UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON D.C. 20460

OFFICE OF THE ADMINISTRATOR
SCIENCE ADVISORY BOARD

October 21, 2011

EPA-SAB-12-001

The Honorable Lisa P. Jackson
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460

Subject: Office of Research and Development (ORD) New Strategic Research Directions: A Joint Report of the Science Advisory Board (SAB) and ORD Board of Scientific Councilors (BOSC)

Dear Administrator Jackson:

The EPA Science Advisory Board (SAB) and Executive Committee of ORD's Board of Scientific Councilors (BOSC) held their first joint review of ORD's new strategic research plans and draft frameworks. This review offered an extraordinary opportunity to provide early input for ORD research planned for FY 2012 and beyond.

ORD has realigned its research from 13 project areas, defined by specific problems and media type, into six new program areas. These include four integrated programs (Air, Climate and Energy; Safe and Sustainable Water Resources; Sustainable and Healthy Communities; and Chemical Safety for Sustainability) related to your major priorities plus two cross-cutting areas (Human Health Risk Assessment and Homeland Security Research). This consolidation and realignment of programs reflects an emphasis on integrated transdisciplinary research, multi-pollutant exposures and sustainability. ORD requested a joint meeting of the SAB, which traditionally has provided advice on ORD strategic research directions, and the BOSC, which has traditionally focused on ORD's implementation of its research programs, to review the six draft research frameworks at an early stage in ORD's process of defining research plans.

Both the SAB and the BOSC strongly support ORD's consolidation and realignment of research programs. Consolidation will bring efficiencies and promote a systems approach to sustainability as an overarching framework for ORD research. Consolidation and realignment of ORD research programs and adoption of such a systems approach to sustainability are bold and necessary steps. Environmental and public health protection requires a deep understanding of environmental

problems and an ability to translate that understanding into information to solve problems. EPA science is likely to resonate more with the public if it is framed in terms of actual environmental systems, rather than traditional scientific disciplines. Framing science in this way will help EPA communicate how science can be linked to preventing and solving environmental problems.

The SAB and BOSC are impressed with ORD's progress in conceptualizing the new research programs. There has been a marked increase in transdisciplinary collaboration as well as coordination across ORD programs over the past year. ORD has involved regional and program office stakeholders in the design of the new programs. As a result, program and regional support for ORD's new approaches is evident. One of the research programs, the Safe and Sustainable Water Resources program, has made more progress than others in formulating problems in systems terms and in articulating clearly the science activities to be undertaken to explore and address those problems. However, all six ORD research frameworks, if revised based on the recommendations in the SAB-BOSC report, will help the EPA build a culture and environmental programs to promote sustainability. Finally, ORD's efforts to foster innovative research are notable. The EPA has thought seriously and operationally about ways to energize the creativity of ORD scientists and has begun to make innovation a fundamental part of ORD programs.

We recommend that ORD strengthen its research planning in several ways. ORD should describe all of its research as six integrated, cross-cutting research programs, rather than as four major programs plus two cross-cutting areas. To be successful, all six ORD programs should look for opportunities for broad problem formulation and science integration. Additionally, as EPA develops a common definition of sustainability, the resulting definition should be used consistently across ORD. To advance sustainability as a goal, the research frameworks for each program should include sustainability as part of the research vision and identify clear metrics for assessing progress toward sustainability goals. Additional comments are included in the attached report.

The success of ORD's new research directions, of course, will depend upon implementation. Planned research must be supported by the financial and human resources needed. ORD's new approach to research will require significant resources to sustain the scientific interactions, stakeholder involvement and integrated transdisciplinary collaboration necessary to develop systems- and sustainability-oriented science. We recommend that the draft research frameworks each be revised to transparently describe the research goals and activities within the scope of ORD resources or active collaboration with external research partners.

The SAB and BOSC also underscore that all the systems of interest to EPA include human behavior. Research on relevant aspects of human behavior is crucial to understanding the systems and implementing solutions or programs that follow from them. Increased emphasis on social, behavioral and decision sciences within ORD is needed for the new research programs to be successful. The SAB and BOSC recommend that ORD take specific steps to enhance its expertise and research in these areas.

The SAB and BOSC seek continued dialogue with ORD as part of their mission to advise on the science and research supporting EPA's decisions. We look forward to any comments you have at this time on these reflections regarding ORD's new research directions.

Sincerely,

/Signed/

Dr. Deborah L. Swackhamer
Chair
Science Advisory Board

/Signed/

Dr. Martin Philbert
Chair
ORD Board of Scientific Counselors

NOTICE

This report has been written as part of the activities of the EPA Science Advisory Board (SAB) and the Office of Research and Development (ORD) Board of Scientific Counselors (BOSC). The SAB is a public advisory group providing extramural scientific information and advice to the Administrator and other officials of the Environmental Protection Agency. The SAB is structured to provide balanced, expert assessment of scientific matters related to problems facing the agency. The BOSC is also a balanced, expert public advisory group. It provides extramural scientific information and advice to the ORD Assistant Administrator. This report has not been reviewed for approval by the agency, and, hence, the contents of this report do not necessarily represent the views and policies of the Environmental Protection Agency or other agencies in the Executive Branch of the Federal government. Mention of trade names of commercial products does not constitute a recommendation for use. Reports of the SAB are posted on the EPA website at http://www.epa.gov/sab, and reports of the BOSC are posted on the EPA website at http://www.epa.gov/osp/bosc.

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FY 2011

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Table of Contents

1. BACKGROUND

The Office of Research and Development (ORD) has realigned its research from 13 project areas, defined by specific problems and media type, into six new program areas for FY 2012 to better understand environmental problems and inform sustainable solutions to meet the Environmental Protection Agency's (EPA's) strategic goals. ORD described these six new program areas as four integrated programs (Air, Climate and Energy; Safe and Sustainable Water Resources; Sustainable and Healthy Communities; and Chemical Safety for Sustainability) related to the Administrator's major priorities plus two cross-cutting areas (Human Health Risk Assessment and Homeland Security Research). This consolidation and realignment of programs reflects an emphasis on integrated transdisciplinary research, multi-pollutant exposures and sustainability. The Science Advisory Board (SAB) provided some initial comment on this realignment in June 2011 in the context of commenting on the President's Requested FY 2012 Research Budget (U.S. EPA SAB 2011a).

ORD requested joint advice from the SAB and Board of Scientific Counselors (BOSC) on this realignment at an early stage in the process of defining strategic program directions to help ORD develop research plans to respond to EPA strategic goals and high-priority needs. The SAB has traditionally provided advice on ORD strategic research directions, and the BOSC has traditionally focused on ORD's implementation of its research programs.

The SAB and the BOSC held a public meeting on June 29-30, 2011 to discuss six draft research frameworks ORD had developed for its major research areas and a draft action plan for the Chemical Safety for Sustainability research program. The SAB and BOSC also held a public teleconference on September 19, 2011 to discuss a draft of this report.

ORD requested the SAB and BOSC address six charge questions for each of the major research areas:

a. To what extent do the draft research frameworks describe EPA's National Program and Regional Offices strategic science priorities? How well do ORD's research programs align with those priorities? If resources allow, what are areas for increased emphasis? If resources decline, what areas might be appropriate for decreased emphasis?

b. How can ORD enhance coordination among its research programs and better ensure that they complement one another?

c. How well do ORD's proposed research directions reflect its commitment to sustainably protecting human health and the environment?

d. How do the six programs fit together as an integrated environmental research strategy, charged with informing decisions on the nation's most-critical environmental issues? Are these programs positioned to address the nation's highest-priority emerging environmental issues in the coming years?

e. Based on Board members' familiarity with efforts in the broader scientific community, how well do ORD's research programs appear to catalyze and complement environmental science programs elsewhere? What suggestions do the members have for how EPA's research programs could improve upon their leveraging with those of others?

f. How does the SAB/BOSC view ORD's activities in stimulating innovative research and what other suggestions would the SAB/BOSC have to promote innovation in EPA research?

2. OVERARCHING COMMENTS AND RESPONSES TO CHARGE QUESTIONS

Overarching comments

First, the SAB and BOSC strongly support the consolidation of research programs to align with the Administrator's priorities. The maintenance of two separate and additional mission-critical research programs (Human Health Risk Assessment and Homeland Security) was viewed by both advisory bodies as necessary. The consolidation of research activities within large thematic areas oriented to systems thinking and problem solving has created possibilities for enhanced collaboration across ORD laboratories and centers and will stimulate transdisciplinary research in ORD. This consolidation is positive and appropriate for an organization that seeks to foster innovation and maintain a nimble, flexible structure for research. Managed appropriately, these larger research programs will encourage ORD researchers to reach beyond potentially narrow disciplinary limits to formulate and conduct transdisciplinary research that meets EPA's current and future high-priority needs.

Second, ORD requested advice both on how well its proposed research directions reflect a commitment to sustainably protecting human health and the environment *and* how well ORD's draft research frameworks describe and meet the strategic science priorities of EPA's national program and regional offices. As a research organization supporting a mission agency, ORD is responsible for translating its vision of sustainability research into practical results. This is "use-inspired" research of the kind called for by the National Research Council's (NRC's) recent analysis of federal climate research (NRC 2010). The concept of sustainability potentially has great power to guide and help communicate ORD research. However, ORD's draft research frameworks were not equally successful in describing how ORD research relates to sustainability and how different research programs would serve regional and program needs. This variation is understandable, because different frameworks reflected research areas with varying scopes and histories. The Safe and Sustainable Water Resources program has a natural focus on water systems, for example, while the Safe and Healthy Communities Program reflected a broad and novel combination of human health and ecosystem-related research.

Ideally, each research framework would include sustainability explicitly in its research vision; invoke a common definition of sustainability; demonstrate clearly how planned research relates to the key components of sustainability (the environment, the economy, and society); and show how regional and program office science needs will be met. As noted in the recently released report, *Sustainability and the U.S. EPA* (National Research Council 2011), it will take time and culture change for EPA to adopt sustainability as a core principle to inform decisions and actions.

Transparency will be essential for introducing sustainability at EPA. ORD's research frameworks can advance EPA's adoption of sustainability as a core principle by more consistently and clearly describing where and how ORD research relates to sustainability. The frameworks also will need to identify more clearly legacy research that relates only tangentially to sustainability. The framework documents should be revised to describe more clearly the research goals and activities that can be accomplished by ORD within the scope of

planned resources, both human and financial. Readers of each framework should be able to understand the research questions that will be addressed, the types of ORD products that would be generated, the general time frame for that activity, and how the planned activities relate to sustainability and/or science priorities of national program and regional offices.

Third, ORD must plan for the human resources needed for the ambitious research described in the draft frameworks. Transdisciplinary, systems-oriented research requires coordination within and across research teams and involvement of stakeholders outside ORD. Both of these coordination activities are time-intensive efforts. Anticipating the resources and the expertise needed for all the activities in the research frameworks will be critical to success. With a focus on sustainability and an increased systems emphasis, all the systems of interest to EPA include human behavior. Although ORD did not request advice about how to enhance its capacity in these areas, the SAB and BOSC provide recommendations on this important topic in Appendix A of this report. Research on relevant aspects of human behavior will be crucial to understanding relevant systems and implementing solutions or programs that follow from them. Increased emphasis on social, behavioral and decision sciences within ORD is needed for the new research programs to be successful.

Below are responses to ORD charge questions that are relevant to all ORD's new research programs and some general comments on the importance of social, behavioral and decision sciences to ORD's new research directions. Section 3 provides responses specific to each major ORD research program. Appendix A provides recommendation for strengthening ORD capabilities in the social, behavioral and decision sciences.

Alignment with regional and national program office needs

Question a: To what extent do the draft research frameworks describe EPA's National Program and Regional Offices strategic science priorities? How well do ORD's research programs align with those priorities? If resources allow, what are areas for increased emphasis? If resources decline, what areas might be appropriate for decreased emphasis?

The one-to-one mapping of ORD programs with the Administrator's priorities provides a structure for aligning and understanding research programs in terms of EPA's strategic goals. The SAB and BOSC commend ORD for involving regional and program offices as stakeholders in the development of the research frameworks. ORD should continue to actively involve EPA offices in implementation of ORD research programs and evaluation of research results. Such involvement will help ORD identify areas for increased and decreased emphasis, should resource levels change.

ORD internal coordination

Question b. How can ORD enhance coordination among its research programs and better ensure that they complement one another?

The increase in the amount of communication among ORD's National Program Directors and Directors of Laboratories and Centers in the development of ORD's research frameworks is readily apparent and very positive. ORD should seek to expand formal mechanisms to promote

networking among internal researchers to improve research coordination throughout the research process in the least time-intensive manner. Examples of such mechanisms might include use of social network technology for relevant topics and co-location of researchers and exchange programs. Directed Requests for Applications (RFAs) that require research projects to coordinate across ORD research programs can also provide an incentive to ensure coordination.

Cross-cutting issues that are a priority of the Administrator, such as environmental justice, should be explicitly identified, wherever appropriate, as part of such RFAs to foster coordination and advance the Administrator's goals.

For both intramural and extramural research, ORD should identify priority cross-program research topics such as nitrogen and climate as vehicles for research coordination and building of interdisciplinary culture. Additional cross-cutting research topics should be explored in the future, such as multiple stressors, measures of ecosystem function, ecosystem services, energy and green infrastructure. Interdisciplinary collaboration and research coordination across all areas could be strengthened by development of community of practice "core" teams in areas such as communication, decision tools and modeling, important to all six ORD research programs.

Initial planning meetings to frame research problems properly at the outset will enhance ORD program coordination. Internal and external stakeholders interested in or affected by ORD's research programs should participate in problem formulation. ORD scientists from other research programs should also be present to identify issues and opportunities for synergy across programs. Problem formulation that frames issues in terms of systems and sustainability will foster increased coordination and identification of innovative approaches to prevent environmental problems before they occur. Social, behavioral and decision scientists provide expertise for problem formulation. Such experts can be especially useful in identifying opportunities for institutional flexibility and framing environmental problems in a larger social, economic, and institutional context.

ORD should also support teams to enhance coordination among research programs as projects are implemented. It will take sustained effort to maintain communication and coordination beyond the research planning phase.

Sustainability

Question c. How well do ORD's proposed research directions reflect its commitment to sustainably protecting human health and the environment?

ORD leads EPA in efforts to build a sustainability-oriented culture within EPA. Section 3 provides additional detail about how different frameworks might be revised to better reflect ORD's commitment to sustainability. Clear and consistent use of the term sustainability in each research framework and clear linkages of the concept to research programs as they develop will require careful, continued attention. It would be helpful for all research frameworks to include a list of definitions of key sustainability terms that would be consistent across ORD's programs.

As noted in the general comments above, the SAB and BOSC recommend that ORD revise each research framework to include sustainability explicitly in its research vision, invoke a definition of sustainability shared across ORD, and demonstrate clearly how planned research relates to the key components of sustainability (the environment, the economy, and society). It may be appropriate for the shared definition to be consistent with the definition used in the NRC report, *Sustainability and the U.S. EPA* (NRC 2011) or to explain why ORD has chosen a different. The NRC derived its definition from language in Executive Order 13514, which established the National Environmental Policy Act. The NRC defined sustainability as a goal and effort "to create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations."

If sustainability is ORD's goal, sustainability metrics for each research program will be needed to gauge whether research helps attain sustainability goals, even if such metrics only provide early markers of these long-term goals. Without metrics, resources may not be wisely allocated and the long-term goals missed completely. This issue is complex and worthy of research in itself because there has been a historical disconnect between the ideal of sustainability and the practice of regulating human health and the environment. Sustainability metrics and explicit discussion of how they relate to regulations would help institutionalize sustainability in a realigned ORD.

Finally, for ORD to reflect its commitment to sustainably protecting human health and the environment, the SAB and BOSC strongly recommend that ORD show leadership in two areas of research. First, ecological research must be a strong priority. Sustainability depends on understanding and protecting the ecosystems vital to human life and all life on earth. Ecosystem structure, function and services are an integral part of sustainability. Section 3.4 discusses this topic in more detail. Second, because sustainability involves policy and social dimensions, explicitly integrating social, behavioral, and decision science research into ORD's research frameworks is important to demonstrate commitment to the sustainability theme.

How ORD's six research programs fit together as an integrated environmental research strategy to address current and future critical environmental issues

Question d: How do the six programs fit together as an integrated environmental research strategy, charged with informing decisions on the nation's most-critical environmental issues? Are these programs positioned to address the nation's highest-priority emerging environmental issues in the coming years?

As noted in the general comments above, ORD's consolidation of research into six major programs aligns them with the Administrator's priorities. This consolidation of research activities within large thematic areas oriented to systems thinking and problem solving should position ORD to address high-priority emerging environmental issues in the coming years.

To be successful, all ORD programs should look for opportunities for broad problem formulation and science integration. To this end, Human Health Risk Assessment and Homeland Security research are important ORD activities and merit treatment as important

programs and so ORD's research program should be described as six inter-related programs, rather than four major programs plus two cross-cutting areas.

Three different conceptualizations of ORD research programs were presented graphically at the June 2011 SAB-BOSC meeting. Figure 1 shows the diagram presented by the ORD Deputy Assistant Administrator for Science; Figure 2 shows the diagram used for the Safe and Sustainable Water and Sustainable and Healthy Communities programs; and Figure 3 shows the diagram used in the Chemical Safety for Sustainability draft research framework.

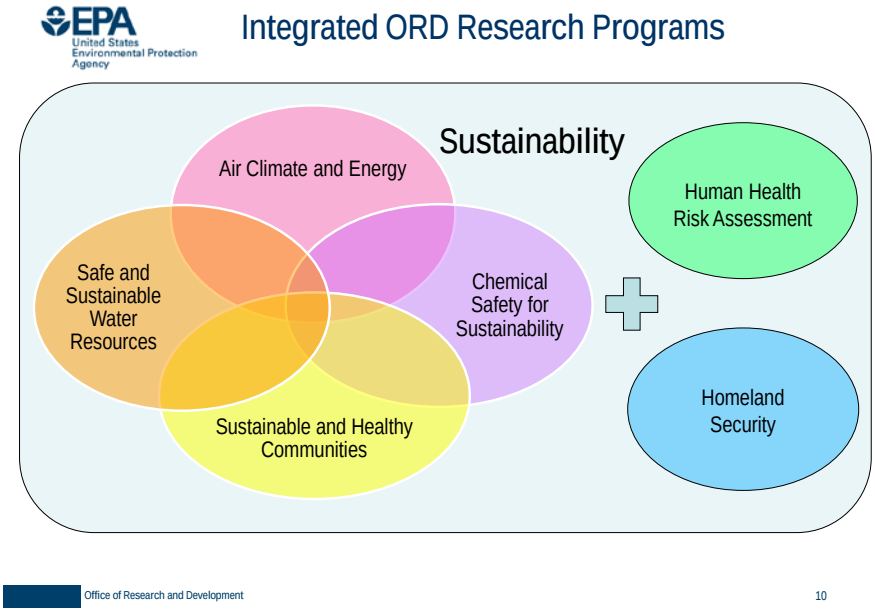

Figure 1: ORD slide showing ORD research as "4+2" programs; slide presented by the ORD Deputy Assistant Administrator for Science for the June 2011 SAB/BOSC meeting

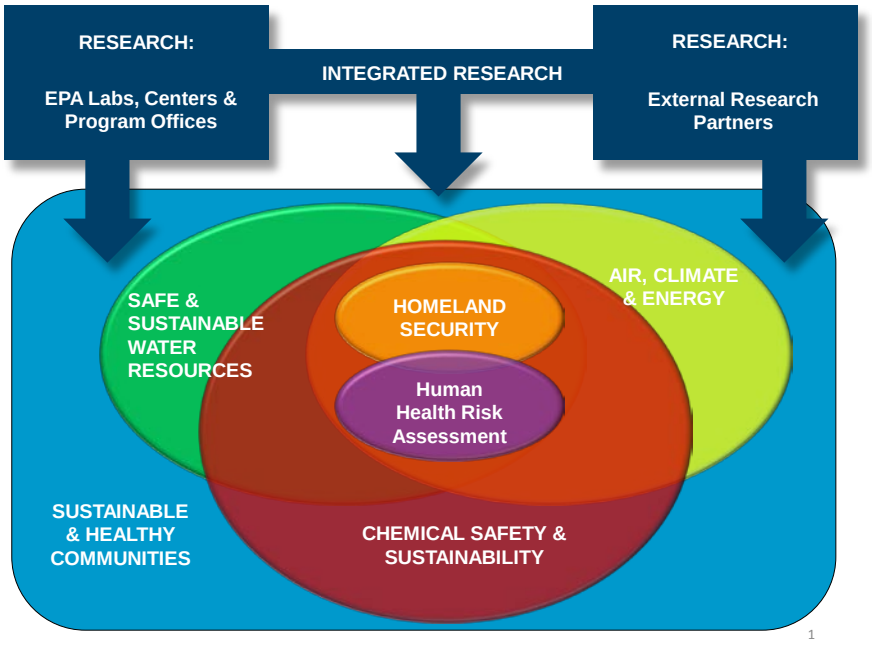

Figure 2 – ORD figure showing the Sustainable and Health Communities program as playing an integrating role across ORD research programs; figure used in the draft Safe and Sustainable Water framework and in the presentation for the Sustainable and Health Communities Programs

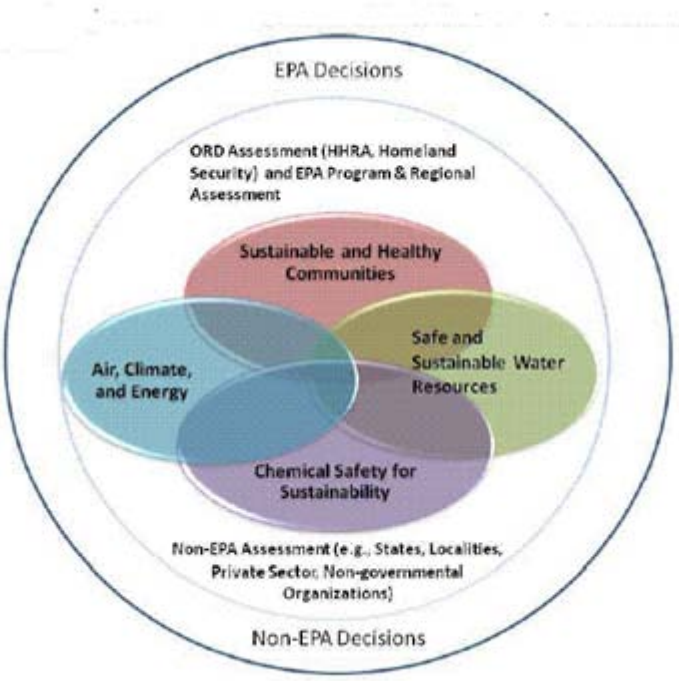

Figure 3 – ORD figure showing "Integrated EPA Research Programs Within EPA and Non-EPA Partner and Stakeholder Contexts;" figure used in the draft Chemical Safety for Sustainability Research Program framework

It is important to have a shared understanding and to use a consistent diagram to clearly communicate how ORD research programs inter-relate and how they fit within larger EPA and stakeholder science contexts. As noted in the draft Safe and Sustainable Water framework, "To provide scientific information and tools that advance environmental sustainability, the four new national program areas must contribute to and reinforce one another, and jointly work with decision makers both inside and outside EPA." The SAB and BOSC agree that Figure 2 was the most successful in conveying the importance of communication and integration among ORD programs, given all the graphics ORD presented.

Figure 2 implies that the Sustainable and Healthy Communities program should be an integrating force within ORD. This program appears to have the largest proposed investment and its draft framework describes a holistic, systems perspective on human health and ecosystem protection. Thus, ORD should provide an additional conceptual diagram with a supporting narrative that clarifies the explicit role of the Sustainable and Healthy Community Program in problem formulation overall for ORD research; its role in evaluation of ORD research products, as they are used by communities; and its role integrating ORD research at community levels.

ORD's involvement of stakeholders in EPA program and regional office and other federal partners in research planning provides a good mechanism to identify environmental issues and prioritize among them. Additional formal mechanisms for peer review and regular consultation with the SAB and BOSC and other external groups will help alert ORD to emerging issues. It may also be helpful for ORD to form an internal committee of cross-program futurists, with representatives from each research program to identify emerging issues and to consult regularly with the SAB, BOSC and other EPA groups and external stakeholders.

In parallel with these discussions, the SAB and BOSC recommend that each ORD program identify the core expertise areas that they wish to maintain or develop within their own program and those they wish to rely on through active collaborations with other ORD or EPA programs or through collaborations with outside research organizations. Because EPA resources are limited, it would be helpful for each research framework to identify the key science partnerships ORD is developing to provide research and expertise to supplement ORD's own science base. ORD should also build capacity to develop responses to emerging environmental issues by evaluating how EPA has responded to science topics that have emerged recently, such as nanomaterials, the Deepwater Horizon oil spill, hydraulic fracturing or natural disasters. EPA could then identify which processes worked to anticipate those topics and to develop the needed science, and which processes were not effective.

Environmental issues are not always predictable. Therefore, the agency needs nimble research and assessment programs to address these unpredictable issues and should strengthen its human resources and organization to provide maximum resilience. Being nimble requires that the workforce be willing and able to undertake new research tasks, work in teams and work in new ways. ORD's re-aligned structure may enhance this by allowing a more free flow of personnel across programs to provide the expertise where it is needed in a timely fashion. Workforce continuing education is also critical. The development of programs (visiting scholars, post-doctoral programs, or other collaborative practices with outside scientists) designed to develop and maintain the appropriate skill sets within the agency will be important.

One area where ORD can increase its capacity to address future critical environmental issues involves the exploration of opportunities offered by computational analysis and modeling of complex environmental data. Such analysis and modeling (sometimes called "Environomics"), includes enhanced monitoring, technologies for understanding data-rich environments, data mining and data simulation. These kinds of efforts may provide new opportunities for EPA to understand the environment and pair this enhanced understanding with chemical forecasting useful for predicting public health and environmental impacts. Such an approach could potentially provide new, creative and innovative approaches for preventing and addressing the causes of complex environmental problems such as Gulf hypoxia and averting water quantity and water quality problems likely to arise from current exploitation of groundwater resources. Similarly, such research could help EPA attain a possible future where EPA could work with the "exposome" (i.e., all cumulative risks to people) and match this "exposome" information with genetic and epigenetic profiles to understand and manage environmental risks.

Ability to catalyze and complement environmental science programs outside EPA

Question e. Based on Board members' familiarity with efforts in the broader scientific community, how well do ORD's research programs appear to catalyze and complement environmental science programs elsewhere? What suggestions do the members have for how EPA's research programs could improve upon their leveraging with those of others?

Collaboration with other federal agencies and partners in other countries is increasingly important for ORD because of the ambitious scope of ORD's new research frameworks and the limitations of EPA's budget and the budgets of all potential partners. The Chemical Safety for Sustainability program offered a premiere model of collaborative and complementary efforts with other federal agencies (i.e., Tox21) and European partners (e.g., the Joint Research Center in Ispra, Italy). This level of effort and coordination needs to be extended to other ORD research endeavors. ORD should actively explore formal and creative informal ways of undertaking inter-agency and international collaboration.

ORD should continuously stimulate interactions between EPA and outside scientists. One mechanism could involve a program of roundtables with outside experts. Visiting scientists could be brought into the laboratories and centers for longer periods (e.g., one year) to cross-fertilize ideas on how to make sustainability an organizing principle at EPA.

To ensure that ORD's new research directions develop deep roots, the office should develop a mentoring and leadership development program. There will be a need to advise young researchers about their projects, publications and career objectives and to foster the culture of sustainability-related research at ORD. Mentors should be trained to ensure that their advice to mentees supports integrated transdisciplinary research and the sustainability research paradigm. This internal human resource effort should complement a strategy to recruit young scientists with expertise and interest in sustainability science.

ORD should set defined goals to catalyze and complement environmental science programs outside EPA and seek BOSC review and assessment related to this topic every two years.

Innovation

Question f. How does the SAB/BOSC view ORD's activities in stimulating innovative research and what other suggestions would the SAB/BOSC have to promote innovation in EPA research?

ORD's efforts to foster innovative research are impressive. The EPA has thought seriously and operationally about ways of energizing the creative nature of ORD scientists and has begun to explore ways of enhancing innovation as a fundamental part of ORD programs. Creating an ORD Chief Innovation Officer position is a bold, positive step, and the Pathfinder Innovation Program is a creative and important initiative. New approaches, such as "crowdsourcing," to meet research challenges can be appropriate ways to tap creative research outside EPA.

To further promote innovative research at EPA, ORD should develop metrics to evaluate the contributions of the Chief Innovation Officer and programs such as Pathfinder. ORD should define "failure" and "success" as it further develops its innovation program and reach agreement on an acceptable failure rate for innovation efforts. The SAB and BOSC recommend that ORD plan to assess the value of key components of its innovation effort, including the role of the Chief Innovation Officer, within the next two years. ORD should also develop and maintain a mentoring and scientist development program that encourages creative and innovative approaches, as well as a reward system, perhaps similar to EPA's Scientific and Technological Achievements Award program to recognize successful researchers who think outside the box. ORD should also look for opportunities to stimulate innovative research in the social, behavioral, and decision sciences related to EPA's mission.

In addition, EPA has a role in promoting innovative environmental research outside EPA and, indeed, in leading the country toward the adoption of more sustainable practices. Innovation could be enhanced by emphasizing innovation in EPA's extramural grant programs and by making EPA data easily accessible to the outside community of scientists who could use these data in creative ways. Highly innovative external scientists can compete for extramural grants, participate in brainstorming sessions or serve as reviewers for Pathfinder proposals and projects. Consortia projects (extramural scientists working very closely with agency scientists on a project) can help build an even greater resource of expertise and innovation throughout the country and not just at EPA. ORD might also consider a multi-agency Pathfinder Innovation Project that would tap the expertise of environmental scientists from other federal agencies. EPA needs to drive innovative research not just inside the agency but also within the external scientific community.

Innovation often comes through interactions among scientists from different fields, as well as scientists from different organizations (academic research, industry, non-governmental organizations, other federal agencies, state and local governments). Thus, workshops where the agency can present proposed approaches and ask for feedback from outside the agency would be extremely helpful.

Social, behavioral and decision sciences

ORD did not request that the SAB and BOSC address a specific question related to social, behavioral and decision sciences, but this topic must be addressed in this report because sustainability goals and all the systems of interest to EPA include human behavior. Research on relevant aspects of human behavior is crucial to understanding the systems and implementing solutions or programs that follow from them. Increased emphasis on social, behavioral and decision sciences within ORD is needed for the new research programs to be successful.

ORD research in the social, behavioral and decision sciences can help with: 1) problem formulation, development of systems perspectives, and identification of alternatives; 2) engagement in participatory processes; 3) understanding behavior, behavioral responses and incentives; and 4) evaluation of alternative options and tradeoffs (e.g., impact analysis, benefit-cost analysis). ORD, however, does not currently have the capacity, internally or through external funding, to conduct this research.

The SAB and BOSC took the initiative to develop Appendix A of this report to outline ways ORD can expand its capabilities in these important scientific disciplines. Appendix A provides recommendations about: specific roles social, behavioral and decision scientists might play in ORD; specific sub-disciplines/fields of social, behavioral and decision science that might best meet identified research and decision support needs; where ORD might find scientists with the relevant types of training, experience, expertise and interests; and how ORD might best organize and support social, behavioral and decision science.

3. ADVICE SPECIFIC TO ORD'S MAJOR RESEARCH PROGRAMS

3.1. Safe and Healthy Communities

Background

The draft research framework identified the following goal:

> To inform and empower decision-makers to equitably weigh and integrate human health, socio-economic, environmental, and ecological factors into their decisions in a way that fosters community sustainability.
>
> To achieve this goal SHC will provide information, approaches, and tools that will help decision-makers in communities and in federal, state and tribal regulatory and community-driven programs to more effectively and transparently assess current conditions in the built and natural environments, to evaluate the implications of alternative policies and management actions, and to identify indicators to measure results.

The draft framework identified the following problems as the focus of attention:

> Current trends in population and the way we use of energy, food, and materials have created environmental threats to sustainability that include the erosion of critical ecosystem services and the compromised ability of the environment to tolerate increasing levels of pollution. While technological breakthroughs will likely continue to slow some negative environmental trends, we still face many challenging problems. Not only are human health and ecosystem services negatively affected by cumulative exposures to multiple toxic pollutants and a changing physical environment, these effects also have economic and social implications, such as resultant costs for health care, cost for technologies to replace some ecosystem services, and costs to enhance social justice, at scales ranging from local to international. Because of the increasing pressures on the environment, it is clear that future approaches to protecting human health and the environment will not support sustainability over the long term if they:
>
> - Fail to adequately consider the inextricable link between our natural environment and human well-being, including economic and social aspects;
> - Focus on regulating one energy or materials stream or chemical at a time, rather than on preventative strategies or strategies that optimize management of multiple chemical and energy streams in order to achieve the most environmentally beneficial, cost-effective and socially acceptable outcome; or
> - Lead to unintended consequences, or fail to produce valuable co-benefits, because of a lack of systems thinking.

The draft framework identified three major themes:

> Theme 1: Working with communities to develop comprehensive approaches to become more sustainable.
>
> Theme 2: Developing decision analysis methods, tools, models, data, and metrics that support community sustainability.
>
> Theme 3: Targeting high-priority agency research, i.e., Contaminated Site Management and Restoration; Waste and Materials Management- Support for Regulations, Policy, and Guidance; Nitrogen- Support for Regulation; Environmental Justice Topic; Children's Health; and the Report on the Environment.

General comments

The Sustainable and Healthy Communities research program is visionary; community-based outreach and interactions are essential to sustainability. The new research area frames environmental issues in positive terms and is not bound by narrow regulatory constraints. The program has the potential to catalyze public support for environmental protection and for the EPA. Several other aspects of the program also are unique: 1) the Sustainable and Healthy Communities program focuses on the local or community level (rather than on national-level issues) because it is place-based; 2) it takes a holistic, systems perspective; and 3) it focuses on public participation and collaboration. Because this program is novel and ambitious, it will require special attention to reorient agency clients and the public to its value and importance. The research program will require a great deal of new and challenging research on place-based environmental problems and social, behavioral, and decision science issues. ORD, however, does not possess the required expertise in social, behavioral and decision sciences to address this need.

The SAB and BOSC understand the value of providing decision support for communities ("empowering" local decision making), but find that the draft framework is vague and lacks focus. The draft framework does not describe the decision-makers/stakeholders or discuss whether the objectives of decision-makers necessarily reflect community goals or EPA objectives. Essential questions regarding the definition of the relevant community and whether community objectives align with broader national objectives are not identified, much less answered, in the document.

The framework should articulate a clearer vision for ORD's role in providing assistance to communities. In its current form, it is not clear whether ORD plans to provide decision tools or technical support at some initial phase or whether it plans to be an active participant in implementing tools. ORD does not currently have experience or expertise in community-based implementation. ORD will need to develop both if it intends to be active implementing environmental tools in communities. The framework should describe clear expectations for ORD's planned community work, as well as an exit strategy so participating communities and readers of the framework documents will understand the extent of the commitment by ORD to actively engage with communities. ORD should clearly describe the metrics to be used for evaluating the program and commit to a process for evaluating it over time.

The nature and level of integration of research across the three themes within the Sustainable and Healthy Communities program is unclear. The three themes represent very different kinds of activities and include "cutting edge" research, as well as support of "conventional" regulatory mandates. Theme 1 is the most innovative but will receive less than ten percent of the program's resources initially. EPA's commitment to this novel activity must be robust and sustained for the program to take root and grow.

Finally, the Sustainable and Healthy Communities program includes essentially all of the ecological research in ORD. As such, there is a need to support ecosystem science within this program. Ecosystem services and benefits are contained as one component, among others, in Theme 2 of the SHC Research Program. The draft framework contains no discussion of ecological science apart from ecosystem services and benefits. Ecological science is necessary to understand ecosystem services and benefits and appears to be under-funded and under-emphasized in the proposed research structure.

Ecosystem science, which has seen a continued decline over the past decade, has been reduced to only $60 million, about ten percent of the ORD budget. Ecosystem science is vitally important for understanding how ecosystems function. From the perspective of EPA, ecological research is important for understanding ecological processes that underlie healthy ecosystems and the quality and quantity of the services offered by ecosystems to communities. In addition to understanding ecological processes, there is important ecological and social, behavioral and decision science research needed to translate ecological processes to ecosystem services. This research will help to analyze the benefits to the community of these services and to predict the changes in the provision of services that would result from various actions/policies/behaviors. Consequently, the SAB and BOSC strongly recommend increased support for ecological research and related social, behavioral and decision science research.

Alignment with regional and national program office needs

The Sustainable and Healthy Communities program clearly reflects an effort to integrate the Administrator's top priorities at the community level. Within the program, areas for increased emphasis might include children's health; social, behavioral and decision science research; and epigenetics to provide markers of exposure to chemicals. Integrated transdisciplinary research and coordination across ORD programs should provide efficiency. ORD may identify areas for reduced emphasis if it finds that other agencies' environmental research programs can complement EPA's research efforts.

Alignment with EPA regions is critically important to this program. ORD should revise the draft framework to identify more clearly how it will work with and through EPA regional offices in its efforts to provide tools to communities. The linkage with EPA regions is important because regions can help build support for this program and also help ORD with implementation.

ORD internal coordination

The Sustainable and Healthy Communities program can serve an essential coordinating role within ORD. Working with communities to define sustainability goals and frame problems in systems terms can help ORD (and EPA) break down media-specific and disciplinary silos. One vision for the program is for it to use, test, and evaluate research products from other ORD programs and provide feedback to guide more focused research from those programs in the future and the SAB and BOSC support this vision. ORD should revise the draft framework for the Sustainable and Healthy Communities program to describe its role in these terms.

There are multiple examples where the Sustainable and Healthy Communities program can utilize the expertise and information developed by other ORD research programs. The Safe and Sustainable Water Resources program is closely aligned, and the Homeland Security program, with its focus on anthropogenic and natural disasters, provides another example.

Sustainability

At a theoretical level, the Sustainable and Healthy Community program directly reflects ORD's commitment to sustainably protect human health and the environment. The SAB and BOSC's introductory general comments in this section, however, identify concerns about how this program will be operationalized at the community level and concerns about possible misalignment between local and national perspectives.

ORD should take special care in designing and evaluating components of its program that develop and provide decision support tools to empower communities. A revised research framework should define the "communities" and "decision makers" ORD envisions and whether communities may need certain kinds of education or information to use the decision support tools ORD provides, because community decisions often are made on shorter temporal scales and smaller spatial scales than EPA envisions. ORD also needs to articulate how its research is scaleable for use by different sized communities as well as at different decision maker levels.

Capacity to address current and future critical environmental issues

This visionary program potentially would have the capacity to address current and future critical environmental issues, but it will need to identify clearly where ORD will provide leadership and where it will play a supporting role in addressing issues. Success in implementing activities related to Theme 1 depends on effective partnerships with other agencies and nongovernmental organizations as they work with communities to address high priority issues. As noted above, the results of the Sustainable and Healthy Communities program may not necessarily align with national priorities if goals of communities differ from national priorities.

Ability to catalyze and complement environmental science programs outside EPA

ORD's progress in adopting integrated transdisciplinary research is consistent with momentum elsewhere to pursue such integrated approaches. ORD has made a positive commitment to

focus on ecosystem services and has developed important partnerships with other agencies and nongovernment organizations. There are, however, significant additional opportunities to work with other countries and international research organizations to advance ecosystem science and research and bring these results to EPA and local decision makers. Current and emerging international initiatives are described in the recent Report to the President *Sustaining Environmental Capital, Protecting Society and the Economy* (President's Council of Advisors on Science and Technology 2011).

There are also opportunities to complement and leverage research being conducted by the Department of Energy and Department of Defense on site contamination and cleanup issues and to explore partnerships with non-governmental organizations that that work closely with communities.

One area for focus is to develop effective mechanisms for catalyzing, complementing and leveraging research in the social, behavioral and decision sciences. ORD should explore new opportunities to partner with the National Science Foundation to support extramural research in this area, such as the Foundation's Sustainability Research Networks Competition (SRN) and its Dynamics of Coupled Natural and Human Systems (CNH) program. ORD might explore establishment of a clearinghouse for community-level data and metrics related to sustainability (e.g., "urban metabolism").

Innovation

Community-based research offers a wide variety of new opportunities for innovation. ORD should promote opportunities for community-based data collection, monitoring and reporting, subject to standard quality controls. The Sustainable and Healthy Communities program could benefit from investments in related technological innovation, such as hand-held monitoring devices or mobile phone applications for collecting and transmitting environmental or public health data. Such new technologies would involve new ways to engage communities, which would be a focus of innovative social, behavioral and decision science research in itself.

Social, behavioral and decision sciences

The Sustainable and Healthy Communities program offers many potential roles for social, behavioral, and decision sciences. Because ORD does not currently have the capacity, internally or through external funding, to conduct this research, it will be important for ORD to explore how other agencies have engaged social, behavioral, and decision scientists in place-based environmental decisions (e.g., the U.S. Forest Service; U.S. Department of Agriculture Economic Research Service; U.S. Department of Agriculture Conservation Reserve Program; the Department of the Interior; the National Oceanic and Atmospheric Administration; and the National Park Service). Appendix A of this report describes how ORD might begin to develop a capability in these disciplines and access expertise outside EPA.

3.2. **Air, Climate and Energy**

Background

ORD is reorganizing this research program around sustainability and environmental solutions. The draft research framework identified the following problem statement:

> Protecting human health and the environment from the effects of air pollution and climate change, while sustainably meeting the demands of a growing population and economy is critical to the well-being of the Nation and the world. As we explore solutions to prevent and reduce emissions, we are challenged by uncertainties surrounding the complex interplay between air quality, a changing climate, and a changing energy landscape, and the subsequent human health and ecological effects attributed to exposure to an evolving array of pollutants in the atmosphere.

The draft framework identified the following problems as the focus of attention:

- The multipollutant nature of air pollution in order to develop effective air quality strategies;
- The impacts of climate change and the interactions between adaptation and mitigation;
- The human health and environmental impacts of current and future energy options;
- The populations most susceptible to poor air quality and the populations and ecosystems most vulnerable to climate change;
- The expanding and contracting scales of environmental problems that range from global to local; and,
- The social, behavioral, and economic factors that influence the effectiveness of air quality and climate policies.

The vision articulated in the framework is:

> To provide cutting-edge scientific information and tools to support EPA's strategic goals to take action on climate change and improve air quality.

The draft framework proposed that ORD would provide the policy-relevant research needed by EPA partners to assess impacts, prevent and reduce emissions, and respond to changes in climate and air policy.

General observations

The vision for the Air, Climate and Energy program includes sustainability as a paradigm for research, but there exists a fundamental disconnect between sustainability and the legislative mandates of the Clean Air Act. ORD should address clearly how it will integrate the two needs for research and how it will trade off between them. This tension will grow and may increasingly need to be addressed if EPA's budget is constrained. One possibility is to build on EPA's historic strengths. Air quality monitoring has been a major strength of ORD in the past and it contains a unique opportunity for changing the future of research and perhaps the future of air quality. Sensor development and reporting networks provide opportunities that are ripe if research is undertaken wisely. In the past, the EPA has conducted monitoring for the sake of compliance. EPA might consider shifting or using some of that monitoring for decision-making and hypothesis testing as well.

In the climate arena, biofuels is one area where EPA has a mandate to prepare an annual report to Congress on greenhouse gas effects from biofuels and the Renewable Fuel Standard. Although EPA has little authority related to energy and little authority on climate other than that provided through the Supreme Court ruling and the Endangerment Finding, the lack of regulatory responsibilities could free ORD to pursue unfettered, innovative and creative research that supports voluntary and/or information-based programs.

Alignment with regional and national program office needs

In general, the draft framework reflects the strategic science priorities of programs and regions. The SAB and BOSC support the increased emphasis on energy choices and the nexus between air, climate, and water. A focus on multi-pollutants also integrates well with this emphasis. The recent SAB report on reactive nitrogen, *Reactive Nitrogen in the United States: An Analysis of Inputs, Flows, Consequences, and Management Options - A Report of the Science Advisory Board* (U.S. EPA SAB 2011b) provides a clear example of the need to address pollutants from a multi-media, multi-source perspective. Research directed at single pollutants is being restructured within the multipollutant framework and that is appropriate. The framework should be revised to describe more clearly where multi-pollutant efforts are under way and how different multi-pollutant activities are being sequenced.

The transition from a focus on single pollutants, single media and end-of-pipe pollution control to a multi-pollutant approach with emphasis on reducing emissions at the source requires creative regulations. Such regulations would go beyond the existing technology-based, pollutant-based standards to consider other regulatory paradigms. Social, behavioral and decision sciences could be used to examine the effectiveness of such approaches relative to the status quo and develop strategies for strengthening the incentives for innovating and adopting techniques for preventing pollution at source.

Despite its obvious strengths, however, the framework could better describe the transdisciplinary nature of the research needed. Greater emphasis is needed on climate change research to reduce greenhouse gas emissions, both from a technological standpoint (like carbon sequestration) and also from a social and behavioral standpoint (how to get the desired environmental behavior from people and industry without mandates or command-and-control

legislation). Research in the social, behavioral and decision sciences is needed on how people come to understand climate change, their risk perceptions and what motivates them to take action. How do these attitudes develop? People value present goods far more than future goods (discounting). What would help people perceive environmental technologies as viable? How do we ensure adoption of sustainable technologies? In addition, the intersection of science and policy should be a distinct research area within the Air, Climate and Energy program. This topic has been a lively focus of research for the past ten years (Mitchell et al. 2006; Clark et al. in press; Sarewitz & Pielke 2007; Graffy 2008; Weible et al. 2010; Dilling and Lemos 2011). The example of the Intergovernmental Program on Climate Change (U.S. Global Change Research Program 2011), among others, has stimulated research on the relationship of policy to science that could be useful to ORD.

It will be important for the Air, Climate and Energy program to regularly check that its research is aligned with regional and national program office needs. Research should begin with the question in mind, clearly stated and properly framed. The NRC report, *Science and Decisions* (NRC 2009), provides a good guide in this respect. ORD should conduct regular synthesis activities to determine whether the research conducted has solved the problem and to identify additional knowledge gaps. In this effort, ORD should formulate the question (hypothesis) clearly and then research its every aspect holistically. One example might be: "black carbon should be the first pollutant to be regulated for overall Air, Climate and Energy program effectiveness including air quality/human health, climate change mitigation, and energy choices." EPA may find that some programs that have fulfilled their original objectives, like the near road program, can be discontinued to leave room for other program areas, such as biomass, to grow. Some modeling exercises (e.g., source apportionment) may be ready for decreased emphasis. Biomass could be emphasized for a period, perhaps, and then be phased out. However, ORD synthesis activities could help illuminate unintended consequences, such as when biomass programs result in wood burning in a school boiler. Smoke exposure to children presents potential hazards that need to be examined.

ORD internal coordination

The Air, Climate and Energy program is closely related to the Sustainable and Healthy Communities and the Safe and Sustainable Water Resources research programs. Integrated assessments, driven by particular problems at the community, regional or national levels can be used to bring them together. Addressing problems related to climate change, water quantity, or reactive nitrogen, as recommended by the SAB (U.S. EPA SAB 2011b) may provide useful foci for integrated assessments.

Sustainability

ORD should reference sustainability as a new paradigm for driving research in the Air, Climate and Energy framework. The vision statement for this research program as well as the problem statement should explicitly reference sustainability. The framework should explicitly address the possible disconnect between the ideal of sustainability and the practice of regulating human health and the environment, as required by the Clean Air Act. Sustainability metrics and how they articulate with regulations would help to better define sustainability in a realigned ORD and how to achieve sustainability.

The SAB and BOSC recommend that ORD undertake research to define the benefits of moving from a more technology-based regulatory system to a performance-based regulatory system that provides incentives for sustainable solutions. There may be solutions that result in ancillary benefits of decreasing the cost of regulations to the regulated community and stimulating innovation. ORD can help EPA change the paradigm for environmental protection through identifying sustainable alternatives for risk managers' consideration. ORD should expand its current portfolio to help decision makers identify and understand decision options related to sustainability. ORD could design and analyze scenarios related to changing air quality and different strategies for adapting to climate change. Any adaptation strategy will almost certainly be accompanied by environmental consequences that might be the focus of future research.

ORD should consider programs to sponsor senior academic researchers for one-year visiting sabbaticals to seek their suggestions about how to transform the Air, Climate and Energy program into a program fully integrating sustainability.

Capacity to address current and future critical environmental issues

ORD's six research programs fit together and offer the possibility of addressing environmental issues that go beyond EPA's direct statutory mandates. The appendix to ORD's draft framework for the Air, Climate and Energy progra articulates science questions and areas of integration within the research program and across ORD programs. Cross-cutting issues such as nutrients (i.e., reactive nitrogen) and climate change are highlighted in the discussion. This design provides an effective roadmap for current and future critical issues and collaboration across ORD research programs. The appendix could even be more effective if it were extended to include collaboration with other key research partners, such as the Department of Energy.

Innovation

The Air, Climate and Energy program should encourage and stimulate relevant behavioral, social, cognitive and decision research both within the agency and extramurally. As an example, research is needed on how to persuade people to change their behaviors regarding energy use. Examples include being receptive to conversion to energy-efficient technologies for lighting, buying higher mileage cars, etc. There is a substantial amount of basic research to be conducted on the psychology of persuasion, on the subjective time-discounting factors that affect people's willingness to spend resources now for future gains and on risk communication. The SAB and BOSC recommend that the Air, Climate and Energy program bring in a few senior behavioral, social, cognitive and decision science experts for one-year visiting sabbaticals to cross-fertilize this new area.

3.3. **Safe and Sustainable Water Resources**

Background

ORD has restructured its historical Drinking Water and Water Quality research programs into a single research program called Safe and Sustainable Water Resources. The new program strives "to develop sustainable solutions to 21st century water resource problems by integrating research on social, environmental, and economic outcomes to provide lasting solutions." The draft research framework identified the following problem statement:

> Increasing demands for sources of clean water, combined with changing land use practices, growth, aging infrastructure, and climate change and variability, pose significant threats to our Nation's water resources. Failure to manage our Nation's waters in an integrated, sustainable manner will limit economic prosperity and jeopardize both human and aquatic ecosystem health.

The draft framework explicitly identified two major challenges:

1. Provide the best science in a timely manner to allow faster, smarter management decisions on our existing problems; and
2. Get our science out in front of tomorrow's problems by developing and applying new approaches that better inform and guide environmentally sustainable behavior.

Two research themes are identified:

> Research Theme 1 – Sustainable Water Resources: Ensure safe and sustainable water quality and availability to protect human and ecosystem health by integrating social, economic and environmental research for use in protecting and restoring water resources and their designated uses (e.g., drinking water, aquatic life, recreation, industrial processes, and other designated uses) on a watershed scale.
>
> Research Theme 2 –Sustainable Water Infrastructure Systems: Ensure the sustainability of critical water resources using systems-integrated water resource management where the natural, green and built water infrastructure is capable of producing, storing and delivering safe and high-quality drinking water, and providing transport and use-specific treatment of wastewater and storm water.

The framework articulates the vision for this research program as follows:

> Safe and Sustainable Water Resources uses an integrated, systems approach to research for the identification and development of the scientific, technological and behavioral innovations needed to ensure clean and adequate and equitable supplies of water that support human well-being and resilient aquatic ecosystems.

Alignment with regional and national program office needs

The Safe and Sustainable Water Resources draft framework effectively describes the alignment of ORD's research with regional and national strategic goals. It also describes an appropriate prioritization process for identification of research focus areas. The prioritization process was notable for its engagement with a wide range of internal and external stakeholders. It will be important for this research program to continue to engage a wide range of stakeholder groups, including EPA programs and regions, as research activities develop. If budget cuts require future reductions, the prioritization process now in place should enable determination of the highest priority needs and activities that can be deferred or cut.

The integration of the drinking water and water quality research programs is a very positive development and will provide important new synergies especially with respect to water treatment technologies relevant to drinking water, wastewater, and storm water; evaluation of microbial risks; and evaluation of aquifer storage and recovery.

ORD internal coordination

The framework includes a section describing how the research program is designed within the context of ORD's restructured research programs. As part of that description, the Safe and Sustainable Water Resources draft framework contains a diagram reproduced as Figure 2 in this report. This figure provides an effective way to communicate how the research program inter-relates with ORD science and science generated outside ORD.

Sustainability

The Safe and Sustainable Water research topics were clearly formulated with the sustainability theme as guide. The framework provides a useful list of definitions that explain what is meant by sustainability and a "sustainable solution."

Ability to catalyze and complement environmental science programs outside EPA

The draft framework provides an excellent, detailed description of research needs, objectives and science questions. The description identifies where science activities of EPA's partners complement ORD's efforts and where collaboration with EPA is needed to stimulate partner's research on topics of importance to EPA. Due to the nature of the challenges and limits to scientific capacity within EPA, ORD should take a leadership role in establishing multi-agency partnerships that leverage resources and provide comprehensive solutions.

ORD should evaluate existing mechanisms for inter-agency collaboration and build on them to maximize the potential to catalyze and complement environmental science programs outside EPA. Programs such as the Strategic Environmental Research and Development Program, the Food Emergency Response Network, the Chesapeake Bay Program and a variety of programs created by U.S. Department of Agriculture's Natural Resource Conservation Service (e.g., the Mississippi River Healthy Basins Initiative, rural programs for small communities and animal feedlot management programs) offer opportunities to learn from and build upon. Such mechanisms can be used to promote networking with external researchers.

Innovation

The draft framework identifies opportunities to use the Science to Achieve Results (STAR) grant program to support technical development and innovation goals. Specific detail is provided within the overall context of objectives and science questions. Innovative technologies are especially important to the water infrastructure theme. The Small Business Innovation Research program may be a resource for this particular area.

Social, behavioral and decision sciences

Social science issues permeate all of the priority research topics for the Safe and Sustainable Water Research program. Social science research should be integrated in all of the programs in explicit ways. Appendix A of this report provides more detail on the types of science and research that the SAB and BOSC recommend that ORD consider undertaking or developing through collaborative efforts.

3.4. **Chemical Safety for Sustainability and Human Health Risk Assessment**

Background

Chemical safety and human health risk assessment are two functionalities that inform each other. The Chemical Safety for Sustainability Program must provide information that is useful to the Human Health Risk Assessment Program, and this latter Program must inform and understand the information derived from the former. Therefore, because these two programs must function in partnership, the SAB and BOSC provided an integrated discussion of ORD's draft frameworks for these programs.

The draft research framework for the Chemical Safety for Sustainability program identified the following problem statement:

> Although chemicals are essential to modern life, we lack innovative, systematic, effective, and efficient approaches and tools to inform decisions that reduce the environmental and societal impact of chemicals while increasing economic value.

The vision articulated in the framework is:

> EPA science will lead the sustainable development, use, and assessment of chemicals by developing and applying integrated chemical evaluation strategies and decision-support tools.

The Chemical Safety for Sustainability identified the following objectives:

- Creating tools that inform sustainable chemical/material design and use
- Developing methods for much faster screening and prioritizing
- Providing the scientific knowledge and tools to effectively understand real-world risks
- Developing assessment approaches that are tailored to specific decision contexts
- Considering where impacts may occur throughout a chemical's life cycle.

The draft framework for the Human Health Risk Assessment program identified the following problem statement:

> Agency decisions must be based on defensible scientific evaluations of data relevant to assessing human health impacts. Currently, the demand for such assessments is not being fully met, particularly in terms of the number of existing and new chemicals in need of assessment, the types of risk characterization outputs needed to inform decision making, and the tools and data needed to support assessments.

The vision articulated in the framework is:

> The Agency will generate timely, credible human health risk assessments to support all priority Agency risk management decisions, thereby enabling the Agency to better predict and prevent risk.

The four primary themes of the Human Health Risk Assessment program are:

- Integrated Risk Information System (IRIS) health hazard and dose-response assessments;
- Integrated Science Assessments (ISA) of Criteria Air Pollutants;
- Community Risk and Technical Support for exposure and health assessments; and
- Methods, models, and approaches to modernize risk assessment for the 21st century

Alignment with regional and national program office needs

In general, the draft framework documents were written from a theoretical perspective. The SAB and BOSC recommend that ORD revise the documents so they more clearly communicate the intended research and its strategic science priorities. The term "sustainable" and its derivative forms were used in different ways in the draft documents and there was little explanation of their meaning. It would be useful to define this term as it is employed in the documents. In addition, there were several other definitional problems, e.g., inherency, etc., that have internal meaning at EPA but are not well known to others. The SAB and BOSC recommend that the terms employed in the framework documents be fully defined in concise, operational ways.

It is evident that ORD is increasing efforts to collaborate internally across research programs and across program and regional offices. This collaboration promotes alignment between ORD's programs and regional and program office needs. To illustrate this alignment, ORD should identify more clearly where there are novel science products that will be developed because of this coordination/alignment with regional and program office stakeholders and how these outputs would be measured. The draft Chemical Safety for Sustainability framework should highlight activities related to green chemistry and computational toxicology and how these may be employed by the Human Health Risk Assessment Program. The draft Human Health Risk Assessment framework should highlight how the program will meet high priority program and regional needs, including the demand for an increased number of values in the Integrated Risk Information System.

Regarding prioritizing programs for increased or decreased emphasis, the SAB and BOSC recommend that ORD conduct analyses to help develop criteria for prioritization. One type of analysis could help identify data gaps and prioritize research based on scheduled regulatory needs and other deadlines. Once such analyses are conducted, ORD should define clear short-term and long-term goals that can be measured with respect to what is to be achieved, the resources required and the timetable needed. In addition, because it is difficult to predict specific environmental issues for the future, it will be important to have a focused and well-

defined path for strategic and rapid responses to emergencies. An analysis of the lessons learned from the 2010 Deepwater Horizon oil spill may help identify gaps. ORD should also conduct or support social, behavioral and decision science research and analyses to understand the public's perception of uncertainty and risk assessment. Shedding light on public attitudes and knowledge will enable the agency to communicate environmental science more effectively.

Streamlining across agencies (e.g., the National Center for Toxicological Research in the Food and Drug Administration, the U.S. Geological Survey and the National Toxicology Program in the National Institutes of Environmental Health Sciences) should continue so that redundancy is minimized. Collaborative efforts need to be defined and the process transparent to minimize any tendency for compartmentalization (i.e., creating 'turf lines' or stovepipes). Collaborations such as Tox21 will provide a better ability to leverage the resources of various agencies toward the EPA mission. This may require a common lexicon to be developed across agencies.

Given EPA's role as a leader in environmental research, extramural research is an important way for the agency to tap the talent and enhance innovation at universities and other research institutions. Extramural research will increase the EPA's ability to react flexibly to changes in priorities and associated personnel expertise needs. SAB and BOSC, however, note that extramural programs should not be undertaken in *lieu* of or at the expense of EPA's intramural research activities.

Ability to catalyze and complement environmental science programs outside EPA

EPA is a clear leader in the fields of environmental sciences – both in terms of technology development and in terms of research in a wide variety of fields that support the technology. For a variety of reasons, academia and industry have fallen behind and it is important for EPA to support and enhance current efforts. This could be enhanced with focused extramural grants on topics of translational or targeted science. In the area of toxicity testing, the National Center for Computational Toxicology (NCCT) has made a significant effort to develop collaborative and complementary efforts with other federal agencies (i.e., Tox21) and European partners (e.g., the Joint Research Center in Ispra, Italy). This level of effort and coordination needs to be extended to other ORD research endeavors.

ORD's research programs are generating novel scientific information that is not yet used in regulatory programs. Mechanisms need be developed to bridge this gap between ORD's innovative work and the scientific information actually used for decision making. There is a need for both the translation of this work into risk assessment as well as the incorporation of this work into guidelines employed by risk assessors. There should also be more coordination between the Chemical Safety for Sustainability program with programs such as Design for the Environment to enhance the activities of each.

The SAB and BOSC recommend that ORD explore mechanisms for industry-government collaboration. There are good examples of industry-government collaboration in Europe, Australia and New Zealand (see the European Union Enterprise and Industry website and Australian Government Department of Innovation, Industry, Science and Research 2011). Such collaboration might be a useful model for the agency to explore. For a U.S. example of

effective collaboration, see the American Council for Technology Industry Advisory Council 2011 website. The Human Health Risk Assessment program might also seek ways to reduce controversy between industry and government over individual risk assessments. New procedures and/or communicate efforts to inform and engage industry could have benefits could possibly stimulate industry funding of toxicology research programs in academic institutions and strengthen the nation's overall environmental research capability.

Social, behavioral and decision sciences

Social, behavioral and decision sciences should be specifically articulated in both the Chemical Safety for Sustainability and Human Health Risk Assessment frameworks. For instance, in sections discussing risk assessment, it should be noted that research should consider how the public perceives "exposure" versus "contamination" and communication issues regarding chemical safety, sustainability and risk. The EPA has spent a great deal of time and effort to get the technical science right, but if the public does not understand the basics of how the agency makes its decisions and misunderstands concepts like "uncertainty," the public will not fully benefit from those investments. The Human Health Risk Assessment program may be able to foster greater public understanding of EPA risk assessment by adding new information to the Integrated Risk Information System process, as recommended by the NRC report *Science and Decision* (NRC 2009). Providing for public input into the design of a risk assessment in its formative stages or exploring how assessments can be used to evaluate the relative merits of various options for managing risk can help people understand ORD products and use them more effectively. The first step is to understand where citizens are with their thinking about chemical safety and risk assessment. The next steps are to address those gaps appropriately.

3.5. **Homeland Security**

Background

ORD's Homeland Security Research Program has a focused mission and did not provide a draft research framework that included a "problem statement" or "vision statement." The draft framework described the mission of the program in this way:

> to conduct research resulting in science and technology products that increase the EPA's capability to meet its homeland security responsibilities, thereby assisting communities' (sic) build their resilience. The program's goal is to plan, execute and produce these products in close concert with our agency partners so that the results of this program are used by these partners in implementing their homeland security programs. A secondary goal of the program is to design research and it (sic) products so that they address natural and inadvertent disasters to the greatest extent possible.

The research framework identified five major themes.

A. Research to Help Protect Water Infrastructure against Attacks
B. Research to Improve Detection of Contamination and Mitigation of Exposure in Water Systems
C. Research to Improve Characterization of the Nature and Extent of Contamination
D. Research to Improve Risk Assessments and Communication
E. Research to Improve Cleanup of Contamination

Alignment with regional and national program office needs

The Homeland Security program aligns with program and regional strategic goals within the specific scope of the program's mission and the framework describes an effective prioritization process for identification of research focus areas. The Homeland Security program has developed effective ongoing engagements with numerous stakeholders and partners, including a formal program of continuous partner engagement. If budget cuts require effort reductions, the prioritization process now in place should enable determination of what can be cut while ensuring that the program continues to meet highest priority needs.

Regions that experience disasters, natural or anthropogenic in origin, can help with identification of research needs for the Homeland Security Research Program in unique ways. The program is well positioned to address natural disasters and is doing so in some ways already. The program should consider expanding research and capabilities in relation to natural disasters and seek opportunities for dual use of research outputs. A good example of a dual use application is the CANARY early detection software tool for drinking water contaminants. ORD should consider reframing the title of this program to indicate that science related to natural disasters can fall within its scope. There appear to be important needs and opportunities in several areas, including climate change and adaptation.

ORD internal coordination and ability to catalyze and complement environmental science programs outside EPA

The Homeland Security model of coordination within and outside the EPA can be a model for other research programs. Within EPA, the Homeland Security program works with agency clients to plan, implement and deliver useful science products. The program is also well-positioned to provide leadership in computer modeling and simulation, so that EPA research in these important areas can consistently generate high quality research products.

Outside EPA, by the nature of its mission, the Homeland Security program actively coordinates with the Department of Homeland Security, the Department of Defense, and the Centers for Disease Control and Prevention. ORD should evaluate these processes to develop lessons learned to apply to other ORD research programs.

Sustainability

The linkage of the Homeland Security research topics with sustainability is not transparent, but the overall program objective of helping communities become more resilient is the sustainability link. ORD should revise the research framework to explain this linkage more clearly.

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APPENDIX A: EXPANDING ORD CAPABILITIES IN SOCIAL, BEHAVIORAL, AND DECISION SCIENCES

The SAB,[1] BOSC[2] and other science advisory bodies[3,4] have over several decades repeatedly recommended expansion of social, behavioral and decision sciences expertise at EPA. To protect human health and the environment, the EPA has traditionally focused on risks from single pollutants in a single medium addressed through end-of-pipe technical controls and the specification of standards. As the focus has shifted to mixtures of multiple-pollutants interacting

[1] Recent advice related to social, behavioral, and decision science from the SAB:

- *Science Advisory Board Comments on the President's Requested FY 2012 Research Budget* (EPA-SAB-11-007)
- *Office of Research and Development Strategic Research Directions and Integrated Transdisciplinary Research* (EPA-SAB-10-010);
- *Valuing the Protection of Ecological Systems and Services* (EPA-SAB-09-012);
- EPA's Strategic Research Directions 2008: An Advisory by the EPA Science Advisory Board (EPA-SAB-09-006);
- *Comments on EPA's Strategic Research Directions and Research Budget for FY 2008 - An Advisory Report of the U.S. Environmental Protection Agency Science Advisory Board* (EPA-SAB-07-004);
- *Science and Research Budgets for the U.S. Environmental Protection Agency for Fiscal Year 2007; An Advisory Report by the Science Advisory Board* (EPA-SAB-ADV-06-003);
- *Science and Research Budgets for the U.S. Environmental Protection Agency (EPA) for Fiscal Year 2006 - An Advisory Report by the EPA Science Advisory Board* (EPA-SAB-ADV-05-002);
- *Advisory Report on the Science and Research Budgets for the U.S. Environmental Protection Agency Fiscal Year 2005*; *A Report by the EPA Science Advisory Board* (EPA-SAB-ADV-04-003);
- *Toward Integrated Environmental Decision-Making* (EPA-SAB-EC-00-011)

[2] U.S. Environmental Protection Agency Office of Research and Development Board of Scientific Counselors, Report of the Decision Analysis Workshop, jointly held by ORD and the BOSC on March 30–April 1, 2009.

[3] Selected National Research Council reports related to social, behavioral and decision science at EPA:

- *New Directions in Climate Change Vulnerability, Impacts, and Adaptation Assessment: Summary of a Workshop* (2008) With effective climate change mitigation policies still under development, and with even the most aggressive proposals unable to halt climate change immediately, many decision makers are focusing unprecedented attention on the need for strategies to adapt to climate changes that are now unavoidable.
- *Population, Land Use, and Environment: Research Directions* (2005) reviews knowledge on interactions between demographic and environmental changes mediated by land use and recommends research directions.
- *Decision Making for the Environment: Social and Behavioral Science Research Priorities* (2005) identifies five areas of high priority research that can contribute to improved decisions affecting environmental quality.
- *Human Interactions with the Carbon Cycle: Summary of a Workshop* (2002) reports on discussions of promising research issues linking social science and natural science analyses of the carbon cycle.
- *Human Dimensions of Global Environmental Change: Research Pathways for the Next Decade* (1999) presents a state-of-the-field review and set of research imperatives.
- *Research Needs and Modes of Support for the Human Dimensions of Global Change* (1994) led NSF to support a collection of centers and research teams.

[4] NACEPT's First Advice Letter on EPA Workforce Planning: Scientific and Technical Competencies to Meet Tomorrow's Challenges, January 31, 2011.

through multiple environmental media to affect particular individuals and communities, new research is needed to support appropriate and effective policies. This research must, for example, address the impacts of human behavior on the production, use, dispersion and disposal of pollutant mixtures, variations in individual and community exposures and susceptibility to toxins, and impacts on the capacity of supporting ecosystems to absorb and transform toxins to less hazardous or even beneficial forms.

The shift toward research to support a more sustainable human environment requires an integrative approach that draws together researchers and users of knowledge and that synthesizes knowledge from across disciplines and practical experience. Such an approach to use-inspired fundamental research is also being embraced in the U.S. Global Change Research Program[5] as well as other organizations.[6] Researchers trained in the social sciences play a central role in use-inspired research. They provide disciplinary expertise on the human dimensions of environmental problems. Even more important, successful integration of user needs and research capability requires the assistance of process experts able to facilitate collaborations across disciplinary and functional boundaries.[7] In contrast to the tendency to add on social science as an afterthought, social scientists are key players in integrative transdisciplinary research. SAB and BOSC realize that such a transition will not happen overnight. The cultural and institutional changes implicit in the current reorganization of ORD will succeed only if staff with training in the social sciences play the roles required to execute use-inspired research directed toward meeting sustainability goals.

Specific needs for social, behavioral and decision sciences were identified in this report for ORD's individual program programs along with needs relevant to all program areas. The following summarizes SAB and BOSC responses to four key questions relating to social, behavioral and decision sciences in ORD:

1. What specific roles should social, behavioral and decision sciences fill in meeting science/decision support responsibilities relevant to the realigned ORD research programs (i.e., what might social, behavioral and decision scientists do)?
2. What specific sub-disciplines/fields of social, behavioral and decision sciences might best meet identified research and decision support needs?
3. Where might individuals having the relevant types of training, experience and expertise be found (e.g., what types of academic programs, research organizations, etc)?

[5] U.S. Global Change Research Program U.S. Global Change Research Program Strategic Plan 2012–2021, September 30, 2011 draft for Public Comment. 2011. Available at http://downloads.globalchange.gov/strategic-plan/usgcrp-draft-strategic-plan.pdf, visited 9/30/2011

[6] National Research Council 2010. Advancing the Science of Climate Change. Part of America's Climate Choices. Washington: National Academies Press, available at http://www.nap.edu/catalog.php?record_id=12782, visited 8/11/2011

[7] Mitchell, Ronald B., William C. Clark, David W. Cash & Nancy M. Dickson, eds. 2006. Global Environmental Assessments: Information and Influence. Cambridge: MIT Press.

4. How might social, behavioral and decision sciences best be organized and supported within the EPA/ORD research and development programs and systems?

Specific roles social, behavioral and decision scientist might play in ORD

Two broad roles were identified for social, behavioral and decision scientists. First, as addressed by the ORD/BOSC workshop on applications of decision sciences (March 2009), social, behavioral, and decision science principles and expertise could be used to improve the way ORD decides, plans and implements its own research activities. For example, social, behavioral and decision science could be productively applied to:

- Elucidate and manage the often problematic boundary between science and policy and to identify and investigate alternative innovative ways to achieve policy goals;
- Use new techniques of research mapping and visualization to identify where its own research activities fit into the emerging problem areas of the fields where they appear;
- Design new ways to encourage breakthrough thinking among its researchers and grantees;
- Use the knowledge base created by evaluations of other applied and regulatory science programs, in the U.S. and elsewhere, to inform its own program design; and
- Upgrade the processes and information tools used for its own program evaluations to improve the knowledge base for program continuation or redesign.

Second, social, behavioral and decision science expertise is needed to support the various ORD research and decision support activities carried out within and across the six major program areas. In particular, there is a need for systematic investigations of individual, community and institutional values, perceptions, motivations, knowledge, beliefs and behaviors that affect, and are affected by, EPA efforts to protect human health and the environment.

There are numerous areas in which specific social, behavioral, and decision science research and expertise are needed. The most common areas for application of these sciences were:

- Perception/understanding of environmental risks and of mitigation alternatives, including awareness, knowledge and feelings associated with particular environmental risks and policy situations;
- Communication/education affecting understandings, feelings and actions relevant to protecting human health and the environment generally and for particular environmental policy contexts;
- Judgment and decision making, including both rational and emotional components;
- Behavior change for individuals, communities and institutions to foster and sustain support for agreed upon policy goals; and

- Values, motives and world views that discriminate among various constituencies/stakeholders and affect their preferences for and reactions to alternative environmental policies.

These potential roles for social, behavioral, and decision sciences are quite consistent with discussions at the ORD National Center for Environmental Research Behavioral/Social Science Town Hall held on June 7-8, 2011.

Specific sub-disciplines/fields of social, behavioral and decision science that might best meet identified research and decision support needs

Social, behavioral, and decision sciences encompass a large and diverse set of disciplines. Each major discipline includes many sub-disciplines and only a small portion of each discipline is devoted to (or relevant to) the protection of human health and the environment as defined within the authorities and aspirations of EPA. Thus, ORD should be quite selective in recruiting the social, behavioral, and decision scientists to help meet the research and decision support needs identified above. Moreover, the social, behavioral and decision scientists must be capable of working effectively in a professional context that by tradition and by legislative authority emphasizes physical/chemical/biological sciences. The success of the ORD effort to effectively develop, integrate and nourish social, behavioral and decision science capabilities depends jointly on the general success of the transformation toward a truly transdisciplinary systems oriented research organization and on the selection of the individual social, behavioral and decision scientists who will enthusiastically join and effectively work within that organization.

A list of disciplines and sub-disciplines potentially appropriate to ORD social, behavioral and decision science needs is presented in the Table below, based in part on the report from ORD National Center for Environmental Research Behavioral/Social Science Town Hall held on June 7-8, 2011. This list is not comprehensive, but at the same time it is also too long to be of much use in actual recruitment efforts, especially given current constraints. The availability of scientists with relevant expertise and interests within each sub-discipline varies as does the current representation within ORD (ranging from none in most cases to a few in the case of economics, for example). Additional ORD interactions with the SAB and BOSC could help to extend, refine and, most importantly, prioritize this list.

Initial list of relevant social, behavioral and decision science disciplines and sub-disciplines relevant to ORD research programs

Discipline	Sub-disciplines/focus
Psychology	Applied cognitive psychology, environmental perception, environmental psychology, judgment and choice, risk perception, attitude-behavior associations, risk communication, social psychology
Sociology	social impact analysis, diffusion of innovation, social networking, social capital assessment/development, social influence, compliance processes, community involvement
Decision sciences	judgment, decision making, value construction, deliberative group decision making, tradeoff identification/negotiation, evaluation
Communication	persuasive communications, risk communication, science communication
Education	environmental education, environmental interpretation
Political science	public policy, environmental policy, institutional behavior, inter-governmental relations
Geography	hazard perception, environmental hazard mitigation, demographics
Economics	applied economics, behavioral economics, ecological economics, resource economics, agricultural economics, behavioral economics

Where ORD might find scientists with the relevant types of training, experience, expertise and interests be found (e.g., what types of academic programs, government agencies, research organizations, etc)?

There are social, behavioral and decision scientists working in many academic, government and private research and application contexts. However, it is more likely that appropriate individuals will be found in interdisciplinary programs that specifically include collaborative education, research and applications related to environmental science and policy. Several federal agencies have considerably more experience with the development and use of social, behavioral and decision science, including the Department of Agriculture (notably the Agricultural Extension Service and the Forest Service) and the National Oceanic and Atmospheric Administration, which recently expanded and integrated social, behavioral and decision science into its Sea Grant program and its Regional Integrated Science and Assessment (RISA) grants program. Applied economics departments, integrated environmental science and policy/management programs, engineering programs that provide opportunities for minors in sustainability/social sciences/law, as well as the National Science Foundation-funded Integrated Graduate Education and Research Training (IGERT) programs are likely sources.

How might social, behavioral and decision science best be organized and supported within ORD?

The SAB and BOSC recommend that ORD have some full time, in-house expertise in social, behavioral and decision science. At the very least, such individuals are needed to access and properly interpret existing social, behavioral and decision science principles and data relevant to ORD's mission, as well as to guide ORD toward the development of useful new social, behavioral and decision science information and science. The SAB and BOSC have little

enthusiasm (or optimism) for the development of a separate social, behavioral and decision science program within ORD. The SAB and BOSC recommend that ORD assign social, behavioral and decision scientists within each of its major programs and encourage coordination among these scientists. There should be at least one social, behavioral and decision scientist at a relatively senior level in each of the six ORD research program areas. These individuals would be charged with directing social, behavioral and decision science activities in their assigned program. They would coordinate regularly with the social, behavioral and decision scientists in other programs to coordinate social, behavioral and decision science activities across ORD. To effectively integrate social, behavioral and decision science in the realigned ORD research programs, social scientists will need to be involved in problem formulation and in the design, development, implementation and evaluation of all research and decision support efforts. The SAB and BOSC recommend that ORD address the needs for a "critical mass" and for effective communication, and physical proximity, if possible, among the social, behavioral and decision scientists. Performance evaluation and reward programs should recognize the special cross-cutting roles of social, behavioral and decision scientists.

Additional social, behavioral and decision scientists for specific projects could be recruited through post doctoral appointments and, at a more senior level, through targeted sabbatical leave support and/or special government employee programs or other visiting or temporary appointment procedures. For longer-term development of social, behavioral and decision science capacity directly relevant to EPA, ORD should increase its support of relevant extra-mural social, behavioral and decision science research grants and other programs to develop the skills and experiences needed by social, behavioral and decision scientists working on environmental issues.

ORD will need to develop and shape its social, behavioral and decision science capabilities over time, learning as it goes about EPA's greatest social, behavioral, and decision science needs and how best to fill them. The SAB and BOSC agree, however, that this process needs to start now. Members of the SAB and the BOSC expressed a strong interest and willingness to assist ORD in meeting social, behavioral and decision science needs that have been apparent for some time.