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EPA-SAB-12-xxx

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

Subject: Science Integration for Decision Making at the U.S. Environmental Protection Agency (EPA)

Dear Administrator Jackson:

With your support, the Science Advisory Board (SAB) undertook a unique activity in 2009 to explore the extent to which science integration for decision making occurs at EPA and to identify ways to strengthen it. Science integration in EPA's context involves integrated thinking about complex environmental problems. This calls for analyses and science assessments to address problems as they occur in the real world with integrated input from the public and interested and affected parties.

To understand EPA science integration, members of an SAB committee conducted 72 interviews in EPA program offices, all ten EPA regions, the Office of Research and Development and other offices supporting decision making. Insights from those interviews support the findings and recommendations ~~—~~in the attached report.

The SAB finds that there are variations in science integration practices at EPA with no full implementation yet of the science integration framework the SAB has ~~recommends~~ recommended for EPA(add reference(s)). The agency's focus on program and disciplinary "silos" remains a significant barrier to science integration. Science assessment, i.e., the evaluation of existing science relevant to EPA decision needs, is a critical function, because the EPA is both a scientific and a regulatory agency. Despite ~~many~~ these barriers to science integration, some EPA leaders and managers actively promote science integration. Finally, because the vast majority of EPA's scientists are located in program and regional offices, there is a need for EPA science leadership beyond ORD.

To strengthen science integration, the SAB recommends that EPA make science integration a more consistent priority, strengthen management oversight ~~for~~ of science integration activities and strengthen support for EPA scientists to participate in science integration.

The concept of science integration resonates with the public and is consistent with your vision of "One EPA," where the agency transcends historical barriers of program and region to use relevant scientific and technical information to help solve environmental problems. It is also consistent with recommendations in the National Research Council's (NRC's) recent report, *Sustainability and the U.S. EPA* (NRC 2011b).

Strengthening science integration at the EPA, like fostering sustainability, will require change: change in agency culture, change in how the agency works, and increased support for scientists and managers

responsible for science integration. The SAB, however, views science integration as essential to achieving your environmental goals, especially as they increasingly relate to sustainability. We thank all EPA personnel who participated in the SAB's science integration interviews for their time and insights. We look forward to any comments you have on our findings and recommendations regarding science integration at EPA.

Enclosure

NOTICE

This report has been written as part of the activities of the EPA Science Advisory Board (SAB), 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. 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, nor of 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.

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Science Integration for Decision Making at the U.S. Environmental Protection Agency (EPA)

In October 2008, the Science Advisory Board (SAB) was asked by then-Administrator Stephen L. Johnson to develop advice on how the EPA can strengthen scientific assessments for decision making. After conferring with you in the spring of 2009 to receive your support for this effort, the SAB undertook a unique activity to explore the extent to which science integration for decision making occurs at EPA. The SAB accepted the following charge:

> The new SAB study will evaluate the extent to which EPA's scientific assessment practices are integrated into environmental decision-making practices as previously recommended by the NRC and the SAB. The study will focus on EPA's application of scientific assessments in environmental decisions concerning chemical and microbial pollutants. *The SAB will identify barriers to implementing NRC and SAB recommendations and suggest immediate and future actions that EPA could take to develop and institutionalize integrated environmental decision-making* (emphasis added)**.** Areas of consideration may include scientific leadership, scientific practices, scientific collaboration across disciplines, and scientific expertise and workforce. The SAB may also make additional recommendations, beyond those previously provided by the NRC and SAB, to improve the integration of EPA's scientific assessments for decision making.

For the purpose of this report, the SAB defines "science" in this report broadly as any enterprise that builds and organizes knowledge in the form of testable explanations and predictions about the world. In the context of the EPA's work, science involves knowledge and data that help the agency answer environmental protection questions. The SAB defines integrated decision making as the deliberate inclusion of results of different types of assessments in the process of decision making. Critical to environmental decision making "integrated thinking about complex environmental problems, integrated ... analyses to address the problems as they occur in the real world, and integrated input from the public and interested and affected parties" (U.S. EPA SAB 2000). Although the concepts of science integration and integrated decision making are distinct, they are logically connected. The SAB described integrated environmental decision making (U.S. EPA SAB 2000) as:

> a broad conceptual way of thinking about environmental problems that responds to criticisms of the fragmented approaches that dominate current national strategies for protecting human health and the environment. At the core of this concept is integrated thinking about complex environmental problems, integrated resources and analyses to address the problems as they occur in the real world, and integrated input from the public and interested and affected parties...Integrated decision-making (sic) approaches should draw upon concepts and methods originating in many different scientific, technical, and scholarly fields (e.g., physical and biological sciences, public health, environmental engineering, political science, social science, philosophy, and economics), as appropriate for any given case. Integrated environmental decision-making (sic) is not just a series of methodologies, but rather is a way of thinking, in a whole and complete way, about any environmental problem in order to maximize the efficient reduction of aggregate risk to populations or ecological systems.

To understand science integration at the EPA, members of an SAB committee conducted interviews between October 26, 2009, and February 4, 2010, in all major program offices and all ten EPA regions. They also interviewed managers and scientific staff in EPA's Office of Research and Development (ORD) and other offices that support decision making. In all, members of the committee held 72 interviews with more than 450 individuals (Appendix A).

EPA offices selected the managers and staff to participate in the interviews, and interviewees received a draft interview protocol and questions in advance (Appendix B).[1] Interviewees were asked to comment on the current and recent past practice of science integration in their organization based on their personal experience. Interviewers stressed their interest in whether and how the EPA actually practiced science integration, not the "nominal" or official approach. The SAB interviewers received extensive background materials from each of the programs and regions prior to the interviews. After the interviews, interviewees were provided a draft interview summary for review ~~and approval~~. A compilation of interview summaries[2] and the background information provided by regional and program offices[3] are available on the SAB website.

Comment [MSOffice1]: We didn't request or require approval as a condition, did we? Just review and comment, as I recollect

The interviews provided qualitative information that varied in detail from one interview to another and focused on issues of particular concern at the time of the interviews. While the interviews were necessarily limited in scope, the conversations gave the SAB strong impressions about EPA science integration practices and the concerns of EPA managers and staff across the agency. These insights provide the foundation for the findings and recommendations in this report.

The interviews were conducted during a time of change as the EPA's Office of Research and Development (ORD) initiated the "Path Forward" (Anastas 2010) initiative to encourage new approaches to integrated transdisciplinary research in ORD with an emphasis on sustainability and innovation. The SAB supports (U.S. EPA SAB 2011) ORD's initial steps to implement this new direction, which has the potential to change science integration practices at EPA. Although the SAB conducted interviews with ORD personnel and ORD science was discussed in many interviews, the role of ORD is not the focus of this study. A full discussion of ORD's new strategic research directions and its relevance for program and regional needs is outside the scope of this effort and will be addressed in future SAB advisory reports.

Rather than focus on ORD science, this reports focuses on science integration in the EPA's program and regional offices. These offices are responsible for integrating science to support the environmental decisions you make as Administrator as well as to support the environmental decisions delegated to

[1] Appendix B provides the interview protocol and advance questions. SAB members asked interviewees to provide information about practices for integrating science to support decision making; consideration of public, stakeholder, external scientific, and other input in science assessment; drivers and impediments to implementing past recommendations for science integration; ways in which programs receive feedback on how science is used in decision-making; and the workforce to support science integration for decision making.

[2] *Science Integration Fact-finding Discussion Summaries 2009-2010 are* available at: http://yosemite.epa.gov/sab/sabproduct.nsf/9E24AF9BA24B1BBE85257860007626C3/$File/SciIntSummaries-02.03.11+with+TOC.pdf (accessed 11/21/11).

[3] SAB Committee on Science Integration for Decision Making Discussion of Preliminary Fact Finding, Meeting Materials, agency-provided background materials are available at: http://yosemite.epa.gov/sab/sabproduct.nsf/MeetingCal/266562906BCF3B0B852576DD0067F2E3?OpenDocument (accessed 11/21/11).

them. Over 6,000 EPA employees are involved in scientific assessments, research, and related activities, with approximately 1,300 full time scientific staff in ORD and approximately 4,700 full-time scientific staff in program and regional offices.

Although the findings and recommendations below concern science integration for decision making, this report does not assume that science is the sole input for environmental decision making. The SAB acknowledges that other factors (such as law, politics, policy and values) play important roles in environmental decision making ~~(Bipartisan Policy Center 2009)~~ (Bipartisan Policy Center 2009). Because the SAB interviews focused on EPA *processes* promoting or impeding science integration, the findings reported here are not an evaluation of the quality of the EPA's decisions or the quality of the science supporting them.

Findings

Science integration practices vary across the agency. The SAB interviews confirmed that agency staff and managers view science as an important component of decision making at the EPA, whether decisions involve ~~regulations~~ regulatory, enforcement or voluntary programs. Nationally significant regulatory decisions involving science are addressed at the level of the Administrator. For these actions and other significant actions to be taken by senior managers, the agency's Action Development Process and associated Analytical Blueprint process provide a structure to encourage science integration.[4] Many regional and site-specific decisions and routine decisions involving science, however, are not part of the Action Development process and are made by senior managers, mid-level program managers, permit writers, enforcement personnel and branch chiefs.

Despite a general recognition that science is critical for decision making, science integration practices vary across EPA. Some programs, e.g., the National Estuary Program (U.S. EPA 2005) and the Superfund Program[5], appear to have well established processes to initiate science integration supporting decisions using a problem formulation exercise[6]; other programs do not. Some programs, such as the Drinking Water Program or the National Ambient Air Quality Standard (NAAQS) program, rely heavily on ORD science and assessments; other programs, such as the Hazardous Waste Program, rely on other federal agencies, such as the Department of Energy and Department of Defense, for key science support.

To meet decision makers' needs for scientific information and assessments, program and regional scientists turn to a variety of sources (contractors, local colleges and universities, other federal agencies, states, Potentially Responsible Parties, and non-governmental organizations). One region (Region III) has used a highly structured approach, the Multicriteria Integrated Resource Assessment (MIRA) Process and

[4] EPA's Action Development Process (U.S. EPA 2011) requires EPA programs and regions developing significant agency actions (e.g., significant regulations or decisions) to generate an analytical blueprint to identify plans for data collection and analysis. EPA guidance calls for these blueprints to describe how information from multiple disciplines will be collected, peer reviewed and used to develop the action. The process relies on a multi-disciplinary, collaborative, cross-office and cross-media process to ensure that a variety of perspectives are integrated for decision making. EPA has developed supplemental guidance on consideration of environmental justice (U.S. EPA 2010) and children's health protection (U.S. EPA 2006) in action development.

[5] For information about problem formulation in the Superfund Program, see http://www.epa.gov/ttn/naaqs/review.html (accessed 10/26/2011) and http://www.epa.gov/oswer/riskassessment/superfund_eco_planning.htm (accessed 10/26/11).

[6] Problem formulation is a systematic planning step, linked to the regulatory and policy context of an environmental problem, that identifies the major factors to be considered developed through interactions among policy makers, scientists and stakeholders. The problem formulation process should result in a conceptual model that identifies the sources,

environmental stressors or health hazards, exposed populations and the relationships among them (U.S. EPA 2004). Problem formulation also includes initial consideration of the options for interventions or risk management.

associated logic models, as a framework to help stakeholders and decision makers understand the relationships between relevant scientific data and decision options (Stahl et al. 2002)[7] . Other programs and regions take a much less structured approach. The Office of Solid Waste and Emergency Response maintains a robust website[8], used actively across EPA, that hosts seminars, offers podcasts, provides a central portal for databases and tools related to clean-up technology, and a central place to share information among EPA scientists and scientists outside the agency. Other EPA programs lack such a resource to foster exchange and integration of a wide variety of scientific information supporting decision making. These few examples convey a sense of the wide variety of science integration approaches and mechanisms at the EPA and the different experiences the public can have when engaging with the EPA on science integration.

No EPA program has fully implemented the science integration framework recommended by the SAB in 2000. The framework for science integration recommended by the SAB (U.S. EPA SAB 2000) (Figure 1) and supported by the National Research Council (National Research Council 2009) has three major components: problem formulation; analysis and decision making; and implementation and performance evaluation. The NAAQS review process for criteria air pollutants comes closest to full implementation[9] and, as a result, has the most effective science integration process among the EPA programs discussed in the SAB interviews. Even the NAAQS process, however, does not fully implement the SAB's recommended approach because the NAAQS process has been limited in two ways. First, NAAQS reviews have focused primarily on single-pollutant air quality issues, with limited consideration of multi-pollutant impacts and impacts of criteria pollutants on water quality and related ecological impacts[10]. Second, NAAQS reviews by law focus on human health and ecological impacts. Health and ecological assessments are not integrated with assessments of benefits and costs and, as a result, decision makers do not have the benefit of an integrated assessment that would help them evaluate the marginal benefits of additional health or ecological protection.

[7] For more information about MIRA and its applications, see http://www.epa.gov/reg3esd1/data/mira.htm (accessed December 12, 2011).

[8] Hazardous Waste Clean-Up Information (CLU-IN). http://www.clu-in.org/ (accessed 11/18/2011).

[9] The NAAQS review for a criteria air pollutant follows a structured process. At the start of a new review cycle for a criteria air pollutant, ORD convenes a public workshop at the start of each review cycle to identify key new science published since the last review. EPA's Office of Air and Radiation (OAR) then prepares an Integrated Science Plan to identify how EPA will review the new science in light of the EPA's statutory mandate to determine whether current standards protect public health and public welfare from known or anticipated adverse effects with an adequate margin of safety. ORD prepares an Integrated Science Assessment reviewing the new science. OAR prepares a Risk and Exposure Assessment related to key aspects of regulating the pollutant and a Policy Assessment that reviews the science as it relates to key aspects of regulations. The goal of the Policy Assessment is to provide a transparent staff analysis of the scientific basis for alternative policy options for consideration by senior EPA management prior to rulemaking. Such an evaluation of policy implications is intended to help "bridge the gap" between the agency's scientific assessments and the judgments required of the EPA Administrator in determining whether it is appropriate to retain or revise the NAAQS. The reviews are iterative, since the EPA must conduct NAAQS reviews for each of the six criteria pollutants every five years and reconsider the science supporting the NAAQS. As a result, the EPA has refined the assessment process over time, identifying risks more precisely and identifying key uncertainties for research to address. NAAQS reviews allow for multiple opportunities for public comment and for peer review by the Clean Air Scientific Advisory Committee, a federal advisory committee dedicated to providing review and advice for the NAAQS process. ORD also developed the Health and Environmental Research Online (HERO) database as a publicly accessible repository for peer reviewed literature used to develop Integrated Science Assessments.

[10] The Clean Air Scientific Advisory Committee (CASAC) has advised the EPA that the NAAQS reviews should be expanded to consider multi-pollutant and multi-media impacts (see U.S. EPA CASAC 2011).

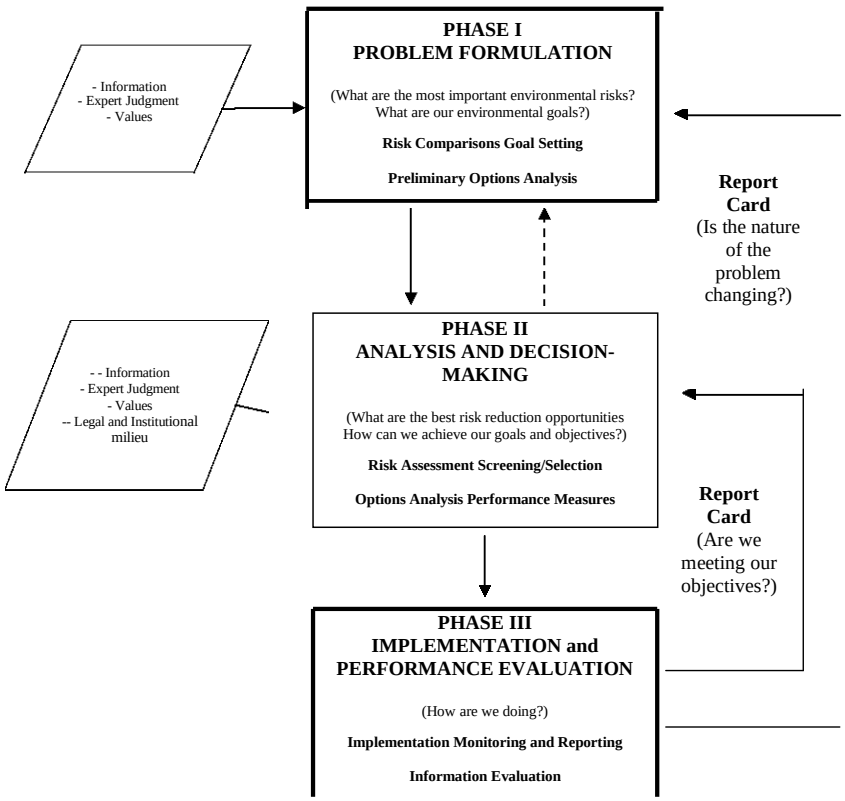

Figure 1 Framework for Integrated Environmental Decision-making (sic) from *Toward Integrated Environmental Decision-Making* (EPA-SAB-EC-00-011)

The agency's focus on program and disciplinary "silos" remains a significant barrier to science integration. The need to implement individual programs complicates the quest for innovative or sustainable ways to achieve the Agency's mission to protect human health and the environment.

Managers and staff in many interviews, especially in program offices, defined the success of their programs in terms of meeting statutory requirements and court-ordered deadlines. This narrow focus on "program silos" and defensibility can be a barrier to formulating problems as they occur in the real world. Such a limited approach can hinder integration of new scientific information into decisions and new applications of science to develop innovative, effective solutions to environmental problems. Inertia within scientific disciplines is another obstacle to science integration. Interdisciplinary work is difficult; experts often speak different languages and have different assumptions. These differences can become intellectual silos when EPA does not implement procedures requiring science integration.

Science assessment is a critical function at the EPA because the EPA is both a scientific and regulatory agency. EPA science assessments require evaluating the state of science relevant to the EPA's decision needs. Scientific literature reviews published in peer reviewed journals generally do not provide assessment information that meets the EPA's regulatory or environmental protection needs. As one regional interviewee noted, "Published literature is out there but it is passive. The question is 'how do you apply it to a practical problem?'" The EPA's credibility can depend on the availability of science assessments. Program and regional decisions are delayed or questioned when the agency lacks assessments of currently available science.

Although the Integrated Risk Information System (IRIS) program, which provides assessments of chronic human health effects used widely by EPA programs and regions, was discussed in many SAB interviews, this SAB report will not specifically comment on IRIS. IRIS has been the topic of several recent reports (U.S. Government Accountability Office 2008; NRC 2009; and NRC 2011a) and recent management attention at the EPA[11]. In addition, as part of EPA's efforts to improve the IRIS process, the agency plans to request advice from the SAB through a new SAB subcommittee on how to accelerate the IRIS program's generation of high quality toxicological reviews of environmental chemicals.

IRIS is only one type of important chemical-specific science assessment at the EPA; program offices conduct many different kinds of chemical assessments to support decision making. The EPA's Toxic Release Inventory program, for example, assesses available science to determine whether a chemical's acute effects merit listing (or "delisting") on the inventory, triggering reporting requirements. The Office of Water generates water quality criteria for implementation of the Clean Water Act and Maximum Contaminant Levels for implementation of the Safe Drinking Water Act. The Office of Pesticide Programs conducts science assessments for new pesticides, new uses of existing pesticides, and registration renewal of pesticides. The Office of Pollution Prevention and Toxics assesses new chemicals using data on chemical analogues through use of Structure-Activity Relationships and peer-reviewed models because manufacturers are not required to test new chemicals and generally provide little or no human health hazard information or information on ecological impacts. Scientists in these organizations work within statutory constraints, often on an extremely short time-table, to assess available scientific information as an input for environmental decisions.

In addition to chemical-specific assessments, the EPA needs science assessments for other kinds of environmental topics. ORD has undertaken high priority assessments in response to concern over potential risks associated with hydraulic fracturing and mountaintop removal. In interviews, scientists and managers across the agency called for additional assessments of existing scientific knowledge to apply to the practical problems they faced. As examples, they noted a need for assessments of existing scientific knowledge about impacts of pharmaceuticals; personal care products and nutrients; ecological impacts that can guide clean-up efforts; and climate change at temporal and spatial scales useful for regional decisions.

Some EPA leaders and managers actively promote science integration. Time and resource constraints are barriers to science integration across the EPA, but notably some leaders and managers make science integration a priority and implement mechanisms within their organizations despite these constraints. As

[11]For EPA information about the IRIS process, see http://www.epa.gov/IRIS/process.htm (accessed 11/4/11).

one manager noted, leadership requires that managers be "committed to listening to staff and supporting science needs... managers must demand such planning for high quality science. They should not expect that good science will 'happen organically'--that things will come together by themselves." Effective leadership for science integration emphasizes the importance of problem formulation to allow EPA to step "out of the box" of narrow programmatic concerns. One manager explicitly noted that "There is a need to recruit, nurture and guide people to make decisions outside the box, while still making timely decisions." Some leaders and managers interviewed provided scientists and managers with training about the potential of programs across the Agency to be used, in conjunction with their own, to achieve the EPA's health and environmental protection goals. They were willing to explore the flexibility of their own statutes and to look for collateral ways to achieve environmental goals.

EPA organizations with successful science integration efforts devote attention to the institutional mechanisms required. Some examples are: (1) explicit problem formulation activities that involve managers, scientists and the public in decision science models or model building exercises; (2) a program-office plan that identifies the research needed to achieve its goals, meet statutory obligations and fulfill court mandates (U.S. EPA 2009); (3) cross-media or cross-disciplinary project teams; (4) effective program and regional-office science policy councils[12]; and (5) meetings where project teams present their integrated science to decision makers in forums open to program or regional staff. These mechanisms increase the transparency of (and remove the mystery from) science integration and make it more understandable and accessible to agency staff and managers.

The EPA needs science leadership beyond ORD. An overarching barrier to science integration is the lack of strong central leadership to support scientists outside ORD. As noted above, the vast majority of the EPA's scientific workforce is employed in EPA regions and program offices. These program and regional scientists play key roles in the integration of science into decisions. Thus, they must collaborate actively in ORD's research activities to ensure that research results meet the needs of program and regional decision makers. Support for science in the EPA's regional and program offices has been recognized as a priority (U.S. EPA Expert Panel 1992) and there have been calls for a top science official with responsibility and authority for all the research, science and technical functions at the agency (NRC 2000, U.S. Government Accountability Office 2011). At present, however, the EPA has not assigned a lead responsibility to manage and strengthen EPA's scientific workforce as a resource for the agency as a whole. ORD principally focuses on ORD scientists, although it supports several small but important programs supporting regional science needs, such as the Regional Science Liaison Program, Regional Research Partnership Program and the Regional Applied Research Effort Program. Program and regional offices manage their scientific workforces relatively independently, with some organizations providing stronger support than others and limited planning for synergies. EPA leadership in science integration requires the recruitment, retention, and development of leading scientists from many fields across EPA programs and regions, as well as in ORD. EPA has not developed a coordinated human resource strategy for building this science base within ORD and beyond.

Comment [MSOffice2]: This could be assigned to the EPA Science Advisor, but, then, that position would have to/should be moved from ORD to the Administrator's Office.

[12]An effective internal EPA science policy council in a program or regional office would have a charter, clear responsibilities and operating rules, and strong support from senior managers. Science policy councils can facilitate science integration by tracking emerging environmental issues and the science integration actions needed; helping to prioritize research needs for development of science to integrate into future decisions; encouraging communication and collaboration across programs and disciplines; and facilitating training and information exchange to strengthen science integration.

Recommendations

Make science integration a more consistent priority. EPA's mission to protect public health and the environment requires a difficult balancing of policy and science considerations. The increasing complexity of environmental decisions and growing emphasis on sustainability as an environmental goal require integration of scientific input from diverse fields of the natural, public health, social, behavioral and decision sciences. The SAB reiterates its recommendation made in 2000 ~~(U.S. EPA SAB 2000)~~ that the EPA implement the framework for science integration depicted in Figure 1 to support decisions agency-wide(U.S. EPA SAB 2000).

The SAB recommends that the EPA's senior leadership communicate that science integration is needed and expected to support the EPA's decisions. Managers should make it a priority to plan for the research and science assessments needed for decisions and then train, encourage, and expect staff to collaborate so that science integration for decision making is realized.

For each decision requiring science, science integration will require an initial problem formulation step, with the following components:

- Involvement of the responsible decision-maker(s) to define the initial questions that will look broadly at the physical, economic, and social context of specific environmental problems to seek a management decision with the broadest environmental benefits;
- Identification of options for intervention and risk management;
- An assessment plan that: discusses the appropriate level of science required for the decision; the type of science; and where one might find the science that is needed, who is involved and their roles and responsibilities.;
- Expectations regarding the required timeline and resources; and
- Stakeholder engagement.

The problem formulation step should inform the data analysis and decision-making phase, where science assessments will provide key information. Once decisions are made, the EPA should evaluate the use of integrated science for decision making with the goal of improving future decision making.

Strengthen management oversight. The SAB recommends that the EPA devote more consistent attention to implementing all the components of science integration. Management oversight is needed to martial integrated thinking about complex environmental problems and integrated analyses to address problems as they occur in the real world with integrated input from the public and interested and affected parties. Attachment C lists several specific recommendations for EPA's consideration. The goal of these recommendations is to get the right science to decision makers and to integrate that science into improved decisions for protecting public health and the environment.

Strengthen support for EPA scientists to participate in science integration. Traditional rewards and recognition for scientific excellence focus on discovery, peer reviewed publication, and international recognition by peers. As a result there are few professional incentives for scientists to focus on support of regulatory decision making or translation. The SAB recommends that scientists throughout the agency be encouraged to participate actively in developing improved approaches to integrate science into agency decisions and be rewarded for their valuable contributions.

The EPA should increase the incentives (e.g., awards, performance evaluations, developmental assignments, career opportunities) for scientists to support the translation and integration of science into decision making. Programs to encourage exchanges of ORD scientists with program and regional offices, and *vice versa* also would facilitate the development of this culture. The EPA should develop an agency-wide human resource plan to attract, develop and retain highly qualified staff scientists in the regions, programs and ORD so that EPA scientists overall will set the international standard for excellence in integrating science to support decision making. The SAB recommends that this plan be peer reviewed by the SAB, the ORD Board of Scientific Councilors, and the National Advisory Committee on Environmental Policy and Technology.

Conclusion

Effective environmental policy making requires the integration of science from many disciplines to inform the decision process. This concept is fundamental to the identity of the EPA. The presidential commission that called for the establishment of the EPA in 1970 noted that "The environment, despite its infinite complexity, must be perceived as a unified, interrelated system." The Ash Commission stated that an environmental protection agency was needed and must have capabilities "to conduct research on the adverse effects of pollution, to gather information on environmental conditions and use it in modifying programs or recommending policy changes" (Ash et al. 1970). The commission proposed an organizational structure for EPA that would:

- Recognize the interrelated nature of pollution problems;
- Address the fact that pollutants cut across media lines;
- Encourage balanced budget and priority decisions between component functions; and
- Permit more effective evaluations of total program performance.

This concept of science integration resonates with the public and is consistent with your vision of "One EPA," where the agency transcends historical barriers of program and region to use relevant scientific and technical information to help solve environmental problems. It is also consistent with the NRC report on sustainability ~~(NRC 2011b)~~, which observed that "Meeting the goal of sustainable development requires an integration of social, environmental, and economic policies, necessitating interdisciplinary coordination among federal agencies with varying missions to address this goal~~.~~" (NRC 2011b)

Strengthening science integration at the EPA, like fostering sustainability, will require change: change in agency culture, change in how the agency works, and increased support for scientists and managers responsible for science integration. The SAB, however, views science integration as essential to achieving EPA's environmental goals, especially as they increasingly relate to sustainability.

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Appendix A: List of SAB "Science Integration for Decision Making" Interviews, 2009-2010

Region 1 Fact-finding Discussions, October 28, 2009

- With Region 1-New England Acting Regional Administrator
- With Region 1-New England Managers
- With Region 1 New England Scientific and Technical Staff

Region 2 Fact-finding Discussions, December 17, 2009

- With Region 2 Managers
- With Region 2 Deputy Regional Administrator
- With Region 2 Technical Staff

Region 3 Fact-finding Discussions, January 19, 2010

- With Region 3 Managers
- With Region 3 Scientific and Technical Staff
- With Region 3 Deputy Regional Administrator

Region 4 Fact-finding Discussions, October 26, 2009

- With Region 4 Senior Managers: Director, Science and Ecosystem Support Division and Director, Resource Conservation and Recovery Act (RCRA) Division
- With Region 4 Managers
- With Scientific and Technical Staff Region 5

Fact-finding Discussions, January 25, 2010

- With the Acting Regional Administrator and Acting Deputy Regional Administrator
- With Region 5 Senior Managers
- With Region 5 Scientific Staff

Region 6 Fact-finding Discussions, December 9, 2009

- With Region 6 Senior Managers
- With the Region 6 Regional Administrator and Deputy Regional Administrator
- With Region 6 Scientific and Technical Staff:

Region 7 Fact-finding Discussions, December 16, 2009

- With Region 7 Managers
- With Region 7 Scientists
- With the Region 7 Acting Regional Administrator
- With the Region 7 Agricultural Team Region 8

Fact-Finding Discussions, December 15, 2009

- With the Region 8 Scientific and Technical Staff
- With Region 8 Managers
- With the Region 8 Acting Regional Administrator

Region 9 Fact-finding Discussions, January 6, 2010

- With the Region 9 Deputy Regional Administrator and Senior Managers
- With Region 9 Managers
- Region 9 Scientific and Technical Staff Region

10 Fact-finding Discussions, December 8, 2009

- With Region 10 Scientists (first group)

- With Region 10 Scientists (second group)
- With the Region 10 Regional Economist
- With Region 10 Scientists (third group)
- With the Region 10 Executive Team
- With the Region 10 Acting Regional Administrator and Acting Deputy Regional Administrator

Office of Air and Radiation, Office of Atmospheric Programs (OAP) Climate Control Division Fact-finding Discussions, November 19, 2009

- With OAP Climate Control Division scientific staff
- With OAP Climate Control Division managers

Office of Air and Radiation, Office of Air Quality Planning and Standards (OAQPS) Fact-finding Discussions, January 12, 2010

- With OAQPS Managers
- With OAPQS Scientists

Office of Air and Radiation, Office of Transportation and Air Quality (OTAQ) Fact-finding Discussions, November 19, 2009

- With the OTAQ Director
- With OTAQ Staff Scientists

Pesticides and Toxic Substances (OPPTS) Fact-Finding Discussions, January 26, 2010

- With the Office of Pollution Prevention and Toxics Acting Director, Managers, and Scientific Staff
- With the OPPTS Deputy Assistant Administrator
- With the Director and Scientific Staff, Office of Science Coordination and Policy
- With the Acting Office Director, Managers, and Scientific Staff, Office of Pesticide Programs

Office of Solid Waste and Emergency Response Principal Deputy Assistant Administrator Fact-finding Discussion, December 1, 2009

Office of Solid Waste and Emergency Response, Office of Resource Conservation and Recovery (ORCR) Fact-Finding Discussions, November 24, 2009

- With the Economics and Risk Analysis Staff
- With the ORCR Director

Office of Solid Waste and Emergency Response, Office of Superfund Remediation and Technology Innovation (OSRTI) Fact-finding Discussions, November 24, 2009

- With the OSRTI Deputy Director
- With the Assistant Director of the Technology Innovation and Field Services Division, Science Policy Branch Chief and Staff

Office of Water, Office of Ground Water and Drinking Water Fact-finding Discussions, January 20, 2010

- With the OGWDW Office Director and Director, Standards and Risk Management Division
- With OGWDW Managers and Scientific Staff (

Office of Water, Office of Science and Technology (OST) Fact-Finding Discussions, January 28, 2010

- With OST Scientific Staff
- With the OST Deputy Office Director and Managers

Office of Water, ffice of Wastewater Management Fact-Finding Discussion, January 20, 2010, with the Office Director and Management Team

Office of Water, Office of Wetlands Oceans and Watersheds (OWOW) Fact-Finding Discussions, January 20 & 28, 2010

- With the OWOW Deputy Office Director and Management Team
- With OWOW Scientific Staff

Office of Environmental Information Toxic Release Inventory (TRI) Program Fact-finding Discussions, December 24, 2009

- With TRI Managers
- With TRI Staff

Office of Research and Development Fact-Finding Discussion, January 29, 2010, with the Assistant Administrator and Deputy Assistant Administrator for Science

Office of Research and Development, National Center for Environmental Assessment (NCEA) Fact-finding Discussion, November 30, 2009, with National Center for Environmental Assessment (NCEA) Director and NCEA managers and scientists

Office of Research and Development, National Health and Environmental Effects Research Lab (NHEERL) and National Exposure Research Lab (NERL) Fact-Finding Discussions, January 25, 2010

- With NHEERL Director and Management Team
- With NHEERL Scientists
- With NERL Director and Management Team
- With NERL Scientists

Office of Research and Development, National Homeland Security Research Center (NHSRC) Fact-finding Discussion, November 30, 2009, with NHSRC Managers and Staff Office of Research and Development, National Risk Management Laboratory (NRMRL) Fact-finding Discussion, November 30, 2009, with NRMRL Managers and Staff

Office of Research and Development, Office of Science Policy (OSP) Fact-finding Discussion, January 28, 2010, with Managers and Staff

Office of Research and Development, Fact-Finding Discussion, February 4, 2010, with National Program Directors and Program Leads

Office of the Science Advisor Fact-Finding Discussions, January 21, 2010

- With OSA Scientific Staff
- With the OSA Chief Scientist and Managers

Office of the Administrator

- Office of Children's Health Protection Fact Finding Discussion, January 21, 2010, with the Director and Staff
- Office of Policy, Economics, and Innovation National Center for Environmental Assessment Fact-Finding Discussion, January 21, 201, with the NCEE Director and Technical Staff

Appendix B: Interview protocol and advance questions

The SAB conducted interviews with EPA Offices and Regions that use science to support decision making. Two or more committee members were involved in each interview. The SAB Staff Office Director or Deputy Director provided introductions, and the Designated Federal Officer (DFO) for the committee took notes and assisted the SAB committee in consolidating and summarizing information gleaned from the interview sessions. The interviews were held at the designated location of EPA Offices.

The SAB requested separate interview sessions with decision makers, policy makers, and scientific and technical staff. SAB members used the following questions as a guide for the interviews. The SAB recognized that not all questions will be relevant and appropriate for all EPA offices. The interview questions cover topics such as 1) practices for integrating science to support decision making; 2) consideration of public, stakeholder, external scientific, and other governmental input in science assessment for decision making; 3) drivers and impediments to implementing past recommendations[1] for science integration; 4) ways EPA receives feedback on how science is used in decision-making; and 5) the EPA workforce related to science integration supporting decision making.

The SAB committee asked interviewees to review the questions below the interviews and to describe one or two important and representative examples of science-based decisions specific to their organization. The committee expressed interest in learning what interviewees viewed as what is and is not working well, and what changes are needed to improve science integration to support environmental decision making. The SAB DFO provided draft summaries of the interviews to the interviewees for comment.

Advance questions for Policy and Decision Makers:

1. Practices for integrating science to support decision making

1.1. What kinds of decisions does your organization make?

1.2. What is (are) your role(s) in the decision-making process?

1.3. For each type of decision please describe the process by which it is made. What types of assessments do you include to inform your decisions?

1.4. Do the decision-making processes used by your office employ planning and scoping, and problem formulation phases? If yes, how are planning and scoping, and problem formulation conducted? What kinds of preliminary assessments are conducted?

1.5. Has your organization applied any of the processes and approaches recommended by the SAB and NRC for integrating science supporting decision making? Has it used other models and approaches? If so, has it been useful to apply these models/approaches?

1.6. As applicable, discuss a particular past recommendation that relates to the example(s) of science-based decisions you have described for the committee. Did the recommendation affect your decision(s)? If it affected the decisions, in what ways did this occur?

[1] With special consideration of decision-making processes and approaches described in the *Toward Integrated Environmental Decision-Making.* (SAB, 2000) and *Science and Decisions* (NRC, 2009) and recommendations related to public participation in science and environmental protection in *Improved Science-Based Environmental Stakeholder Processes* (SAB, 2001) and *Public Participation in Environmental Assessment and Decision Making* (NRC, 2008).

1.7. How do you assess the level of analysis needed for a particular science assessment, and when is the analysis judged to be sufficiently completed to allow decision making?
1.8. Is the science assessment and decision-making process altered to accommodate different locations in the United States or different spatial scales? Do science assessment and decision-making processes change to address short-term and long-term needs?
1.9. What scientific data or information do you need to support decisions? Do you have the data/information that you need, when you need it? If not, what do you do? Are you constrained from using all available scientific information in decisions or generating new data and information to support decisions?
1.10 How are different assessments in different disciplines (including social and decision sciences) integrated as part of the science decision-making process?
1.11 How do you like information about the uncertainties in scientific assessments presented? What are some examples of presentation of uncertainties in scientific assessments that have helped you understand the science related to a decision and had an impact on that decision?

2. Consideration of public, stakeholder, external scientific, and other governmental input in science assessment for decision making

2.1. What role do the regulated community; non-governmental organizations; and the general public play in your organization's science assessment process? If involvement occurs, how is it accomplished? At what steps in the process are these groups involved?
2.2. To what degree and how do you coordinate scientific assessments with international organizations, other federal agencies, states and tribes? How does this coordination happen?
2.3. What role does the external scientific community play in integrating science to support decision-making in your organization? How does your organization engage the external scientific community to help your decision makers get the science needed to support decisions?
2.4. Has your organization applied any of the SAB's or NRC's recommendations relating to public participation in science supporting environmental decision-making? Have these reports influenced how public/stakeholder input has been used in your organization's science assessments? If so, has it been useful to apply these models/approaches?

3. Drivers and impediments to implementing past recommendations for science integration

3.1. Are there perceived or actual barriers for developing and/or implementing new or existing decision-making processes or frameworks that integrate the best available science? If yes, what are they?

4. Ways EPA receives feedback on how science is used in decision-making

4.1. How does your organization determine the effectiveness of implemented decisions (whether the decision resulted in reduced risk and improvement to public health and the environment)?
4.2. Does your organization use feedback on decisions to detect emerging science, influence future policy, set priorities? If so, how?

5. EPA workforce related to science integration supporting decision making

5.1. How does your organization's scientific and technical workforce adapt to shifts in priorities and resources?
5.2. How do scientists stay current in their areas of expertise, or expand their expertise based on current and future scientific needs?

5.3. What is the current balance between near-term program support research and longer-term research to advance the science?

6. Are there other questions we should ask that would help us understand how science and scientific assessments are integrated to support your decisions?

Questions for Scientific and Technical Staff:

1. Practices for integrating science to support decision making

1.1. What kinds of decisions are made in your organization and what is your role(s) in the decision-making process?

1.2. What types of science assessments are done to support your organization's decisions (e.g., technology, benefits, human health, ecological, behavioral/social/economic, etc.)?

1.3. Who actually conducts science assessments (e.g., your organization's staff, contractors, other EPA offices/personnel)?

1.4. How are assessments in different disciplines (including social and decision sciences) integrated as part of the science decision-making process?

1.5. How do you work within your own office, and with other EPA Offices and Regions to coordinate analyses needed for decision-making? What science data, models, analyses, etc. do you obtain from other units to support decision making in your unit?

1.6. Do you conduct formal uncertainty analyses? How are analyses matched to the needs of decision makers? How is uncertainty communicated to decision makers, stakeholders and the public?

1.7. What roles do computational models have in science integration for decision making in your organization. Do you make use of EPA's Council for Regulatory Environmental Modeling or the Models Knowledge Base, and if so, how?

1.8. What improvements are needed to integrate science assessments to support decision-making processes?

1.9. What are current interactions among your organization and the Agency's laboratories (e.g., ORD, Regional, Program-specific)?

2. **Consideration of public, stakeholder, external scientific, and other governmental input in science assessment for decision making**

2.1. To what degree do you coordinate development of your organization's scientific assessments with international organizations, other federal agencies, states and tribes? How does this coordination happen?

2.2. What role do the regulated community, non-governmental organizations, other international, federal, state or tribal governments and the general public play in your organization's science assessment process? If involvement occurs, how is it accomplished? At what steps in the process are these groups involved?

2.3. What role does the external scientific community play in integrating science to support your organization's decision-making? How does your organization engage the external scientific community in getting the science needed to support environmental decisions?

3. Drivers and impediments to implementing past recommendations for science integration

3.1. Are there perceived or actual barriers for developing and/or implementing new or existing decision-making processes or frameworks that integrate the best available science? If yes, what are they?

4. Ways EPA receives feedback on how science is used in decision-making

4.1. How does your organization determine the effectiveness of implemented decisions (whether the decision resulted in reduced risk and improvement to public health and the environment)?

4.2. Does your organization use feedback on decisions to detect emerging science, influence future policy, set priorities? If so, how?

5. EPA workforce related to science integration supporting decision making

5.1. How do you stay current in their areas of expertise, or expand their expertise based on current and future scientific needs?

6. Are there other questions we should ask that would help us understand how science and scientific assessments are integrated in support of your organization's decisions?

Appendix C: Strengthening management oversight - specific suggestions for consideration.

1. The EPA's Action Development and analytical blueprint process should:
   - Be structured to include a problem formulation step for every new action, as described in this report
   - Encourage scientists and decision makers to identify environmental management options that can achieve multiple environmental protection goals
   - Include a new requirement that action plans include a plan for inclusion of stakeholder science perspectives, from problem formulation through evaluation of decisions.
   - Include a new requirement for science integration evaluations for major agency actions.
2. The EPA should commission case studies in each region and program office documenting a problem formulation process, as described in this report. Reports of the case studies should be made available for discussion at a public workshop to study the practical implications of the problem formulation approach across EPA.
3. Senior managers and scientists from programs and regions should continue to participate in planning ORD research activities ***and*** ORD should regularly inform them about and involve them in research at key stages of development.
4. Regions and program offices should develop regular plans to identify the science needed to support upcoming environmental decisions. These assessments would identify needs to be met by internal program or regional scientists and sciences needs to be met by sources outside the region or program. These plans should be independently peer reviewed.
5. The EPA should build on Superfund's communication and training infrastructure to support cross-disciplinary exchange of information across all of EPA programs and between EPA and external scientists.
6. The EPA's programs and regions should identify and implement mechanisms to strengthen transparency and documentation of how science is integrated into decisions.
7. The EPA should review EPA's 1995 Risk Characterization Policy[1] and 2003 guidance on assessment factors[2] to identify how they might be updated in light of current needs for science integration.
8. The EPA should pilot ways to build on Superfund's public involvement infrastructure to strengthen involvement in science integration across EPA programs and regional offices.
9. The EPA should design and deliver training to managers and scientists about the potential of programs across the agency that can be used, in conjunction with their own, to achieve EPA's protection environmental goals.
10. The EPA should implement a mechanism for reviewing SAB and NRC reports with a broad agency scope, communicating their possible implications for EPA programs and regions, and engaging EPA program and regional scientists in responding to recommendations from these science advisory bodies.
11. The EPA should seek opportunities to engage the SAB and NRC more actively in fostering science integration throughout the agency, including advisory activities at the regional and program level to encourage broader science integration.

[1] U.S. Environmental Protection Agency. 2001. Risk Characterization Handbook. EPA 100-B-00-002. http://www.epa.gov/spc/pdfs/rchandbk.pdf (accessed 11/04/11).

[2] U.S. Environmental Protection Agency. 2003, A Summary of General Assessment Factors for Evaluating the Quality of Scientific and Technical Information, EPA 100/B-03.001. http://www.epa.gov/spc/pdfs/assess2.pdf (accessed 11/176/11).