timely way. Through the proper decision support tools, EPA will be able to maintain standards that are appropriate for the future, in the presence of a changing climate. A number of factors, meteorology, emissions, and chemistry all come into play to predict future adaptation measures for sound air quality standards. Information must be available at all levels—local, state, and federal—to adequately protect the health of our country in a changing air quality environment forced by climate change. An example involves a 30-year planning model to determine urban-scale transportation infrastructure, pricing, land use policies, and projected demographic and economic trends on mobile sources. The UrbanSim open source modeling system involves dynamic interactions between many “players” involving stepwise decision processes within an urban environment.

Is the emphasis on stakeholder engagement in the planning and prioritization of the research appropriate for meeting Program goals? If so, are the regional or place-based assessments useful test beds for learning how to do stakeholder-relevant assessments and decision support?

For assessments to be relevant to their needs, it is essential that stakeholders be involved in the planning and prioritization of the research. This also is essential to meet Program goals. Examples of stakeholder engagement were provided to the Subcommittee. By partnering with the NESCAUM, the Program was able to develop a decision support system that represents electricity generation, industrial, commercial, residential, and transportation sectors across a six-state region to effectively prepare for long-term air quality changes and identify the benefits of using adaptation strategies.

What insights or suggestions might the Subcommittee offer with respect to changes in priority or in the structure and content of the work of the Program?

See Section VII.4 Recommendations.

VII.3 Question 2: Does the Air Quality Focus Area Conduct Its Research and Assessment Activities “Well”?

Has the Program demonstrated consistent, superior scientific quality in its research and assessment products?

Most surely it has. The quality of the work is demonstrated by the technical capability of EPA researchers as well as extramural academic researchers and the institutions involved, the superior recognition of the journals in which the work has been published, and the national meetings at which the research has been reported.

Examples include:

- ✧ Effects of future climate change on regional air pollution episodes in the United States, published in *Geophysical Research Letters* by researchers in the Division of Engineering and Applied Science, Harvard University, and National Aeronautics and Space Administration’s (NASA) GISS.
- ✧ Real-time nested mesoscale forecasts of lower tropospheric ozone using a highly optimized, coupled-mode numerical prediction system presented at the Symposium on Interdisciplinary Issues in Atmospheric Chemistry of the American Meteorological Society by researchers from MCNC-North Carolina Supercomputing Center, Research Triangle Park, and the Department of Meteorology, The Pennsylvania State University.
- ✧ On the future of carbonaceous aerosol emissions, published in the *Journal of Geophysical Research* by researchers from Argonne National Laboratory through an Interagency Agreement, the University of Illinois, and EPA’s Office of Air Quality and Planning and Standards at Research Triangle Park, North Carolina.
- ✧ Simulating changes in regional air pollution over the eastern United States due to changes in global and regional climate and emissions, published in the *Journal of Geophysical Research* by researchers at the State University of New York–Albany; Columbia University; New York State Department of Environmental Conservation, Bureau of Air Quality Analysis and Research at Albany; and NASA’s GISS in New York.

There were many other excellent papers, too numerous to mention.

Has the Program effectively integrated intramural and extramural research and assessment activities to attain its goals?

The Program has demonstrated an increased awareness of global change issues on the part of air quality managers and research and has developed decision support tools for designing effective control strategies for improving air quality using technology assessments and databases. Tools have been developed for understanding the impacts of technology changes at the regional level, for example, the NESCAUM. Stakeholders include the CCSP, EPA’s OAR, NESCAUM,

California Air Resources Board (CARB), and others identified through development of Decision Assessment Support.

Examples of work that EPA reported to the Subcommittee include:

- ✧ Identified the need for methods to link global environmental changes to local changes in air quality by determining impacts on meteorology and emissions and considering projected technological, socioeconomic, and adaptive responses (this was completed in 2004).
- ✧ Recognized the need to provide air quality modelers and the climate change community with unique temporal, spatial, and environmental data to perform modeling of future year air quality that incorporates climate scenarios (on track to be completed in 2005).
- ✧ The Program is working to provide air quality managers in state, EPA regional offices, and the air quality research community a quantitative evaluation of the direct effect of climate change on regional emission and air quality (to be completed in 2007).
- ✧ The Program is planning for air quality managers to possess and use scientific information and models to project the effects of climate change on future regional air quality (including potential long-term emissions changes) and to use this information and other tools that will be provided by the EPA Program to evaluate and select future technologies and strategies that, based upon modeling, can ameliorate the air quality effects of global climate change (to be completed by 2010).

Has the Program made significant progress toward each of its LTGs?

The Program has made great strides towards its LTGs. It has demonstrated the linkages of global to regional changes in climate-forced air quality, it has quantified the linkages between climate change impacts and emissions and land cover changes, and has identified the implications on regional air quality based upon future technology scenarios. It also has made good progress in developing decision support tools for regional adaptation to global change.

Has the Program achieved important environmental outcomes?

EPA has collaborated with academic researchers and local stakeholders to make them more able to understand the tradeoffs involved in the many conflicting objectives that surround environmental planning decisions. These results are adaptable and allow the stakeholders to use their own models instead of being locked into pre-established ones. Through EPA efforts, decision makers can share their project results with others, thus expanding the usefulness of the environmental outcomes they have identified.

Have the Global Change Research Program and its scientists played leadership roles in the global change research community and in furthering global change science?

Yes. The Program and its scientists have worked to understand stakeholder needs and build connections between decision makers and resources available in the research community. Examples include regional air quality planning and regional transportation planning.

What insights or suggestions might the Subcommittee offer to improve the effectiveness of the operations of the Program?

See Section VII.4 Recommendations.

VII.4 Recommendations

1. No changes in the structure or the priorities in the air quality portion of the Program are suggested at this time.
2. Although the air quality modeling has been demonstrated most effectively, it would be beneficial if the Program could extend its efforts to develop a means for demonstrating the broad ranges of outcomes that surround the impacts that are obtained using, for example, the GISS model for climate and the chemical model for obtaining air quality under climate stressed conditions. These assessments by EPA are the very best approaches the country has available to plan for the future in spite of their limitations. The work is very important and should definitely be enhanced.
3. Using the tools that are being developed for the Semantic Web (e.g., see <http://www.w3.org/2001/sw/>) could possibly enhance the efforts in developing complex decision support systems. Although this Web activity is quite new and is just being developed by various government agencies across the country, the W3C promises to be an integral part of developing sophisticated tools for Homeland Security. It would be most beneficial if EPA's use of it were made compatible with other uses of similar types of information. This compatibility would allow a much larger community of stakeholders to interact.

VIII. REGIONAL AND PLACE-BASED FOCUS AREA

VIII.1 Regional and Place-Based Focus Area Overview

The role of a regional or place-based focus, in general, occupied a considerable amount of the Subcommittee's time and attention. Research conducted within a "place," with a connection to specific stakeholders focused on specific outcomes, is clearly essential to this Program's success. Place-specific circumstances—physical, hydrological, ecological, industrial, and social—and the role they can play in terms of connecting research and assessment were discussed throughout the review.

The Global Change Research Program's regional assessment effort includes three regional efforts: the Mid- and Upper-Atlantic, the Great Lakes, and the Gulf Coast. Overall, the regional assessment effort has provided the Program with a laboratory for stakeholder-inspired research and interdisciplinary team building. Each of these research projects has undergone a competitive process and moved from a focus on synthesizing and articulating the impacts of global change, as they might present in a particular region, to investigating decision-making processes and their information needs.

Well into Phase II of its regional assessment strategy, the Program has a diversified portfolio of investments in almost every sense of the word as it relates to this activity: diversity across stakeholders, methods, sectors, and mix of research and direct capacity building activities. In the case of the Mid- and Upper-Atlantic Region, the focus has been broadly based across the region and in consultation with a wide range of stakeholders, with an emphasis on developing a climate information service. In the case of the Great Lakes Region, interaction with stakeholders has been far more specific, focusing primarily on particular industries that expect to be influenced by a change in background climate conditions. In the case of the Gulf Coast Region, the focus is a study of the salience of climate change information for stakeholders and how information is actually used in decision settings. The assessments were established as components of a larger, national effort to study the impacts of global change that would be of highest relevance to decision makers and policy makers. These assessments are raising questions and issues critical to the continued evolution of the Program overall as it moves more deeply into areas of decision support.

A separate investment in assessments defined by place was considered by the Subcommittee to be essential to the goals of a truly integrated program sensitive to the complexities of global change and accessible to practitioners interested in realistic adaptation options. It has been the "right" work and the EPA Program has tackled a highly complex set of scientific issues with great sensitivity to the challenges of putting scientific information to practical use. Strategy, performance, and accountability have been adhered to every step of the way.

The question on the minds of the Subcommittee members had to do with whether the right strategy for EPA's *existing* regional assessment program was the right strategy for its *future* investments in regional assessments. Given rather substantial changes in context (evidenced both in major changes across the federal agencies and in interest across stakeholder communities) and progress in the development of stakeholder-influenced research and the data, methods, tools, and techniques to reduce uncertainties relevant to risk management, the Subcommittee members thought that the Program should take stock of the lessons and insights achieved thus far and design an advisory process to assist in the creation of an updated strategy for sponsorship of regional integrated assessments.

Among the issues discussed by the Subcommittee that informed recommendations regarding a regional assessment strategy for the Global Change Research Program were the following:

- ✧ **Place-based research assessments should be endorsed, in concept, as an appropriate method to merge latest scientific insights with pressing issues/decisions associated with environmental policy.** Place defines context of the problem. Place defines the institutional capacities to address anticipated and realized changes in environmental and social conditions, and to a large extent, place is an effective way of determining who is making the decisions relevant to outcomes of public concern. There are a wide variety of ways in which the Program could define "region" and it may be that the drive toward initiating research around a set of decisions and the individuals and institutions involved will invite considerable innovation into the approach the Program takes to framing place-based assessments.
- ✧ **EPA's current regional strategy was "right" for its time.** The selection of regions was based on connections to EPA historically as well as the expectation that these regions would be 3 of 19 and that a Synthesis Team and a federal working group would exist to orchestrate protocols and periodic assessment exercises under the U.S. National Assessment. EPA was able to take steps to adopt its strategy to its own mission-oriented assessment goals, but the Agency has taken a phased approach. Even though there is not a single cohesive federal effort still underway, the federal global change research effort still embraces place-based science (as does its principal advisor, the NRC) and will likely increase its emphasis on regionally defined work as its decision support agenda develops further. The experience of the EPA regional assessments program clearly is a tremendous asset to the CCSP.
- ✧ **Today's context creates different requirements for a regional assessment effort.** When the National Assessment and its constituent efforts were launched, experience with building a research agenda in consultation with practitioners, (and, to some extent the public), was hardly a regular or even an accepted practice in global change research. Today, this program and others have gained considerable experience in studies of climate impacts that incorporate the social and economic context and yield results tailored to existing decision-making criteria. Recent climate-related events, such as drought, the most severe hurricane season in modern record, and air quality decline, have inspired greater interest and expertise across stakeholder communities and opened new areas of opportunity and need for applied research. Whereas the breadth and diversity of the

assessments have been an advantage for EPA, given its resource limitations and the increasing need for research with strong, regular, and verifiable connections to decision need, there is a call for greater focus, depth, and rigor in the Agency's regional effort.

- ❖ **The Program's managers are highly capable scientists who understand the importance of ensuring that science achieves the capacity to contribute to expanded options for decision makers in the face of adaptation to climate change.**

VIII.2 Question 1: Is the Regional and Place-Based Focus Area Engaged in the "Right" Work?

Are the Program activities that target these focus areas of the highest priority, consistent with resource availability and likelihood of success?

In aggregate, the Program has focused on areas of high priority (in general, how can our emerging knowledge of climate impacts be characterized to be accessible and what can be learned about how decision makers incorporate information) and high likelihood of success within the realities of the resources available. The Mid- and Upper-Atlantic Assessment, with a case study approach and a broad base of stakeholders, has undertaken activities that bring the study of global change and its information resources to a wide-ranging public sector risk management agenda. The Great Lakes Assessment is deep into tool development that affords the decision maker a greater ability to evaluate options in such specific instances associated with crop management. The Gulf Coast Assessment is furthering research on the salience of climate change for particular stakeholders and expects to recommend strategies for enhancing the utility of climate information for practitioners.

In assessing the extent to which the activities are high priority and likely to succeed (within resource availability), it is important to recognize that these activities were launched with a particular assessment infrastructure in mind that no longer exists. The assumption, under the National Assessment, was that EPA's investment would be matched in other regions by other agencies and that a national program of global change impacts and information would emerge. There was programmatic machinery associated with this coordinated investment, such as a federal working group and a Synthesis Team, and a pacing item in the anticipation of a snapshot of our latest insights of global change impacts every 4 years. EPA has done an excellent job adapting and mining the assessments for the needs of its own programmatic development and development of decision support.

An important challenge for Agency sponsors and investigators alike in the area of regional assessments is that there are so many related points of "success" and the very notion of success keeps shifting as progress is made. Teams are expected to be successful at engaging stakeholders, building partnership, building and maintaining highly integrated research teams (expected to engage in "nontraditional" activities in the context of mainstream academic research), creating educational materials and opportunities, and conducting outreach that is scientifically sound and effective in various areas of public policy. Activities deemed high

priority *should* shift as progress moves from describing circumstances to collaborating on methods, tools, and information, to evaluating the role of scientific information in risk reduction.

An important related question then would be: Do the Program activities have the capacity to adjust over time their definition of what is high priority (presumably through a cooperative process in response to interaction with stakeholders)? How, for example, will the experience of the hurricanes in the Gulf influence and be incorporated by the regional assessment team? What would be a set of stakeholder-driven activities appropriate to the EPA mission and focus on water quality, ecosystems, and health? The capacity of the current assessments in this regard remains to be seen, as Phase II is still underway.

One set of priority activities that should be more prominent in the regional assessments are those associated with internal evaluation at various stages. In the context of the model building in the Great Lakes, how are uncertainties and probabilities reflected and are they meaningful to stakeholders? Have the teams devised effective mechanisms to evaluate the contribution of their efforts to climate-related risk exposure in their region? These are enormously challenging questions, but ones that would help determine priorities.

Is the enhanced role of decision support as a guiding principle for Program activities consistent with and appropriate to the overall mission of the Program? If so, do the Program's planned activities support an increased emphasis on decision support?

Yes. To a certain extent, decision support leading to more informed environmental decision making *is* the overall mission of the Program. The ORD mission has everything to do with directed research ready to apply to “environmental questions the Agency must address.” The challenge of decision support as a guiding principle for Program activities is one of scope (which decisions, who is being supported) and one of depth (is there capacity to evaluate the role of new information and then develop sufficient feedback to inform the research agenda, refine decision support activities, and evaluate again?), almost in an adaptive management framework.

In this way, EPA's regional assessments have introduced a healthy breadth of exposure for the Program, putting regional saliency above strict adherence to focus area definition. Ideally, the result will be the Program's ability to produce new knowledge and insights important to managing water, ecosystems, air pollution, and health that adequately reflect multiple stresses, institutional complexities, and decision points of specific relevance to specific stakeholders. That's a tall order and one that in most cases takes a very long-term investment to achieve. Continued breadth within the regions without an emphasis on specific decision support goals may not continue to be of service to the ultimate goals of the Program.

In the shift from Phase I to Phase II, the regional assessment program's planned activities certainly supported an increased emphasis on decision support. Although the Gulf Coast Assessment has more of a process research quality to it, albeit one grounded in the social sciences as it is set up to analyze decision-making and policy-making processes as a basis for decision support, the collection of partnerships made with both state and federal agencies has the potential to advance its contribution to decision support in the region. One hurdle visible in

elements throughout the regional projects is a tendency toward sustained development of information resources, which is not the same as actual decision support. Information resources, on their own, will not add up to decision support.

The EPA managers were very attuned to these challenges. Their planned decision inventory activity and planned study activity with the NRC to explore the existing knowledge base relevant to decision support in global change and bring more definition to areas in need of further research, will help the Program revise and clarify its LTGs in the area of regional assessment.

Is the emphasis on stakeholder engagement in the planning and prioritization of the research appropriate for meeting Program goals? If so, are the regional or place-based assessments useful test beds for learning how to do stakeholder-relevant assessments and decision support?

The emphasis on stakeholder engagement in the planning and prioritization of the research not only is entirely appropriate but essential. The USGCRP, now the CCSP, has learned repeatedly over the years that if the knowledge and insights the program struggles to achieve are to be useful in practical public policy and decision challenges, the individuals ultimately responsible for making those decisions must be a part of the process of knowledge creation.

As far as the utility of regional assessments as test beds, here again, the diversity in approaches evident in the regional assessments is useful and important. The three regions offer three separate methods, one including broadly defined stakeholder guidance, one that is confined to specific stakeholders but that draws them in as highly involved partners, and one that starts with an analysis of stakeholder orientation to climate information.

As Phase II comes to a close, the Program should establish a firmer connection between what is being learned in the regions from a more open stakeholder-led research agenda, and what is being developed in the focus areas. The Subcommittee had an appreciation for the fact that it simply takes a very long time to build mature stakeholder networks. Indeed, the Program managers have a challenging task ahead: Are there particular ways of partnering with stakeholders most suitable to EPA's Program goals? How can these assessments be designed to focus on key issues of national relevance that happen to present regionally? Is there evidence in the place-based impact assessments of learning or techniques developed in the regions? Are the regions designing new methods of managing stakeholder processes that are being picked up in the focus areas? Have any of the focus area projects chosen to make use of the regional investments in terms of evaluating the extent to which capacity for integrating scientific information has been achieved? To what degree will these "test beds" need to provide closer coupling with the focus areas?

VIII.3 Question 2: Does the Regional and Place-Based Focus Area Conduct Its Research and Assessment Activities “Well”?

Has the Program demonstrated consistent, superior scientific quality in its research and assessment products?

The Program ensures layers of independent peer review extending beyond grant programs to include review of ORD laboratories and centers. Since receiving advice to shift the objectives of the Program to those associated with assessment and adaptive capacity, the Program has undergone a peer review of its research strategy, conducted peer reviews of the proposals received through open competitions, and conducted a review in cooperation with ICF Consulting designed to result in a “synthesis of the interim results of three place-based assessments.” This synthesis of results is evidence of the Program’s capacity for introspection and interest in being deliberate about the evolution of the Program. Plans to review this document externally should be pursued. There is, in addition, a respectable list of articles in recognized academic journals that has resulted from the regional assessments. The management team clearly is committed to high scientific quality as a core element of its efforts and has demonstrated close involvement and overview of the efforts in its role as manager of cooperative agreements. The regional assessments have undergone peer review following an open, competitive announcement of opportunity.

Elements that would strengthen the scientific quality of the assessment products include external committee peer reviews, onsite if possible, to assess more thoroughly questions regarding the specifics of utility and quality of the assessments from the perspective of practitioners. For example, the teams should have a clear understanding of decisions that have been influenced by their work and evaluate their scientific quality in part by the extent to which decision makers with real challenges find their methods, tools, insights, and information useful. There is some anecdotal evidence here, but the EPA Program needs to go deeper in terms of analysis of *outcomes* associated with its teams’ activities. Again, the Subcommittee appreciates that stakeholder processes require considerable time to bear fruit, but thought that it was in the interest of the Program to ensure that regional assessments emphasize verified stakeholder traction. Further, to the extent that the EPA Program values the regional assessments for their insights into stakeholder-driven (as opposed to their more sector-based) efforts, it would be helpful to see the influence of findings from the regional studies emerge in the focus area research. Finally, it is not clear to what extent this particular set of assessments is identifying knowledge gaps critical to particular decisions that are articulated as feedback to research programs, both inside EPA and, ideally, in the interagency science planning context. It seems to be a highly uneven process across the assessments.

Has the Program effectively integrated intramural and extramural research and assessment activities to attain its goals?

The effective integration of intramural and extramural activities is a truly formidable task in a mission agency with a deep culture of laboratory and in-house research. This Program, and particularly the NPD, seems uniquely committed to achieving meaningful, logical integration.

The creation of the NPDs was a positive step in the direction of giving senior managers the authority required to make programmatic change. The extent to which the regional assessments then influence dialogue and planning across the Agency is hard to see through an exercise such as this. In an atmosphere of tight budgets, this Program is to be commended for having sought to maintain balance (i.e., maintaining open access extramural resources) as well as effective integration. Often in times of tight budgets, agencies tend to turn inward, which is a strategy that runs counter to their long-term interests.

In the area of integration of research and assessment, the regional assessments should be demonstrating more capacity to utilize latest research results in the process of assessment (be they results from cutting-edge climate research or from social science offering new methods for adoption of new tools or insights into communication strategies). Similarly, EPA needs more from the regional assessments in terms of highlighting knowledge gaps important to adaptation. The entire interagency research program would benefit from decision support results that could contribute to the process of building research agendas.

Has the Program used the results of assessments together with stakeholder feedback to identify key research gaps and to update the Program's research agenda?

This is one of the areas where the infrastructure of the National Assessment would have been helpful. Part of that process included a deliberate activity on the part of the National Assessment Synthesis Team to review the results of the assessment and draft a document highlighting key knowledge gaps in need of a research investment. Such a step would be useful for EPA, or any agency invested in stakeholder inspired research, to pursue either on its own or in partnership with other federal programs. It forces a seriousness and regularity to the task of identifying research gaps and provides a means to communicate them widely back to the more process-oriented programs. In the case of the regional assessments, interestingly, the first phase of research had a greater emphasis on the identification of knowledge gaps. The second phase is more concerned with information gaps, as opposed to knowledge gaps. The EPA Program needs feedback on both.

Looking across the three regional assessments, preliminary feedback on the information needs of decision makers perhaps has been as relevant to the whole of the interagency (CCSP) decision support enterprise as it has been to EPA. In other words, information on which systems or communities are most vulnerable and how and under what circumstances stakeholders are using finer scale climate data is important to the broader federal effort to make research investments more relevant to practical risk management issues. This is not surprising, given the origins of the effort in the interagency National Assessment, and the necessary breadth of a regionally defined research process deliberately designed to pursue research topics defined by practical challenges specific to the region.

Although it is clear that the Program managers—who have portfolios designed to keep them involved in both the management of the assessments and in focus areas—have been influenced by the process and the particular interim findings of the assessments (and thus themselves been conduits of “feedback”), it is not clear exactly how or whether findings from the assessments

have influenced or been incorporated by either the assessments or the research in the focus areas. The key research gaps being identified by the regions seem to cluster around a greater need for finer scale information (much of it in the area of climate information) and the need for further attention to the communication of information. The process of the regional assessments may be contributing indirectly to new methods of integration across water, ecosystems, air, and health; it is difficult to see direct contributions from the two regional efforts that include water management and ecosystems management.

Has the Program provided useful information and tools to stakeholders in a timely manner, and has it communicated its results effectively to its clients and to the broader scientific community?

The teams, to varying degrees, have partnered with stakeholders across a range of scales of governance and decision making. The Program made a proper choice, for its time, in allowing a great diversity in approaches across the three assessments. The Subcommittee would not be able to raise questions as effectively today about what is best for EPA without an experience that was sufficiently broad and instructive.

Because the Phase II announcement emphasized the development of decision support tools, but not their evaluation necessarily, detailed information from stakeholders about the performance of the regional assessments is difficult to come by. The Subcommittee would have benefited from information on these assessments that better characterized, in a critical fashion, the Program's thinking today on which stakeholders and why, which decisions and why, which (specific) information needs, and what outcomes (have already been realized and are desired). There is information describing the involvement by the tourism industry and the tart cherry industry in the Great Lakes, for example, that explains their level of involvement in providing data and the types of decisions that could be affected by the decision support tools. These stakeholders would not participate if they did not think that the information was useful and delivered effectively.

In the case of the Mid-Atlantic Assessment, the team has acted as information provider and developer of analytical tools. More than 90 stakeholders are involved at various levels, but it is difficult, at this level of review, to identify the true partnerships. It may turn out in the time to come under Phase II that the models being adapted for the Web site elicit a substantial user community and have the effect of wide distribution and high utility. It is difficult to see what activities are being undertaken by the team to assess the salience and credibility of the information it is providing. It is curious that the team has elected to invest its resources in the establishment of a Web-based climate service, "similar in concept to a weather service Web site." Are there plans to partner with parts of the National Oceanic and Atmospheric Administration (NOAA) that already provide climate services?

To advance its strategy in the area of regional assessments, particularly given resource constraints, the Program will need to address more rigorously its reason for investing in regional assessments. Information, preferably from participating stakeholders, describing how the regional assessments have addressed areas of particular concern would be useful should the Program decide to conduct an in-depth review of the regional assessments. The publication records are impressive but also necessary is evidence of the integration of climate analysis or

assessments inside specific decisions, with attention to the outcomes achieved and the role of the assessors or assessment products in affecting those outcomes.

Has the Program evolved over time to provide decision support more effectively to its clients?

The Program management itself clearly is coming to terms with exactly this question. Decision support requires involvement in the full context of decisions, including institutional realities, the role of both public and private agents, community capacity, and overall readiness for change. The Decision Inventory, the work with the NRC to further define decision support *research*, and this review represent very positive steps being taken to ensure that the Program can provide effective decision support.

In the case of the regional assessments, Phase II work is still underway so the picture regarding the effectiveness, per se, of decision support is incomplete. Indeed, investigators should be urged to answer this question in specific terms in their final reports to EPA.

One of the possible limitations in the current effort is that in the case of two of the assessments, the Gulf Coast and the Mid-Atlantic, their approach to stakeholder interaction has included a broad range of sectors at almost every imaginable scale of decision making, as well as decision agents from public agencies, and private interests. Although this vast range has utility for discovery and potentially for public education, it makes it difficult to get to the point of evaluating the effectiveness of decision support in specific cases.

In the case of the Great Lakes Assessment where the focus is on the tart cherry industry and the tourism sector, the deep involvement and partnership on the part of industry representatives—even to the extent of providing data and testing tools—provides the assurance that clients are being reached. Further evaluation from these stakeholders (e.g., when internal risk assessment models incorporate scenario-based or other information and are used in actual decision making) will provide the final loop connecting the applied research to support of decisions. It may turn out that the techniques being developed with both the tart cherry and tourism industries could be generalized to other industries interested in tools that assist investment decisions or analyzing impacts of alternative decisions under conditions of uncertainty. One question that should be important to the Program as it considers its next strategy for regional assessment is the potential of the work to be integrative and capable of incorporating multiple stresses. Are the decision makers receiving analysis that accurately reflects the complexities?

One challenge faced by this set of assessments in the area of proving its decision support value is the long-term, generally capital-intensive nature of the decisions on which they tend to focus as a result of looking out several decades in terms of changes in temperature. The tourism sector of the Great Lakes Assessment is looking seasonally, but their objective appears to have more emphasis on information resources rather than iterative decision support.

Has the Program made significant progress toward each of its LTGs?

The regional assessments program had goals for Phase I and Phase II, but no LTG. There is every reason to expect that this program would be involved regionally over the long term to achieve its overall mission, and the defining of a LTG should come with revisions to the program strategy as future investments are considered.

Has the Program achieved important environmental outcomes?

The reason that stakeholder interaction is critical to applied research programs is because if change is to be affected, the agents of change must be engaged early on in the process. If EPA is to affect capacity across policy makers and decision makers to adapt to the effects of climate change—the important environmental outcome in a most general sense—the Program must sponsor activities at a range of scales that address problems of concern to the public and private sector.

There are certainly instances of contributions to important environmental outcomes associated with the individual assessments, such as the “use of assessment results in the Louisiana Wildlife Federation resolution to consider accelerated sea-level rise in coastal management plans” (Poster: Gulf Coast Regional Assessment). Even in Phase I, the assessments provided an information resource and an identifiable collection of university-based experts for deliberations important to environmental outcomes. Research that helps operational agencies (particularly at state and local levels) understand how decision makers use scientifically based information will be critical to any efforts to incorporate enhanced resiliency into the rebuilding of the Gulf states. It will be the basis and foundation of important environmental outcomes for agriculture to have had the experience of being deeply involved in the actual modeling and research process (Great Lakes), and the fact that private industry is involved will be meaningful to elected officials.

Have the Global Change Research Program and its scientists played leadership roles in the global change research community and in furthering global change science?

The team that manages the Global Change Research Program is dedicated, highly skilled, and used to operating as a team amongst themselves and in cooperation with the investigators they sponsor, both internally and externally. The NPD has been a major player both as a scientist and as a senior federal official who long ago urged the interagency program to orient itself to the production and delivery of knowledge that had practical value of direct relevance to health and human welfare. He has established a motivated, innovative group that brings to EPA enormous talent and recognition within the global change community.

What insights or suggestions might the Subcommittee offer with respect to changes in priority or in the structure and content of the work of the Program?

See Section VIII.4 Recommendations.

What insights or suggestions might the Subcommittee offer to improve the effectiveness of the operation of the Program?

See Section VIII.4 Recommendations.

VIII.4 Recommendations

- ✧ **The Subcommittee recommends that EPA design, in consultation with the CCSP (as a whole or in partnership with individual agencies), a new strategy for place-based investment.** EPA should use as its initial guide the work the Agency has done, formally and informally, to take stock of lessons learned since the beginning of the assessment process. Some of these lessons showed the need for greater attention to understanding the sources of information demand, closer attention to analysis of decision-making processes (including constraints that influence adaptive capacity), and the need for arriving at a framework for prioritizing the stakeholders the program serves, looking especially closely at those whose decision challenges exist into the longer term.

Recommendations and insights from the EPA managers should be reflected in a charge to an advisory committee to assist in the development of a new strategy for the Program. There is tremendous opportunity for innovation. The following are additional points that such a committee might consider:

- ✧ “Regions” do not have to be defined in traditional terms. The definition should be constructed to reflect and serve a national interest. The Program might want to consider alternatives such as coasts, biomes, or urban environments.
- ✧ EPA’s next generation of investment in regional assessments should be about integrative research, partnership across federal science and mission agencies (perhaps partnerships with state agencies), and a clearer commitment to contributions to the development of options for adaptation closely associated with the health and well being of the nation. Programmatic options should include consideration of a mixture of an announcement for activities in a place coupled with an announcement on some of the component issues (e.g., modes and methods of communication). The Program might benefit from a research announcement in partnership with another CCSP agency on the topic of methods and metrics for stakeholder interaction, for example.
- ✧ Numerous opportunities exist for connections to both other science agencies (with access to highest quality, cutting-edge global change information) and other mission agencies in need of outcome-oriented research relevant to their management agendas (e.g., U.S. Department of Agriculture [USDA] or U.S. Department of the Interior). In the area of climate information services, EPA should establish a range of linkages to the resources of NOAA, including its Climate Diagnostics Center, Climate Prediction Center, Climate Services Division, Geophysical Fluid Dynamics Laboratory, Aeronomy Laboratory, and National Weather Service. Similar opportunities for partnership, consultation, or

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leveraging may exist with the U.S. Geological Survey, USDA, National Institutes of Health, and CDC.

- ✧ Emphasis should be placed on developing methods for evaluation of assessments research to continually inform the research team's agenda (EPA's and CCSP's) and to ensure that gaps in knowledge identified as critical to new innovation in adaptation strategies are communicated effectively to research programs across the CCSP.

IX. APPENDICES

Appendix A: Charge to the Global Change Subcommittee

August 1, 2005

1.0 Objective. The objective of this review is to evaluate the relevance, quality, performance, and scientific leadership of the Global Change Research Program within the EPA Office of Research and Development (ORD). The panel's evaluation and recommendations will provide guidance to ORD to help:

- plan, implement, and strengthen the program;
- compare the Global Change Research Program to other programs designed to achieve similar outcomes in other parts of the EPA and in other federal agencies;
- make research investment decisions over the next five years;
- prepare EPA's performance and accountability reports to Congress under the Government Performance and Results Act; and
- respond to evaluations of federal research such as those conducted by the Office of Management and Budget.^{1,2}

2.0 Background Information. The independent expert review of ORD's Global Change Research Program being conducted by the BOSC Global Change Subcommittee is consistent with recommendations of the NRC of the National Academies (formerly known as the National Academy of Sciences). The NRC recommended that independent expert reviews be used to evaluate federal research programs.³ Such reviews can include evaluations of the relevance, quality, performance, and scientific leadership of a particular program.

Responding to this recommendation from the NRC, ORD's Global Change Research Program is initiating periodic retrospective analyses of its research and assessment activities to evaluate the scientific quality and performance of the work being done, to identify situations in which clients are applying research results to strengthen environmental decisions, and to assess the extent to which research investments have resulted in timely and useful environmental outcomes. Periodic retrospective reviews will be conducted at intervals of four to five years.

In a separate evaluation of science and research at EPA, the NRC recommended that the EPA substantially increase its efforts to explain the significance of its research products and assist clients inside and outside the agency in their application.⁴ Consistent with this recommendation, the "stakeholder oriented" Global Program strives to provide timely and useful information to decision makers, resource managers, and other stakeholders through its research and assessment activities.⁵ The program accomplishes this by actively engaging its clients in the process of identifying research priorities and information needs,

as well as in the conduct of research and assessments. (For example, the National Program Director for ORD's Global Program engages science advisers from EPA Program Offices and Regional Offices to help identify research activities that would yield timely information with the highest value to decision makers.) Once priority research and assessment questions are identified and the time frame of the information need is understood, performance goals are developed that serve as indicators of progress. Meaningful environmental outcomes are attained when research and assessment results are applied by clients to strengthen environmental decisions. These decisions and resulting actions (e.g., adaptive responses by water resource managers to increase a system's resilience to climate change) may lead to improvements in human health and environmental quality.

Despite the inclusion of stakeholders in the Global Program, it often is challenging to ensure—and demonstrate—that particular research and assessment activities have led to measurable environmental outcomes. The program must rely on its clients to utilize the science in their decisions and implement programs and adaptation strategies that lead to meaningful environmental improvements.⁶ This problem is reinforced by the program's stated objective of *informing* decision makers, while not making specific policy recommendations. This reflects the belief that the science must remain unbiased, and a recognition that policy decisions are based on multiple criteria and types of information.

Given the challenge of demonstrating that particular research and assessment activities have led to measurable environmental outcomes, ORD seeks the review panel's evaluation of the Global Program's design and the extent to which it has effectively informed client decisions and increased the likelihood that better environmental outcomes will be achieved.

3.0 Charge Questions for the BOSC Subcommittee's Review of the ORD Global Change Research Program

(Note: A description of the *Research and Development Investment Criteria* developed by the Office of Science and Technology Policy (OSTP) and the Office of Management and Budget (OMB) is attached. The investment criteria are intended to promote the relevance, quality, performance, and leadership of a scientific program, and are pertinent to the draft charge questions below.)

This review is organized around two fundamental questions:

- (1) Is the Global Program engaged in the “right” work?**
- (2) Does the Program conduct its research and assessment activities “well?”**

QUESTION 1: Determining whether the Program is pursuing the “right” work entails an assessment of the relevance of the Program's activities and of the priority each is given, considering EPA and overall national program goals. The Subcommittee may consider a subset of more specific questions, such as:

- Does ORD’s Global Program have, and is its direction guided by, a clearly defined and articulated mission with an under girding rationale?
- Do its strategic goals flow from and support this mission? If so, are these goals structured to be consistent with the goals of the EPA Office of Research and Development (ORD)?
- If achieved, will these goals optimally serve both the Agency and the interagency U.S. Climate Change Science Program (CCSP), as well as the larger public interest they both serve?
- Are the four focus areas of the program—Air Quality, Water Quality, Ecosystems, and Human Health and the emphasis on place-based assessments—consistent with EPA’s mission, EPA’s role in the CCSP, identified scientific needs, and stakeholder interests?
- Are the Program activities that target these focus areas of the highest priority and consistent with resource availability and likelihood of success?
- Is the enhanced role of decision support as a guiding principle for program activities consistent with and appropriate to the overall mission of the Program? If so, do the Program’s planned activities support an increased emphasis on decision-support?
- Is the emphasis on stakeholder engagement in the planning and prioritization of the research appropriate for meeting program goals? If so, are the regional or place-based assessments useful test beds for learning how to do stakeholder-relevant assessments and decision support?
- What insights or suggestions might the Subcommittee offer with respect to changes in priority or in the structure and content of the work of the Program?

QUESTION 2: To evaluate whether the Program has conducted its research and assessment activities “well,” the committee may consider a number of questions focused on program performance, quality, and scientific leadership, such as:

- Has the Program demonstrated consistent, superior scientific quality in its research and assessment products?
- Does the Program further promote high quality research through competitive, merit-based funding? And, when funds are not competitively awarded, does the alternative process for allocating funds also help to ensure quality?
- Has the Program effectively integrated intramural and extramural research and assessment activities to attain its goals?
- Does the Program use peer-review properly and effectively to improve, and to ensure the quality of, its products?
- Does the Program utilize performance measures effectively for evaluating progress towards its long-term goals?
- Has the Program provided useful information and tools to stakeholders in a timely manner, and has it communicated its results effectively to its clients and to the broader scientific community?
- Has the Program evolved over time to provide decision support more effectively to its clients?
- Have the Global Program and its scientists played leadership roles in the global change research community and in furthering global change science?

- Has the program used the results of assessments together with stakeholder feedback to identify key research gaps and to update the program's research agenda?
- Has the Program made significant progress toward each of its long-term goals?
- Has the Program achieved important environmental outcomes?
- What insights or suggestions might the Subcommittee offer to improve the effectiveness of the operation of the Program?

4.0 Potential BOSC Approach for Program Review

The Subcommittee will hold two conference calls in the month preceding a face-to-face meeting in September 2005. These conference calls will:

- Allow the ORD to present background materials to the Subcommittee for initial orientation;
- Allow the Subcommittee time to review and comment on the charge; and
- Allow the Subcommittee to ask clarifying questions about the program under review.

The Designated Federal Officer (DFO) will distribute background materials and documents requested by the Subcommittee in the weeks prior to the face-to-face meeting.

The Subcommittee Chair will:

- Make review and writing assignments to Subcommittee members in advance of a face-to-face meeting.
- Hold a 3-day face-to-face meeting for the program review at a location where a critical mass of ORD scientists is located. The first half of the face-to-face meeting will include ORD presentations and poster sessions. During the second half of meeting, the Subcommittee will prepare a draft report that addresses all of the charge questions. The goal of the face-to-face meeting is to complete a draft report that is available for comment soon after the end of the face-to-face meeting.

If needed, the Chair will hold one to two conference calls in the month following the face-to-face meeting to complete the draft report. The goal is to develop a report approved by the Subcommittee to be made available for discussion and approval by the BOSC Executive Committee at the January 2006 BOSC Executive Committee Meeting.

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Appendix C: List of Acronyms

APG	Annual Performance Goal
APM	Annual Performance Measure
BASINS	Better Assessment Science Integrating Point and Non-point Sources
BOSC	Board of Scientific Counselors
CARB	California Air Resources Board
CCSP	Climate Change Science Program
CDC	Centers for Disease Control and Prevention
CMAQ	Community Multi-scale Air Quality
CSO	Combined Sewer Overflow
CWA	Clean Water Act
DFO	Designated Federal Officer
EPA	U.S. Environmental Protection Agency
FACA	Federal Advisory Committee Act
GIS	Geographical Information System
GISS	Goddard Institute for Space Studies
GPRA	Government Performance Results Act
HHS	Department of Health and Human Services
LTG	Long-Term Goal
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NESCAUM	Northeast States for Coordinated Air Use Management
MYP	Multi-Year Plan
NOAA	National Oceanic and Atmospheric Administration
NPD	National Program Director
NRC	National Research Council
OAR	Office of Air and Radiation
OMB	Office of Management and Budget
ORD	Office of Research and Development
OSTP	Office of Science and Technology Policy
PART	Program Assessment Rating Tool
PNNL	Pacific Northwest National Laboratory
POTW	Publicly Owned Treatment Works
RFA	Request for Applications
RFP	Request for Proposals
STAR	Science To Achieve Results
TMDL	Total Maximum Daily Load
USDA	U.S. Department of Agriculture
USGCRP	U.S. Global Change Research Program
UV	Ultraviolet