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EPA

Integrated Environmental Decision-making in the Twenty-first Century: Summary Recommendations ---Peer Review Draft

U.S. Environmental Protection Agency
Science Advisory Board
Integrated Risk Project Steering Committee
_____ 1999

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The Science Advisory Board (SAB) of the U.S. Environmental Protection Agency is a body of independent experts who provide advice to the EPA Administrator on scientific and engineering issues. The SAB was established in its present form by the Congress in 1978. The SAB's approximately 100 members and more than 300 consultants include scientists, engineers, and other specialists drawn from a broad range of disciplines–physics, chemistry, biology, mathematics, engineering, ecology, economics, medicine, and other fields. Members are appointed by the Administrator to two-year terms. The SAB meets in public session, and its committees and review panels are designed to include a diverse and technically balanced range of views, as required by the Federal Advisory Committee Act (FACA).

The Board's principal mission is to review the quality and relevance of the scientific information being used to support Agency decisions, review research programs and strategies, and provide broad strategic advice on scientific and technological matters. In addition, the Board occasionally conducts special studies at the request of the Administrator to examine comprehensive issues, such as anticipating future environmental problems and developing new approaches to analyze and compare risks to human health and the environment.

Integrated Environmental Decision-making

in the Twenty-first Century: Summary Recommendations

---Peer Review Draft

U.S. Environmental Protection Agency

Science Advisory Board

Integrated Risk Project Steering Committee

Letter to the Administrator

, 1998

Science Advisory Board
U.S. Environmental Protection Agency

Washington, D.C.

Ms. Carol Browner
Administrator
U.S. Environmental Protection Agency
Washington, DC 20460

Dear Ms. Browner:

TO BE DRAFTED

NOTICE

This report has been written as part of the activities of the Science Advisory Board, a public advisory group providing extramural scientific information and advice to the Administrator and other officials of the Environmental Protection Agency. The Board is structured to provide balanced, expert assessment of scientific matters related to problems facing the Agency. This report has not been reviewed for approval by the Agency and, hence, the contents of this report do not necessarily represent the views and policies of the Environmental Protection Agency, nor of other agencies in the Executive Branch of the Federal government.

This particular project was conducted at the request of the EPA Administrator and addresses a broader range of issues and concerns than most SAB reports. Consequently, many of the recommendations in this report have more of a policy orientation than is usually the case.

ABSTRACT

At the request of the EPA Deputy Administrator, the Science Advisory Board developed a framework for Integrated Environmental Decision-making (IED). The IED builds on the successes of environmental protection over the past three decades and expands the process by integrating a fuller range of scientific information, the practice of comparative risk, a wider spectrum of management options, explicit economic considerations, the impact of decisions on actual outcomes, and the pervasive impact of public values. This overview report describes the three integrated Phases of the IED: Problem Formulation, Options Analysis, and Decision-making. The report elaborates on the IED in a set of 10 specific recommendations.

The overview report was drawn primarily from an extensive report on integrated environmental decision-making (EPA-SAB-EC-98-XXX) which describes the framework and the contributions of the five Subcommittees that developed elements that led to the framework in greater detail.

Keywords:

U.S. ENVIRONMENTAL PROTECTION AGENCY
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A. Environmental Integration: The Next Phase

Concern for the environment has become an important part of the American value system. We care about the environment as it relates to human health, the viability of ecosystems, and our children's future. We care about the quality of life, today and in the future, and in the interconnected environmental conditions that play such an important role in determining life's quality.

Starting in 1970, our national environmental values led to the enactment of a series of major federal environmental laws designed to protect human health and environmental quality. Most of those laws mandated targeted actions to control specific pollutants in the air, water, or land. Those actions were intended to protect specific aspects of human and/or ecological health -- e.g., human lung functions, estuarine water quality -- from the effects of specific pollutants like carbon monoxide in the air or phosphorus in water bodies. Thus, for most of its history the Environmental Protection Agency (EPA) has tended to respond to its legal obligations by emphasizing the control of single pollutants affecting specific aspects of environmental quality.

Although this collection of federal laws and regulatory requirements is neither systematic nor comprehensive, it has been largely successful in controlling many of the targeted pollutants and in providing a strong national underpinning for an effective environmental protection program. This program, a mixture of federal, state, and local controls, has led to substantial environmental benefits.

Yet this piecemeal approach to environmental protection, in part because of its past success, may obscure our vision of the ultimate environmental goal, i.e., protecting the overall health of people and the long-term viability of whole ecosystems. Further, by paying primary attention to the trees -- the specific risks caused by individual pollutants -- we might have lost sight of the forest -- the human health and ecological outcomes that are critically important to our quality of life. For the reasons stated below, we suggest that making ever smaller reductions in selected single risks may not necessarily be the best policy either for protecting overall environmental quality or for making the best use of society's resources.

In other words, in terms of sources, receptors, and effects, environmental risks are to a large extent integrated. They can be assessed, measured, and controlled individually, but they affect the real world in the aggregate.

For example, reducing emissions of carbon monoxide from automobiles is not an end in itself; it is one important step in improving and protecting human health. Reducing concentrations of copper in the San Francisco Bay is not an end in itself; it is one important step in improving and protecting the Bay's ecological productivity. Similarly, measuring environmental success in terms of downward trends in national emissions of individual pollutants, or in terms of concentrations of individual pollutants in the air or water, may lead us to a false sense of confidence that our environmental goals are being achieved. Even if specific symptoms of environmental deterioration improve, overall health -- whether of humans or ecosystems -- still can decline.

Neither humans nor ecosystems experience environmental risk one stressor at a time. They are not exposed to risk through one environmental medium at a time. Sources of pollution do not typically impose environmental risks one chemical or one process at a time. Consequently, risk reduction efforts should be designed to control more than one pollutant at a time, protect more than one kind of human or ecological receptor at a time, and thus

realize broader benefits at lower costs.

In the largest sense, environmental stressors are the adverse side effects of a dynamic economic system of production and consumption that poses multiple risks operating simultaneously, but with varying effects, on a variety of receptors that include subsets of the human population and different kinds of ecosystems. Those multiple risks vary from place to place and from time to time, as do their sources.

To respond effectively to such diverse, aggregate risks that can involve a variety of special populations, we need to assess them as they occur simultaneously, operating across many different routes of exposure, and affecting many different human and ecological endpoints. We need to design risk reduction strategies that are more consciously attuned to the environmental outcomes the public desires and expects. We need to think less about reducing single risks and to think more about efficiently reducing collective risks using all the mitigation and management tools, both regulatory and non-regulatory, at hand. In short, we need to develop and apply an integrated, outcomes-based environmental decision-making process that allows us to reduce aggregate risks efficiently and effectively, even when those risks are caused by multiple sources and affect multiple receptors, both human and ecological, through multiple pathways.

To achieve the full benefits of a new, more integrated approach, environmental problems should be defined as they manifest themselves in specific contexts; e.g., in terms of the risks posed by whole industries, or the risks faced by particular communities, particular ecosystems, or particular subsets of the population. Answers must be found to questions that were not asked when the current pollutant-by-pollutant system was established.

These new kinds of questions include, What are the most serious risks facing children, or the elderly, across the nation? What are the factors that pose an aggregate set of risks to everyone living in urban areas? What are the interrelated risks to human and ecological health associated with a particular industrial sector? Of all the risks affecting a particular geographic area or subset of the population, which are most serious, and which are we most capable -- economically, technologically, and politically -- of limiting? How can we achieve the right balance between protecting the health and the welfare of the present generation and those which come after and assure ecological security for the long term? What combinations of risk management tools -- regulatory and non-regulatory, technological and non-technological -- can be used in concert to achieve the overarching human health and ecological goals in particular communities or ecosystems? How can we measure our progress in solving integrated environmental problems and reaching our long-term goals: protection of ecological integrity, human health, and quality of life?

The evolution in environmental decision-making called for in this report is not meant to detract from past environmental accomplishments nor supplant existing regulatory processes and requirements. Rather, an integrated framework is meant to be tested, further developed and used in conjunction with existing environmental management approaches including federal and state regulations. The immediate value of a new approach lies in its potential to strengthen current risk reduction programs, not replace them. A new system can emphasize the results of actions taken to protect humans and ecological systems thereby helping the public to see more clearly the benefits of national investments in environmental protection.

Finally, an integrated decision-making system can help EPA fulfill its mission. While continuing to implement its current legal responsibilities, EPA has an opportunity to use its substantial flexibility to identify environmental risks, and then act to reduce them, in ways that promise greater environmental benefits and more efficient resource use. By using a more integrated approach to addressing either individual risks, or when addressing multiple risks at a variety of scales, as advised in this report, EPA can help move the nation towards its environmental goals.

B. Origins of This Report

The assessment of relative environmental risks to humans and ecosystems from different environmental stressors is beneficial within a system of targeted, single-pollutant environmental laws and regulations. Comparisons can provide environmental decisionmakers with a better sense of which problems are most serious, a perspective that can be used to help focus programmatic activities across

TYPES OF INTEGRATION IN THE IED FRAMEWORK

The Integrated Environmental Decision-making framework requires that information and viewpoints be integrated at multiple points in the decision-making process in order to select management options that most effectively, efficiently, and demonstrably reduce total risk. Six critical types of integration are involved:

Integrated Risk Assessment:
developing scientific data and analytical methods for determining risks from multiple exposures, and multiple outcomes in order to more accurately represent real world situations.

Risk Comparisons:
considering a wide range of environmental risks simultaneously so that the seriousness of risks can be characterized relative to one another.

Integrated Analysis of Management Options:
investigation of options to reduce subsets of ranked risks, rather than considering single risks in isolation, to achieve greater aggregate risk reduction.

Integrated Analysis of Economic Consequences:
identifying the full range of benefits and costs, both monetized and non-monetized, associated with reduction of multiple risks.

Integration of Performance Information:
using performance evaluation measures to devise course-corrections.

Integrating Multiple Disciplines and Points of View:
understanding and utilizing information from all concerned parties in the IED process.

The details of the IED process are discussed in the SAB report *Integrated Environmental Decision-making in the Twenty-first Century* (EPA-SAB-EC-98-xxx).

integrated analyses to design effective and efficient environmental policies.

At the national level, EPA was instrumental in two distinct efforts to rank environmental risks nationwide. In one, a select group of professional managers and experts from within the Agency, supplemented by a group of outside ecological experts, produced *Unfinished Business: A Comparative Assessment of Environmental Problems* (EPA, 1987). That report compared 31 different problems in four different classes; i.e., cancer risk, non-cancer human health risk, ecological risk, and welfare effects.

In the second effort, the EPA Science Advisory Board (SAB) reviewed the findings of "*Unfinished Business*," identified major human health and ecological risks, examined strategies for reducing major risks, and recommended improved methodologies for assessing and comparing risks and risk reduction options. The SAB's report, *Reducing Risk: Setting Priorities and Strategies for Environmental Protection* (EPA/SAB 1990), identified relatively high, medium, and low ecosystem risks, and listed four types of pollutant exposures associated with likely significant impacts on human health.

Both reports discussed the considerable scientific uncertainty, methodological inadequacy, and insufficient data that have limited attempts to compare environmental risks. Both reports suggested that setting priorities for risk management at EPA and across the country as a whole should reflect the relative importance of particular risks, so that better use could be made of the funds available to protect the environment.

After "*Reducing Risk*" was published, many states, counties, cities, and regional groups conducted their own comparative risk studies. Some went beyond the scientific issues to incorporate community values.

The SAB moved forward in a 1995 report to EPA, *Beyond the Horizon: Using Foresight to Protect the Environmental Future*, in which the Board identified issues which might become problems in the future. One issue identified by many of that project's committees, integration, became the seed of the integrated risk project (IRP). *Beyond the Horizon* suggested that in the future "Emphasis [will be] placed on multiple endpoints and exposures requiring new management criteria." This emphasis was reinforced when the Food Quality Protection Act of 1996 required EPA to examine the risks to children from pesticides using a multiple exposure paradigm for risk rather than a single agent approach. The concept of integration of exposures and risks has also been recommended to the EPA by several committees since that time. As the next logical step in this progression, the current report developed by the IRP attempts to help the EPA consider this concept of integration, not only within the context of the science of risk assessment and management, but throughout the steps of policy practice used in decision-making.

The Integrated Risk Project was initiated by a request to the SAB from EPA and the U.S. Congress to revisit the comparative risk issue by updating the assessment of environmental risks and risk reduction strategies contained in "Reducing Risk." In addition, EPA requested that the SAB: explore additional techniques and criteria for identifying environmental risks; identify risk reduction opportunities and strategies; identify uncertainties and data quality issues associated with risk rankings; provide an assessment of the costs and benefits of various risk reduction options; and propose a new framework for assessing ecosystem value.

To fulfill this request, the SAB Executive Committee established the Integrated Risk Project, consisting of a Steering Committee and five separate subcommittees, each with a specific charge:

a) The IRP Steering Committee (IRPSC) was charged with overall direction for the project, including the definition of its scope and timing and the integration of scientific elements.

b) The Ecological Risks Subcommittee was charged with developing a methodology to assess and rank risks to ecosystems at various geographical

scales, from local to regional and national, and with establishing the relative risks to the environment at the national scale.

c) The Human Exposure and Health Subcommittee was charged with developing a methodology for assessing and ranking risks to human health, considering ways in which an integrated risk ranking could include both cancer and non-cancer risks, and testing the methodology for a limited set of environment-related health issues.

d) The Risk Reduction Options Subcommittee was charged with developing a methodology for identifying an optimal set of risk reduction options for controlling human health and/or ecological risks.

e) The Economic Analysis Subcommittee was charged with assessing current methods for estimating the costs and benefits associated with environmental risk management.

f) The Valuation Subcommittee was asked to look beyond traditional economic analysis approaches and consider new ways for assessing the value of ecosystems, including ecology-related quality-of-life values.

In the course of this project, the IRP Steering Committee and its five subcommittees held over 25 publicly-accessible meetings and conference calls, including meetings in Washington, DC, Berkeley, San Francisco, Atlanta, New Orleans, and Baltimore. The committees consisted of SAB members and consultants who explored the discipline-specific issues. The complete SAB report from which this summary is drawn, *Integrated Environmental Decision-making in the Twenty-first Century*, can be obtained by contacting the SAB at:

Mail: EPA/SAB, (1400), USEPA, Washington, DC 20460
Telephone: 202-260-4126
Fax: 202-260-9232
World Wide Web: http://www.epa.gov/sab

C. Results

1. Reformulating the Charge

In conducting this project, the IRP Steering Committee decided that, even though it would focus on developing a science-based approach to integrated decision-making, it would look beyond the scientific aspects of risk comparisons and explore the entire environmental decision-making and management process from their perspectives as scientists. To develop a more integrated, science-based environmental protection approach, the IRP Subcommittees considered the various technical analyses that underlie the process -- including risk assessment, risk comparison and ranking, benefit/cost analyses, selection of risk reduction options, implementation of selected actions, and evaluation of results.

The IRPSC decided to expand the scope of this project, in part, because scientific understanding of the causes and effects of environmental risk, including the interrelated effects on humans and ecosystems from multiple stressors, has improved substantially in the past decade. Those advances can help improve environmental decision-making.

In the area of human health, for example, scientific capabilities have evolved from crude measurements of human mortality related to episodes of severe air pollution (e.g., Pennsylvania's Donora Valley) to the analysis of more subtle developmental and behavioral changes in children from exposures to lead early in life.

Today scientists are beginning to understand more clearly the complicated human health problems that can result from the interactions of multiple stressors. For example, there is accumulating evidence that, although noise alone can damage hearing, the effect of that physical stress is enhanced in the presence of chemicals such as carbon monoxide. Thus, the presence of both stressors will change the risk of hearing loss from exposure to noise alone.

In the area of ecology, science has gone beyond an ability to consider only the effects of single chemicals on single species (e.g., effects of specific pesticides on bald eagle populations) to assessments of ecological change at the landscape

scale (including evaluation of the relationships among ecosystem types).

Scientific tools needed for integration are becoming available and it is now possible to begin to consider and respond to multiple stressors through science-based processes. These processes can be used to identify important risks; find common points such as stressors or sources which can be targeted to prevent risks; and evaluate the effectiveness of actions in improving total environmental health.

Seen from a scientific perspective, integration can improve the environmental decision-making process in several ways. Interrelated and cumulative environmental risks, as they are found in specific integrated contexts such as particular ecosystems, local communities, segments of the population, or industrial sectors, can be assessed and compared. Formal benefit/cost methodologies can be improved so they weigh the full costs and benefits of different risk management options, and so they begin to weigh difficult-to-monetize values, such as ecological sustainability and intergenerational equity, deeply held by individuals and society. Risk management strategies can be tailored to specific community or geographic circumstances so they simultaneously reduce multiple risks to both human health and ecosystems. They can be designed not only to control well-understood risks and prevent potential risks, but also to manage emerging risks whose implications are just beginning to be studied. Finally, the outcomes of complex environmental decisions designed to simultaneously protect both human health and ecosystems can be measured in new, more comprehensive ways, and these outcomes then can be compared with defined environmental goals to evaluate past actions and to guide future ones.

In fact, the focus of decision-making on goals that are defined in terms of improved human health and ecosystem outcomes, rather than simply documenting steps taken, is consistent with accountability mandates that EPA must meet as a result of the Government Performance and Results Act (GPRA). GPRA now requires government agencies to plan their activities and to evaluate the success of their programs in relation to the outcomes of the actions.

The idea of integrating environmental actions with outcome measures as the point of evaluation did not originate with this SAB report. "*Reducing Risk*" began to raise the issue almost eight years ago, and EPA has begun to incorporate elements of integration into its reinvention and demonstration programs.

But the concept is worth reinforcing and developing more fully. Society has yet to take full advantage of a more extensive integrated evaluation of complex, multi-stressor environmental problems. Integration is an idea still in its infancy, with much of its potential for reducing aggregate risk still unrealized.

To help speed the evolution of integrated environmental decision-making, the IRPSC reformulated the charge given by EPA and Congress. In this report the IRPSC lends its support to the goal of integration and provides a conceptual framework and some analytic tools needed to move toward that goal. Integrated environmental decision-making is the natural next evolutionary step from the calls for setting priorities for risk management with an eye toward the relative importance of particular risks in *Unfinished Business* and *Reducing Risk*, and the need for emphasis on multiple endpoints and multiple exposures noted in *Beyond the Horizon*. In a sense, the IRP's conceptual framework for integrated decision-making begins to lay out a scientifically-based approach for considering multi-faceted environmental problems in a manner that leads to the most efficient and effective overall reduction in environmental risk. The framework also examines the factors in decision-making that are not the province of science.

2. The IED Framework

The IED framework is an integrative scheme for making decisions where many different variables, often interacting across physical, regulatory, and

organizational boundaries, can be considered simultaneously rather than in isolation by may types of participants. It allows for: a) the consideration of related clusters of risks; b) the development of multiple risk reduction scenarios; c) the definition of markers for evaluating progress toward specific environmental goals; and d) consideration of public preferences and values throughout the process.

Integrated environmental decision-making should foster a transition to a systematic way of thinking about and managing multiple environmental risks. It should build on the current system, incorporate advanced scientific capabilities, and focus on environmental outcomes. Transition to a more integrated approach will require changes in -- the types and amount of information collected, the kinds of analyses used to support decision-making, the roles of different levels and agencies of government, the ways in which progress is measured, and the specific environmental goals to be achieved. These changes will result in making risk reduction decisions at a place most appropriate to where the problem is being addressed (i.e., Federal, state or local). This could lead to actions that differ from place to place.

The transition to a more flexible integrated system requires clear, consistent decision-making procedures that the public understands and in which it is willing to participate. These procedures should make clear to the public the reasoning behind environmental decisions and include a stronger system of public accountability to ensure that the new integrated approach delivers what it promises, is insulated from manipulation, establishes clear responsibility for results, and provides the expected level of environmental protection.

Accordingly, the IRPSC spent much of its time and energy developing a framework that provides a transparent and systematic way of thinking about integrated environmental problems. As part of the framework, the IRP developed a methodology for comparing human health risks, developed and applied a methodology for comparing ecological risks, and developed a methodology for evaluating menus of integrated risk management options. In addition, IRP subcommittees assessed the applicability and limitations of economic analysis for valuing ecological systems, and provided insights on issues critical to a more complete valuation of additional environmental goals such as sustainability and equity.

In developing a conceptual framework for integrated thinking, the IRPSC concluded that risk rankings should not be the sole driver of environmental decision-making. Nor should decision-making be conceived of as a step-wise process leading in one direction from risk ranking to risk reduction options assessment to comprehensive benefit/cost analysis to the final decision. The approach suggested attempts to circumvent the limitations of unidirectional assessment by proposing a dynamic system that allows risk, hard-to-monetize values, and benefit/cost information to be considered iteratively.

The IRP's proposed framework is shown schematically in Figure 1. It is described in detail in the SAB document, *Environmental Decision-making in the Twenty-first Century* (EPA-SAB-EC-99-___).

Integrated decision-making can be initiated for a number of reasons; for example as a result of public concern, a series of events, or requirements contained in an environmental law. Once initiated, consideration of integrated environmental problems should occur in an iterative manner that proceeds in phases. For convenience of discussion, these phases are shown as separate and distinct in Figure 1 with each phase having its own special emphasis. These phases include Problem Formulation, Options Analysis and Decision-making, and Implementation and Performance Evaluation. In practice, however, there is not always a clear boundary between these phases of activity.

The activities in each phase should be conducted through the close cooperation of scientists (hazard, exposure, economics, engineering, etc.), decisionmakers, and stakeholders from regulated entities and the public. Activities can include the evaluation and comparison of human and ecosystem risks; the identification and analysis of risk reduction

tools; prediction, monitoring, or evaluation of the performance of environmental management actions; and communication among those involved. Comprehensive and complete communication among the participants is one of the most important requirements of integrated decision-making, because it insures that all activities are coordinated and complementary, not fragmented and isolated.

Integrated decision-making should begin by defining the scope of an interrelated set of problems that will be considered concurrently, i.e., Problem Formulation. Specific activities can include goal setting, data gathering, risk identification and comparison, identification and preliminary screening of a broad range of feasible risk management tools, and extensive communication among the participants in decision-making. Goals for decision-making must be established to reflect public values, both those elicited during decision-making events and those embedded within environmental laws.

In the next phase, Analysis and Decision-making, the integrated problems should be analyzed in detail to determine how risk might change under a variety of combined environmental management actions. The intention of this detailed and iterative evaluation activity is to determine how alternative courses of action contribute to achievement of the goals set for decision-making. This should also include evaluation of the costs associated with implementing alternative actions and the benefits of the action as described quantitatively and qualitatively. Evaluations in this phase provide decisionmakers with the information needed to decide on the appropriate response to the defined problem. This phase of activity culminates in a decision on needed actions.

In the concluding phase, Implementation and Performance Evaluation, activities directed at achieving the human health and environmental goals identified during Problem Formulation should be planned and implemented by responsible parties. The results of those actions must be monitored over time and the knowledge gained fed back into the system to allow accountable parties to decide on the need for continued or modified actions. A critical part of this phase should be the reporting and comparison of actual performance of the system against the previously established benchmarks of human and ecological system health.

An integrated decision-making framework should be inclusive and flexible in order to be applicable to problems of different scope and at different places or so it can be used by different levels of government or by combinations of government and non-government groups.

Integrated decision-making should involve risk assessors and risk managers working together to more clearly inform decision-making. Further, it should strive to elicit public input in an organized and effective way so that hard-to-quantify public values, as well as public knowledge and insight about the matter, are included in the decision-making process. It should also be based on the understanding and a clear statement of the points where scientific fact, uncertainty, value judgment, and opinion play a role in order to provide needed transparency. This transparency should foster improved accountability for achieving the identified human health and ecosystem protection goals.

The conceptual framework proposed by the IRPSC is not a finished product. Rather, it is a work in progress that will be improved through practical application. This way of thinking about environmental problems will advance the state-of-the-art and provide a useful basis for further efforts to refine and apply integrated thinking to environmental problems at local, regional, and national levels. Such thinking will be critical to achieving the nation's desired economic and environmental sustainability.

3. Recommendations

National environmental risk management systems have evolved over the past quarter century in response to several factors, including a better understanding of environmental problems, improvements in analytic techniques, and the testing

and use of a number of innovative, non-regulatory risk management tools. The SAB is convinced that this system has to continue to evolve to meet the changing needs of the twenty-first century, and that the principle of integration should guide that evolution. Integrated decision-making has enormous potential for the future if it is widely applied. It can be used fruitfully in the near term because it builds on the environmental protection system already in place, and most elements of the integrated system are already well understood. Other parts are being tested. What remains is to tie the pieces together more rigorously, and then use the integrated decision process more consciously and more extensively to mitigate environmental problems.

This report provides an overarching rationale for an integrated environmental decision-making system from a scientific perspective. The recommendations made by the IRP Steering Committee are summarized in Table 1 of this report. Each recommendation is then explained more fully in the sections that follow. An expanded view of the thinking that led to the concepts explained in this document is contained in the accompanying full report, *Environmental Decision-making in the Twenty-first Century* (EPA-SAB-EC-99-___).

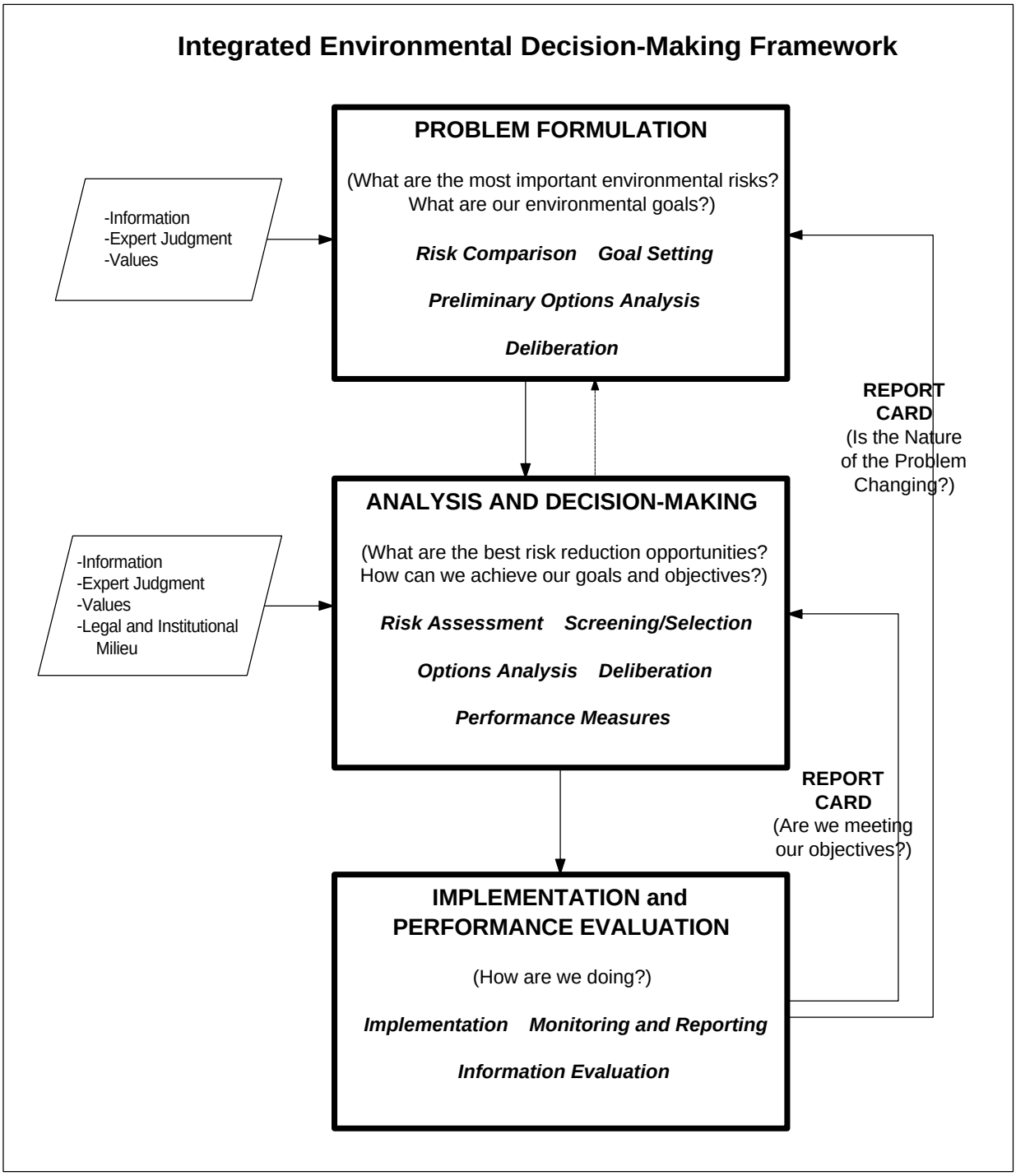

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Table 1.

Recommendations of the EPA Science Advisory Board on Integrated Environmental Decision-making

1:	**EPA should accelerate the transition to integrated, outcomes-based environmental protection, and apply an integrated environmental decision-making framework in selected cases while maintaining the safeguards afforded by the current system.**
2:	**Because science plays a critical role in protecting the environment, EPA should commit the resources necessary to expand the scientific foundation for integrated decision-making and outcomes-based environmental management.**
3:	**EPA should apply and encourage the broader use of risk comparison methodologies, such as those described in this document, that clearly identify how scientific information and judgment are incorporated into risk comparisons.**
4:	**EPA should use a broader range of risk reduction options in combination to manage environmental risks.**
5:	**When evaluating risk reduction options, EPA should weigh the full range of advantages and disadvantages, both those measured in dollars as costs and benefits and those for which there may not be a comprehensive dollar measure, such as sustainability and equity.**
6:	**EPA should make fuller use of the scientific methods available to characterize public values and incorporate those values into goal-setting and decision-making.**
7:	**EPA should identify, collect, and disseminate scientifically-based environmental metrics organized in new ways to support a more integrated approach to managing environmental risk.**
8:	**EPA should develop a system of "report cards" to organize and disseminate information on the status of ecological and human health and the quality of life in order to assess the effectiveness of its environmental decisions and to guide future environmental management.**
9:	**EPA should expand and develop new collaborative working relationships with other federal and non-federal agencies and others who also will be involved in integrated environmental decision-making.**
10:	**EPA should aggressively explore options for reducing risks from significant stressors that currently are addressed inadequately by the nation's environmental institutions.**

RECOMMENDATION 1
NEW APPROACH TO DECISION-MAKING
EPA should accelerate the transition to integrated, outcomes-based environmental protection and apply an integrated environmental decision making framework in selected cases while maintaining the safeguards afforded by the current system.

The first step in an integrated environmental decision-making framework is to set goals which reflect scientific knowledge, expert judgment, and public values. The time has come to base the goals on an outcomes-driven approach to protecting and improving the health of humans and ecological systems. The gains made by using the current system of controlling individual chemical pollutants must not be undermined. But the next generation of environmental decisions should go beyond the end-of-pipe control focus and should aim to achieve the explicit outcome-directed goals that society directs.

Over the past quarter century this country's environmental protection system has evolved and improved as we learned more about managing environmental risk. Refinements in the system -- such as expansion of the kinds of tools used to reduce risks -- have helped increase environmental benefits while making more efficient use of the nation's risk reduction resources.

However, much of our environmental protection activity remains focused on single pollutants, from single sources, emitted into a single medium. This approach to environmental protection has led to many "environmental standards" that are useful tools for regulators, decisionmakers, and enforcers. However, the outcome of this activity on environmental conditions is much more difficult to assess.

In the next generation of environmental decision-making, the focus will be on results; that is, on demonstrable outcomes (improvements) in the environment resulting from integrated action, rather than on a simple single pollutant strategy that infers, but does not demonstrate, a connection between end-of-pipe or process-based compliance and improvements in the environment. The need to consider outcomes comes from a number of forces:

a) Expanded public expectations for environmental protection that includes both public health and ecological issues.
b) Demands for greater accountability on the part of governmental and other institutions whose decisions affect environmental quality.
c) Recognition that the approach to environmental decision-making during the past generation has accomplished much of what it was designed to do in the United States and further efforts in this direction will have diminishing benefits at higher costs. It is likely that the greatest remaining threats to the environment and public health involve multiple stressors, sources, endpoints, and routes of exposure. Therefore, the greatest opportunities for risk reduction need to be sought by an integrated examination of risks.
d) Advances in the state of scientific knowledge that enable environmental decisions to increasingly be based on projected outcomes.

In order to make the most effective, outcomes-based environmental decisions to improve human and environmental health, a more expansive approach will be needed that will:

a) Bring a wide range of scientific information to bear on a problem.
b) Identify the priorities among and interrelationships between the major environmental and human health problems.
c) Expand appropriately the decision-making process to include deliberative stages that will involve non-technical experts to reflect public values and knowledge in the setting of environmental goals and informing decisionmakers.
d) Broaden the horizon of risk reduction options to seek opportunities to reduce aggregate risk.
e) Make more transparent the bases of environmental decisions; i.e., the role of both technical and non-

technical factors.
f) Establish a "report card" system for evaluating the results of actions on the health of the environment and/or the human population.

In the course of conducting this project, the SAB has developed a science-based conceptual framework for integrated environmental decision-making that incorporates these requirements. Further development and implementation of an integrated approach by the Agency would help facilitate the transition to a new phase of environmental protection in the next century.

The integrated framework developed by the SAB, which is described in this report, and the companion exposition reinforces ideas advocated in several recent studies, such as *Understanding Risk: Informing Decisions in a Democratic Society* (National Research Council, 1996) and *Framework for Environmental Health Risk Management* (Presidential/Congressional Commission on Risk Assessment and Risk Management, 1997). The fact that the current SAB reevaluation, which began as a revisitation of comparative risk issues, concurs with the findings and recommendations of these other groups demonstrates the importance and timeliness of the concept of integration and its potential for reducing aggregate environmental risk.

Moreover, it should be noted that the concept of integration underlies much of EPA's recent agenda for reinventing environmental regulation. In fact, over the past few years, EPA has taken several positive steps to address environmental issues in a more integrated way. A number of EPA projects embody some of the elements of integrated decision-making, though none contain all elements. For example, in the early 1990s the Agency introduced the Green Lights Program, the Comparative Risk Projects, and the 33/50 Project as experiments in voluntary, cost-effective energy conservation, community involvement in agenda setting, and large-scale, cross-media emissions reductions respectively. More recent Agency projects containing such elements include the Common Sense Initiative, Project XL, the National Environmental Performance Partnerships, and implementation of the Food Quality Protection Act (FQPA) have moved beyond single pollutant, single receptor concerns in order to reduce environmental risks in a more integrated and comprehensive way.

But most of the integration now underway at EPA remains confined to experimental or demonstration programs and many do not emphasize the incorporation of science as an essential consideration for integration. The Agency's agenda seems still to reflect a narrow interpretation of what respective environmental laws require it to do, rather than a proactive interpretation of what the laws allow it to do.

EPA should build on its promising experiments in integrated risk management and work to incorporate this innovative way of thinking throughout the Agency and its programs. The Agency should use all the flexibility allowed under existing law to more completely characterize environmental risks and the options it considers to manage them. EPA should be prepared to use innovative, multi-faceted mitigation strategies and be prepared to defend such use on the grounds of improved environmental benefits achieved more efficiently.

EPA should incorporate integrated thinking more thoroughly across its programs, and it should select a few test cases where the framework can be applied explicitly. The best way to test the potential of IED, identify its weaknesses, improve its methodologies, and gain its benefits is by applying it to real-world problems.

As EPA's integrated risk management processes evolve, the Agency should give ample incentives to the agents and programs of change, because aggressive action is one of the keys to success. At the same time, this new approach to managing risk need not cause sudden disruptions in the old system. Rather, it should build on and strengthen the old system by both defining problems and designing more comprehensive solutions.

Integrated decision-making can be applied

to environmental problems of different magnitude and in different locations. It can be used effectively by different levels of government. Indeed, by looking at environmental risk as a complex, interrelated set of effects operating in defined contexts (e.g., in urban areas, in watersheds, across the whole nation), integrated risk management will often demand the involvement of different levels of government. Though applicable to single stressor risks, its greatest value will be in situations where several different stressors operate simultaneously.

RECOMMENDATION 2
THE ROLE OF SCIENCE

Because science plays a unique and critical role in protecting the environment, EPA should commit the resources necessary to expand the scientific foundation for integrated decision-making and outcomes-based environmental management.

Science has a unique and critical role to play in protection of the environment. It is through scientific investigation that most environmental problems are first discovered. Such investigations can be theoretical, laboratory-oriented, and/or field-oriented. For example, the ozone depletion story originated in theoretical and lab investigations and was only later confirmed by field measurements. Similarly, it took the integration of the results of studies by various scientific disciplines to develop a cohesive hypothesis about environmental endocrine disruptors, a story that is still evolving in research institutions around the world.

Science also is instrumental in developing, testing, and evaluating risk reduction options. This activity includes both "hardware options" from the traditional hard science and engineering community (e.g., control technologies and process changes) and "social ware options" from the social sciences community (e.g., market incentives and educational materials). For example, over the past decade emissions of dioxins from some stationary sources have been reduced by as much as 90% through a combination of new end-of-pipe controls on outputs and innovative alternatives in inputs and process conditions. Also, the predictions of some in the economic community as to the effectiveness of emissions trading for SOx and NOx have been borne out in large measure in the real world, while educational efforts have led to reductions of risk from radon gas in homes.

Of course, addressing environmental risks involves much more than science and scientists, where science includes the traditional scientific disciplines, engineering, and social sciences. Legal, ethical, and political considerations all play an indispensable role. It is through harnessing all of these considerations, including the scientific ones, that society can take the most appropriate, effective, and efficient steps in risk reduction .

At the same time, the unique nature of the scientific contribution in spotlighting the fundamental truths underlying environmental problems cannot be ignored or replaced by a popular vote.

In confronting today's environmental problems, we are asking more realistic -- but increasingly complex -- questions. To generate the needed answers to these questions requires increasingly sophisticated science. Because our scientific capability is increasing at a rapid rate we can realistically expect to get the answers we need.

For example, a range of new techniques exists for gathering large amounts of data; cf., the satellite-based and other remote sensing technologies that provide a larger-scale, synoptic view of the environment. Today new algorithms and model constructs enable us to simulate the complexity of ecological and human systems to a degree of realism unknown before. This theoretical analytic capability is complemented by high-speed computing capabilities and enormous data storage and handling capacities that allow the acquisition, storage, and analyses of data at a level of sophistication commensurate with the complexities of environmental problems. The sophisticated display devices of geographic information systems have actually simplified what would have been a daunting chore of comprehending and extracting meaning from this mass of information. Innovative tools and techniques begin to allow us to ask -- and answer -- questions that were undreamed of only a few decades ago; e.g., "What is the cumulative risk in a given situation to an individual whose genomic susceptibility to pollutants is known?" Improved electronic communications have permitted a new

level of integration within and between scientific disciplines to the point that knowledge is assimilated at an increased rate and the very boundaries between disciplines are disappearing.

However, if the promise of these advances is to be realized in an era of increasingly complex problems and in which there are increasing calls to demonstrate the results of environmental protection actions, EPA and the nation will have to make the requisite investments. These investments will be in the form of scientific capital -- both hardware and intellectual capital -- that will provide the information for an accurate characterization of the state of ecological and human health, the risks posed to them, and the results of applying innovative corrective measures to them.

RECOMMENDATION 3

METHODOLOGIES FOR COMPARING RISK

EPA should apply and encourage the broader use of risk comparison methodologies, such as those described in this document, that clearly identify how scientific information and judgment are incorporated into risk comparisons.

Science plays a particularly important role in comparing the relative seriousness of environmental risks, especially early in decision-making. In fact, scientific information on risk, such as quantified risk assessments and scientifically-demonstrated linkages between stressors and effects, provides the essential underpinning which make objective risk comparisons possible.

Past efforts to compare and rank different environmental risks, like those undertaken in *Unfinished Business* and *Reducing Risk*, were an important step in the evolution of the nation's environmental protection system. They were among the first attempts to impose some order on an *ad hoc* protective system that assumed all environmental problems were equally serious and equally amenable to amelioration. They provided scientific information and a science-based rationale for beginning to set priorities among the many environmental issues competing for public attention and funding.

Often, the desired scientific information is incomplete or absent, and the scientists have to use their best professional judgment to bridge important gaps in the data; e.g., best estimates, default assumptions, and the like. In other cases, scientific information and analyses, by themselves, are not sufficient for rating and comparing risks; e.g., human health risk versus ecosystem risk, cancer risk in adults versus neurologic risk to children, or risks to wetlands versus upland habitats . In these instances, it is public values that come into play in making these comparisons.

Thus it is important that any methodologies used to compare and rank environmental risks -- whether human health risks, ecosystem risks, or both -- not only incorporate the most up-to-date scientific information, but that they also identify explicitly where professional judgment and values have influenced the results. By clearly pointing to the role and impact of professional judgments and public values in such comparisons and rankings, the decisionmaker and the public will better appreciate the basis for the decisions that have to be made.

As part of this project the SAB developed two risk comparison methodologies that require analysts to be clear about which elements come from science, which are based on professional judgment, and which ones reflect public values.

First, the SAB's Human Exposure and Health Subcommittee (HEHS) developed a methodology for soliciting a defined group's input to ranking the relative risks to human health from exposures to different environmental stressors and to capture information on the group's judgment and values.

The Subcommittee's goal was to develop a methodology that was relatively easy to use so that information could be gathered quickly and inexpensively from any group of respondents, technical experts, stakeholders, or the general public. The methodology utilizes scientific information and methods to derive ratings, analyze variabilities in the ratings, and identifies factors and confidence levels influencing the ratings. The results are amenable to analysis of correlations within and between respondents.

The methodology is capable of simultaneously comparing both current and possible future health risks, in light of existing and emerging scientific knowledge, and is applicable on any geographic scale. It is capable of incorporating quickly any new information on stressors, exposure standards, or public concerns.

A complete description of the Web-based human health risk rating methodology developed by the HEHS can be found in the SAB's *Integrated Environmental Decision-making in the Twenty-first*

Century (EPA-SAB-EC-99-___).

The Ecological Risks Subcommittee (ERS) took a different approach in developing an ecological risk ranking methodology. The ERS first summarized in an ecological risk profile the nature of each stressor and its potential ecological effects. Each risk profile identified the co-occurrence of the stressor and related ecological effects at some specific scale. Ecological effects were assessed in terms of changes in ecological endpoints, defined to be those specific ecological attributes that can be used to characterize the health of ecological systems, ranging from population- and species-level attributes (e.g., presence of endangered species or the productivity of economically important species) to landscape-level attributes (e.g., the diversity of the mosaic of habitats across the landscape).

The ERS risk ranking methodology then applied a series of multiplicative factors that translate generic stress-effect relationships into an estimate of the relative magnitude of the risk at particular scales and for particular ecological systems. Examples of multiplicative factors used include the spatial scale of the stressor, the duration of ecological effects, the potential for irreversibility, and the potential for effects on critical components of ecological systems. These multiplicative factors were developed through the expert judgment of the ERS scientists and are clearly identified as such. The methodology was designed to make transparent the underlying assumptions, the risk factors, and the specific values for each risk factor used in developing the ecological risk rankings.

A complete description of the risk rating methodology developed by the Ecological Risks Subcommittee can be seen in the SAB's *Integrated Environmental Decision-making in the Twenty-first Century* (EPA-SAB-EC-99-___).

The two risk ranking methodologies developed by the SAB are complementary and can be used in tandem. The Web methodology of the HEHS providing a survey of a broad set of experts, and the consensus methodology of the ERS providing an analysis based on intensive considerations of the nature of environmental systems. These methods can be used, either singly or together, in different geographic areas, at different levels of government, or by non-governmental users. Both clearly reveal the processes, which include technical data, professional judgment, and respondents' values, by which they arrive at their conclusions. It is possible to subject the results of both to sensitivity analyses to determine how they would change in response to changing variables.

In summary, the SAB developed two prototype methodologies that clearly reveal the science, expert judgment, and values that together lead to a rating and comparison of environmental risks. These approaches should be points of departure for the Agency as it seeks to develop and use science-based methodologies to compare relative environmental risks at various levels.

EPA could help other groups of decisionmakers apply these methodologies in specific communities and ecosystems. National risk comparisons always have had limited applicability to local or regional circumstances. Risks that may rank low on a national list, as was the case with the ranking of contaminated Superfund sites in the SAB's "Reducing Risk," may rank very high in a particular community. As efforts to protect the environment evolve in the years ahead, it is likely that many risk comparisons will continue to be conducted at the state, regional, and local levels. EPA should assist others to develop and use these improved risk comparison methodologies to meet their unique needs.

RECOMMENDATION 4
INTEGRATING TOOLS FOR MANAGING INTEGRATED RISKS.

EPA should use a broader range of risk reduction options in combination to manage environmental risks.

Historically, the range of risk reduction options considered by risk managers has often been limited by narrowly defined, statute-driven goals. This fragmented approach can result in missing benefits that could accrue from simultaneously controlling several pollutants. Further, little or no attention may be given to the negative consequences of ignoring some options entirely. Narrowly targeted approaches can miss opportunities for reducing aggregate risk more efficiently.

Integrated strategies, on the other hand, attempt to assess multiple-stressor problems and then determine combinations of control or management options that provide the most overall risk reduction for the least cost. They are focused on the ultimate ecological and human health outcomes that society desires. They lend themselves to the simultaneous use of several policy tools (e.g., government regulations, economic incentives, or voluntary initiatives), depending on the risks in question. In fact, integrated decision-making can foster the use of non-traditional policy tools like economic incentives and education as decisionmakers try to find the best mix of strategies to reduce aggregate environmental risks. Because of the flexibility inherent in such decision-making, risk reduction strategies can be tailored to fit local and regional circumstances, a result that is often missing in the traditional regulatory system.

In 1990 the SAB recommended in *Reducing Risk* that the nation make greater use of all the tools, including market forces, information, and product specifications, available to reduce risk. Now, almost a decade later, many of those tools are being used to a greater extent than ever before. From the emissions trading caps and tradeable discharge permits in the 1990 Clean Air Act to the widespread use of environmental audits to the vastly expanded environmental information available to the American public, we now have available a much broader and more flexible array of options for controlling risk.

Now the challenge for EPA is not only to expand the use of those various tools but also to use them in creative, coordinated ways to reduce multiple risks to multiple receptors in communities and ecosystems across the country.

A risk reduction options evaluation methodology was developed during the Integrated Risk Project. This method can be applied fruitfully to single stressors, such as a heavy metal. However, it will be especially useful for identifying multi-dimensional strategies intended to control complex environmental problems involving many sources, stressors, and receptors. (A complete description of the risk reduction options methodology is contained in the SAB's *Integrated Environmental Decision-making in the Twenty-first Century* (EPA-SAB-EC-99-___).

Seven categories of tools that can be used, either singly or in combination, in tailored control strategies are noted in the description of this methodology. They are: a) communication and education; b) enforcement; c) conventional and innovative engineering; d) international and intergovernmental cooperation; e) environmental management systems; f) market incentives; and g) regulations.

Determining the best tool, or mix of tools, to be used in specific contexts will be a complex task, but it will be worth the result: more effective risk management strategies tailored to specific situations (e.g., urban areas, children's health, watersheds, etc.) at different levels of government (local, regional, and national). The best possible risk management strategy will emerge only after the full array of options available for managing a set of interrelated risks is defined through broad participation of those inside and outside EPA and analyzed for their

applicability.

The best strategy, by definition, is not necessarily the one that reduces the worst risk to a *de minimis* level, but the one that reduces the most risk with the resources available, with due regard to any legislatively mandated risk reduction requirements. In this respect this methodology goes beyond the suggestions in the SAB's 1990 *Reducing Risk* report. While ranking risks is important for gauging the relative magnitude of individual risks, it is more important to focus on the reduction of total risks resulting from risk management decisions than it is to focus on the reduction of any particular risk, *per se*. In short, we should target the most first, not the worst first.

The proposed approach to risk management options selection is consistent: it can be applied in the same way to simple or complex environmental problems. It is flexible in the sense that any number of a wide range of tools can be applied to a particular problem. It can -- and should -- be transparent so that people standing outside the process are able to understand how decisions are reached.

In summary, when assessing its options for the control of complex risks in integrated contexts, EPA should not limit its analyses to the sources or stressors defined by existing laws, regulations, or traditional approaches. The Agency should identify and analyze different combinations of control options -- regulatory and non-regulatory, technological and non-technological -- that, when implemented in a coordinated way, can best improve the overall quality of life for the American people.

RECOMMENDATION 5
FULL COSTS AND BENEFITS

When evaluating risk reduction options, EPA should weigh the full range of advantages and disadvantages, both those measured in dollars as costs and benefits and those for which there may not be a comprehensive **dollar measure, such as sustainability and equity.**

Environmental actions are intended to efficiently and effectively achieve community and national goals; e.g., clean air and water, safe food, sustainable resources and equitable access to them, biodiversity, etc. The value of an environmental management action is related to how that action contributes to these goals.

The valuation framework that undergirds environmental decisions is the simple formulation of whether the gains that accrue from protective actions are worth what is given up to attain them. There is a subsidiary question: would other possible actions be preferable? This question highlights the importance of taking all effects, including long-term effects, into account. It also raises the sometimes hidden issue of how people value different aspects of the environment. Ultimately, it is this value that determines both the relative worth of protecting the environment and the relative investments society is willing to make to achieve environmental and health goals.

Some of society's environmental values can be measured directly in monetizable terms, and others can be inferred and translated into monetizable terms with some confidence. Tools are available to measure such value in terms of efficiency in allocating resources. Chapter 4 in the SAB's *Integrated Environmental Decision-making in the Twenty-first Century* discusses a number of these methods (EPA-SAB-EC-99-___).

Other things that people value, such as sustainability and equity, may not have comprehensive quantitative expressions, yet they are of no less importance for that reason. Because integrated thinking about human health and environmental risks is likely to suggest a broader range of environmental values to be considered for simultaneous protection, a broader array of control options will need to be assessed; thereby, requiring more information about more options. Both sides of the benefit/cost equation will be more complex. In assessing all of the costs and benefits of possible management options, analysts will have to untangle an interlocking array of variables.

Complicated qualitative issues are certain to emerge as decision-making becomes more integrated. Not all costs and benefits can be quantified, much less translated into dollar terms. Difficult-to-quantify goals like fairness, sustainability, and biodiversity have to be interwoven into the decision-making process as explicitly as monetized costs and benefits are, with care that value measures for the goals not be double-counted; i.e., that they are not already part of the monetized calculation. Qualitative assessments, and the methodologies that support them, can be as important as quantitative measures, depending on the risk management options being assessed. Qualitative methods should not be dominated by quantitative, and vice versa, but the two should be considered together with all the implications of alternative courses of action made as explicit and as transparent as possible.

In order to incorporate qualitative and quantitative values information properly, new methods of decision-making may be needed. One such method, formal deliberation among stakeholders, can be useful in raising and defining qualitative issues and in assuring that quantitative issues are fully and properly included. Deliberative processes bring together diverse groups of people to examine findings, interpretations, and/or economic and non-economic values and their measures in order to elucidate different management options from a variety of perspectives. Although the results of deliberation are not necessarily quantifiable, in many cases they may be indispensable in assuring that all

relevant elements are included in the analysis, providing insight and evidence about the value of each element, and assessing the full range of benefits and costs likely to accrue from a control action.

For deliberation to contribute meaningfully to decision-making, care must be taken to ensure that it is conducted in a manner that does not bias the outcome. The document *Integrated Environmental Decision-making in the Twenty-first Century*, discusses this issue further. The document discusses four types of deliberation, each of which is related to the sufficiency of knowledge underlying the environmental issue and the level of controversy that attends it.

In "Reducing Risk" the SAB asserted that ecological benefits often are underestimated in traditional benefit/cost analyses. That report recommended that EPA undertake a broad national effort to develop analytical techniques that assess more adequately the real long-term value of ecosystems. Such an improvement in assessing ecological benefits will be even more important in an integrated system, where management options often will incorporate measures to protect human health and ecosystems simultaneously, and where tradeoffs between human and ecosystem health and quality of life concerns may be necessary.

While a framework for comparing costs and benefits is a necessary and appropriate part of the decision-making process, formal benefit/cost analyses alone are not a sufficient basis for choosing among different possible actions. Neither a low net benefit estimate nor a high risk ranking should be the sole factor that dictates an expenditure of resources. Risk rankings and benefit/cost analyses are useful tools that inform the decision-making process and increase the probability that effective, efficient risk-reducing strategies acceptable to society will be designed and implemented. Neither analysis is sufficient, by itself, to determine the need for and best action to take.

As a part of this project, the SAB has described the applicability and limitations of the benefit/cost framework, and suggested areas where new approaches to characterizing values are essential. The SAB also has attempted to define better the full range of relevant questions that must be considered in ecological valuation. See Chapter 5 in the SAB's *Integrated Environmental Decision-making in the Twenty-first Century* (EPA-SAB-EC-99-___).

In short, the SAB has found that the benefit/cost framework is a valuable tool for helping determine the most efficient responses to environmental problems. It will continue to inform decisionmakers when environmental problems are defined in a more integrated way. In fact, the economic analysis can provide an integrating function, because it can lead decisionmakers to integrate different kinds of information about people's preferences.

To support the new decision-making procedures, EPA should expand its economic analysis framework to include more and different kinds of information. For example, when assessing options for the control of complex, multi-stressor, multi-receptor problems, EPA should look at the costs of a wider more complex range of management options that are capable of controlling a number of different stressors simultaneously. On the benefits side, EPA also should begin to quantify the range of benefits likely to result from different kinds of control strategies when combined. This analysis should include both easily quantified and difficult-to-quantify values held by the people affected by risk management strategies.

In fact, because qualitative value descriptions can be as important to decision-making as quantitative costs and benefits, separate analyses of valued attributes like sustainability, biodiversity, and equity should be conducted in parallel with, and as a complement to, standard benefit/cost analyses. These separate analyses will help provide a complete and balanced picture of the full consequences of alternative courses of action. All these analyses should be provided to decisionmakers and reproduced as part of the public record.

At the same time, EPA should develop

improved ways to measure and communicate the value of attributes like sustainability, biodiversity, and equity. This should be a key area of EPA research in the future.

RECOMMENDATION 6
CHARACTERIZING PUBLIC VALUES

EPA should make fuller use of the scientific methods available to characterize public values and incorporate those values into goal-setting and decision-making.

Community and national values have been and will continue to be the primary driver of community-level and national desires to protect the environment. These values have led to laws that provide the authority to address environmental problems. Values also work alongside science, and within the structure authorized by environmental laws, to influence specific decisions about which risks to control.

However, values usually are not weighed transparently in the decision-making process. Rather, they are usually implicit in the judgments made by decisionmakers. Thus, they influence decisions in ways that are not clear to, or reviewable by, the public. They operate in a kind of "black box" hidden from the view of everyone but the immediate decisionmakers.

Because public values undoubtedly help shape environmental decisions, it is important to understand and document their role in and influence on decision-making. It is also important to elicit public values systematically, differentiate values from technical information as a part of decision-making, and include their effects on decisions as part of the public record. In this way, value judgments will be neither disregarded nor disguised. Just like quantitative information, they will be clear, open, reviewable elements of the decision-making process.

Public values are incorporated at several points in integrated decision-making. The attitudes and values of people affected by environ-mental risks reflect concerns that must be considered when environmental problems are defined for consideration. Public values also must be considered in setting goals for risk reduction. Communities must understand the risks affecting them and the environmental management actions intended to reduce those risks, because widespread public support for protective action is essential to success.

Procedures for incorporating public values into environmental decisions require more than simply gathering people. Public opinion regarding environmental goals must be sought in a systematic and unbiased fashion. These procedures are likely time-consuming and complicated, but they are essential for providing adequate public input.

Over the past several years EPA, as well as many other agencies at all levels of government, have made a greater effort to include stakeholder input in their decisions. This proliferation of stakeholder-based decision-making derives from the assumption that stakeholders reflect the interests and values of all parties interested in environmental decisions, including the sources of risk and the communities that are exposed to them. Incorporating individual and community values into environmental decisions undoubtedly will strengthen those decisions, and strengthen public support for them.

However, it is important to take care that stakeholder values solicited systematically as part of the response to particular environmental problems really represent broad community values and preferences and not simply the narrow interests of vocal individuals or groups. In many cases, it will not be adequate to convene meetings and invite representatives of particular interested groups, and then incorporate their preferences at face value. In complex cases sophisticated techniques are necessary to bring together an effective and representative group.

Community values should be solicited systematically by social scientists and other appropriately-trained individuals. The deliberative processes that are used in arriving at decisions should involve professionals trained in fields like consensus-building and dispute resolution. A number of organizations today are conducting research into

effective ways to elicit broadly representative public values, and others are helping communities apply these kinds of techniques in response to specific local or regional environmental problems. EPA should make more extensive use of existing expertise in the areas of behavioral science and decision logic, so a more complete representation of community values is incorporated into the Agency's decisions.

Multiple types of deliberation can be used in integrated decision-making. They can help elicit public values and respond to public desires to be involved in decisions that affect their lives. At the same time, it is important to recognize that formal deliberation may not be necessary in every case. EPA should make clear to the public exactly in what ways and to what extent community values affect its decisions and whether formal deliberation has been used in its decision-making For a more complete discussion of the deliberative process, see the SAB's *Integrated Environmental Decision-making in the Twenty-first Century* (EPA-SAB-EC-99-___, Chapter 5).

EPA's experience with the methodical solicitation of public values also will be useful at other levels of government. Because EPA will continue to be recognized as the environmental leader at the federal level, the Agency should be prepared to assist other agencies in communities and states in soliciting public values. Therefore, EPA should expand its efforts to make current techniques, findings, and professional expertise available wherever environmental decisions are made.

RECOMMENDATION 7

THE NEED FOR NEW METRICS

EPA should identify, collect, and disseminate scientifically-based environmental metrics organized in new ways to support a more integrated approach to managing environmental risks.

The transition to and effectiveness of integrated, outcomes-based environmental protection will depend to a large extent on the availability and utilization of appropriate information in the area of exposure, human health, ecological health, and quality of life.

Current data collection efforts fall short. For example, exposure variables are now collected only at limited locations for short periods of time. Human health data on non-fatal outcomes, such as asthma, are not being collected except in a rudimentary manner or at fragmented sites. Ecosystem information being collected today is either insufficient, inadequately organized and disseminated, or focused on inappropriate endpoints and/or scales.

Therefore, in order to support a more integrated, goals-driven environmental protection system, EPA needs to develop a systematic data collection mechanism that more appropriately describes exposure, human health, and ecosystem health.

For example, in the area of ecological health, EPA, in conjunction with other government agencies and the private sector, should collect, aggregate, and disseminate information that could be used to characterize the current status of different types of ecosystems such as wetlands, lakes, forests, and grasslands (See Recommendation 8). This information should include the extent to which each ecosystem is exposed to and affected by the cumulative impacts of non-chemical stressors such as habitat conversion, habitat fragmentation, and invasions of exotic species.

EPA also should help develop indicators of ecological condition and sustainability to be used by decisionmakers at the local, regional, and national levels. These indicators would suggest the relative health and productivity of different ecosystems subject to different kinds and levels of stressors.

The Agency should keep in mind that this information is needed to answer environmental management questions. In this regard, the Agency should review its current monitoring programs to determine whether additional or alternative parameters should be added, or additional analyses conducted, to characterize ecological conditions and sustainability better and to estimate more accurately the costs and benefits of different options to protect ecosystem health.

The human health data needed to evaluate environmental effects include outcomes such as reproductive performance, asthma, neurological deficits, behavioral changes, respiratory function, hearing, vision, and any other health measures that can be used to evaluate relatively short-term effects. Data on confounding variables are needed. Meeting this need is complicated by the fact that all medical data systems are subject to issues of ethics and privacy. Yet, to conduct surveillance on the links between human health and environmental pollutants, these data are necessary.

In addition, data on population exposures must be measured and related to individuals by residence either directly or through modeling. The Agency needs to move beyond current exposure data systems that usually are limited to a few monitoring sites and, in some cases, to episodes of non-compliance with environmental requirements which does not allow determination of cumulative exposures.

In order to better link human health effects to environmental exposures, information systems should contain not only exposure data for various locations but also -- to the degree consistent with privacy rights -- data on the individuals who lived in those locations at the time of disease susceptibility. An example of data collection that provides such

relevant data is infant mortality records which, unlike adult mortality records, are tied to the birth record (here the baby's residence is noted on both the birth and death record). Thus it is possible to identify residential exposures for the first year of a child's life.

As a first step, EPA could provide an extraordinarily valuable service simply by beginning to assess information needs and resources in an integrated way. It will not be enough to pull together in one office, or in one report, different sets of data collected by different government agencies, federal or state. There should be the possibility of combining those data so as to paint a picture of environmental conditions affecting specific places or specific subsets of the population (See Rec. 8). In some cases, the necessary data already exist; they just need to be integrated better. In other cases, the right kinds of data are not being collected at all. Integrated thinking within EPA will help identify data gaps and then fill them.

In short, EPA needs to support efforts to coordinate the extensive, and largely fragmented, data collection exercises already underway, and determine what other data might be useful for future evaluation of environmental effects. Then it needs to strengthen its methods for disseminating that information to environmental decisionmakers and the public nationwide; e.g., the "report card" process described in Recommendation 8. To guide its efforts, EPA should ask: what information is needed to make integrated decisions and then evaluate the results of those decisions? Who needs that information? Is it being collected today? Who is best suited to collect it? How can EPA help communicate such information to the public and decisionmakers so they can use it effectively?

RECOMMENDATION 8
ENVIRONMENTAL REPORT CARDS

EPA should develop a system of "report cards" to organize and disseminate information on the status of ecological and human health and the quality of life in order to assess the effectiveness of its environmental decisions and to guide future environmental management.

One of the most valuable uses of environmental data is to measure the results of the actions society takes to reduce environmental risk. However, even if such data did exist, through a vigorous implementation of Recommendation 7, the country lacks procedures for translating this information into easily comprehensible assessment of the overall conditions or evaluations of the impacts of environmental decisions. The lack of widely accepted and commonly used methods for evaluating a) the state of our environment or b) the success of national environmental protection efforts -- where success is measured in terms of the overall health of humans and ecosystems -- is a serious shortcoming of the existing system. It has limited the public's ability to link actions taken, and money spent, with tangible improvements in their quality of life. This shortcoming will be felt even more as environmental issues become more complex and as the cost of risk mitigation is scrutinized more intensely.

Regarding the status of the environment, EPA should work with federal and state entities to develop indicators of ecological and human health conditions in our country. Such an overall "environmental report card (ERC)" reflecting cumulative impacts of decisions should be readily comprehensible to the public and policy makers alike, serving to galvanize them on action toward specific, measurable goals.

The concept of a report card is also useful for evaluating the impact and effectiveness of individual decisions made under integrated evaluation systems; i.e., an environmental decision report card (EDRC).

Information useful for measuring results -- for either an ERC or an EDRC – will be even more important as a more integrated system evolves and becomes outcome-driven. Integrated decision-making will foster greater flexibility for both government agencies and private companies as they search for innovative ways of reducing the risks posed by multiple sources to multiple receptors. Because the overarching goal will be to reduce total aggregate risk, isolated information on the emissions of a particular pollutant or on a particular aspect of water quality will fail to tell the whole story since one or more parameters of environmental health can improve while overall health declines.

New, more integrated information also is needed so that the responsible program managers and institutions can be held accountable for the results of outcomes-based decisions. Accountability for program results, in terms relevant to improved human health and ecosystems, is an essential part of any effective management system.

Many current single-stressor risk management strategies also measure progress against pre-established goals -- the management of criteria air pollutants, for example. What differentiates the measurement of progress in an integrated system is the fact that many different, but interrelated, goals may be set, including combinations of human health and ecosystem goals. Determining which parameters to measure, and then compiling those measurements into a coherent evaluation, will be a formidable challenge, and current programmatic evaluation mechanisms do not appear adequate to meet it.

Fortunately, the technologies needed to support this type of informational activity are becoming available. Modern society now has the technological capacity to generate, aggregate, and widely disseminate vast quantities of information. The time has come to use that technological capacity to satisfy more complex environmental information needs.

Therefore, building upon

Recommendation 7, EPA should begin to collect, aggregate, and disseminate data that will make up the national ERC and individual EDRCs. This new kind of reporting system, which evaluates the results of integrated decision-making -- an outcomes-driven, not a process-driven, system -- will emphasize outcomes and accountability. It will bring more focus and discipline to EPA by expressing the relationship between investments (measured in time, money, or information) and results. It will help EPA retarget its efforts to be more outcomes-based and less procedure-based. It will help other federal, state, and local agencies assess the results of their control efforts. Finally, a well-designed, outcomes-based information system will strengthen public support for environmental programs, because people will see how the expenditure of public and private funds leads to measurable, tangible improvements in the quality of their lives.

Such report cards will only be as useful as the information contained within them. Therefore, to assess progress toward environmental goals, the report card should include information that characterizes both the short-term and long-term results of environmental protection activities. Information on short-term results will help determine 1) whether outcomes-based risk reduction decisions are being implemented as conceived, and 2) whether these actions are producing the desired reductions in stressor levels.

The information on longer-term results will help determine whether risk management decisions and the consequent reductions in stressor levels, in fact, have led to the desired improvements in human and ecosystem health and the overall quality of life, outcomes that may be discernible only after years, or even decades, have passed. Such long-term results will be most valuable for determining whether 1) goals have been met, 2) further actions are needed to control well-recognized stressors, or 3) new actions are needed to control new stressors.

Information on short-term results is important because it can give impetus to course corrections that help achieve long-term goals. Moreover, measures of short-term results enhance accountability, in contrast to long-term results, which will only rarely be useful in assessing accountability constructively because of the time-spans involved. In many instances the measurement of an early marker of health or environmental improvement will be the most effective way of judging risk reduction results in the short term.

To strengthen their credibility and usefulness, report cards should contain information, whether related to short-term or long-term environmental conditions, that is derived in a clear and methodical fashion from objective measurements. Whenever expert judgment is required to aggregate information, the method of aggregation should be laid out explicitly so that the public can better understand it. Clear documentation also will help assure continuity over time, so report cards can be compared from one decade to the next.

Finally, the report cards should provide an aggregated source of information measuring progress toward both specific and broad societal goals, and the data sets on which the report cards are based should be accessible for use at the local and regional levels.

RECOMMENDATION 9

EVOLVING PARTNERSHIPS

EPA should expand and develop new collaborative working relationships with other federal and non-federal governmental agencies and others who also will be involved in integrated environmental decision-making.

The sources of environmental risks are not always located where the effects are manifested. The risks considered most serious, and most amenable to reduction, vary from place to place. Similarly, environmental protection goals vary from region to region and from place to place within a region. For some problems, the most effective risk reduction strategies will depend on local or regional circumstances. For all these reasons, one of the most valuable aspects of integrated environmental decision-making is its capacity to be applied in the geographic area, at the level of government, or by non-governmental or private sector entities most appropriate to the problem at hand, where the relative seriousness of different kinds of risks are most apparent, and where the inevitable tradeoffs between the costs and benefits of environmental protection can be made. Simply stated, integrated evaluation of and response to environmental problems allow those responsible to match the scale and location of environmental actions to the scale and location of the problems being addressed.

In some cases, decisions may be most effective when local or state governments, non-governmental groups or the private sector plays the primary role. In others, coordinated action across several levels of government or among a number of state and/or local governments or groups may be required. In still others, the current emphasis on centralized decision-making within the federal government may be the preferred approach. In any event, integrated thinking about environmental problems will tend to drive decision-making to the agency, to the level of government, or to other entities or multiple agencies where decisions are most appropriately made.

Thus, the expanded use of integrated decision-making will shift the roles played by different agencies, groups, or levels of government. It also will change cooperative relationships across agencies and levels of government. Local entities may play a larger role, for example, in determining the range of actions that could be taken to reduce the environmental risks facing a particular community or ecosystem. In such cases, decision-making responsibility at the state and local levels may be expanded.

These changes in the roles of responsible institutions do not mean that an overarching federal presence is no longer necessary, or that EPA's role will be diminished. Rather, the Agency's role will evolve to one in which depth of control gives way to broader involvement in partnership with others. There will continue to be a national interest in local issues and decisions and their net effect on the national level. EPA will continue to be responsible for implementing and enforcing federal environmental laws and regulations. Even in a fully mature, fully integrated system, some environmental risks undoubtedly will be controlled most effectively through direct action at the federal level. Also, the Agency will continue to conduct research and development, and carry out stressor-specific risk assessments, that will be valuable across the country.

But EPA's role sometimes will be different within an integrated system from what it has been historically. At times, the Agency will participate in integrated risk decisions where the federal government is only one of several cooperative decisionmakers. In these cases, EPA will be responsible for ensuring that risk management systems put in place in specific communities or ecosystems provide a basic level of protection. Perhaps most importantly, EPA will play an essential leadership role through encouragement and assistance to decisionmakers at the local, state, and regional levels by providing them with information that helps them fulfill their responsibilities more effectively.

EPA also should continue to provide leadership among the other federal agencies whose environmentally related activities are expanding. “Reducing Risk” discussed the growing importance of other federal agencies in managing environmental risk, and recommended that EPA work to ensure that environmental considerations be included within the policy frameworks at other federal agencies whose activities affect environmental quality. That recommendation is as relevant today as it was in 1990. Many risk reduction options involving multiple stressors and/or multiple receptors will likely involve actions related to EPA's mission but they will also require involvement of other agencies in areas such as energy development or use, transportation systems, land use, forest management and timber harvesting, housing, farm management practices, and education -- to name just a few. In each of these areas, federal agencies other than EPA have primary responsibility at the national level. In short, in order to reduce today’s most serious environmental risks, more extensive coordination and cooperation among different levels of government will be needed, and the different agencies of the federal government will have to better coordinate their decision-making as well.

In summary, recognizing that human health and ecological problems can have very serious long-term consequences, including economic, the Agency should take steps to ensure that the appropriate agencies, private sector, and non-governmental groups are involved in addressing these problems. EPA can exert national leadership by bringing together the appropriate local, state, and federal stakeholders to begin exploring integrated solutions to these serious problems.

RECOMMENDATION 10
UNADDRESSED RISKS

EPA should aggressively explore options for reducing risks from significant stressors that currently are addressed inadequately by the nation's environmental institutions.

While the SAB was developing its conceptual framework for integrated environmental decision-making, it came to a troubling conclusion. From the scientific perspective of the SAB, it appears that a number of important human health and ecological risks are not being addressed adequately by the nation's environmental institutions. Moreover, those inadequacies are likely to continue without a broadly integrated decision-making system.

Throughout this project, the SAB had the advantage, as non-EPA scientists, of exploring a broader range of environmental risks than those regulated by EPA. Many of these risks are being inadequately addressed because risk management responsibility either is not clearly assigned to any one government entity, or responsibility is scattered over many agencies and/or levels of government. This fragmented approach results in uncoordinated and incomplete efforts to identify cause and effect linkages and to manage those risks.

Concern exists for inadequately addressed ecological risks. The SAB's Ecological Risks Subcommittee (ERS) assessed a wide range of stressors affecting ecosystems nationally. Through this exercise, several high-ranking risks were identified (see Table 2). These risks are largely associated with physical and biological, rather than chemical, stressors, which -- as in the case of many human health stressors -- do not fall clearly within the purview of any single federal agency. Responsibility for these stressors often is fragmented across a variety of federal, state, and local agencies. Sometimes the physical stressors have an international dimension, suggesting that risk reduction actions at the multi-nation level will be necessary.

For example, three types of physical stressors -- habitat conversion (such as building a housing tract in a grassland), hydrologic alteration (such as damming or diverting water or draining wetlands), and habitat fragmentation (the partial disruption of ecosystems by dividing them into smaller pieces by roads, fences, or land use changes) - pose especially serious risks to the nation's ecological health. At the other end of the spatial scale, the introduction of exotic (e.g., non-native) species is disrupting many ecological systems around the globe as organisms are transported from their native areas. Similarly, the increase in global temperatures and related climate changes predicted over the next century would have serious effects on several types of ecosystems, particularly those located in low-lying, coastal areas.

Table 2: High-Ranking Ecological Risks * (National Scale)

Hydrologic Alterations
Harvesting Living Marine Resources
Habitat Conversion
Climate Change
Introduction of Exotic Species

* Assuming compliance with existing regulations

The fragmented approach to responding to environmental risks limits the ability to systematically address many of these serious risks affecting ecosystems and human well-being today. Control of hydrologic alteration, for example, is distributed among several layers of government. Although the physical stressors responsible for habitat conversion usually operate -- and are regulated -- at the local level, it is difficult for local governments, by themselves, to find the expertise, funding, or public support necessary to change patterns of development whose ecologically destructive effects can only be seen at larger scales.

An environmental decision-making system focused primarily on controlling individual stressors in the environment, or operating primarily within a single agency or a single level of government, will not be as effective in reducing the risks posed by such wide-spread, multi-faceted, and integrated stressors.

Concern also exists for human health issues that remain unaddressed. One group includes observed health effects that appear to be increasing in incidence at a rate that suggests causation by some environmental agent, such as personal lifestyle choices or from an environmental stressor. Several examples of increasing rates of disease which have caused concern in the health professions are asthma, brain cancer, and non-Hodgkins lymphoma.

Another category of health issues for which a coordinated response is needed is in the area of the effect of environmental pollutants on susceptible and/or compromised human populations. While children have appropriately been identified as one such population and a cross-agency response has been launched, the full extent of the program has not yet developed. Further, the needs of the fastest growing segment of our population, the elderly, have not been examined in relation to environmental impacts and risks in this susceptible group.

To control many of these inadequately addressed risks will require the kind of integrated decision-making system envisioned in this document. An effective response will depend on a decision-making system that is capable of evaluating complex sets of stressors affecting multiple endpoints over broad regions of the country. It will depend on an improved scientificability to assess the current overall health of humans and ecosystems and then measure future changes in health status.

Most of all, it will depend on a new kind of integrated leadership. Although no single agency, level of government, or other entity now has primary authority to control many serious ecological and human health risks, EPA is uniquely situated at the federal level to coordinate a combined effort. When serious risks are not being addressed effectively by existing environmental institutions or decision-making systems, the Agency has a responsibility to inform the public about those risks and bring together the appropriate federal, state, and local agencies, and other institutions to explore ways of controlling them. Further, it will be necessary to identify and develop new kinds of risk reduction tools needed for controlling national-scale problems like habitat fragmentation, water diversion, and indoor air pollution, and to assist in fully evaluating the costs and benefits of different control options, including difficult-to-monetize environmental benefits.

There are some hopeful examples in the area of human health in which interinstitutional cooperation has led to substantial advances in managing environmental stressors that have resulted in healthier conditions for human populations. In these cases, collaboration among federal agencies, various levels of government, and industry have contributed to these advances. Such examples include innovations in waste disposal, reductions in emissions of environmental contaminants, and introduction of safe industrial practices.

EPA should take the principles of integrated environmental decision-making described in this report and quickly take steps to address the root of many of these outstanding risks to human and ecological health. The Agency should be able to take these steps without new legislative authority and thereby help the country to develop risk management actions that reduce the most risk in the most efficient and effective way.

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