Science Integration for Decision Making

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1. Introduction

Decision makers at EPA face the daily challenge of making difficult decisions to protect the environment. This report explores the practice of science integration at EPA to help meet that challenge. It attempts to determine the extent to which EPA decision makers have access to "robust science" that characterizes a problem to the extent possible (given available science and data) so that they will have flexibility to make the best management decision, a description of science integration offered by a regional Superfund Division Director interviewed for this report. This report discusses current practices described to members of the SAB Committee on Science Integration for Decision Making by EPA senior leaders, managers, and scientific staff. The report highlights EPA best practices and areas where science integration can be strengthened.

To undertake this report, the SAB committee studied how EPA, across a wide range of activities, has identified, collected, developed, and applied scientific data, models and concepts to support "integrated decision-making" in the recent past. The data, models and concepts EPA uses in its regulatory, voluntary, and information-based programs comes from multiple scientific disciplines and sources. The SAB committee was particularly interested in whether and how EPA used "integrated science" for "integrated decision making." As defined in the 2000 SAB report, Toward Integrated Environmental Decision-Making, "Integrated decision-making 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 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." The 2000 SAB report had found that an integrated science approach to inform decision making was needed to effectively address new and complex environmental problems and make use of increasingly complex science from a wide array of relevant disciplines.

This SAB Committee undertook this study at the request of the EPA Administrator (Attachment A) in 2009. The initial request sprang from his desire to understand why issues were sometimes narrowly framed when they came to the Administrator for a decision and why the science needed to fully understand an issue was not presented. The SAB was especially interested in this topic because the SAB's 2000 report had proposed a framework to address new and complex environmental problems. This Framework emphasized the importance of problem formulation to help EPA decision makers understand complex environmental problems and consider the trade-offs required to achieve multiple, often competing goals, and select appropriate risk management options. In 2009, The National Research Council (NRC) issued the report *Science and Decisions: Advancing Risk Assessment*, which found that EPA needed a more coherent, consistent, and transparent risk assessment process to address the complexities of current problems and potential decisions and to ensure that the best available options for managing risks were considered. Given these broad, conceptual reports that emphasized the goal of integrating science and decision making, the SAB undertook this study to understand the

actual state of science integration practice at EPA and some of the major barriers to science integration at the Agency.

While the SAB conducted this study, EPA's leadership introduced a new vision for EPA research, which also emphasized the importance of integration. In his "Path Forward" memorandum to ORD Staff of March 4, 2010, the Office of Research and Development (ORD) Assistant Administrator Paul Anastas described a vision for a problem-solving, trans-disciplinary, systems-oriented approach to research aimed at sustainability. ORD has taken interim steps to implement this new direction, which likely will change many science integration practices at EPA. This SAB report provides some comment on program and regional needs for ORD science, assessment, and technical assistance related to science integration, but a full evaluation of ORD's new strategic research directions is outside the scope of this report. The SAB will be addressing ORD's new approach to research as part of a separate advisory activity.

The goal of this report on science integration for decision making goes beyond activities just within ORD and is intended to identify what needs to be done across EPA to make science integration happen more consistently, more fully, and more effectively. Although the report focuses on science integration for decision making, it does not, however, assume that science (integrated or not) is the sole input for environmental decision making. Other factors, such as law, politics, policy, and values also play important roles (Bipartisan Policy Center. 2009), both for successful policies and for failures of policies. However, the report does assume that increased use and better integration of science will reduce uncertainties for decision makers, although it recognizes that some level of uncertainty will always be present when environmental protection decisions must be made. Finally, this report focuses on EPA processes promoting or impeding science integration; it does not provide an evaluation of the quality of EPA's decisions or the quality of EPA science.

The remainder of the report is organized as follows. Chapter 2 details the charge given to the SAB committee and its approach to implementing the charge. Chapter 3 provides examples of science integration cited by EPA programs and regions. Chapter 4 describes the wide variation in science integration practices across EPA. It highlights what the committee believes to be good examples of science integration practices and examples of science integration practices that need strengthening. Chapter 5 lists the underlying reasons for differences in science integration practices at EPA and comments briefly on the roles of ORD and advisory committees in science integration. Finally, Chapter 6 provides recommendations related to leadership on science integration; science and research planning to promote integration; institutional change; and human resources related to science integration.

2. Background: Charge and approach

In 2009, the EPA Administrator presented the following charge to the SAB for this study:

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 …. 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. 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.

To implement this charge, an *ad hoc* SAB committee, the committee on Science Integration for Decision Making, was formed. The committee held a public meeting on June 9-10, 2009 to hear briefings from three senior EPA managers on science integration and to develop a draft study plan. The committee's preliminary study plan was approved by the committee on September 16, 2009 (Attachment B). The study plan identified an initial set of areas of focus for committee fact-finding:

- 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 program receives feedback on how science is used in decision-making
- Workforce to support science integration for decision making.

These areas became the focus of 72 fact-finding interviews conducted by members of the committee between October 26, 2009 and February 4, 2010. Members of the committee interviewed senior managers and scientific staff from all EPA major program offices and all 10 regions, as well as managers and staff from ORD and other offices supporting decision makers (See Attachment C for a list of EPA offices that participated in fact-finding interviews). Over 450 EPA employees participated in the interviews. EPA offices selected the managers and staff to participate in the discussions and provided committee members with background materials prior to the interviews. EPA interviewees received a copy of the SAB's Preliminary Study Plan in advance. At the start of the interviews, SAB committee members typically asked interviewees to comment on the current and recent past practice of science integration in their organization based on their personal experiences. SAB members stressed their interest in whether and how

EPA actually practices science integration, not the "nominal approach" or "how EPA officially describes its processes for science integration."

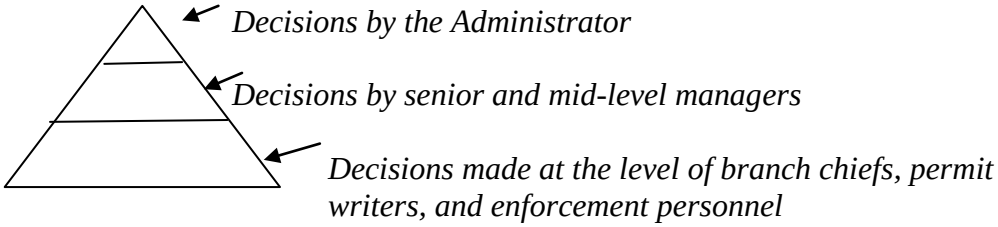
SAB interviewers asked participants to address the five main areas of focus in their comments. Individual or small group interviews generally lasted from one hour to an hour and a half and varied in length and emphasis. Interviewees were provided a draft interview summary for review and comment and approved meeting summaries were provided to the SAB committee and posted on the SAB Web site[1] Although the interviews provided qualitative information that varies in detail at a defined "snapshot" in time, the conversations gave the SAB strong impressions about EPA science integration practices and the concerns of EPA managers and staff across the Agency. These interviews provide the foundation for the findings and recommendations in this report.

[1] http://yosemite.epa.gov/sab/sabproduct.nsf/MeetingCal/266562906BCF3B0B852576DD0067F2E3?OpenDocument

3. Examples of science integration at EPA

All EPA program and regional interviewees emphasized that science was an important component of decision making at the Agency, whether the decisions involved regulations, enforcement, voluntary programs, or information-based programs. The SAB committee defined science broadly for the interviews as any enterprise that builds and organizes knowledge in the form of evidence-based explanations and predictions about the world. In the context of EPA's work, science involved knowledge and data that could help EPA answer environmental protection issues. Science could include a wide variety of disciplines including chemistry, biology, ecology, engineering, hydrology, statistics, and toxicology, and the social, behavioral, and economic sciences

The interviews showed that EPA decisions requiring science are made at many levels, the Administrator, senior and mid-level managers, branch chiefs, permit writers, enforcement personnel, and other staff. The highest priority decisions requiring science input reach the Administrator's desk, although many decisions requiring science are made by managers, first-line supervisors, and staff throughout the Agency.



As SAB members reviewed the wide range of activities described by EPA interviewees across EPA's programs and at different levels in EPA's organization, it became clear that science integration is multi-faceted. From the perspective of the committee, full science integration involves:

- Problem formulation: An activity designed to meet the needs of Agency decision making in which the goals of the assessment/action are identified and fully articulated, assessment endpoints are selected, the conceptual model is prepared, and an analysis plan is developed.
- Acquisition of the science required. Scanning sources for existing science and acquiring new science (i.e., through research), if needed.
- Assessment of available science. Evaluating the state of existing science on a particular issue as it relates to EPA's mission.
- Integration of available science across different disciplines and sources. Cross-disciplinary and collaboration across sectors to provide the science needed by decision makers.

- Communicating about integrated science with decision-makers and the public. Communicating the major findings of integrated science activities, including its complexities and uncertainties.
- Evaluating the use of integrated science for decision making. *Post*-decision evaluation of the use of science for improved decision making in the future.

EPA interviewees generally described examples that highlighted a subset of the dimensions described above. Because science integration is a complex concept and all the aspects of science integration are important, this report distinguishes different aspects of science integration practice and processes to organize its analysis of interview findings presented in Chapters 3 and 4.

The examples in Table 1 and the descriptions that follow highlight the contributions made by particular aspects of science integration to selected Agency decisions, as described in committee interviews. They are intended as examples of how science integration affected EPA decision making in practical ways. Although the examples differ in many ways (e.g., by the aspect of science integration highlighted; by the role/level of the decision maker in EPA's hierarchy; by the type of environmental decision made), they all share a key feature. All the examples reflect a careful consideration of how EPA drew on the science it needed to address a specific problem without using a one-size-fits all, pro forma analysis or relying only on standard defaults. These examples illustrate how EPA used science integration to:

- Reframe problems to address root causes through problem formulation
- Refrain from an automatic response to a reported problem
- Maintain focus on problem solving, rather than pursuing science for its own sake
- Use information relevant to the problem from a wide variety of available sources and types
- Help develop effective, efficient, and/or innovative solutions to environmental problems
- Develop communication strategies to explain EPA's decisions more effectively

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Table 1: Interview examples that highlighted different facets of science integration

Example	Level of decision	Interview source	Value for decision making	Science integration aspects					
				Problem formulation	Acquisition of needed science	Assessment of available science	Integration of science across different disciplines and sources	Communicating with decision-makers and the public	Evaluating the use of integrated science for decision making
Reframing the PCBs in caulk issue to look broadly at PCB exposure issues in schools:	Senior mgmt	R2	Science-informed options best suited to address the risk	X					
Use of decision-science model for air quality determinations	Senior mgmt	R3	Helped managers make a large number of air attainment decisions based on complex information and explain decisions to the public	X			X		
Approving scientifically credible state sulfate water quality criteria to protect aquatic life	Senior mgmt	R5	Multi-party process to update toxicity assessment built support for a new management option	X	X	X		X	
Superfund site decision to use point-of-entry and point of use filtration , rather than bottled water	Senior mgmt Branch chief	R7	More health protective, more implementable management decision	X			X	X	
Evaluating potential risks to infants from consumption of human milk as an input for fish advisories and health assessments for Superfund sites in Oregon.	Senior mgmt Branch chief	R10	Assessment of alternative models helped Regional managers identify ways to evaluate a key exposure pathway as part of risk assessments supporting management decisions	X		X			
NAAQS iterative review process for criteria air pollutants with CASAC review	Administrator	OAR	Increased confidence and support for decisions with major impact	X	X	X	X		X
Radon proposal- Evaluation of science for choosing among risk management options (indoor air posed higher risk and regulation of municipal water supplies)	Administrator	OAR	Proposal would have resulted in more health protective outcome, based on comparative risks	X		X	X		
FDA/EPA joint advice on consuming fish contaminated with methyl mercury	Senior mgmt	OW	EPA found a management options that supported increased fish consumption and appropriate management of mercury risks	X		X	X	X	X

Example	Level of decision	Interview source	Value for decision making	Science integration aspects					
				Problem formulation	Acquisition of needed science	Assessment of available science	Integration of science across different disciplines and sources	Communicating with decision-makers and the public	Evaluating the use of integrated science for decision making
Pesticide registration decisions that consider Total Maximum Daily Loads (TMDLs) and impacts on fisheries wildlife.	Branch chief	OPP	A broader set of environmental goals are achieved	X		X	X	X	

Reframing the PCBs in caulk issue to look broadly at PCB exposure issues in schools.

Region 2 used a science integration approach to develop an agreement in principle with the City of New York related to polychlorinated biphenyls (PCBs) in caulk. PCBs have been used historically to make caulk malleable, but regulations under the Toxic Substances Control Act (TSCA) require that materials with PCBs that exceed 50 parts per million (ppm) must be removed. After PCBs were identified in caulk and local media focused on the problem, nine schools tested their caulk and identified PCB levels over 50 ng/m^3. The city took remedial action at those sites and the Parents and Teachers Association began to sue the school system.

As a decision maker, the Deputy Regional Administrator (DRA) faced a difficult challenge. Regulations require PCB removal, but PCB removal is very expensive and New York City schools have major budget issues. There is no requirement for testing, and even if PCBs are found, removal of the caulk may cause additional risks if not conducted appropriately. To make a more informed decision, after consultation at the highest levels of the Agency, he decided to defer decisions on testing caulk until the region and the public understood the overall context for PCB exposures (e.g., whether there are PCBs in floor tiles, or fluorescent lights) and was convinced that there was an unacceptable risk. The school system conducted air sampling, Region 2's risk assessors identified acceptable levels for cumulative exposures to PCBs (e.g., 450 ng/m^3 for students 12-15 years old, assuming a background scenario of no significant PDC contamination in building materials and average exposures from other sources, a concentration that was estimated to keep total exposures below the reference dose of 20 ng/kg-day), and ORD provided information about PCB detection technology. The DRA took a Superfund-site characterization approach, rather than a regulatory approach based on TSCA. In his view, "science opens the door, helps the decision maker to frame questions, and get solutions…Science may even help to identify options that may not even exist within a specific regulation."

Use of decision-science model for air quality determinations

Region 3 has integrated the use of Multi-criteria Integrated Resource Assessment (MIRA) with logic models to integrate science for decision making. MIRA is an approach that provides a transparent means for stakeholders (including decision makers) to learn the relationship between the data and the decision options and provide a rationale for the final decision. MIRA organizes data, engages expert and non-expert stakeholders in different but integrated roles, and incorporates stakeholder values by facilitating discussion within context of the decision. Region 3 uses MIRA to facilitate discussions among managers and staff in order to prioritize those outcomes. Region 3 also uses a modified version of the Kellogg business logic model, modified to accommodate EPA mission and outcomes.

In 2004, EPA Region III used MIRA to evaluate 24 criteria (including air emissions, air quality data, pollution transport, etc.) for the determination of ozone nonattainment areas under the Clean Air Act. This was the first application of the use of MIRA in EPA

decision making. Part of the MIRA process included engaging state and industry stakeholders during the construction of the nonattainment analysis. The result of using MIRA in the ozone nonattainment designation process was that Region III's designation decision was not challenged when it was announced.

Approving scientifically credible state sulfate water quality criteria to protect aquatic life.

Region 5 worked across disciplines and organizations to fill a key data gap involving sulfates in water bodies. EPA's existing water quality criteria for sulfate was set at a level designed only to protect livestock from drinking water contaminated by sulfates. EPA has no national criteria recommendation for sulfates to protect aquatic life. Environmental groups asked Region 5 to review and object to State of Illinois National Pollutant Discharge Elimination System (NPDES) permits for mine wastes contaminated by sulfates because Illinois EPA was issuing mining permits based on a less stringent alternative effluent standard for sulfate, rather than limits based on the sulfate water quality standard.

Upon review, EPA agreed to object to the issuance of numerous subsequently proposed permits. As a result, Illinois EPA backlogged the issuance of more than 80 existing mining permits and permits for six new mining facilities because the applicants could not comply with water quality-based effluent limits to meet Illinois' water quality standard for sulfate.

The issue became controversial as coal companies contacted the Administrator and Regional Administrator about permit delays. To address the problem, Region 5 collaborated over 10 months with a diverse group (including Office of Water scientists, a representative from ORD's Duluth laboratory who authored EPA's aquatic guidelines, a representative of the coal company and their contractor, and environmental groups) to develop a new assessment of the science, including a review of the literature and new toxicity data. The resulting assessment determined that sulfate toxicity is affected by chloride and water hardness and resulted in complex criteria equations that the state adopted, were approved by EPA and that the "coal companies and environmental groups could live with." Several other states are working to adopt the approach. The effort was successful because EPA kept the focus on using defensible criteria that were protective of aquatic life, while remaining open to new information.

Superfund site decision to use point-of-entry and point of use filtration rather than bottled water.

Region 7's Superfund Division cited effective collaboration with ORD's National Risk Management Laboratory in providing point-of-entry and point-of-use water filtration for homes in a community after a Superfund On-Site Coordinator discovered that "people sometimes don't use bottled water" provided by the Region. The coordinator brought this practical concern to the attention of the "Regional Decision Team" of risk assessors, the site manager, and counsel. The ORD National Risk Management Research Laboratory

responded to the need to provide the filtration system, a more effective source of water that addressed both inhalation and ingestion routes of exposure.

Evaluating potential risks to infants from consumption of human milk as an input for fish advisories and health assessments for Superfund sites in Oregon.
Region 10 scientists, in collaboration with the Oregon Department of Environmental Quality (ODEQ), ATSDR, the Oregon Department of Human Services and other researchers, reviewed several models for evaluating the risk to infants from consumption of human milk contaminated with environmental contaminants, because IRIS does not contain short-term toxicity values, including this type of exposure. The Region 10 scientists focused on lipophilic compounds, such as polychlorinated biphenyls (PCBs), chlorinated dioxins/furans and chlorinated pesticides that can concentrate in human milk. They compared three published models, including an EPA model (a single compartment, first-order kinetic model based on EPA's Human Health Risk Assessment Protocol for Hazard Waste Combustion Facilities). They concluded that the EPA model is accurate and protective and may be a good choice for risk assessors and fish advisory practitioners. Region 10 and ODEQ will be developing guidance for evaluating risks to infants from consumption of human milk based upon estimated exposures of the mother from environmental contaminants at hazardous waste sites and other environmental media. This guidance will incorporate the EPA single compartment, first-order kinetic model. Oregon DHS will be evaluating this pathway in their Public Health Assessments done for Superfund sites and for fish consumption advisories.

NAAQS iterative review process for criteria air pollutants with CASAC review.
Through the National Ambient Air Quality Standards (NAAQS) review process, EPA sets air quality standards based on an assessment of "what the current science says" about what level of ambient air pollutions will protect public health with an adequate margin of safety (Hubbell et al., 2009). Because of the significance of these standards for EPA's air program, is working to meet the challenging statutory mandate to conduct a major review of each of the six criteria air pollutants every five years. ORD plays a key role in developing Integrated Science Assessments (ISAs) for each NAAQS review and designs them to address the key science issues that must be considered in developing each standard. The Office of Air and Radiation (OAR) relies on the ISA to develop Risk and Exposure Assessments and Policy Assessments for each NAAQS decision. ORD scientists work closely with program office scientists. All these technical documents are peer reviewed by the Clean Air Scientific Advisory Committee and receive extensive public comment. At NAAQS decision meetings, the Administrator hears the views of different parts of EPA (e.g., Office of General Counsel, Office of Congressional Liaison, OAR, and ORD). The Administrator typically turns to ORD and asks whether the science has been properly portrayed in the assessment documents provided to support her decision.

Proposed radon in drinking water decision regulation.
In a November 1999 proposal (64 FR 59246) that was never finalized, EPA considered science in choosing among the best risk management options to address radon risks and

the consideration of science overcame regulatory barriers. Radon in indoor air posed a higher risk than did municipal water supplies. The Office of Water could have required municipalities strictly to reduce radon exposures radon in their system's drinking water to 300 pCi/L but proposed a Multi-Media Mitigation (MMM) option to allow municipalities to divert resources from water control technologies to mitigating airborne risk in homes while allowing individual water systems to reduce radon levels in drinking water to 4,000 pCi/L or lower. EPA proposed providing states with flexibility in how to limit exposure to radon by allowing them to focus their efforts on the greatest radon risks - those in indoor air - while also reducing the risks from radon in drinking water. EPA encouraged States to adopt this option because it is the most cost-effective way to achieve the greatest radon risk reduction.

When EPA proposed the regulation in 1999, the Agency received many comments opposed to the radon in drinking water regulation. A key concern was that it is inappropriate to address a public health problem caused by indoor air (drinking water contributes 1-2% of the radon exposure) with a regulation that is imposed upon public water systems and the State drinking water primacy agencies. Many of the of the State Agencies were among the organizations that provided comment and they raised significant concerns about their ability to implement the MMM option under the rule. This would leave affected public water systems in those states with the choice of either implementing their own MMM program or treating water to comply with the lower MCL. Because of these significant implementation concerns, EPA has delayed final action and focused on other regulatory priorities for drinking water

FDA/EPA joint advice on consuming fish contaminated with methyl mercury.

An example of science integration that involved problem formulation and interactions across federal agencies was the joint advice developed by EPA and the Food and Drug Administration (FDA) on consumption of fish contaminated with methyl mercury. After evaluating the science, FDA and EPA agreed that the overall message should be that fish is good food and we can reduce exposures to species contaminated with high levels of methyl mercury. Since no one can "extract mercury out of the fish," the fish advice focused on encouraging fish consumption while reducing exposure to mercury. EPA developed a reference dose (RfD); that is, an amount that can be consumed over a lifetime without expectation of adverse effect. This was based on the best publically available science of methyl mercury effects, and included input from both the National Academy of Sciences as well as another independent expert group. This RfD was used by FDA as a comparison point in analyses to determine the optimal means for promoting fish consumption while minimizing mercury exposure. EPA and FDA initially developed a four-page fish advisory, which was too long and complicated to be understood by the target audience. The Agencies subsequently involved risk communication specialists. FDA held focus groups, and both Agencies engaged stakeholders, as well as asked for and responded to public comments.

EPA and FDA issued brochures giving simple steps to follow to select and eat fish low in mercury. These brochures are available in eight languages via the internet and target

pregnant women. Women following these steps have some assurance that mercury body burden will stay below significantly harmful levels.

Pesticide registration decisions that consider Total Maximum Daily Loads and impacts on fisheries wildlife.

The pesticide statute requires decisions to be made within a certain time frame, while not explicitly requiring consideration of impacts on the Clean Water Act's Total Maximum Daily Loads, and/or coordination with the National Marine Fisheries Service, and Fish and Wildlife Service. Office of Pesticide Programs (OPP) scientists think "outside the box" about those other dimensions, have processes and relationships in place to integrate information, and coordinate decisions with others. Add additional text providing some specific applications.

4. Science integration practices at EPA: exemplary practices and areas to strengthen

EPA makes thousands of science-based decisions each year. The EPA interviewees described several hundred of those decisions in varying levels of detail to the committee. This report looks across the science and decision-making activities described in these interviews to identify where there are well-developed processes to integrate science and decision making and where integration needs to be strengthened

4.1. Problem formulation

The formative stages of the scientific assessment process should include planning and scoping, and problem formulation. A good definition of the problem may be the most important step in helping EPA reach effective decisions. It should begin with a deliberative discussion between decision makers and agency scientists to assure that the key questions and options are identified, The product of the problem formulation is a detailed framework outlining an approach to identifying and acquiring the scientific information needed to evaluate options and support decisions. EPA programs and regions have developed processes and practices to help define problems that science will be needed to address. Nonetheless, there are also areas where problem formulation processes should be strengthened.

4.1.1. Examples of well-developed processes

Some parts of EPA use mechanisms that involve the public up front to help frame issues for risk managers to address. For criteria air pollutants, ORD convenes a public workshop at the start of each NAAQS review cycle to identify key new science published since the last review. This key science helps EPA determine whether current standards protect public health with an adequate margin of safety and public welfare from known or anticipated adverse effects. In the Superfund program, each project starts with a problem-framing exercise, where potential human health issues are scoped, there is a problem formulation process to identify ecological risks, and a site-specific conceptual model is developed. Guidance developed by the national Superfund Program establishes clear expectations for regions, regulated parties, and the public. In the National Estuary Program, stakeholders are similarly involved in problem formulation at key points. Develop text to expand on these examples.

To help frame issues new to EPA, many offices reach across EPA and outside EPA. External peer review helped OAR's Office of Transportation and Air Quality frame risk management and science issues related to biofuels regulated under the Energy and Independence Security Act of 2007 and a workshop helped the Office of Pesticide Programs better understand the science related to nano particle pesticides and options for managing their potential risks. Similarly, ORD's National Center for Environmental Assessment and Ecosystem Research Program, for example, have formed Agency work groups, and coordinated across federal agencies and with outside scientists to frame problems related to biofuels, climate change, and ecosystem services as the focus of ORD research. Develop text to expand on these examples.

Some EPA regions take a structured approach to problem formulation within their organizations. EPA's Region 3 uses the Multicriteria Integrated Resource Assessment (MIRA) model to use science and data in a structured, transparent way to identify regional priorities and formulate approaches to address problems, such as air attainment designation decisions. The MIRA paradigm provides a process for scientists to contribute to problem formulation and scoping. Once a decision context is identified, it allows scientists to identify disparate data that will be significant and to index their significance. Other regions cited formulation of a Quality Assurance Program Plan (QAPP) as a structured approach to problem formulation that helps to ensure that EPA's decisions will be supported by needed high-quality science and that the science generated will be appropriate for the decisions to be made.

Two regions described less structured processes for problem formulation they viewed as effective. Region 1 relies on an active Regional Science Council to plan two years ahead for the science needed for site clean-up decisions and to inform the Regional Administrator of key science needs. Region 5 spoke of the importance of consciously delegating problem formulation activities. Typically, the Regional Administrator and Deputy Regional Administrator become involved in problem formulation when an issue involves complex, novel, or controversial science; the region delegates other types of problem formulation down the management chain.

Problem formulation requires engagement of both scientists and decision makers. ORD's Homeland Security Research Center emphasized that for their work, as for all ORD's research, Agency clients need to be participants in development of a science product, starting with joint development of a Quality Assurance Program plan that captures the research objectives in writing, so that both ORD and the customer have a common understanding of who would use the product and for what purpose.

4.1.2. Areas where problem formulation should be strengthened

Interviewees called for increased focus on problem formulation for two main reasons. Some interviewees saw the need for problem formulation to support many Agency initiatives and priorities where the links between science and EPA's role are not clear (e.g., environmental justice; sustainability, and an integrated "One Air" program that includes climate change). Other interviewees saw a need to explore how emerging science might redefine environmental problems. Those interviewees called for problem formulation discussions of emerging science related to multiple and cumulative risks; non-cancer impacts, computational toxicology; and ecosystem services and impacts. Some managers and scientists voiced frustration that new science points to significant stressors that EPA may not be able to address using traditional regulatory authorities. Pharmaceuticals in drinking water or multiple stressors identified through ecological risk assessments, for example may have significant impacts outside the scope of EPA's historical regulatory authority.

Although EPA has an "Action Development Process" to guide development of major regulations and major program actions, the process is primarily driven by rulemaking initiatives and not by the unique characteristics of the problems to be solved. Rather than focusing on problem formulation, the initial stages of the process focus on tiering Agency actions by

complexity and impact, assigning clear decision-making authority, and developing a work plan, which includes an analytical blueprint (ADD TEXT RE: HOW WELL THE BLUEPRINT PROCESS IS IMPLEMENTED, ESPECIALLY HOW IT MAY HELP THE AGENCY LOOK OUTSIDE THE BOUNDS OF CURRENT/SINGLE MEDIA REGULATORY AUTHORITY TO BETTER SEE THE FULL IMPLICATIONS OF A THREAT AND OF THE RESPONSES TO IT) to coordinate input from across the Agency. (ADD TEXT HERE HIGHLIGHTING EPA's ACTION DEVELOPMENT GUIDANCE FOR CHILDREN'S HEALTH AND PLANS TO DEVELOP EJ GUIDANCE HERE – HOW THEY MAY HELP WITH PROBLEM FORMULATION). Although the Action Development process does not fulfill the need for problem formulation, it does provide a mechanism for science input and coordination from across the Agency related to upcoming actions initiated by program offices. In contrast, there is no similar coordinated process for Agency-wide input, including science input, into development of regional decisions.

At times, when some regional interviewees recognized the need for problem formulation, they identified barriers to spending more time "problem scoping, identifying real questions." As one scientist in Region 9 noted:

> Sometimes statutes or regulations don't "lend themselves" to scientists working with a multi-stakeholder process to identify the core questions. Regions have guidance and latitude for making nonattainment decisions but often do not take the time to fully scope the issue. "Defining question up front is not built into the culture." Deadlines and political pressures force decisions. Sometimes it seems like there are "three months of briefing and one week of analysis."

In the absence of an EPA requirement for problem formulation, many program and regional offices do not conduct problem formulation, as understood by the SAB. When asked about problem formulation in their organizations, some decision makers viewed problem formulation as focused narrowly on meeting specific regulatory requirements, such as issuing water quality standards or a ballast water rule. Considerations of cross-program impacts, designing risk management strategies that might have multiple benefits or use novel cross-program management approaches are secondary concerns, if considered at all. Managers did not generally share a commitment to look broadly at the physical, economic, and social context of specific environmental problems to seek a management decision with the broadest environmental benefits. Many managers, especially in program offices, defined environmental problem solving in terms of the success of their own environmental programs.

EPA interviewees advocating broader problem formulation called for several changes. They noted is need to develop expectations for problem formulation, including documentation and evaluation of the process and a need to develop a set of tools to support the process. Interviewees pointed to a range of problem formulation tools, such as conceptual modeling, model building (which offers an opportunity to formulate complex nonlinear problems), use of decision-science tools like MIRA, and life-cycle analysis. A problem formulation approach, many interviewees noted, may have prevented children's exposures to tire crumb waste and anticipated many of the risks associated with introduction of Methyl Tertiary Butyl Ether (MTBE) as a gasoline additive. Although interviewees offered many different suggestions about

tools, they all agreed that scientists and policy and decision makers should jointly participate in discussions, to facilitate science input into defining and solving problems.

4.2. Acquisition of science

All the fact-finding discussions with representatives of program and regional offices focused attention on acquiring the science needed for decision making. These interviewees viewed acquiring needed science as a major aspect of science integration, whether "acquiring the science" involved scanning available sources for existing science or generating new science, either by developing it within program and regional offices or by turning to ORD or researchers outside EPA. Although interviewees recognized that science integration for decision making was an iterative process (i.e., that thinking about science integration for a specific decision context may shift the definition of what science is needed), they emphasized that EPA faced intense pressures to make decisions under regulatory and court-ordered deadlines. EPA needed to have the "right science" at hand before science could be integrated to support decision making most credibly.

4.2.1. Examples of well-developed processes.

When programs and regions claimed success in locating the existing science needed for a decision, they tended to use a combination of scientific professional networks and electronic tools. Every regional office emphasized the importance of ORD's Regional Science Liaison and Superfund and Technology Liaison programs, which provide funding for a regional scientist and Superfund liaison scientist in each region to help staff and managers access ORD science. Every region also praised the Office of Solid Waste and Emergency Response's (OSWER's) mechanisms for sharing scientific and technical information. OSWER's Clu-In Web site (http://www.clu-in.org/), dedicated to "providing information about innovative treatment and site characterization technologies while acting as a forum for all waste remediation stakeholders" stood out as a premiere mechanism for accessing science. Clu-in provides a platform for training, seminars, podcasts, and OSWER's electronic Technology Trends newsletter, sent monthly to over 25,000 people." OSWER also sponsors a variety of forums (i.e., the Groundwater Forum, Federal Facilities Forum, and Engineering Forum), organized groups of Agency scientists that support the Superfund and Resource Conservation and Recovery Act (RCRA) programs by exchanging up-to-date information and promoting consistency in the interpretation of guidance and application of policy. Program and regional scientists rely on these forums, as well as the Economics Forum, maintained by EPA's Office of Policy, to keep keep them informed about research. In addition, some regions reported success using ORD's Environmental Science Connector, a password-protected web-based tool designed for project management and information sharing with EPA researchers and external collaborators.

Where EPA must develop new science to support an environmental decision, programs and regions reported a variety of successful strategies. The Office of Pesticide Programs has the strongest authority to require regulated entities to conduct scientific studies to generate the data needed for EPA decisions. Data requirements in Part 158 of the Code of Federal Regulations identify the tests that pesticide registrants must conduct before EPA evaluates pesticide products to ensure that they meet federal safety standards to protect human health and the environment.

In contrast, as described in section 4.2.2 below, most EPA programs lack strong authority to require generation of new science or information from regulated parties to support decision making.

To obtain needed science in those instances, some EPA organizations decide to "grow talent in house." Region 1 cited an example, its need for applied science required by interpreting and applying the Clean Water Act 316(b) regulations related to cooling water intake and the discharge of heated water. As part of a power plant permit decision, the region needed to justify a decision requiring the plant to implement closed cycling. To support its decision, the region invested in a staff person to return to graduate school for a Ph.D. The regional scientist worked with ORD's Narragansett laboratory to conduct a study of the impact of thermal discharge on flounder fecundity and juvenile flounder. The Regional Administrator noted that "If we don't have the right tools from EPA's research program…if we can't develop capabilities to have our biologists operating at the highest levels, we'll be outgunned." Other regions spoke of similar success in building expertise, such as Region 6's expertise in air quality modeling, Region 7's expertise in speciation for lead to help determine the source of lead contamination, or Region 8's expertise in metals toxicity. EPA's Office of Transportation and Air Quality (OTAQ) also emphasized the importance of building and maintaining a strong technical staff. The Office Director noted that two thirds of OTAQ's 400 employees are scientists or engineers with technical backgrounds and that 40-50% of those employees hold master's or Ph.D. degrees. In her view, OTAQ's effectiveness depended on the talent of its engineering, scientific, policy, and legal staff.

Regions and program offices highlighted the key importance of ORD research to their decisions. Regional offices also spoke of the importance of ORD's Regional Applied Research Effort (RARE) Program to fund near-term research (1–2 years) to address high-priority, regional, applied science needs. The Office of Air and Radiation noted, for example, the significant contributions of ORD's intra- and extra-mural research programs to decisions to regulate particulate matter. The Director of the Ground Water and Drinking Water Program highlighted her office's reliance on ORD for developing the "health effects research needed to do our job." The Deputy Assistant Administrator in the Office of Chemical Safety and Pollution Prevention spoke of continued ongoing interactions between managers and senior scientists in his office and ORD to explore the potential of computational toxicology for future chemical safety decisions. Each time the meetings happen, "new light bulbs go off…we will have a need to conduct assessments for about 40,000 chemicals and managers are beginning to see the potential value of computational toxicology research."

Many offices emphasized that they sought needed science outside EPA for their decisions, because the Agency, including ORD, does not provide the science or research results needed. The Office of Air Quality Modeling and Standards turns to universities and contractors for science associated with air quality modeling and exposures and the Office of Transportation and Air Quality seeks science and engineering information from the Health Effects Institute, an independent non-profit research organization funded primarily by EPA and the motor vehicle industry and from stakeholders, such as automobile companies, who can both contribute to and challenge EPA's analysis. In 2010, the Office of Water developed the National Water Program's first *Research Strategy*, which identified research, science, and technology needs. It aimed to

expand partnerships and collaborations across EPA and the federal research family and engage the broader research community in the investigation of water research needs. Within the Office of Water, the Office of Wetlands, Oceans and Watersheds noted that ORD does not undertake demonstration studies important to its voluntary programs or conduct landscape ecology research useful to its non-point source or watershed programs. For this type of science, the Office turns to the U.S. Department of Agriculture, state and local governments, and non-governmental organizations. Similarly, OSWER generally does not turn to ORD for research on innovative treatment, site characterization, and its new materials management initiatives. Instead, it turns to the Department of Defense, the Department of Energy, the National Aeronautics and Space Administration, Argonne National Laboratories, and U.S. Army Corps of Engineers for the science it needs for treatment and site characterization decisions and the World Resources Institute and Sustainability Consortium for the science needed for materials management.

Regional offices demonstrate creativity and entrepreneurialism in working with a wide variety of parties outside EPA to obtain the science needed to support decisions. Regions have worked with local academics and community groups to identify chemical hazards in inner-city gardens; they have worked with permittee's discharge data to validate models, they have funded state research on exposure assessments; they have turned to other Federal agencies, such as the Agency for Toxic Substances and Disease Registry when EPA lacked information on disinfection byproducts in water or the U.S. Department of Agriculture on science relating to nutrients and sedimentation, bioenergy, and watershed initiatives,; and they have formed partnerships with associations and non-governmental organizations to address novel issues, such as materials management.

4.2.2. Areas where science acquisition should be strengthened

Many interviewees underscored the lack of needed data and science tailored to particular decisions as a major obstacle to science integration for decision making. Regions ideally seek human health exposure data or ecological data specific to a particular site. Even if ORD or major program offices provide a consensus hazard assessment for regions to use, a region may lack exposure data to complete a risk assessment. Several interviewees noted that "without scientific data, decision making is difficult and raises questions about EPA's credibility." Guidance such as the *Exposure Factors Handbook*, which provides standard factors to calculate human exposure to toxic chemicals, is helpful, but still may be challenged if a decision is novel, complex, or costly for the regulated community. And EPA lacks similar guidance for many types of decisions, especially those involving ecosystem protection, where standard factors or standard assumptions could be useful.

EPA program offices also highlighted the need for more adequate data to support decision making. Some offices, like the Office of Pollution Prevention and Toxics, must meet a high legal hurdle[2] under the Toxic Substances Control Act to require testing. That office

[2] "In accordance with TSCA Section 4, EPA must make the following statutory "findings" in order to require the chemical industry to test chemicals they manufacture, import and/or process:
* Hazard or "A" Finding - EPA must determine that existing data show that the subject chemical "may present an unreasonable risk of injury to health or the environment" and that the probability of exposure to the subject chemical substance is more than just theoretical; and/or

generally makes decisions about new chemicals with very little or no information about their potential risks to human health and the environment, based on an assessment approach called "Structure Activity Relationships" (described in 4.3.1 below). Other offices also noted barriers to obtaining needed hazard and exposure data. The statutes implemented by the Office of Water, for example, provide no authority to mandate generation of health effects data. The Office of Air and Radiation has limited authority to collect information on hazardous air pollutants, pollutants that are known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects. In addition to these limits of environmental statutes, the Paperwork Reduction Act constrains EPA in the collection of data useful to understand human exposures to pollutants or human behavior related to pollution prevention and control. Interviewees reported OMB's Paperwork Reduction Act review as a major barrier to developing needed surveys.

ORD research planning was not the focus of this SAB report, but many regional and program office interviewees reported a desire for ORD research to be more closely aligned with their decision needs. Nearly all regions voiced frustration with the time-intensive nature of ORD's research planning process. One program office noted the importance of biofuels and the need to shift ORD attention from "well-studied chemicals" to ORD biofuels and their potential impact on climate change. Another program office focused on the mismatch between ORD's focus on eco-toxicology and regions and program office's focus on emerging ecosystem problems at a landscape scale. Several offices also spoke of the need to make better use of results from ORD's extramural research program, the Science to Achieve Results program, especially to address regional needs. Regions also spoke of the need to obtain needed science from program offices as well. There were calls, for example, for implementation guidance for Clean Water Act and Safe Drinking Water Act standards, where significant technical issues arise in applying standards to regulated entities. There were also calls for science to help align air quality models to unique regional conditions.

In addition to research, regional interviewees spoke uniformly (outside the Superfund Program) of the need for more technical assistance from ORD in such areas as assistance with ORD-developed analytical methods, models, and assessment protocols and an improved mechanism for technical assistance. Many interviewees noted that technical assistance was not institutionalized as an important Agency function and that regional scientists relied on personal contacts, rather than formal processes, to seek technical assistance from ORD. Where scientists had no personal networks, they often found it difficult or impossible to obtain the technical assistance they needed.

Finally, regions spoke of key areas where EPA lacked sufficient internal disciplinary expertise to acquire science needed. Most commonly, regions spoke of the need for more sophisticated expertise in statistics; modeling and monitoring; and social, economic, and

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* Exposure or "B" Finding - EPA must show that the chemical is produced or imported in substantial quantities, and either enters the environment in substantial quantities or there is substantial or significant human exposure; and
* "Data Adequacy" Finding - EPA must show that existing data are inadequate for risk assessment; and
* "Testing is Necessary" Finding - EPA must show that testing is needed to develop the data necessary to conduct the needed risk assessment.

behavioral science. Regional staff and managers identified a range of needs to strengthen capabilities in social, economic, and behavioral science:

- For improved exposure assessments that better reflect actual human behaviors.
- For the assessment of benefits so regions could adequately compare benefits and costs, especially for decisions with ecological or ecosystem impacts
- For clear articulation of information needs and decision logic to promote better integration of science, characterization of uncertainties, and integrated decision making
- For improved communication of science and risk to decision makers and the public
- For strengthening implementation of environmental justice policies
- For strengthening EPA's efforts to collaborate with other organizations
- For improved understanding of tribal culture, needs, and activities, and
- For strengthening voluntary programs, stewardship programs, enforcement, and homeland security programs through a better understanding of human behaviors

4.3. Assessment of science

All of the science integration interviews with EPA programs and regions stressed the importance of EPA assessments of existing science in light of the Agency's mission and specific environmental mandates. Academic scientific literature reviews generally do not provide information that meets EPA's regulatory or environmental protection needs. As one regional scientist noted, "Published literature is out there but it is passive. The question is 'how do you apply it to a practical problem?'" Regional offices generally look to ORD or program offices to provide assessments of existing science, especially related to human health hazards. Some program offices, because of their individual history and legislative mandates, often develop their own science assessments; other program offices generally rely on ORD for this important information.

Since the SAB Committee on Science Integration for Decision Making was specifically charged to "focus on EPA's application of scientific assessments in environmental decisions concerning chemical and microbial pollutants," the committee took special note of examples of well-developed assessment processes and areas where science assessment should be strengthened.

4.3.1. Examples of well-developed processes.

The NAAQS review process for assessing science for criteria air pollutants is viewed at EPA as a highly successful science assessment process, because of several reasons. The NAAQS reviews follow a structured process, where different types of science assessments (the Integrated Science Assessment, Risk and Exposure Assessment, and Policy Assessment) relate to key aspects of regulating criteria air pollutants. ORD scientists work closely with scientists in EPA's Office of Air and Radiation. The reviews are iterative, since EPA must conduct NAAQS reviews for each of the six criteria pollutants every five years. As a result, EPA has learned from and refined the assessment process over time, identifying risks more precisely and identifying

key uncertainties for research to address. Compared to many EPA science assessments, NAAQS reviews are more transparent; they 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. 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.

EPA points to other high-profile science assessments that share some features of the NAAQS Review. EPA's 2009 Endangerment Finding on greenhouse gases relied on the ORD's synthesis report, *Assessment of the Impacts of Global Change on Regional U.S. Air Quality: A Synthesis of Climate Change Impacts on Ground-Level Ozone*. To develop this assessment, ORD scientists worked independently through two administrations to engage external researchers through EPA's STAR program and scientists in OAR and other federal agencies in constructing climate change models and developing and reviewing EPA's assessment. External peer review strengthened EPA's confidence in the assessment. ORD has also undertaken other high priority assessments in response to concern over potential risks associated with hydraulic fracturing and mountaintop removal. As these assessments have developed, ORD has emphasized the importance of working closely with regional and program offices and turned to the Science Advisory Board for peer advice and peer review.

ORD and EPA program offices conduct a wide variety of other kinds of assessments to support EPA decision making. EPA regions and several major programs (EPA's water, waste, Superfund, Air Toxics) look to the ORD-managed Integrated Risk Information System (IRIS) to provide robust, well-understood, and peer reviewed assessments of the chronic human health hazards of chemicals. Where those assessments are available or the schedule for developing assessments for priority chemicals is clear, decision makers feel well-supported. Where IRIS values are not available, managers must rely on default guidance, such as OSWER's 2003 Human Health Toxicity Values memorandum, which outlines a hierarchy of other assessment information [e.g., Provisional Peer Reviewed Toxicity Values, toxicity values prepared by the California Environmental Protection Agency, non-cancer Minimal risk Levels developed by the Agency for Toxic Substances and Disease Registry, or older (pre 1997) Health Effects Assessment Summary Table data] for decision makers and scientists to use. IRIS values provide a common starting point for decision-making. Regions and program offices can then tailor assessments to the specific regulatory issues they face. As one manager in EPA Region 8 noted, her approach to using IRIS information for the Libby Montana Superfund site in a critical way was a good example of well-developed practices for science assessment.

> Her unit includes toxicologists, hydrogeologists, and modelers, who respond when a remedial project manager requests technical support. Libby is a large and complicated site that will have far reaching implications on other asbestos sites. Key decisions are made throughout the analysis process: in the development of sampling and analysis plans, definition of exposure, choice of toxicity factors, and exposure factors. The region typically convenes a technical work group with risk assessors from OSWER, other regions, and ATSDR for peer review of technical documents like sampling and analysis plans. If the community feels methods are insufficiently sensitive, the region seeks their input so that site-specific

> investigations can include local knowledge. The regional team holds public meetings on a regular basis to provide progress updates to the community. The analysis might "pull in a number" from IRIS, but if the region feels that the IRIS toxicity values are not relevant, site-specific studies will be conducted such as animal laboratory studies to derive a site-specific cleanup standard.

Some EPA programs take an entirely different approach to science assessments and make little or no use of IRIS assessments. The Toxic Release Inventory (TRI), for example, uses TRI scientists and outside contractors to evaluate available science to determine whether a chemical's acute effects merit listing or "delisting" that chemical on the inventory. Scientists in the Office of Pollution Prevention and Toxics (OPPT) commonly evaluate 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. While managers wish for more complete information for assessments, they have developed a well-documented mechanism to use available information and have assessed more than 45,000 new chemicals over OPPT's 30-year history.

The Office of Pesticide Programs uses its scientists and outside contractors to conduct science assessments for new pesticides, new uses of pesticides, and registration renewal of pesticides. These structured processes generally make little or no use of ORD's IRIS process. Like ORD, OPP regularly seeks external peer review and science advice on significant or novel issues and has developed processes for public participation and public input. Its legislative authority (FIFRA) mandates the establishment and maintenance of the Scientific Advisory Panel which serves as an open forum for external scientific peer review. In addition, OPP has taken advantage of international opportunities for science collaboration to leverage resources and strengthen OPP's science assessments. As one manager noted:

> Many new active ingredients involve global reviews, which facilitate earlier access to the global market of newer and lower risk chemicals. For example, Australia, Canada, and the European Union have been involved. The countries may divide up initial analysis. OPP may do the residue chemistry and human toxicology and then collaborate and communicate with scientists in other governments. Through discussion, they come to agreement on the scientific endpoints of interest, but may not arrive at the same regulatory decisions because regulatory authorities differ. Collaboration involves work in itself, but OPP reaps benefits from the additional peer involvement and peer review resulting from global review. OPP scientists have gained confidence about their science through these interactions. The collaborative work across several countries also results in a higher degree of public confidence in the regulatory system.

Openness and transparency is a common theme as managers discussed science assessment practices that have benefited individual decisions and strengthened their organizations. A senior manager in Region 1 noted that:

> …an important regional mechanism supporting high quality, neutral science is use of a "community of practice." At key stages in the decision, especially in the clean-up programs, project teams are required to make a presentation to the responsible managers. The region invites other project teams to hear their approach to the science supporting record of decision. These open discussions "gradually ratchet up the quality of dialogue over time" and the quality of science improves. Scientists exchange ideas and interpretations and advance the community of practice.

Managers in several other regions spoke of the benefits of such a practice and scientific staff in other regions spoke of the difficult "black box experience" created when scientific input goes to a project manager and division directors who make decisions, but technical staff do not learn how the decision was made. Consistent with the theme of transparency, many programs spoke of the benefits of peer review. Peer review provides different, external perspectives needed to help EPA address novel complicated issues and many scientists and managers acknowledge that peer review process helps develop more thoughtful scientific documents.

4.3.2. Areas where science assessment should be strengthened

EPA regions and many programs voiced consensus that EPA's needs for IRIS assessments outstripped ORD's capacity for timely production IRIS values. Interviewees identified several major issues. They noted that EPA lacked IRIS assessments for many chemicals of concern (e.g., 17% of hazardous air pollutants) and that many IRIS assessments were outdated or incomplete, lacking information on major health hazard endpoints. They observed that the IRIS process was lengthy and that stakeholder challenges can lead to delays in completing IRIS assessments because "arguments about how to interpret the available science are perpetuated to keep new science from being implemented." Simultaneously, new risk assessment approaches, such as EPA's 2005 *Cancer Guidelines*, calls for increasingly high quality, nuanced science assessments, which no longer default to linear low-dose extrapolation for cancer or assume that a cancer value trumps all other effects. With all the focus on and expectations for IRIS, many managers voiced concern that EPA lacked a reliable schedule for generating IRIS assessments on which the whole Agency could depend.

Interviewees also spoke of the need for an increased number of assessments in many different areas. They spoke of the need for the Office of Water to generate more water quality criteria for implementation of the Clean Water Act and more Maximum Contaminant Levels for implementation of the Safe Drinking Water Act. They spoke of the need for scientific assessments for emerging chemicals, such as pharmaceuticals and personal care products, standard procedures and action levels for ecological clean-ups and regulation of nutrients, and assessment of climate change at temporal and spatial scales useful for regions. Scientists and managers across the Agency called for an increased flow of assessments of existing scientific knowledge that would help them apply that information to the practical problems they faced. One regional manager observed: "Currently, the public is aware of new scientific findings and 'blames EPA' for not basing clean-up decisions on recent science. The lag in integrating available science into regional decisions creates a transparency issue difficult for regions to address."

Regional interviewees especially looked to ORD and program offices for this information, because many staff reported they had limited time and expertise to review the external scientific literature and even science generated by state and local partners and regulated entities. Several regions also reported problems implementing peer review of regional science assessments. Region 2 managers, for example, found that peer reviewers did not help the region resolve "dueling science" on a sediment contamination issue, but instead led to the region's investment in expensive and lengthy additional studies that did not provide information useful for decision makers or protect the region from challenge by external parties. Because experiences with peer review can be so variable and often very time-consuming, there is a need to strengthen peer review planning and management oversight of the peer review process.

4.4. Integration of available science across different disciplines and sources

SAB interviewers sought information about regional and program efforts to facilitate cross-disciplinary and trans-disciplinary collaboration and decision makers' use of the results of such integration. Interviews also shed light on opportunities for strengthening integration of science across different disciplines and sources.

4.4.1. Examples of well-developed processes.

Several regions and program offices make explicit efforts to use models and tools to foster exchange of information across different disciplines and perspectives. Region 3's use of the MIRA decision science model and related logic model helps the region integrate multiple kinds of expertise and multiple levels of data through indexing data for comparisons and explicitly incorporating human preferences and expert judgment. With the help of a scientist trained in this analysis, Region 3 used this decision-science approach in several policy contexts to integrate multiple kinds of expertise and managers who were "comfortable and confident" enough to use the new tool for reasons described in Chapter 3 of this report.

Similarly, the Office of Air Quality Planning and Standards views model building as a tool to encourage cross-disciplinary dialogue, as well as exchange between Agency staff and stakeholders. Air quality modeling offers an appropriate tool for science integration because of the complex systems involved, unique to the meteorology and geography of different locations. Several other offices noted that maps and geographic information systems help decision makers understand clusters of different effects over space and time.

Many EPA organizations reported success organizing work processes to encourage inter-disciplinary collaboration. Several offices (e.g., OPP's Antimicrobial Division and the Biopesticides and Pollution Prevention Division or OSWER's Office of Resource Conservation and Recovery's Economics and Risk Analysis Staff) have organizational structures that combine scientists from different divisions to encourage team work. Other offices rely on problem-driven teams or work groups of scientists, whose members reflect the disciplines, expertise, and experience needed to solve particular problems.

There are regional science councils in all but one of EPA's ten regional offices. Where the science councils play an active role in research planning, facilitating ongoing training, and discussions of the science needed to implement Agency policy, EPA benefits from increased dialogue among scientists with different backgrounds. A science policy council also operates within OPP to keep track of emerging issues and related science integration. OPP reports that the mechanism works well because it has a charter, clear responsibilities, and operating rules. OPP managers evaluate the OPP council's work plans every year.

4.4.2. Areas where integration of science across different disciplines and sources should be strengthened

Recruitment and encouragement of qualified scientists dedicated to inter-disciplinary collaboration is a primary area that needs to be strengthened. Regions cited inertia and disciplinary elitism as factors that impede cross-disciplinary efforts. One regional scientist noted that interdisciplinary work is difficult because scientists in different disciplines "often speak different languages and have different assumptions." Managers must clearly communicate expectations for cross-disciplinary collaboration and plan to recruit scientists interested in and equipped to work in inter-disciplinary teams. In addition, EPA programs and regions currently lack the social, economic, and behavioral scientists required to address the expertise needs described in section 4.2.2 of this report.

Although there is the occasional case where EPA will send a scientist out to obtain new or cross-disciplinary training, there is no systematic program for doing this. As a result the initial disciplinary training of scientists becomes less relevant over time. There is a need for the Agency to implement programs that encourage scientists to obtain new skills, or learn new disciplinary languages. Sabbaticals or leaves of absence are examples of ways this can be encouraged. Rotations in university or other government agency labs may be another.

Regional and program offices also spoke of the need for more integration of EPA's data systems so that scientists expert in different program areas could collaborate more effectively.

4.5. Communicating integrated science with decision-makers and the public

Once science is integrated, it must be communicated to decision makers and the public. After EPA scientists obtain, assess, and integrate all the relevant kinds of science that might help a decision maker make the best possible management decisions, EPA must consider how to communicate this information to managers and the affected public in an understandable way so that the science adds value to the decision process.

4.5.1. Examples of well-developed processes.

Several themes emerged across the science integration interviews. Many regions and program offices emphasized the importance to decision makers of the science "translator" role played by such groups as the Regional Science Liaisons, ORD's Office of Science Policy, special assistants with highly developed technical skills and senior policy experience (e.g., as in

OAR's Office of Air Quality Planning and Standards and Office of Atmospheric Programs). Interviewees also emphasized that successful science communication requires senior managers to take time to understand the science underlying Agency policy, the different types of uncertainties associated with that science, and the groups affected by those uncertainties. Several interviewees noted that "The best communications involve ongoing conversations, where scientists communicating a complex issue get feedback that helps them understand when they are communicating effectively about these uncertainties." Some organizations, by necessity, like ORD's National Homeland Security Research Center, must develop science products on a short time-line and be prepared to release them, when needed, to Agency customers. The Center follows ORD quality assurance procedures, but if the center can provide information useful to internal customers at an early stage, they make the information available with the proviso that "this is what we know right now." They try to communicate uncertainties associated with products "transparently and fully."

Communication of integrated science to the public involves communication of complex information that may change over time, as research provides new information for EPA to consider. Although many interviewees expressed concern that communicating complex, integrated science to the public was difficult (see 4.5.2), some interviewees emphasized the importance of communicating this complex information to fully engage the public in decision making. One regional scientist noted:

> Regional scientists…need to understand science and decision making and translate science for communities." She expressed confidence that even poor, uneducated communities can help make sound decisions when they understand the central principles and findings underlying EPA science. As an example, in the Animas watershed, a stakeholder process was used for developing science-based TMDLs. To maintain this transparency, regional scientists and decision makers must have access to the full scientific assessment for a chemical and be able to describe uncertainties. An example is metal toxicity. It is important to look at different metal compounds, bioavailability, and speciation because different metal compounds behave differently in the environment. Regional decision makers can make more effective, practical decisions, if they can take more complete risk information into account. In her view, EPA needs to be more resilient and respond to changing issues and science more quickly to provide the information regions truly need.

Interviewees cited a wide variety of existing mechanisms are used for effective communication: formal notice and comment; federal advisory committee meetings; use of Superfund Technical Assistance grants; Superfund's Community Involvement Coordinators, who have developed a dedicated "area of practice;" use of Regional Public Affairs Offices; and public involvement activities of major voluntary programs. All of these mechanisms can be effective, given a commitment to ongoing, interactive communication with the public about complex science issues.

4.5.2. Areas where communicating science to decision-makers and the public should be strengthened

Interviewees acknowledged that communicating integrated science is challenging, especially because science is dynamic, often complex, and often difficult to understand. Many participants called for investment in research on risk communication and training in communicating science and risk for both scientists and managers. EPA faces an increasingly informed and skeptical public that does not "accept experts as the sole source of credible information." Some interviewees requested explicit guidance about how EPA should communicate conflicting data and uncertainties to the public and expressed concern that EPA's Office of General Counsel may not welcome full disclosure of this information. Many interviewees spoke of the need to plan for managers to take time to understand uncertainties. They also emphasized that EPA should not confuse lack of support for EPA's decisions with lack of effective communication and public understanding.

4.6. Evaluation of the use of science

Few of the SAB interviews devoted significant attention to how programs or regions evaluated use of science. SAB interviewees often responded to questions about evaluation by responding that EPA gets "lots of feedback" – from the public, from advisory committees, and from the courts. If a decision and its associated rationale met a legal test and is publically acceptable, then the use of science was deemed successful.

The amount and pace of EPA's workload are barriers to evaluation. As managers in one region noted, "decisions in the regions are fast paced and often there is no time to reflect when something (i.e., enforcement, corrective action, sampling, and delisting efforts) doesn't work right. The highest profile issues may be publicized and highlighted in an accomplishments report, but often incremental improvements addressing routine issues don't get attention."

One set of scientists, however, in Region 3, explicitly recognized the important role evaluation plays in science integration. These interviewees noted "that integration is more than looking at the sum of program impacts sequentially and it is more than looking at transdisciplinary knowledge. It is the use of these insights for good decision making, explicit consideration of the benchmarks for evaluating whether an upcoming decision is a good one, and ongoing evaluation of decisions by explicit criteria. Such science integration for decision making requires a long time frame." The observations below are presented to encourage EPA to consider using the examples of well-developed processes below as benchmarks towards the full vision of science integration evaluation voiced in Region 3.

4.6.1. Examples of well-developed processes.

Programs that review and use science iteratively for decision making have natural opportunities to evaluate EPA's use of science and how it can be improved. The NAAQS process and pesticide registration renewal are two examples where EPA uses this dynamic at the national level.

OSWER has implemented several notable evaluation efforts. At a site-specific level, the Superfund mandate for five-year review of remedy decisions has the potential for evaluating the science used for decision making and the effectiveness of decisions reached and then factoring in new science, such as findings related to vapor intrusion, that might alter the remedy selected. OSWER Staff also conducted a peer-reviewed evaluation of public participation in Superfund activities (Charnley and Engelbert, 2005) and has expressed an interest in using social media tools for evaluation of future Superfund Technical Assistance Grants. OSWER issues an annual report evaluating the use of new and emerging clean-up technologies.

Interviewees noted specific efforts to get feedback to help evaluate the effectiveness of Agency science. ORD's National Center for Environmental Assessment (NCEA) noted that it generally relies on a "participatory research approach" for involving external stakeholders and scientists. To follow up on studies on the mid-Atlantic region, Great Lakes, and Climate Ready Estuaries, NCEA's Global Team sought information from the users of NCEA reports to determine if they find them useful. Similarly ORD's National Homeland Security Research Center spoke of its success in taking management action based on customer feedback. The Center dropped an academically acclaimed project because the client office determined it was not useful. Shifting resources to a more clearly defined Agency need was claimed as a distinct benefit of evaluation.

5. Major Findings

5.1. Barriers to science integration

A major barrier to science integration is a "silo" approach to implementing individual programs, rather than a consistent effort to find ways EPA can achieve its broader integrated mission to protect human health and the environment. Managers and staff in many interviews, especially in program offices, defined success in terms of meeting statutory requirements and court-ordered deadlines in a litigious society. One manager identified the key science question she faced as "how do I get a pretty good answer that is not arbitrary and capricious, which I can defend in a regulatory arena." Regional scientists made a complementary comment when they noted that the best science is "science which our resources allow us to use and retains legal defensibility."

A narrow focus on "program silos" and defensibility can prevent new interpretations of science or new applications of science for environmental protection, including sustainability. Some regions voiced a "a fear of going rogue," a "tendency to go with what works – what has passed muster legally-- and to ensure consistency across regions." One manager mentioned that her office refrained from integrating social science into regulatory analysis because many perceive that it would weaken EPA's analysis. In several interviews, scientists called for clearer guidance for communicating scientific uncertainties; their experience made it difficult to know how much and how best to communicate the unknowns associated with the science underlying a decision. Integration of uncertainty information into decision making depends on the political or policy context. If there is a bias against regulatory action, uncertainty information can become an "excuse not to do anything." Many interviewees spoke of the difficulty of exploring complex, controversial topics in the public arena, where viewpoints are polarized and litigation biases EPA towards responding to crises, rather than root causes of problems.

Some environmental statutes and regulations create impediments to science integration. Although some statutes, like Title 2 of the Clean Air Act provides specific criteria for EPA decision making, along with some flexibility in how those criteria are to be used, other statutes, such as the Toxic Substances Control Act have led to regulations for PCBs that are prescriptive, limiting managers' discretion in finding solutions appropriate to different sites. Similarly, although some regulations have an iterative component, like the National Ambient Air Quality Standards program, which requires review of the science associated with criteria air pollutant standards every five years, as must the Drinking Water program review its MCLs,, the scientific process may not fit well with many of EPA's regulatory programs, where there are disincentives to revisit hard-won regulations. In addition, extremely short statutory deadlines (e.g., 90-day review for Premanufacture Notifications for new chemicals; 30-day review for Total Maximum Daily Load Determinations; 45-day reviews for Environmental Impact Statements; and a one-year requirement to develop a proposed rule including lifecycle assessment for greenhouse gases under the Energy Independence and Security Act) make it difficult to formulate environmental problems broadly or carefully. And finally, while some environmental statutes, like FIFRA, provide a mechanism for regulatory programs to obtain the data needed for analysis and assessment, other environmental statutes (e.g., the TSCA, SDWA, and the CWA) do not provide

regulatory programs with the authority to collect needed data easily or efficiently. And voluntary and information based programs, which rely on science and data to help understand human behavior and communicate environmental benefits, lack authority and resources to collect information and suffer especially from lack of scientific data to make their programs effective.

Paralleling these statutory differences, lack of integration across Agency databases poses an obstacle for science integration. Beyond EPA, lack of science integration across federal agencies with environmental mandates (e.g., Centers for Disease Control and Prevention, Food and Drug Administration; and U.S. Fish and Wildlife Services) pose ongoing problems for environmental scientists and decision makers.

Many interviewees pointed to limited resources as a barrier to science integration. In nearly every region, the water, waste, pesticides, toxics, and voluntary programs compared their lack of resources to the Superfund Program's extramural and intramural funds. They called for EPA generally to use Superfund as a model for training, information-exchange, and regional and risk assessment support for all programs.

Science integration was more difficult for programs and regions that did not plan explicitly to meet their science needs and did not explicitly seek opportunities to promote training opportunities and advancement for staff, as well as staff scientists' collaboration across disciplines. Scientists in most regional and program offices spoke of a limited career track and limited training budget.

Many programs and regions reported uneven or disappointing experiences seeking technical assistance, assessments, and research results from ORD as a barrier to science integration. The tension between EPA customers' desires for ORD products and ORD's vision of its work and related willingness and ability to produce the scientific products needed by its internal customers was a major theme of SAB interviews and is discussed in section 5.3.

An overarching barrier to science integration was the lack of strong central leadership for science outside ORD. Although EPA estimates its scientific workforce to number 6,000, with 4,800 scientists employed outside ORD, there is no coordinated effort to manage and strengthen EPA's scientific workforce as a resource for the Agency as a whole. Interviewees reported that the principal historical mechanisms for coordinating science across EPA (e.g., the Risk Assessment Forum and the Science Policy Council) now engage only in a limited set of activities with participation in them not a priority even for programs and regions that do contribute their scientists' time. On-line initiatives to coordinate Agency science (e.g., the Science Inventory, designed as a searchable database of EPA science activities and ORD's Science Connector) were populated and used principally by ORD and not generally seen as an effective tool by regions and programs seeking to access and share science information for their purposes.

5.2. Practices that promote successful science integration

Despite the barriers described above, many EPA program and regional offices succeed in science integration to support decision making. The most important factor linked to success is leadership that expects science integration to happen and that follows up to assure that

expectations are met. As 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 also emphasizes the importance of problem formulation to allow EPA to step "out of the box" of narrow programmatic concerns." OPP managers, for example, noted that "There's a need to recruit, nurture, and guide people to make decisions outside the box, while still making timely decisions. Scientists and managers may need training to be knowledgeable about the potential of programs across the Agency that can be used, in conjunction with their own, to achieve EPA's health and environmental protection goals. Managers must be willing to explore the flexibility of their statutes and look for collateral ways to achieve environmental goals."

EPA organizations that successfully integrate science devote attention to institutional mechanisms that promote integration. Examples are explicit problem formulation activities that involve decision science models or model building exercises, well-developed Science Policy Councils, cross-media or cross-disciplinary project teams, or mechanisms where project teams presented their integrated science to decision makers in forums open to all Agency staff. These mechanisms increase the transparency (and remove the mystery) from integration and make science integration more understandable and accessible to agency staff and managers.

Although many interviews acknowledged the need for succession planning to replace Agency scientists likely to retire in the next five to ten years, only a few regions and programs described human resource plans in place to promote science integration. Several managers noted that the "next EPA generation of scientists and engineers" would be individuals with highly developed technical skills, trained in information technology, teamwork, and communication skills. They noted that current graduate education in engineering, public health, and environmental sciences fostered inter-disciplinary collaboration and that a new cohort of scientific and technical employees would enhance EPA's capability for science integration.

Managers who succeeded in integrating science for decision making also devoted attention to workforce retention and managing scientists as a key Agency resource. One region has developed a special training program and career pathways for scientific staff. Some programs and regions actively promote scientists' involvement in professional meetings, societies, and workshops. Some managers emphasize the importance of helping staff use Individual Development Plans to increase their technical competence and science integration skills. Finally, ORD's Regional Research Partnership Program, which offers regional scientists the opportunity to work with scientists in ORD Laboratories and Centers on research projects of interest to the regions, helps strengthen individual scientists' technical skills and EPA's networks for scientific exchange and science integration.

Finally, managers who make science integration a priority consider it as an ongoing learning experience. These managers demonstrate willingness to improve science integration over time. They turn to peer review and evaluation as mechanisms to demonstrate effective science integration and improve Agency processes. In Region 1, for example, the General Electric Housatonic River Superfund case, for example, involved public health and ecological risk. EPA and the responsible party agreed to a consent decree involving an independent review

of science supporting EPA's decision. EPA and the litigant jointly agreed on peer reviewers. Those reviewers vetted EPA's view of the science supporting the environmental decision and supported EPA's interpretation, thereby sustaining the Superfund decision.

5.3. ORD and science integration

As mentioned above, a major theme of the SAB's fact-finding interviews was tension between the desires of programs and regions for ORD work products and ORD's limited ability and willingness to provide the research results, assessments, and technical support needed. Programs and regions expressed three main areas of tension: 1) need for technical assistance; 2) a desire for a more effective, transparent process for research planning that produced science products useful for decision making; and 3) more IRIS assessments and more assessments of scientific knowledge (e.g., lifecycle analysis, nutrient loadings) that would evaluate external literature and address how programs and regions could use this information for regulation or enforcement. Regions, especially, expressed concern that ORD research was primarily focused on future science issues and issues of concern to national program offices, while regions had immediate needs to apply (or develop and apply) science related to site-specific exposures or hazards. While the RARE program (see page 19) is designed to allow ORD to help regional offices with technical problems, the regions noted that the use of that program required knowing someone at ORD who is willing to support the project.

ORD emphasized in SAB fact-finding interviews that it had limited resources and could not meet all of EPA's science and research needs, especially since program offices and regions account for two-thirds of EPA's scientists in the Agency's work force. ORD also emphasized its focus on research to create the science to address future environmental problems as well as to address current problems more effectively. An ORD manager acknowledged that regions may contact ORD for technical support on issues that are "so yesterday." ORD may no longer have expertise in a particular area, such as an analytical method, where regions need technical support. Although some managers acknowledge technical assistance and scientific leadership as part of ORD's mission, ORD did not have a centralized process for providing technical assistance or a method for tracking requests and responses. Regions, in response, voiced frustration, with one senior manager noting that for issues that do not rise to senior management attention, ORD technical assistance depends on personal connections. He suggested that ORD work with programs and regions to clarify expectations for providing technical assistance and that ORD or some other part of the Agency assume a new "broker" role, to help programs and regions find the science they need both inside and outside EPA.

As noted in Chapter 1, the SAB's science integration interviews occurred before the ORD Deputy Administrator issued his "Path Forward" memorandum calling for a new approach for ORD research focused on sustainability and a trans-disciplinary, systems orientation to identify and address root causes of environmental problems. The SAB's science integration interviews with managers and scientists in ORD Laboratories and Centers confirm the potential value of this initiative to improve science integration at EPA. Improved research planning that involves EPA regions and programs in problem formulation and that focuses on root causes and solutions to environmental problems is needed to reinvigorate the research planning process and meet the most important regional and program needs. This new approach will also tap the innovative

inter-disciplinary research team at ORD's National Risk Management Laboratory, which formerly had no ongoing Agency client for its sustainability research. Consolidation and streamlining of ORD research programs in four major areas (air, climate and energy; sustainable water; safer products for a sustainable world; and safe and healthy communities) will encourage collaboration and integration across ORD Laboratories and Centers. ORD's "Path Forward" will require engagement from scientists and managers in EPA regions and program offices to participate in problem formulation exercises, priority setting, and ongoing research development.

ORD's role in assessing existing science for EPA decision making is ORD's third critical role. As noted by one senior manager, "The IRIS program fits naturally with the Administrator's concept of 'One EPA'," since IRIS provides a central source for critical health hazard information. Although it seems logical that EPA would have a central, expert, authoritative source for assessments with a major impact on Agency decisions, it is not clear how best to manage this function, so that EPA has a dependable process for generating high quality, credible assessment on a schedule that will meet program and regional needs. This topic deserves attention from EPA's senior leadership, just as ORD's "Path Forward" memorandum has outlined a new approach for ORD's research activities.

5.4. Advisory committees and science integration

Most scientists and managers interviewed had little direct contact with federal advisory committees or the National Research Council (NRC). Interviewees who had received expert advice generally agreed with one scientist who reported that he found "a lot of review useful and at times painful." Interviewees acknowledged that preparing for advisory committees helps them to see their work in a larger context and that advice from the SAB sometimes forces EPA to integrate science in ways it had previously ignored. SAB, CASAC, and NRC advice sometimes raises key issues (e.g., about revisiting default assumptions) that need Agency attention.

Interviewees also pointed out ways advisory committees could be more effective. Many interviewees noted that SAB is often slow to develop its advice and sometimes delivers advice without recognizing restrictions on Agency action or Agency activities already under way. Many SAB reports make too many recommendations and do not prioritize among them. Sometimes advisory reports do not focus on the appropriate level of science required for different kinds of decisions. An interviewee noted that advisory reports would be more helpful, if they focused on the "granularity of science" appropriate to different types of decisions. Interviewees in EPA regions encouraged the SAB and NRC to consider how to translate their advice for EPA regions and to plan workshops to "roll out" advice when a report is completed. Several interviewees suggested that EPA should have a mechanism for reviewing NRC and SAB reports that have a broad Agency scope and communicating their possible implications for the regions.

Finally, some interviewees encouraged the SAB to play a more active role in science integration, perhaps designing workshops or other events to help build community among EPA scientists across the Agency or by helping to fill EPA's science needs by identifying complements to EPA's expertise, given the Agency's limited resources.

6. Recommendations

Science integration, as defined in Chapter 1, provides a mechanism to implement the Administrator's key principles, (transparency, and the rule of law, and the fundamental role of science) to support the decisions linked to EPA's major priorities. Although science integration requires foresight, planning and coordination, it provides a way to maximize all of EPA's scientific resources to address current environmental challenges and prepare to meet new ones. At a time when EPA, like other federal agencies, must efficiently use resources, science integration across the whole Agency helps to link science to decision making, integrate existing science, and plan research to help achieve wise use of public funds.

Several recommendations to improve science integration at EPA spring directly from the findings described in chapter 5. The SAB recommends that managers in regions and program offices adopt or adapt the practices described in Section 5.2 and summarized in the table below that promote science integration.

Practices that promote successful science integration

- Leadership practices
  - Setting an expectation that needed science integration will happen and following up to assure that expectations are met.
  - Planning for high quality science.
  - Emphasizing the importance of problem formulation
  - Guiding staff to think broadly about environmental protection
  - Exploring the flexibility of the statutes and look for collateral ways to achieve environmental goals
- Institutional mechanisms that promote integration.
  - Explicit problem formulation activities that involve decision science models or model building exercises,
  - Well-developed Science Policy Councils,
  - Cross-media or cross-disciplinary project teams,
  - Open forums where project teams present integrated science to decision makers
- Human resource planning
  - Recruitment of individuals with highly developed technical skills, trained in information technology, teamwork, and communication skills.
  - Attention to workforce retention and managing scientists as a key Agency resource.
    - Well-identified career pathways for scientific staff
    - Support for scientists' involvement in professional meetings, societies, and workshops
    - Use of Individual Development Plans to increase technical competence and science integration skills.
- Commitment to improving science integration over time
  - Use of peer review and evaluation as mechanisms to demonstrate effective science integration and improve Agency processes.

The SAB also recommends that ORD: 1) continue to pursue the new approach to research planning described in the "Path Forward" memo, 2) work with regions and program offices to clarify expectations related to technical assistance; and 3) work with program and regional offices to seek options for strengthening EPA's approach for generating science assessments (see below). The SAB also will consider suggestions from interviewees about how to make SAB advice more effective for the Agency.

At an Agency-wide level, the SAB recommends that EPA take several actions to ensure science integration happens more consistently across the Agency as a whole. The SAB recommends that EPA's senior leadership communicate that science integration is the responsibility of every EPA employee, i.e., that everyone at EPA has the responsibility to help the Agency use the best available science to achieve effective protection of health and the environment. EPA's senior leadership should communicate the vision that EPA should have the highest standards for environmental protection and environmental science in regional and program offices, where managers actually use science for environmental decision making. Managers should promote the goal of scientific excellence for decision-making, with excellence defined as "thoughtful and holistic" science that has full access to and makes full use of available data. Managers should model how problem solving requires science integration and train/encourage/expect staff to think outside historical program boundaries and scientific defaults to integrate science for decision making.

To realize this vision, the SAB recommends that EPA programs and regions undertake a transformation in how they use science as a resource. This transformation in regional and program office science programs would complement ORD's "Path Forward" in research planning. The SAB recommends that senior leaders at EPA should:

A. Engage fully in ORD's "Path Forward" research effort by:
   - Supporting ORD's "Path Forward" by engaging senior managers and scientific staff in helping to plan ORD's new environmental research program.
   - Complementing ORD's "Path Forward" by integrating new research results (e.g., results of computational toxicology or life-cycle analysis) into environmental decisions or by using new risk management strategies to address significant problems formulated by the Agency (e.g., using FIFRA authority to get data on chemicals that are pesticide precursors and may cause drinking water problems, where EPA does not have authority under the SDWA to mandate such studies or by using voluntary programs, such as Design for the Environment to address problems that regulatory programs find difficult to address).
   - Providing ORD leadership with ongoing feedback regarding the utility of scientific and technical products make research planning successful.

B. Strengthen planning and management of science programs in regional and program offices by:
   - Strengthening problem formulation efforts.
     - Integrating problem formulation, as described in this report, into EPA's Action Development Process for program offices and regional decision making.

        - Developing a set of tools for problem formulation and case studies showing how they were used.
    - Requiring regions and program offices to develop regular plans to identify the science needed to support environmental decisions. These assessments, like the National Water Program's first *Research Strategy*, would identify needs to be met by internal program or regional scientists and sciences needs that must (or can be better) be met by sources outside the region or program.
    - Making it a high priority for senior managers to review their organizations' plans for peer review and peer advice, including plans for the use of federal advisory committees.
    - Piloting ways that program offices can leverage Superfund's communication and training methods to support scientific exchanges within EPA (programs, regions, and ORD) and between EPA and external scientists.
        - One possibility: Regions might develop best practices networks along the model of Exxon's global regions, which set up networks of peers who interact electronically and occasionally meet face-to-face.
    - Creating an Agency award, comparable to the Science to Achieve Results award, for integrated science that makes a major contribution to environmental problem formulation and problem solving.
    - Developing regional centers of expertise that provide expertise for the Agency as a whole. Some possible areas might include decision support, air quality monitoring, and risk communication.

C. Create new mechanisms to address Agency-wide science integration needs or re-invigorate old ones. Such mechanisms would:
    - Provide a dependable process for generating high quality, credible assessments of available science on a schedule that will meet program and regional priority needs.
    - Act as a broker or clearinghouse to help programs and regions acquire, peer review, and share priority science that ORD is not able to provide
    - Provide tools, training, and underlying research results to help EPA managers and scientists communicate with external scientific and lay audiences about the science supporting EPA decisions.
    - Support interactions with external experts and the public, because external interactions strengthen Agency science and confidence in policies based on science.
    - Develop mechanisms to evaluate efforts to integrate science for decision making and to document outcomes and lessons learned.

D. Recognize the importance of strengthening EPA's community of scientists; attract and retain highly qualified scientific staff with an aptitude for science integration by:
    - Developing a pilot project for engaging social scientists explicitly in science integration activities in ORD and program and regional offices.
    - Developing an Agency-wide human resource plan for scientists in the regions, programs, and ORD to attract and retain highly qualified staff with training. The SAB recommends that this plan be jointly peer reviewed by the SAB, the Scientific Advisory Panel ORD Board of Scientific Councilors, and the National Advisory Committee on Environmental Policy and Technology (NACEPT).

- Developing an exchange program for Agency staff and managers to promote details in other regions, program offices, and ORD laboratories and centers.
- Developing career ladders for managers and scientists that would foster integration. Managers should be expected to work in regions, ORD, and program offices. ORD scientists should work in program and regional offices; *vice versa*, regional and program scientists should spend time in ORD laboratories and centers.

Insert final paragraph describing the importance of implementing these recommendations:

Some ideas

- urgent message that EPA must reconsider its organization and support for science to prepare for future challenges that will require collaborative approaches and new disciplines.
- vision that EPA should have a system that prepares and organizes scientists to work collaboratively with each other, with external scientists, with the public, and with decision makers so they "play off each other and expand and enrich" EPA's scientific output and science-based decision making.

Table of Acronyms

CASAC	Clean Air Scientific Advisory Committee
FDA	Food and Drug Administration
HERO	Health and Environmental Research Online
MIRA	Multicriteria Integrated Resource Assessment
MTBE	Methyl Tertiary Butyl Ether
NAAQS	National Ambient Air Quality Standards
NPDES	National Pollutant Discharge Elimination System
OAR	Office of Air and Radiation
ORD	Office of Research and Development
OPP	Office of Pesticide Programs
OPPT	Office of Pollution Prevention and Toxics
OSWER	Office of Solid Waste and Emergency Response
OTAQ	Office of Transportation and Air Quality
PCBs	Polychlorinated Biphenyls
RfD	Reference Dose
TRI	Toxic Release Inventory
TSCA	Toxic Substances Control Act

Attachment A: Request for the Study

Attachment B: Preliminary Study Plan

U.S. Environmental Protection Agency
Science Advisory Board
Committee on Science Integration for Decision Making
Preliminary Study Plan

In response to an Agency request, the Science Advisory Board (SAB) is undertaking a study to evaluate the extent to which EPA's scientific assessments are integrated to support environmental decision making. To conduct this study, the SAB formed the Committee on Science Integration for Decision Making. The SAB committee held an initial public meeting on June 9-10, 2009 to develop its study plan. Subgroups of the SAB committee held subsequent discussions to develop the study objectives and refine the preliminary study plan.

Study Objectives

Since it is important that there is a common understanding of the definitions of "science integration" and "integrated decision making" and the relationship between them, the SAB committee makes the following distinctions: "science integration" refers to the identification, collection, and application of scientific data, models and concepts from multiple scientific disciplines to support decision-making, while "integrated decision making" refers to the deliberate inclusion of results of different types of assessments in the process of decision making. The SAB committee has adopted the definition as described in the SAB 2000 report Toward Integrated Environmental Decision-Making. "Integrated decision-making 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 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."

Based on the SAB charge and this definition of integration, the SAB committee developed the following initial set of objectives for the study. These initial study objectives may need to be refined as information is obtained through the SAB's fact-finding efforts.

- **Evaluate EPA practices for integrating science to support decision making**: The SAB will examine aspects of existing EPA decision-making processes and approaches that are relevant to the role of scientific information and assessments and how these processes might vary between program and regional offices. The SAB members will evaluate what models for integrating science into decision making work well for different types of decisions and why.

- **Evaluate consideration of public, stakeholder, external scientific, and other governmental (i.e., states, tribes, foreign governments, international organizations) input in science assessment for decision making**: The SAB will examine when and how this input occurs when integrating science into decision-making. Differences between program and regional offices on their use of public input will be examined.

- **Evaluate drivers and impediments to implementing past recommendations for science integration:** The SAB will determine to what extent EPA scientists, policy makers, and decision makers have implemented past recommendations of the EPA SAB and the National Research Council of the National Academies (NRC). The members will examine why and how success was achieved.

- **Evaluate ways EPA receives feedback on how science is used in decision-making:** The SAB will identify ways in which the Agency receives feedback on how science is used in decision-making and where feedback can be used to identify emerging science and opportunities for future policy.

- **Evaluate EPA workforce to support science integration for decision making**: The SAB will determine how EPA adapts its workforce to shifts in priorities, resources and scientific expert need. Also, it will examine how scientists in the Agency stay current in their areas of expertise, or expand their expertise based on current and future scientific needs.

Overall Plan and Timeline:

The first step of the study is for the committee to become familiar with EPA's programs and environmental decisions. The committee will gather information through interviews with Agency personnel to learn more about current science assessment and decision-making practices. Those interviewed will include scientists, policy analysts, and senior managers across EPA (Attachment 1).

The committee will evaluate its fact-finding processes and any data and knowledge gaps to provide the fullest picture possible of the science-integration process throughout the Agency. The committee will clearly document: the interview process, discussions with interviewees, analysis of findings, and the data and knowledge gaps inherent in the study approach.

In addition, the SAB will conduct a public workshop to seek further input from EPA as well as input from interested members of the public, stakeholders, external scientists, and scientists from other governmental entities. Following the workshop, the SAB will hold public meeting(s) to discuss its findings and prepare a draft advisory report. The draft report will be subsequently reviewed and approved at a public meeting of the chartered SAB. EPA and public comments are sought throughout the advisory process.

The SAB will adapt the plan as it gathers and analyzes information. The SAB will explicitly address the strengths, limitations, and uncertainties of the information collected and how they relate to the overall findings and recommendations to be developed in the committee's draft report.

Approximate Study Timeline:

The following timeline contains proposed milestones and dates for completing the study on Science Integration for Decision Making. These key dates may change, if the SAB committee determines a need to adapt its plan.

Date	Milestones
June-September 2009	Develop preliminary study plan
October 2009–January 2010	Fact-finding interviews with EPA offices (see Attachment 1) conducted by committee subgroups
February 10-11, 2010	Committee public meeting to discuss: - Fact-finding lessons learned - Identify external input needed on preliminary lessons learned - Workshop planning - Identification of any additional information needed
May/June 2010	Public workshop to seek EPA and public input on preliminary lessons learned
May–September 2010	Committee meeting(s) to discuss draft advisory report
November 2010	Review of committee draft report by chartered SAB
December 2010	Publication of final report

Attachment 1: Interview Sessions with EPA Offices

The SAB will conduct interviews with EPA Offices and Regions that use science to support decision making (see list of EPA Offices and Regions to be interviewed). Two or more committee members will be involved in each interview. The SAB Staff Office Director or Deputy Director will provide introductions, and the Designated Federal Officer (DFO) for the committee will take notes and assist the SAB committee in consolidating and summarizing information gleaned from the interview sessions. The composition of the fact-finding groups will be based on a SAB member's expertise and interest, as well as their geographical location. The interviews will be held at the designated location of EPA Offices.

The SAB will hold separate interview sessions with decision makers, policy makers, and scientific and technical staff. SAB members will use the following questions as a guide for the interviews. The SAB recognizes 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* 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 asks interviewees to review the questions below before the interviews and describe one or two important and representative examples of science-based decisions specific to their organization. The committee is especially interested in learning what interviewees view 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 will provide draft summaries of the interviews to the interviewees for comment.

<u>Questions for Policy and Decision Makers:</u>

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?

*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).

1.5. 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?

1.7. 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?

<u>Questions for Scientific and Technical Staff:</u>

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?**

<u>EPA Offices and Regions to be interviewed:</u>

Office of Air and Radiation
Office of Children's Health Protection
Office of Environmental Information
    Toxics Release Inventory Program
Office of Prevention, Pesticides and Toxic Substances
Office of Solid Waste and Emergency Response

Office of Water
Office of Policy, Economics and Innovation
National Center for Environmental Economics
Office of Research and Development
Office of the Science Advisor
EPA Regions (1-10)

Attachment C: List of fact-finding interviews

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 Region 7 Scientists
- With the Region 7 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

OAR 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

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

- With OAQPS Managers
- With OAPQS Scientists

OAR 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

OSWER Principal Deputy Assistant Administrator Fact-finding Discussion, December 1, 2009

OSWER Office of Resource Conservation and Recovery (ORCR) Fact-Finding Discussions, November 24, 2009

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

OSWER 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

OW 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 (

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

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

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

OW 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 (OEI) Toxic Release Inventory (TRI) Program Fact-finding Discussions, December 24, 2009

- With TRI Managers
- With TRI Staff

ORD Fact-Finding Discussion, January 29, 2010, with the Assistant Administrator and Deputy Assistant Administrator for Science

ORD 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

ORD 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

ORD National Homeland Security Research Center (NHSRC) Fact-finding Discussion, November 30, 2009, with NHSRC Managers and Staff

ORD National Risk Management Laboratory (NRMRL) Fact-finding Discussion, November 30, 2009, with NRMRL Managers and Staff

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

ORD 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

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References

Bipartisan Policy Center. 2009. Science for Policy Project. Improving the use of science in regulatory policy. Final Report. Washington, DC August5, 2009

Charnley, S. and Engelbert, B. 2005. Evaluating public participation in environmental decision-making: EPA's superfund community involvement program. *Journal of Environmental Management* 77(3):165-182

Hubbell, B.J., Crume, R.V., Evarts, D.M., Cohen, J.M. (2010). Policy monitor: Regulation and progress under the 1990 Clean Air Act amendments. *Review of Environmental Economics and Policy*.. 4(1):122-138. Advance access publication on December 22, 2009..

National Research Council (2009). *Science and Decisions: Advancing Risk Assessment.*, National Academies Press. Washington, D.C.

Principia Cybernetica Web. Retrieved 12/21/10, from http://pespmc1.vub.ac.be/ASC/PROBLEM-FOR.html.

U.S. EPA Science Advisory Board (2000). *Toward Integrated Environmental Decision-Making*