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ANALYTICAL STUDIES FOR THE U.S.
ENVIRONMENTAL PROTECTION AGENCY

VOLUME III

Research and Development in the Environmental Protection Agency

A report to the
U.S. Environmental Protection Agency
from the
Environmental Research Assessment Committee

Commission on Natural Resources
National Research Council

NATIONAL ACADEMY OF SCIENCES
Washington, D.C. 1977

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Contents

APPENDIXES

Foreword

This report is one of a series prepared by the National Research Council for the U.S. Environmental Protection Agency.

In June 1973 the Subcommittee on Agriculture, Environmental, and Consumer Protection of the Appropriations Committee of the U.S. House of Representatives held extensive hearings on the activities of EPA, and the ensuing appropriations bill for fiscal year 1974 directed the Agency to contract with the National Academy of Sciences for a series of analytical advisory studies (87 Stat. 482, PL 93-135). EPA and the Academy agreed upon a program that would respond to the Congressional intent by exploring two major areas: the process of acquisition and use of scientific and technical information in environmental regulatory decision making; and the analysis of selected current environmental problems. The Academy directed the National Research Council to formulate an approach to the analytical studies, and the National Research Council in turn designated the Commission on Natural Resources as the unit responsible for supervising the program.

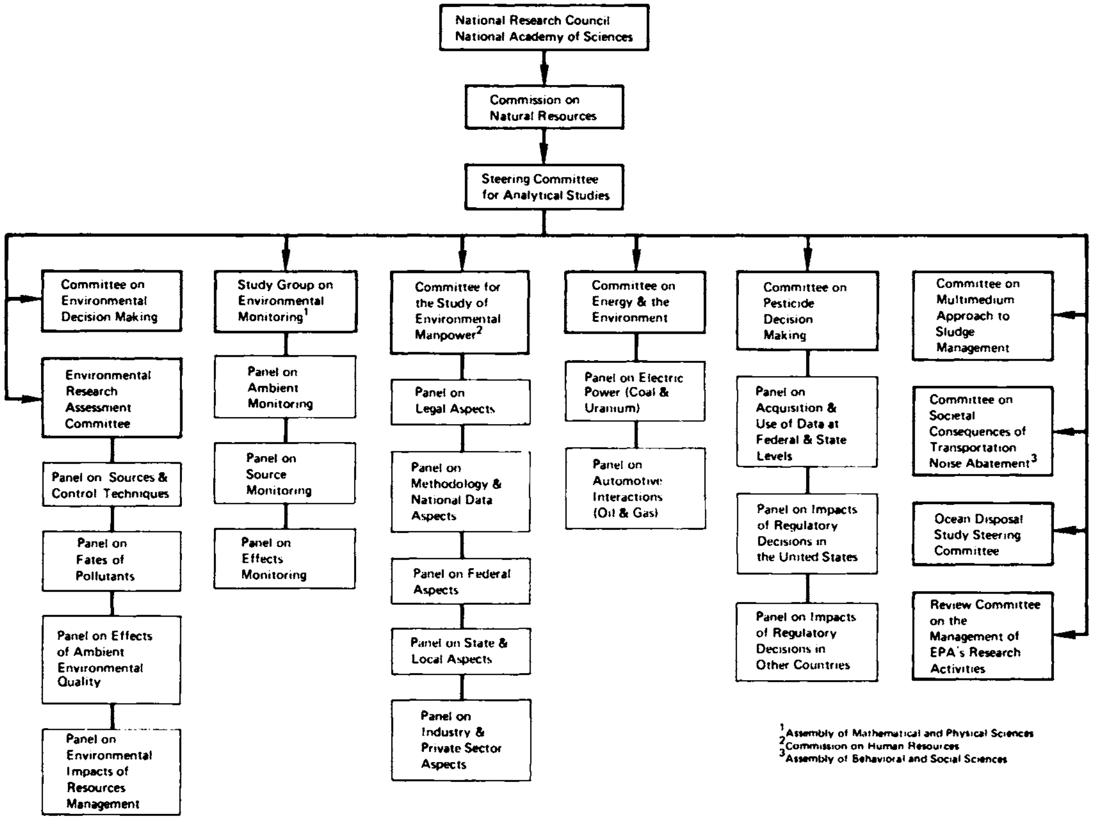
The other studies in the series, and a diagram of the structure of the program are presented on the following pages. Each of the component studies has issued a report on its findings. Volume I of the series, *Perspectives on Technical Information for Environmental Protection*, is the report of the Steering Committee for Analytical Studies and the Commission on Natural Resources. It describes in detail the origins of the program and summarizes and comments on the more detailed findings and judgments in the other reports.

Components of the NRC Program of Analytical Studies for the U.S. Environmental Protection Agency

Project	Project Chairman	Sponsoring Unit of the NRC
Steering Committee for Analytical Studies (SCAS)	R. M. Solow	Commission on Natural Resources
Environmental Decision Making (CEDM)	J. P. Ruina	Environmental Studies Board, Committee on Public Engineering Policy
Environmental Research Assessment (ERAC)	J. M. Neuhold	Environmental Studies Board
Environmental Monitoring (SGEM)	J. W. Pratt	Committee on National Statistics, Environmental Studies Board, Numerical Data Advisory Board
Environmental Manpower (CSEM)	E. F. Gloyna	Commission on Human Resources
Energy and the Environment (CEE)	S. I. Auerbach	Board on Energy Studies
Pesticide Decision Making	W. G. Eden	Board on Agriculture and Renewable Resources, Environmental Studies Board
Multimedium Approach to Municipal Sludge Management	H. O. Banks	Environmental Studies Board
Societal Consequences of Transportation Noise Abatement	W. J. Baumol	Assembly of Behavioral and Social Sciences[b]
Disposal in the Marine Environment	D. S. Gorsline	Ocean Affairs Board
Review of Management of EPA's Research Activities	R. W. Berliner	Commission on Natural Resources

[a]In cooperation with the Building Research Advisory Board.
[b]In cooperation with the Building Research Advisory Board and the Transportation Research Board.

Structure of the NRC Program of Analytical Studies for the U.S. Environmental Protection Agency



[1] Assembly of Mathematical and Physical Sciences
[2] Commission on Human Resources
[3] Assembly of Behavioral and Social Sciences

Preface

In 1974, the National Research Council appointed an ad hoc Review Committee on the Management of EPA's Research and Development Activities. This committee recommended changes in the organizational arrangements and planning procedures of EPA's Office of Research and Development (see Appendix C). Following on the work of this committee, the Environmental Research Assessment Committee (ERAC) was organized to examine the relationship between the research and development program and the regulatory activities of EPA, focusing on the acquisition of scientific and technical information for use in regulatory decision making.

Two topics designated for study by the charge to ERAC were identified as both central to EPA's needs and appropriate for study by a committee of the National Research Council. The first topic, which encompassed the purposes of the Agency's scientific and technical program, the program's relationships to environmental research conducted elsewhere, and its conduct and management within EPA, was studied by the Committee itself. The ERAC, composed of scientists and administrators with extensive experience in the management of research and development programs both in and outside government, conducted its study by interviewing knowledgeable people at nine meetings held over the course of two years. Biographical sketches of Committee members may be found in Appendix A. The list of people interviewed, which includes scientists and nonscientists from all levels in EPA, from other Executive agencies, from the Congress, and from private organizations, may be found in

Summary

In discharging its regulatory responsibilities, EPA must make decisions that require sound scientific support. The purpose of this report is to suggest how the Agency might organize and use research to meet these needs for critical information.

Consideration of the complexities of regulatory decision making for environmental protection and of the legislative directives and constraints under which the Agency must work has convinced the Environmental Research Assessment Committee (1) that it is both appropriate and necessary for EPA to continue to perform and sponsor research, and (2) that the primary purposes of the Agency's research program should be to provide technical support to the decision-making process and to anticipate future environmental problems.

These two conclusions, and recognition that the Agency performs its regulatory functions in an adversary legal system, are basic to the argument of this report. In this framework the Committee formulated its conclusions and recommendations.

This report examines: the need for research (see Chapter 1); the components of an effective research program, and where and how they should be carried out (see Chapter 2); and the organization and management of this program, from planning to transfer of results (see Chapters 3, 4, and 5).

The major recommendations are summarized below. Some of them address important policy issues: the need for a coordinated federal environmental research and development program; the role of EPA's Office of Research and Development in providing support for the Agency's decision-making process; and the scope of EPA's research mandate. Other recommendations in the report, some of which are highlighted in this summary, are intended to improve both the effectiveness and the credibility of the Agency's research and development program.

MAJOR RECOMMENDATIONS

THE ROLE OF RESEARCH IN EPA

- *EPA's research and development should concentrate primarily on support of the Agency's decision making and anticipation of future problems.*

- *EPA should supplement its primary research responsibilities with some fundamental research to help advance understanding in environmental sciences and technology.*

- *A new legislative mandate will be required if EPA is to conduct effective anticipatory and fundamental research.*

For an agency whose principal mission is regulation, and whose funds for research are necessarily limited, the emphasis of its scientific and technical activities must be support of the regulatory function. At present, the legislative mandates for EPA's research come from the individual programs of ten major laws. While this situation is appropriate and necessary for providing support for decision making in these programs, there is also a need for research that goes beyond this immediate support. The Agency has been restrained from conducting or supporting the research of longer range and wider scope needed to anticipate problems and to advance understanding by having its research authorities associated only with specific programs for environmental protection. EPA should not, however, be considered a lead agency in fundamental research on environmental science and technology. (For full discussion see the sections in Chapter 1 on Purposes of Environmental Research and Assessing the Role of EPA in Environmental Research and in Chapter 2 on Investigation of Fundamental Physical, Chemical, and Biological Processes.)

THE NEED FOR A COORDINATED FEDERAL ENVIRONMENTAL RESEARCH AND DEVELOPMENT PROGRAM

● *We recommend that the Office of Science and Technology Policy (OSTP) develop a federal environmental research, development, and demonstration strategy that includes designation of the appropriate roles of all participating federal agencies and existing interagency coordinating committees, and delineation of the relationships between federal and nonfederal research and development. The OSTP should coordinate the implementation of the strategy through its mandated consultations with the Office of Management and Budget (OMB) about the scientific programs of federal agencies.*

If protecting the environment is to be accorded a status commensurate with the impacts of environmental problems on national domestic affairs, more of the national research and development effort must be devoted to these problems than can or should be deployed by EPA alone. To provide information needed for sound environmental decision making, the federal environmental research and development program must be more effectively planned and coordinated than it is at present. Because the potential partners in the needed cooperative effort are located at several levels of administration in the federal bureaucracy, and because the budgetary process is the most effective tool for implementing a coordinated research plan, responsibility for overview and coordination should lie in the Executive Office of the President. The recommendation specifies OSTP because of its mandates to assist the President in providing leadership and coordination of federal research and development programs and to consult with the OMB on the scientific programs of federal agencies. (See the section in Chapter 1 on Coordination of Research Programs.)

ORGANIZATION OF EPA'S RESEARCH

● *We recommend that the management of all research and development in EPA be centralized in the Office of Research and Development (OR&D).*

There are advantages and disadvantages, detailed in Chapter 3, to centralizing responsibility for the Agency's research and development activities in OR&D. On balance, the advantages, such as encouragement of research whose concerns are not limited by artificial boundaries in the environment often prescribed by legislation, outweigh the disadvantages. Further, some of the disadvantages can be overcome by good management practices, some of which are detailed in Chapters 4 and 5. (An example is the use of personnel from Program Offices on detail to OR&D to act as project managers for extramural research.) The recommendation applies to all the Agency's ongoing, substantial research and development, but not to routine laboratory and technical services now being performed in Program and Regional Offices.

● *EPA's research program needs to be better organized for balance and continuity, through planning developed around a logical conceptual framework of environmental protection (such as we propose in Chapters 1 and 2).*

More attention should be given to systematic assessment of existing information for decision makers, analysis of environmental trends, integration of studies of impacts in different media, and socioeconomic research. The Agency should continue its recent efforts to plan research farther ahead so that more research can be done in anticipation of decisions, rather than in response to crises.

● *A central function of scientific support to decision making should be to provide integrated assessments of available scientific, technical, and economic data pertinent to pending decisions in forms suitable for use by Agency decision makers. We recommend that the importance of this function be recognized by giving it formal status and organization in OR&D.*

Integrated analysis of available data transfers technical information from the research community to decision makers, a service vital to the decision-making process. At present this function is being performed on an ad hoc basis with personnel "borrowed" from other activities. (For a description of this function, see Chapter 2 on Assessment and Integration of Available Information, and Chapter 5 on Applications of the Results of R&D. For detailed suggestions on the organization of the proposed office, see Chapter 3 on Consequences for OR&D's Program.)

● *The research planning system now in use in OR&D, characterized as "top-down" in structure, should be retained for research in support of decision making. For anticipatory and fundamental research, however, we recommend a "bottom-up" scheme that relies on the scientific community to identify research needs.*

Research in support of decision making should respond to needs identified by the potential users, decision makers in EPA, entailing a "top-down" scheme. The scientific and technical communities, both inside and outside EPA, are best qualified to identify needs for anticipatory and fundamental research, entailing a "bottom-up" scheme. (Both are described and illustrated in the section in Chapter 4 on Identifying Research Needs.)

● *We recommend that block funding of extramural grants, contracts, and interagency agreements be considered as a mechanism to establish centers of excellence, federally funded contract research and development laboratories, and umbrella interagency agreements to supplement the intramural research and development program.*

The increased flexibility and continuity of the recommended funding arrangements will reduce the time required to initiate research. Block funding establishes and maintains extramural research capabilities that perform as extensions of the intramural program, and results in work more closely attuned to the Agency's programs and purposes than that performed by extramural researchers selected on an ad hoc basis (see Chapter 3 on The Extramural Program).

TECHNICAL QUALITY OF RESEARCH

● *All proposals and completed research should be subjected to review on their technical merits by scientific and technical peers.*

To judge scientific and technical merit, there is no substitute for review of proposals, progress, and results of both projects and programs by peers in the scientific and technical communities, both inside and outside EPA. Peer review of the scientific merit of proposals will assure that work plans are technically sound and determine whether the proposed research has already been conducted elsewhere (see Chapter 4 on Managing Scientific Activities for discussion of this and other recommendations for improving the technical quality and effectiveness of EPA research).

● *We recommend the use of a parallel grade advancement system, based on performance of research, that does not require researchers to assume administrative or managerial tasks to attain promotions.*

Improving working conditions in this way may be expected to help attract and keep the best research talent and consequently to improve the quality of research programs (see Chapter 4 on Personnel and Facilities for discussion of this and other recommendations for managing the Agency's research personnel).

1 Environmental Protection and Research

The impetus for the mission of the U.S. Environmental Protection Agency is the potential threat to health and welfare posed by physical, chemical, or biological agents in the environment. The function of EPA, assigned by the statutes under which it operates, is to protect the health and welfare of the nation's population from such agents. In discharging its responsibilities, EPA must weigh risks, benefits, and costs to arrive at balanced judgments on whether regulatory action is warranted and what form that action should take. Although such judgments are therefore based, in the final analysis, on political as well as scientific considerations, sound scientific and technical evidence is essential at all stages of the decision-making process, from its initiation as a result of the indication or evidence of harm, through analysis of the nature and magnitude of that harm, to the selection and implementation of protective measures.

The purpose of this report is to suggest the role that research and development might play in EPA and how the Agency might obtain the needed scientific and technical information through its own research and development program and those of other agencies and institutions. In appraising the role research should play in the Agency, the report examines the purposes for which environmental research is conducted, the mandates and capabilities of EPA to conduct research, other environmental research programs, both public and private, and the difficulties of coordinating the work so that the results can be useful to EPA and ultimately to the citizenry. Succeeding chapters examine the different scientific and technical activities that make up environmental research and development, describe how they can be effectively organized, planned, and managed, and consider how the eventual use of results may affect the way these activities should be conducted.

Our report has been written with recognition of the difficulties that beset the program of scientific and technical activities in EPA: the legislation that requires the Agency to conduct research to support regulation without providing incentives to the regulated to make use of the results; the difficulties of coordinating federal environmental research and development performed or supported by agencies other than EPA to provide information useful to EPA's program; the Agency's limited budget; the difficulty of changing and redirecting the mix of technical skills and facilities EPA inherited from other agencies; the enormous range of applicable scientific and technical activities; and changing public perceptions of environmental problems. Our recommendations are intended to provide practical guidance to EPA, the Executive Office of the President, and the Congress for more effective acquisition, through research, of scientific and technical information for use in making decisions.

A FRAMEWORK FOR ENVIRONMENTAL PROTECTION

Figure 1.1 schematically depicts our view of the ways in which man interacts with the environment; the critical elements are indicated by boxes and the causal relationships by arrows. Our model considers the environment as a whole, intentionally avoiding representations for air, water, soil, and biota. To understand and control the effects of man's interactions with the environment, information is required on the totality of physical, chemical, biological, and social components of this model, and their interrelationships.

Since Figure 1.1 depicts the framework in which the present report is set, some explanation of the elements depicted and the way in which they relate to each other is in order here. Beginning at the bottom of the figure, the fundamental "decisions to control effects"—that is, decisions involving the balancing of environmental damages and risks with traditional measures of growth, employment, capital formation, and profit—are inherently intensely political. As such, they are properly matters for legislatures and elected officials to deliberate and act on. Once a decision to control has been made, the means by which the desired level of environmental quality or degree of protection is to be attained must be selected (for instance, discharge standards, prohibitions on production or application of certain chemicals, or specification of required waste treatment processes).

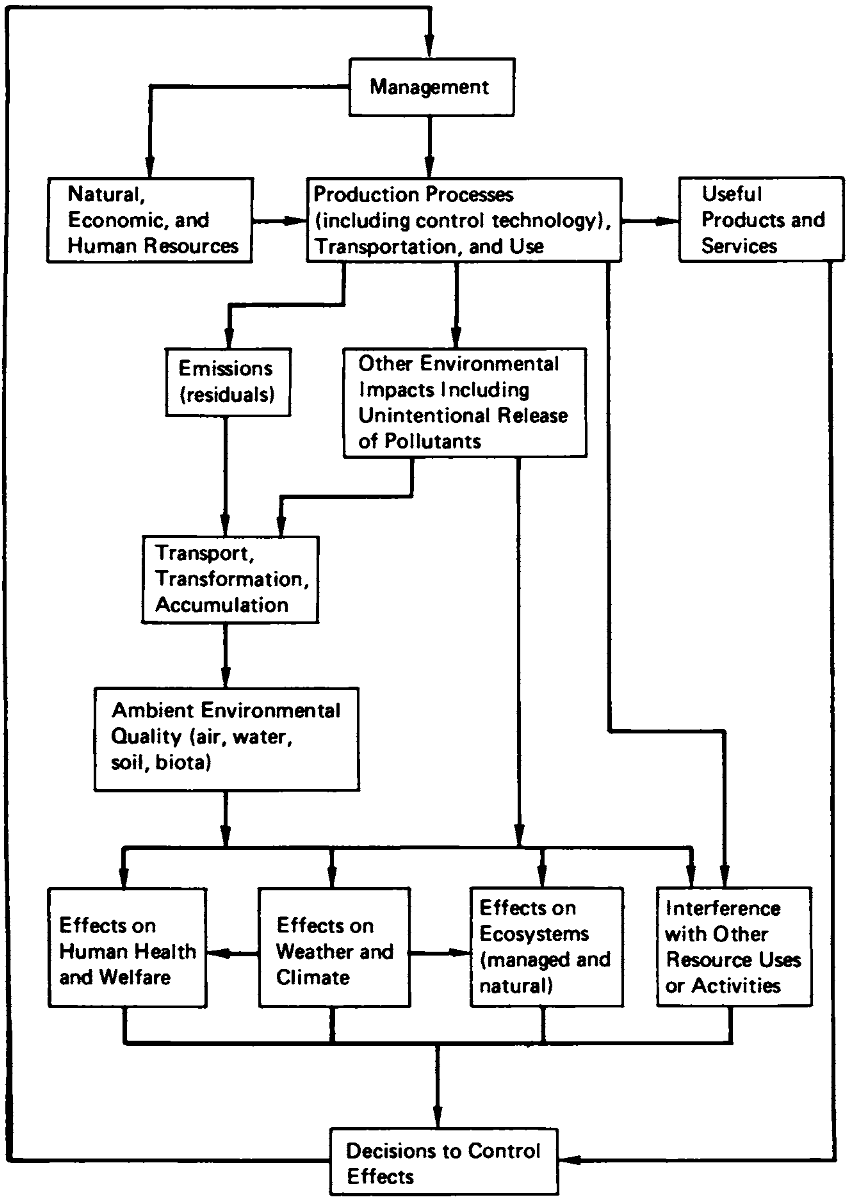


FIGURE 1.1 Framework for environmental protection.

The choice of control methods might be considered a technical task, appropriate for an executive agency such as EPA, were it not for the fact that environmental problems do not respect existing political boundaries, and that particular means of control have side effects that include important social and economic impacts, such as effects on the distribution of income. In fact, of course, the line between political and technocratic decisions such as these is not distinct. Often, legislative decisions about desirable levels of environmental quality are couched in very general terms, and acquire meaning only when translated by EPA. A case in point is the need to translate the directive "to protect the public health" of the Clean Air Act (84 Stat. 1685, PL 91-604) into specific primary ambient air quality standards for SO_2 and suspended particulates. On the other hand, legislation often gives content to general policy statements by specifying policy instruments and administrative arrangements. The Federal Water Pollution Control Act Amendments of 1972 (33 USC 1251–1256 et seq. Supp. 1975, PL 92-500), for instance, establish detailed procedures for controlling the level of pollutants in wastewater discharges to attain very broadly worded goals about desirable water quality.

In this complex and demanding situation, EPA is frequently called on by legislation to balance risks, benefits, and costs of alternative actions, and to do so in very political areas. This task is made especially difficult by the fact that many of the adverse impacts cannot be assessed in monetary terms, at least with current methodology. Moreover, the required balancing must often be done in the context of adversary proceedings, such as the pesticide cancellation hearings, in which technical and scientific information is used to support a particular position. Thus, an essentially political issue may turn into a quarrel over experimental method or the interpretation of statistics. This atmosphere and the accompanying techniques of argument may be carried over and, indeed, intensified, if the original decision is challenged in court.

The strategies for attaining specific goals of environmental quality so far permitted or specified by environmental legislation include the promulgation of regulations and standards, issuance of discharge permits and guidelines, review of state and regional plans, and control of the production and distribution of pesticides and other potentially hazardous substances. These measures are designed to constrain management decisions in industry, agriculture, transportation, commerce, and municipal services (see Figure 1.1). Other strategies for environmental management, such as effluent charges, have been devised to influence production decisions by providing incentives rather than constraints (Kneese and Schultze 1975). In all cases, the objective of intervention is to alter the behavior of managers so that the environmental impacts of production processes will in turn be altered.

The major undesirable by-products of production fall into two broad categories: (1) discharge of pollutants or waste products, and (2) interference with alternative, desirable uses of the resource. In the first category, some pollution is the result of the deliberate disposal of residues into the air or water, or onto the land, while other pollutants are an unintentional consequence of the production process (for instance, acid mine drainage, the runoff of nutrients and pesticides from agricultural activities, or accidental spills of all kinds). An example of the second category is the draining and filling of a coastal wetland for residential or commercial purposes which precludes its use as a nursery to sustain coastal ecosystems.

Once agents have been released into the environment as by-products of production, natural physical, chemical, and biological processes transport, transform, and accumulate them into reservoirs. Resulting changes in the quality of the ambient environment have consequences, potentially adverse, for human health and welfare, weather and climate, managed and natural ecosystems, and the use of resources for alternative purposes.

RESEARCH WITHIN THE FRAMEWORK OF ENVIRONMENTAL PROTECTION

Ideally, no part of the interrelated system depicted in Figure 1.1 should be considered in isolation. For practical purposes, however, the focus of research must be narrowed to areas of manageable scope, while the importance of interrelationships is constantly borne in mind. For convenient discussion, the Committee therefore divided the scientific and technical issues into the four categories listed below, and assembled four panels to submit reports, within the categories, on the state of knowledge and national needs for information to support environmental decision making, without specific limitation to EPA or its current mandate (see Preface). Throughout the present, more general report the analyses and recommendations of the panel reports are cited as specific examples. The four categories are as follows:

1. *Sources of residuals and techniques for their control* (see report of the Panel on Sources and Control Techniques, National Research Council [NRC] 1977f), which concerns the residuals produced by human activities and control of these residuals with technology, with alternative management strategies and incentive systems, and with improved institutional mechanisms for environmental management.
2. *Fates of pollutants* (see report of the Panel on Fates of Pollutants,

NRC 1977e), which concerns the processes by which residuals are transported, transformed, and accumulated in water, air, land, and biological reservoirs.

3. *Effects of a polluted environment* (see report of the Panel on Effects of Ambient Environmental Quality, NRC 1977b), which concerns the effects of the altered environment on human health and welfare; on weather and climate; and on plants, animals, and ecosystems.

4. *Environmental impacts of resources management* (see report of the Panel on Environmental Impacts of Resources Management, NRC 1977c), which concerns disruption of landscapes and ecosystems and foreclosure of alternative uses of land associated with the management of natural resources such as forests, agricultural lands, and minerals.

Each of the elements and relationships in Figure 1.1 is directly included in one or another of the four categories, with the exception of the elements "decisions to control effects" and "useful products and services." The decision-making process itself (including the use of scientific and technical information acquired through research and development or elsewhere) is the subject of a report (NRC 1977a) of the Committee on Environmental Decision Making (see Foreword).

PURPOSES OF ENVIRONMENTAL RESEARCH

Each of the 14 federal agencies significantly involved in environmental research and development conducts R&D for one or more of the following purposes: to provide technical support to that agency's decision making, to anticipate future problems, and to advance fundamental scientific understanding. For example, the primary emphasis of EPA's current research program is direct support of regulatory decision making (Talley 1975), whereas the environmental programs of the National Science Foundation (NSF), except for studies conducted under the program Research Applied to National Needs, deal primarily with advancement of fundamental science.

The three purposes are interrelated. Clearly, research designed to support a specific decision may also advance knowledge or identify a potential future environmental problem, while research aimed primarily at advancement of knowledge may disclose problems or information relevant to the immediate needs of decision makers. Eventually, basic scientific understanding will be used for future decisions, just as present decision making uses the understanding developed from fundamental research conducted in the past.

We have concluded that because EPA is primarily a regulatory agency with limited resources, the principal reason for its research must be to support decision making. EPA should also conduct research to anticipate future environmental problems. Research intended primarily to advance fundamental scientific understanding may sometimes be appropriate (see Chapter 2 for examples); nevertheless, the Agency should not, in our opinion, take the lead in advancing the broad front of fundamental scientific understanding potentially relevant to the solution of environmental problems.

SUPPORT FOR DECISION MAKING

Examples of research and development activities that directly support EPA's immediate regulatory activities are: studies of costs, benefits, and risks; the development and standardization of measurement technology; the development and demonstration of control technology; and the development of protocols for the design of monitoring systems (see Chapter 2). Additional examples are the various activities that will be required to implement the Toxic Substances Control Act (15 USC 2601 1976, PL 94-469); for instance, estimation of the concentrations of substances to which receptors will be exposed and assessment of the implications of toxicological data for the decision at hand.

ANTICIPATION OF FUTURE PROBLEMS

EPA must also perform research designed to facilitate anticipation of environmental problems if it is ever to overcome the "current crisis syndrome." This does not imply that EPA should be expected to foresee all crises that may arise, particularly since not all "crises" are real. There is, however, much that EPA can do to improve its ability, and that of the public, to anticipate problems. Examples detailed in Chapter 2 include efforts to characterize the pollutants in industrial, agricultural, and municipal waste streams, and to identify the parameters that influence the generation of residuals from industrial, agricultural, and municipal activities.

ADVANCEMENT OF ENVIRONMENTAL SCIENCE

Research designed to advance our fundamental understanding of environmental processes that is not being supported by other, research-oriented agencies may properly be conducted by EPA. A prime example is research on fundamental ecological processes (see Chapter 2 on Analysis and Modeling of Ecosystems). Additional examples are research on metabolic processes that determine the fates of environmentally important substances, and studies intended to elicit basic properties that can be used to classify substances for purposes of screening for potential for environmental concern (see Chapter 2 on Determination of the Fates of Pollutants and Characterization of Pollutants and Discharges, respectively).

ASSESSING THE ROLE OF EPA IN ENVIRONMENTAL RESEARCH

The necessity for a federal program of research and development to support environmental decision making is largely a result of the legal strategies for environmental protection adopted by Congress. The current set of legislative mandates to EPA, for example, does not take full advantage of self-interest by instituting incentives for private parties to perform research, especially on pollution control technology, in their own behalf. Some legislation may even have the effect of discouraging private research initiative. As a consequence, the government is forced to conduct research that might be more effectively performed in the private sector where competitive pressures, diversity of interests and experience, and decentralized decisions are more likely to produce advances in environmental engineering and control technology that are most suitable for application.

More fundamentally, the adversary nature of our legal structure for environmental protection complicates the conduct of environmental research and development by EPA. EPA enforces its legislative mandate in the public interest and, as a practical matter, conducts or sponsors studies designed to support decision making. To obtain wide acceptance of its decisions by the scientific community and to survive challenge by regulated parties, the Agency's decisions must be based, as far as possible, on sound, credible scientific information. At the same time, the Program Offices in the Agency that are responsible for developing proposed decisions for consideration by the Administrator feel that EPA's research should be directly responsive to their needs. Furthermore, the Agency conducts research in response to judicial directives or to support the activities of the Office of the General Counsel; again, this research should be responsive to its intended use in an adversary legal procedure. The validity of research conducted by EPA to support its decision making will always be suspect merely because the Agency is viewed as one party in the adversary process of regulation and standard-setting. Research conducted by regulated parties, of course, suffers from the same problem. Thus the dilemma: the clear need, under the present system of legislation, for EPA to conduct research in support of its decision making limits the usefulness to the Agency of the results of that research. High technical quality may be enough to establish the scientific credibility of EPA's research (see Chapter 4), but may not be adequate to offset the widespread presumption of institutional bias that results directly from the adversary nature of the enforcement of regulations and standards.

Ten major legislative acts authorize EPA to conduct research.[1] The mandates for research contained in these acts are summarized in EPA's five-year plan for its environmental research (U.S. EPA 1976b).[2] The sum of these authorities is quite broad. Indeed, it is difficult to imagine an environmental research project that cannot be described in the terms of the overall mandate provided by these acts taken together. Yet the authorities of most of these acts are restricted to such specifics as drinking water, noise, air, or radiation.

The problem of environmental protection is more complex than the individual legislative acts recognize (with the possible exception of NEPA and the Toxic Substances Control Act). Attempts to abate air pollution, for instance, are now widely recognized as having implications for fresh waters, the oceans, and the land. In almost every such intermedia case, realistic approaches to environmental problems, including research, must be problem-oriented rather than medium-oriented. Consequently, it may not be possible to justify an effective research project under a single provision of a single act. EPA recognizes the importance of considering interactions among the media in research and has attempted to organize portions of its research program into groups of projects that, taken as a whole, address this need.

Mandating research under the separate acts may obscure the interme-

[1]The acts that authorize EPA to conduct research are as follows: The Clean Air Amendments of 1970 (42 USC 1857 1970, PL 91-604); Federal Water Pollution Control Act Amendments of 1972 (33 USC 1251–1265 et seq. Supp. 1975, PL 92-500); Safe Drinking Water Act (42 USC 300 et seq., PL 92-523); Solid Waste Disposal Act of 1965 (42 USC 3251–3259 1970, PL 89-272) as Amended by the Resources Conservation and Recovery Act of 1976 (42 USC 6901, PL 94-580); Federal Insecticide, Fungicide, and Rodenticide Act as Amended (7 USC 121 et seq. 1970, PL 88-305); Public Health Service Act as Amended (42 USC 264 1970); Noise Control Act of 1972 (42 USC 4901–4918 1975, PL 92-574); Marine Protection, Research, and Sanctuaries Act of 1972 (16 and 33 USC, PL 92-532); the Toxic Substances Control Act (15 USC 2601 1976, PL 94-469); and the National Environmental Policy Act (NEPA) of 1969 (42 USC 4321 et seq. 1970, PL 91-190).

[2]Two mandates are not included in this document: (1) that under Section 204(5) of NEPA to conduct ecological research, which was transferred from the Council on Environmental Quality to EPA by Reorganization Plan No. 3 of 1970 (5 USC, App. 1970, 35 F.R. 15623) and (2) that under section 10 of the Toxic Substances Control Act, which was signed into law on October 11, 1976.

dia nature of environmental problems. Nevertheless, since a primary focus of the Agency's scientific and technical activities should be to support the decision making prescribed by the individual mandates, the Committee recognizes the expediency and necessity of conducting research under them for that purpose.

There is also, however, a need for research that goes beyond the immediate support of decision making: for example, the Committee believes that, as a consequence of budgetary constraints and of the Agency's priorities for carrying out its legislated mandates, needs for research to anticipate future problems or advance fundamental understanding are largely being overlooked (see Chapter 4).

To facilitate the establishment of research programs other than those directly supporting current decisions, and to insulate the programs adequately from the regulatory process, we recommend specific Congressional authorization for EPA to perform anticipatory and fundamental research be enacted. This authorization should be separate from and in addition to authorization for research and development intended to support implementation of the pollution control legislation that EPA administers. In particular, some of EPA's research designed to anticipate future problems and all the research performed to advance fundamental understanding through considerations of the total environment should be conducted under such a mandate, permitting the Agency to direct some of its scientific efforts to problems independent of its programmatic functions. Examples of scientific activities, taken from Chapter 2, that would benefit from being funded under such an independent authority are: the development of biological monitoring systems; the characterization of agricultural, industrial, municipal, and commercial waste streams; development of understanding of ecosystem processes; and support of programs in environmental toxicology and epidemiology. Chapter 4 describes how the research conducted under this mandate might be planned to maintain its independence from EPA's regulatory functions while at the same time keeping the research relevant to the Agency's overall mission.

Congress should also strengthen its own procedures for coherent review of all of EPA's research and development. In the House of Representatives, a committee reorganization has centralized the review function in the Committee on Science and Technology, particularly its Subcommittee on the Environment and the Atmosphere; a similar action in the Senate would greatly aid EPA's own efforts to achieve a more coherent program. The need for coherent and integrated procedures for congressional review of EPA's research programs has been amply demonstrated in the past five years. The Agency's own efforts to reorganize its laboratories have been blunted by conflicting congressional guidance; the investment authorized by Congress in the Agency's central problems of air and water quality has been too little and too late in most cases; and the requirement that EPA and other federal environmental research and development be coordinated has received mostly lip service.

COORDINATION OF RESEARCH PROGRAMS

While EPA's legislative mandates to conduct research may be broad, its resources, like those of every other agency, institution, or firm, are limited. Budgetary and other constraints have made and possibly will continue to make it impossible for EPA to carry out all the research functions mandated by all the legislation under which it operates. It cannot meet all of its immediate needs, much less conduct all the research vital to future decision making. Nor should EPA be expected to carry such a burden, since there are about 14 other agencies of the federal government, many state agencies, and hundreds of public and private institutions and firms conducting environmental research and development relevant to EPA's missions.

FEDERAL ENVIRONMENTAL PROGRAMS

Environmental programs in the federal government are many and diverse, totaling about $6.2 billion in budgetary authority in FY 1978 exclusive of construction grants (U.S. Office of Management and Budget [OMB] 1977, Special Analysis Q). Table 1.1 shows the level of effort proposed for these programs in each of three budget categories: pollution control and abatement; understanding, describing, and predicting the environment; and environmental protection and enhancement. These budget categories are defined by the OMB, but each agency is responsible for designating the categories into which its programs fall. Thus Table 1.1 reflects each agency's perception of its mission in environmental matters. For example, all of EPA's requested operating budget of $802.4 million is classed as being for pollution control and abatement, including $266 million for research and development (U.S. OMB 1977, Special Analysis P). Similarly, research and development programs may be included in each of the three budget categories of Table 1.1. No part of EPA's research program is designated by the Agency as falling in the categories of understanding, describing, or predicting the environment, or of

TABLE 1.1 Estimated Budget Authority for Environmental Programs, FY 1978 (in millions of dollars)

Department or Agency	Pollution Control and Abatement	Understanding, Describing, and Predicting	Protection and Enhancement
Agriculture	136.0	165.6	104.6
Commerce	33.8	431.6	79.6
Defense (Civil)	37.3	11.0	184.2
Defense (Military)	486.2	228.1	–
Health, Education, and Welfare	50.2	204.1	–
Housing and Urban Development	139.9	–	146.5
Interior	95.3	374.3	1,378.8
Transportation	104.2	15.9	–
EPA	802.4	–	–
ERDA	362.6	152.4	–
NASA	76.8	182.8	–
NSF	–	169.4	–
Smithsonian	–	14.1	–
TVA	–	–	5.0
Others	51.8	9.3	2.2
Total	2,376.5	1,958.6	1,900.9

SOURCE: U.S. OMB (1977) Special Analysis Q.

environmental protection and enhancement. It therefore seems clear that budget categories are of limited usefulness for assessing the extent and purposes of the federal environmental research and development program.

As might be inferred from Table 1.1, a considerable amount of environmental research and development is being conducted in such agencies as the Departments of Agriculture (USDA); Commerce; Health, Education and Welfare (HEW); and Interior (DOI); and in the National Science Foundation (NSF) and the Energy Research and Development Administration (ERDA), as well as in EPA. The total authority for environmental research and development requested in the President's budget for FY 1978 is $1.81 billion (U.S. OMB 1977, Special Analysis Q). Much of this research could be applicable to EPA's needs. However, information on the scope of these programs and their potential value to decision making for environmental protection is generally not sufficiently detailed for purposes of planning and coordinating the federal effort.

A critical review of the overall program was last conducted in 1970 by the Office of Science and Technology (OST 1971). Annual reviews conducted by NSF deal only with the magnitude and distribution of research and development programs and are based on budget data submitted by agencies, rather than on substantive review (NSF 1975). The House Subcommittee on the Environment and the Atmosphere has also conducted a useful survey by hearing testimony from the heads of participating agencies, but the information was too general to be of practical guidance for coordinating these programs (U.S. Congress, House 1975). Several detailed surveys of research in specific areas associated with developing energy sources and technologies have been undertaken recently (U.S. EPA 1976c, U.S. ERDA 1975a, Council on Environmental Quality [CEQ] 1976). Despite the potential utility of these latter studies, both a detailed knowledge of what other federal research programs might be applicable to EPA's needs and a mechanism for coordinating the planning of these programs and allocating resources to them have heretofore been lacking.

COORDINATING THE FEDERAL RESEARCH PROGRAM

Various mechanisms exist for coordinating the planning and conduct of research in the federal government and the private sector, including interagency working groups and coordinating committees, formal interagency agreements, and memoranda of understanding between agencies or between agencies and private firms or trade associations (U.S. Congress, Senate 1962). The most effective mechanisms are those that serve the interests of the participants as well as of EPA and the purse strings are the most powerful instrument for coordinating research planning. Certain interagency working groups have been relatively successful, especially when their work was performed under the auspices of and advisory to OMB.[3] Congress could coordinate effectively through its oversight and appropriations functions, but appears to be limited in this capacity by the fragmented jurisdictions and interests of the subcommittee structure and by insufficient staff support.

It is not likely that EPA will ever have the financial resources to

[3]Examples are the Gage (U.S. Interagency Working Group on the Federal R&D Program for Environmental Control Technology for Energy Systems 1974) and King-Muir (U.S. Interagency Working Group on Health and Environmental Effects of Energy Use 1974) studies, which were successful in coordinating the special appropriations for energy-related research in FY 1975, the first year of that special five-year appropriation. These working groups were disbanded after their initial studies, and the research plans in subsequent years have been developed by individual agencies and coordinated through memoranda of understanding and interagency agreements.

perform or sponsor all the research needed to support its responsibilities, in which hundreds of billions of dollars are at stake. Indeed, we doubt that it would be wise public policy to spend the enormous sums required through a single agency, however central its role. Our doubts arise from a recognition of the legitimate substantive interests of other agencies, of the great range of scientific disciplines involved in this research, and of the difficulties a regulatory agency inevitably faces in maintaining capabilities in basic scientific research. If, however, protecting the environment, for which EPA has the prime responsibility among federal agencies, is accorded a status commensurate with the impacts of environmental problems on national domestic affairs, it appears to us necessary to marshal for environmental protection more of the national research and development effort than can or should be handled by EPA alone.

We have concluded that because the potential partners in the needed cooperative effort are located at several levels of administration within the federal bureaucracy and because the budgetary process is the most effective tool for implementing a coordinated research plan, the responsibility for overview and for coordination should lie within the Executive Office of the President. At this level, there are three organizations that might perform such functions: the Council on Environmental Quality, the new Office of Science and Technology Policy (OSTP), and the Office of Management and Budget.

OMB has an interest in coordinating research programs to avoid unnecessary duplication of effort, but does not have the purpose or expertise to coordinate the program to achieve either scientific or environmental objectives. OMB is also probably too deeply involved in interagency politics to take an independent view of environmental research and development. CEQ has access to the scientific interest and expertise, but has had neither sufficient resources nor political influence to effect cooperation from the wide range of agencies necessarily involved. The new OSTP may not be allocated sufficient resources to coordinate the federal environmental research program, but it will have access to the widest range of scientific interest and expertise and, potentially, the political influence to carry out such an effort. While OSTP is too new to have established a record of performance, the National Science and Technology Policy, Organization, and Priorities Act of 1976 (42 USC 6601, PL 94-282) gives OSTP the statutory responsibility of consulting with OMB on problems of national significance in which scientific and technical considerations are of major importance. Presumably, OSTP could use this authority to review the scientific programs of agencies and provide advice and assistance to OMB in preparing the President's budget so that it might better reflect scientific and technological policy.[4] Furthermore, a function of OSTP is to "assist the President in providing leadership and coordination of the research and development programs of the Federal Government" (42 USC 6613, PL 94-282).

Bearing these factors in mind, we recommend that the Director of OSTP establish a permanent working Committee on Environmental Research and Development. This committee should be charged with defining a national strategy for environmental research and development; assessing the roles of participating federal agencies, existing interagency coordinating committees, and nonfederal institutions; designating leadership responsibilities in specific areas among federal agencies; and coordinating the federal environmental research program. Staff and financial resources for the development of the national research strategy should be obtained from each federal agency having environmental interests. OSTP should coordinate the implementation of this strategy by participating agencies through discharge of its responsibility to consult with OMB on the scientific programs of federal agencies.

DEVELOPING A NATIONAL STRATEGY FOR ENVIRONMENTAL R&D

Developing a national strategy for environmental research and development requires (a) determination of the research needed to accomplish established and potential national environmental goals, (b) evaluation of the factors that determine the scientific strengths and limitations of potential participants, and (c) development of a strategy for acquiring the needed research based on a comparison of the needs for research and the exploitable strengths of all potential participants, including EPA. Once a strategy has been determined, EPA and other participants should establish appropriate research programs to implement it.

To determine the national research program needed to accomplish national environmental goals, the objectives of environmental protection must be understood, the state of knowledge in the relevant areas of science and technology assessed, and judgments made on what research

[4]Coordinating committees under the auspices of the Federal Council for Science and Technology (FCST) have generally not been very successful (J. Granger, Federal Council for Science and Technology, personal communication, September 29, 1975, recorded in the minutes of the Third Meeting of the Environmental Research Assessment Committee. We expect, however, that those under its successor, the Federal Coordinating Council for Science, Engineering, and Technology of the OSTP, will be more effective, particularly since FCST did not have a similar statutory relationship with OMB.

is likely to be both productive and influential. The four panels established by our Committee were charged with making such judgments in their respective areas of competence. Their problem was complicated by the fact that our national environmental goals are not always clearly defined and consistently formulated. Beyond the specific needs perceived and reported by these panels, research and development to support environmental decision making consists of a variety of scientific and technical activities that are detailed in Chapter 2.

The national research strategy designed to acquire information needed for environmental decision making must address both highly specific objectives, such as the development of a certain technology, and less well-defined goals, such as the acquisition of fundamental knowledge in relevant disciplines. The overall strategy and the resultant aggregated research plan must strike an appropriate balance between fundamental and applied research, between short-term and long-term programs, between the development of methodologies and their application, and between theoretical and experimental studies. The plans of specific participants, however, need not necessarily reflect this same balance. In addition, if the skilled people needed to accomplish the goals defined by the strategy are not available, then part of the strategy must be to develop those resources through training programs, incentives, or some other device.

Two objectives of coordinating the federal environmental research program should be to increase the applicability of federally sponsored research to decision making by EPA and to improve the effectiveness of this research by tapping the best available federal resources in each instance. A by-product of coordination may be to save public money by eliminating some unnecessary duplication of effort. (It should be recognized that duplication is not always unnecessary and may even sometimes be highly desirable to obtain independent verification of results.) Specification of policies and leadership roles would be especially helpful in the areas of environmental health, particularly epidemiology,[5] development of measurement technology and design of monitoring systems, and ecology (see Chapter 2).

[5]Development of a federal research strategy in this area was begun in 1972 by the Ad Hoc Committee on Environmental Health of the President's Office of Science and Technology (OST) but was discontinued when OST was abolished in 1973.

2 Scientific and Technical Activities in Environmental Research

The term "environmental research and development" as used here includes a wider range of activities than might generally be attributed to "research and development" by the academic community. We have identified 12 separate scientific and technical activities which, taken together, constitute what we understand to be the range of interests of environmental research and development. The delimitation of the 12 activities, since each overlaps with the next and all are interconnected, is arbitrary and presented simply for convenience of discussion. Further categorization or grouping according to function is, however, likely to entail misleading simplification. The range of primary purposes for performing each of these activities is indicated in Figure 2.1.

The 12 research and development activities represent a continuum, progressing in a general way from those most closely related to current decision making, through those intended to anticipate future problems, to those whose principal objective is to advance scientific understanding. They are:

1. Assessment and integration of available information
2. Determination of economic and social costs, benefits, and risks
3. Development and standardization of measurement technology
4. Development of control and process technology
5. Design of monitoring systems
6. Characterization of pollutants and discharges
7. Assessment of trends in environmental quality

8. Determination of the fates of pollutants

9. Determination of the effects of pollutants and other man-caused environmental disturbances

10. Investigation of fundamental physical, chemical, and biological processes

11. Analysis and modeling of ecosystems

12. Investigation of alternative economic, social, and legal strategies for environmental management.

This chapter describes each of the 12 activities in the context of the system depicted in Figure 1.1; assesses the purposes for EPA involvement in their conduct; recommends a role for the Agency's scientists and engineers; and addresses, when appropriate, organizational and institutional considerations.

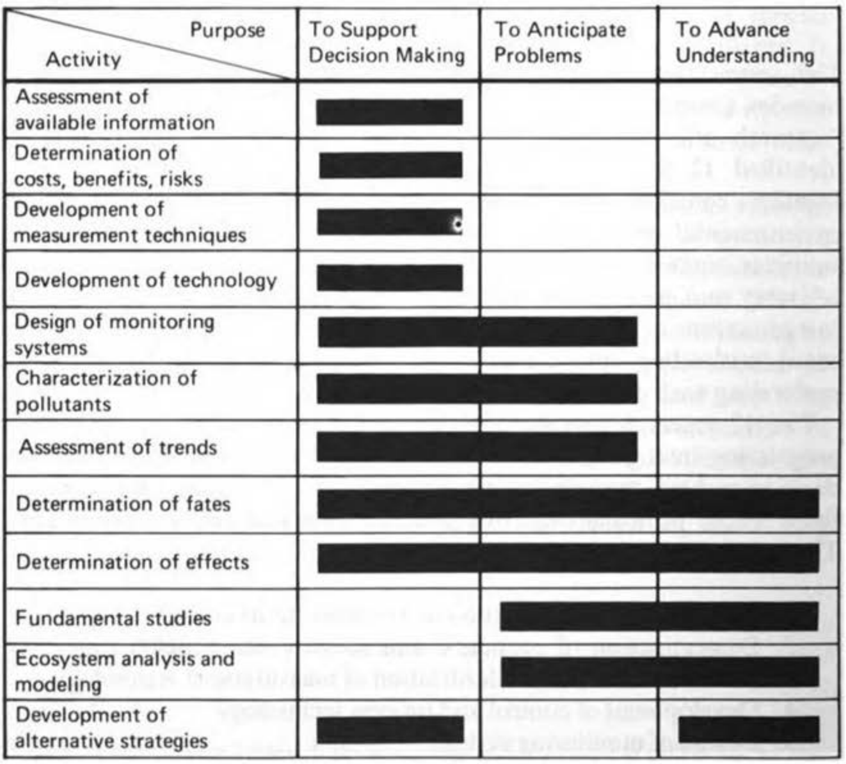


FIGURE 2.1 Primary purposes for conducting environmental research and development.

EPA's research and development activities, conducted by OR&D or by other offices in the Agency, encompass most, if not all, of the activities listed above. However, EPA's program is not organized in a manner that permits logical and systematic evaluation of its scientific foundations. Furthermore, not all of the Agency's research and development is performed by OR&D. The work of OR&D is organized into five programs and fourteen subprograms as follows (U.S. EPA 1976b):

Health and Ecological Effects Program
Health Effects
Ecological Processes and Effects
Transport and Fate of Pollutants

Industrial Processes Program
Minerals, Processing, and Manufacturing
Renewable Resources

Public Sector Activities Program
Waste Management
Water Supply
Environmental Management

Monitoring and Technical Support Program
Monitoring Techniques and Equipment Development
Quality Assurance
Technical Support

Energy/Environment Program
Health and Ecological Effects
Extraction and Processing Technology
Conservation-Utilization Technology Assessments

This chapter refers to projects within OR&D programs that are appropriate examples of the kinds of activities described.

ASSESSMENT AND INTEGRATION OF AVAILABLE INFORMATION

If EPA's regulations are to be based on scientific and technological understanding as well as on social and political considerations, the assessment and integration of available information has an essential part to play in the Agency's decision making (see NRC 1977a for a discussion of the use of technical information in EPA). The function of such analyses is to assess the usefulness of existing scientific and technical knowledge relevant to specific environmental problems and to organize the knowledge in a form usable by decision makers.

Assessment of available data begins with the collection of physical, chemical, statistical, biological, economic, social, and technological data from existing sources. The data are then analyzed for accuracy and relevance, and synthesized and interpreted in terms suggested by the people who will use the results. To be useful to decision makers for the task of assessing available options, the analyses must organize the information in a form that clearly defines relationships among different aspects of a problem and places the data on each aspect—for example, health hazard—in the context of the overall framework of human interaction with the environment (see Figure 1.1). Limits of confidence in the data and uncertainties in the analyses must be stated explicitly (NRC 1975b). The results of such analyses may also be used to identify critical research needs, and thus would also be useful for planning research activities in EPA.

Analysis of scientific and technical information for use in decision making is most adeptly conducted by natural and social scientists and engineers knowledgeable in the pertinent disciplines. In EPA three methods of assessing the accuracy and relevance of technical data are currently employed: participation in ad hoc Working Groups of the Agency Steering Committee by one or more staff members of OR&D, informal consultation with research managers in OR&D, and preparation in OR&D of background documents called Scientific and Technical Assessment Reports (STARs). A disadvantage of the first method is that the scientist selected to serve on an ad hoc Working Group may regard that service as an inconvenient digression from laboratory work rather than as a central function of support to the Agency. Furthermore, an important drawback of relying on a single individual, whether as a representative of OR&D on a Working Group or as a consultant, is that the scientist or administrator consulted cannot be expected to have sufficient breadth of technical knowledge and experience to evaluate information from such a diversity of disciplines.

The preparation of STARs, on the other hand, is an organized, systematic attempt to collect and analyze scientific and technical data on identified or potential pollutants. STARs have been and are being prepared for pollutants for which EPA is both under and not under pressure to regulate. While guidelines for the preparation of STARs call for examination of the complete range of scientific, technical, and social information, early documents did not evaluate the economic and social consequences of possible alternative regulatory decisions in the context of a comprehensive framework, such as that depicted in Figure 1.1. More recently, there has been a laudable trend to making STARs more comprehensive in practice and to addressing more immediate needs to support decision making. However, whether because of deficiencies in applied resources or of other reasons, most STARs to date have fallen short of being truly integrated analyses.

Because the primary purpose of EPA's research program is to support decision making, we conclude that one of the central functions of the scientific and technical staff of EPA should be to provide decision makers with integrated analyses of available scientific, technical, and economic data on request. This function, if it is to be effectively performed and its results given maximum credibility, must be given formal status and organization within the scientific arm of the Agency.

Accordingly, we recommend that an office be organized within the present Office of Research and Development to perform this function. For convenience of future reference in this report, we refer to this function as being performed by an Office of Integrated Technical Analysis. Since the questions posed for technical analysis are likely to require multidisciplinary responses, such a group must be broadly representative of the disciplines involved in environmental science. (See Chapter 3 for detailed discussion of the consequences of this recommendation for OR&D.)

Examples of the type of analysis that should be performed in or under contract to the new office are those required to implement the new Toxic Substances Control Act (15 USC 2601 1976, PL 94-469). Under this act, manufacturers are required to submit data on the production, distribution, and toxicity of new chemicals they wish to introduce into the market, and EPA must decide on short notice whether and how each chemical should be controlled. The contribution of the Office of Integrated Technical Analysis in this instance should include evaluation of the toxicity data and assessment, based on information about potential production and marketing and about the likely fates of substances in the environment, of the probability of exposure, the benefits of new substances, the costs of control options, and the hazards associated with the use of new substances with alternatives. Such analyses will have to be performed repeatedly for different substances under this act, and similar assessments will constantly be called for by the other acts that EPA administers.

As described in detail in Chapter 3, concentrating this effort in OR&D rather than distributing it through the several Program Offices avoids duplication of expertise, helps develop expertise in integrated assessment, encourages a holistic view, and facilitates consideration of interactions among different but applicable legislative mandates. Most importantly, technical analyses can be more independent of the regulatory decision-making process and hence more credible to affected parties outside the Agency. The proposed Office of Integrated Technical Analysis in OR&D can also provide independent judgments to the Office of the General Counsel and to the Regional Offices.

Under the five-year plan of OR&D, the subprogram for Energy Conservation, Utilization and Technology Assessments of the special Energy/Environment Program is to perform analyses of the environmental, economic, social, and institutional impacts of selected energy technologies under alternative schemes of environmental management (U.S. EPA 1976b). The analytic capability should be expanded beyond this focus on energy technology to deal with the full variety of environmental problems on which EPA must make decisions.

DETERMINATION OF ECONOMIC AND SOCIAL COSTS, BENEFITS, AND RISKS

Estimation of the costs, benefits, and risks associated with potential actions is of direct value to regulatory decision making, to devising alternative environmental protection strategies, and to applying new technology. The scientific and technical work involved includes study of the costs of alternative technologies and control strategies; of the distribution of costs geographically, over time, and among demographic groups; and of the benefits of goods and services whose production might be subject to control for environmental purposes. Research on these issues provides information directly relevant to most of the relationships illustrated in Figure 1.1, and the resulting data are vital to the discharge of EPA's regulatory functions, except where the Agency is expressly prohibited from considering costs in its decision making. While EPA should take advantage of economic and social data available elsewhere, to perform its regulatory functions the Agency must assume responsibility for conducting some of the relevant socioeconomic research and analysis.

The commitment to socioeconomic research within EPA has in our judgment been neither consistent nor strong. Rather than pursuing a carefully devised program, EPA has tended to concentrate its resources on a few glamorous enterprises. For example, for some time considerable effort was devoted to the development of a macroeconomic model based on an input/output table for the national economy, the Strategic Environmental Assessment System (SEAS) (U.S. EPA 1975a). Recently, most of the capability for continuing that development was all but dismantled and the program transferred to the Bureau of Labor Statistics of the Department of Labor, though the SEAS model is still being used in EPA and in several other agencies. The Office of Planning and Management also performs socioeconomic analyses, and some useful work continues to be done by individuals in EPA, but apparently without the benefit of an integrated program.

OR&D now devotes comparatively little effort to analyses of costs of alternative process and control technologies, and the studies that have been done are inconsistent in their approaches (see Recommendations 6, 7, and 8 of NRC 1977f). At a different level, analysis of the costs of regional pollution control programs does not seem to us to be sufficiently emphasized. Methodologies to assess monetary and nonmonetary costs and benefits at both micro and macro levels must be developed and applied, since current methods for estimating them are in most cases unsatisfactory.

The first five-year plan of OR&D does indicate that a program in socioeconomic research is to be established within OR&D's Office of Health and Ecological Effects but does not indicate how that program will relate to analyses now being conducted elsewhere in the Agency, for instance in the Office of Energy, Minerals, and Industry of OR&D, in the Office of Planning and Management, and in the Program Offices. The development of methods for measuring benefits is to be a major focus of OR&D socioeconomic research for FY 1977 and beyond (U.S. EPA 1976b).

We conclude that EPA should undertake a coordinated program of economic and social research to apply methodologies for determining the costs, benefits, and risks associated with environmental decisions. To make Agency research in the development of alternative technologies more useful, the program should also establish protocols for determining the costs of alternative technologies (see, for example, Recommendations 6 and 13 of NRC 1977f). The results of this program should be useful to the Office of Integrated Technical Analysis, the establishment of which was recommended earlier in this chapter.

Because the recommended capability for socioeconomic research would, in our opinion, benefit the entire Agency in the same ways as other research, we recommend that this program be established entirely within OR&D (see Chapter 3). Such a concentration of economic skill would reduce the potential for duplication of expertise and effort, and would help to ensure that political considerations of the decision-making process are not masked in economic analyses. Performing economic studies in OR&D rather than in the Program Offices would also be conducive to more comprehensive, multimedia analysis.

DEVELOPMENT AND STANDARDIZATION OF MEASUREMENT TECHNOLOGY

To develop and standardize measurement technology, physical, chemical, and biological principles must be applied to methods, equipment, protocols, and equivalence standards for detecting and quantifying pollutants and other constituents in discharge streams and in the ambient environment. This capability is needed for characterizing discharges, determining the fates and effects of pollutants, enforcing standards and permits, and assessing trends in environmental quality. Clearly, measurement directly supports the regulatory process since only what can be measured, both in the laboratory and in the field, can be regulated.

EPA's primary roles in developing and standardizing measurement technology are now, and should continue to be, to devise or improve quantitative methods of detection suitable for field use, to develop standards of equivalence among alternative techniques, and to establish protocols for ensuring the quality of measurements for substances that are regulated or likely to be of environmental concern.

Two subprograms of the Office of Monitoring and Technical Support, one on Measurement Technology and Equipment Standardization and the other on Quality Assurance, account for most of the research and development on measurement technology performed in OR&D. The former subprogram includes development of methods for identifying contaminants in drinking water and demonstrating the equivalence of water monitoring methods. (Detection of foreign substances in drinking water is also part of the Water Supply subprogram of the Public Sector Activities program in OR&D.) The Quality Assurance subprogram has projects aimed at standardizing bioassay procedures for the National Pollutant Discharge Elimination System and calibration procedures for water and waste discharge measurements, and at developing guidelines for water and waste sampling and sample preservation. Elsewhere in OR&D work is being done on measurement techniques for pesticides and insect pathogens in the program on Health and Ecological Effects, and for aerosols associated with the combustion of fossil fuels in the Health and Ecological Effects/Energy program (U.S. EPA 1976b).

Other federal agencies, private institutions, professional organizations, and firms are also engaged in this kind of work, notably the National Bureau of Standards (NBS), the Public Health Service (PHS), the Energy Research and Development Administration (ERDA), the National

Aeronautics and Space Administration (NASA), the American Society for Testing and Materials, the American Public Health Association, the Water Pollution Control Federation, and the instrumentation industry. EPA should continue to supplement its intramural expertise in measurement technology with extramural competence through interagency agreements and contracts and through consultations with professional societies. EPA's legislated responsibilities in environmental protection, however, require that its own program develop and adopt standards for equivalent measurement and protocols for assuring the quality of measurements.

Because several federal agencies are involved in developing measurement techniques applicable to environmental monitoring, and because most routine field measurement is conducted by state and local governments or private parties, we conclude that EPA's scientific programs in measurement technology and monitoring would benefit from coordination of efforts and cooperative exchanges of views with these other parties (see also NRC 1977d). Accordingly, we recommend that a Coordinating Committee for Environmental Monitoring be established by the OSTP. This committee should be composed of representatives from all federal agencies concerned with environmental problems, from interested professional organizations, and from a representative group of state and local agencies and private firms engaged in measuring environmental parameters. The committee should be a forum where information on monitoring and measurement problems can be exchanged, and should be responsible for coordinating federal research and development on these topics. The terms of reference for this committee should be determined by the OSTP as part of its development of a national environmental research strategy, as recommended in Chapter 1.

DEVELOPMENT OF CONTROL AND PROCESS TECHNOLOGY

Development of control and process technology involves scientific and engineering work to invent means of reducing discharges into the environment; assessment of comparative costs; and, under current legislative directives, demonstration of economic and technological practicality. The state of technology determines what can be done to modify the discharge of residuals and how much the modification will cost. As a practical matter, decision makers need to know the range of practical technological options for modifying processes or discharges, whether the system for managing environmental protection is based on regulations and standards or on economic incentives.

Many of EPA's legislative mandates deal directly with technological capabilities for controlling emissions. The Clean Air Act, the Federal Water Pollution Control Act, the Safe Drinking Water Act, and the Solid Waste Disposal Act all authorize or direct EPA to conduct research and development on methods to control specific environmental problems.

Approximately 43 percent of the OR&D budget is categorized as being for development (NSF 1976). Within OR&D, research, development, and demonstration of control and process technology is conducted in the Industrial Processes, Public Sector Activities, and Energy/Environment programs. The Industrial Processes program includes work on selected closed- and open-cycle industrial water systems and on control of accidental spills of hazardous materials, while the Public Sector Activities program is mainly concerned with technologies for municipal wastewater treatment and analysis and control of drinking water quality. The Energy/Environment Program handles a miscellany of control projects, principally on specific problems arising from the combustion of coal and synthetic fuels.

As stated in Chapter 1, current environmental legislation generally does not provide incentives for development and adoption of new technology by the private sector; the government must therefore frequently develop technology itself. A prime example of federal development of control technology is the extensive program for controlling emissions of sulfur oxides from power plants, an interagency program in which EPA participates with ERDA, DOI, and the Tennessee Valley Authority (TVA). Other examples are provided by development activities linked to the requirement of the Federal Water Pollution Control Act that EPA designate "best practicable" and "best available" technologies for the elimination of water pollution in 1977 and 1983, respectively.

The incentive structure aside, an Agency program to develop technology, as any centralized development program, has several potential disadvantages. Because funds are usually limited, an Agency program may select one of several technical options too early in the development program, foreclosing future developments that might ultimately have proved attractive. (A healthy diversity of technological approaches is more likely to result from decisions made under competitive pressures as ideally exist in private industry.) In addition, a sizable intramural development program is likely to take some time, during which an entrenched, tenured scientific and technical cadre may develop. As a result, governmental development programs may be difficult to discontinue, even after the technology has been sufficiently demonstrated, and when a project is terminated, Agency researchers may require extensive reorientation before they are able to work productively on another.

Therefore, despite the pressures on EPA to develop and demonstrate technologies to control or abate pollution, we conclude that the Agency should undertake extensive research, development, and demonstration for control and process technology only when there is no other recourse. To avoid the disadvantages of intramural development programs outlined above, however, we suggest that the Agency contract as much new work and expansions of current programs as possible with nonfederal institutions (see Chapter 3).

An example of a need that EPA should continue to fill is the development of advanced municipal wastewater treatment processes, since the primary beneficiaries—local or regional governments—lack the infrastructure to conduct research and development on the scale required. Another example of a likely need for federal development is for technology to remove potentially harmful substances from drinking water; although there are about 40,000 public drinking water supply systems in the United States, few purveyors of water are able to develop the needed technology. (The industry that supplies water pipes, treatment equipment, and chemicals may, however, have the capability.)

Criteria are also needed to judge when Agency support of development should be terminated; while the tendency to prolong a development program unnecessarily needs to be guarded against, under existing legislation potential users will rightly feel development has been terminated prematurely unless they are persuaded that no effort has been spared to reduce costs. The economics of new developments are more difficult to demonstrate than technical feasibility. Criteria for terminating development projects should reflect an explicit federal policy on the relationship of private industry to federal environmental programs, developed and stated in conjunction with the development by OSTP of a national environmental research and development strategy (see Chapter 1).

DESIGN OF MONITORING SYSTEMS

Design of monitoring systems consists of the development of cost-effective systems for collecting, retrieving, and integrating the results of systematic measurements of environmental parameters. The relevant parameters and methods for measuring them must be selected, sampling sites located and frequency of sample collection determined, quality assurance programs developed, and a system designed for organizing, storing, transferring, and analyzing the data.

Monitoring of the nature, time pattern, and total quantity of emissions from production processes is clearly needed to determine compliance with regulations. Effective monitoring is also needed to identify the nature of environmental problems and the best means of solving them by determining how pollutants move through the environment, are modified, and alter the quality of the ambient environment, with resultant effects on human health and welfare. Thus, while the rational design of monitoring systems supports the regulatory process, data from monitoring may also be used for anticipating future environmental problems.

Although EPA itself conducts only a small part of the national monitoring program, it funds much of the monitoring conducted by state and local governments and oversees the monitoring of emissions required of permit holders. The Agency also maintains extensive files of air and water quality data. This oversight role makes it appropriate for EPA to assume national responsibility for developing methods for designing complete monitoring systems, while itself doing most of the work on quality assurance and data management.

At present, EPA's programs for improving monitoring are widely scattered throughout the Agency (NRC 1977d). The prime concern of OR&D and the Regional Offices appears to be quality assurance, while the Program Offices are responsible for the data management systems. The Monitoring and Technical Support program is responsible for most of the monitoring research and development in OR&D, although monitoring studies are also conducted in the Health and Ecological Effects and Energy/Environment programs (U.S. EPA 1976b). Work on both quality assurance and data management needs to be expanded and improved, and would benefit from closer coordination within the Agency and with researchers and users outside EPA. In particular, OR&D should expand efforts to develop biological monitoring systems.

The arguments advanced earlier for increased coordination of federal, local, and private work on development and standardization of measurement technology apply equally to the design of monitoring systems. Coordinated work on design of monitoring systems is a critical first step in improving monitoring. Accordingly, the Coordinating Committee for Environmental Monitoring previously recommended (see section on Development and Standardization of Measurement Technology) should be concerned with the integrated design of complete monitoring systems, from measurement of parameters to storage and retrieval of data. EPA, as the logical lead agency, could take the initiative in advancing such cooperation through fostering multilateral arrangements among federal agencies, where possible using pass-through funds to accomplish this objective.

CHARACTERIZATION OF POLLUTANTS AND DISCHARGES

To characterize pollutants and discharges, the significant constituents of discharges to the air, water, and land must be identified; the factors that influence the generation of residuals from production processes assessed; and the physical, chemical, and biological properties of substances introduced into the environment determined. Three types of scientific and technical activity are involved in this task. One is research on the characteristics of substances and on methods of characterization, so that substances can be identified experimentally in emissions and in the environment, and screened for their potential as pollutants by comparison with substances known or suspected to be harmful. The second is the development of statistically valid inventories of point and nonpoint sources to assess the range of substances, both regulated and unregulated, that are being discharged from these sources. The third is the quantification of the relationships between discharges and such influences on residuals generation as process technologies, demand, recovery and recycling opportunities, and prices.

EPA should take the lead in performing the activities described above. The Agency must systematically gather data needed for identifying problems and providing early warning, whether the data are analyzed by EPA or by others. OR&D is currently conducting a number of projects, most of them in the Energy/Environment and the Industrial Processes programs, to develop data on the nature and quantity of discharges to air and water, particularly point discharges from selected industries and municipal wastewater treatment facilities and the major pollutants from typical nonpoint sources. EPA's work on generation factors is concentrated on energy technologies. Specific substances are being characterized for toxicity in the Health and Ecological Effects program.

An inventory program would be especially useful for providing baseline data for anticipating and evaluating future problems. Therefore, we recommend that EPA augment its program to characterize the waste streams of major polluting activities, both point and nonpoint sources, with detailed analysis of samples. The program should concentrate on the most serious industrial, agricultural, municipal, and urban sources of pollution and should be statistically designed so that the results are representative of the sources studied by class of discharger, geographical location, and season of the year (see also Recommendation 9 of NRC 1977f). The responsibility of polluters under current law to characterize their effluents should be rigorously enforced. The recommended program could be justified under the present legislative mandates of EPA, but because it is long range and will require continual up-dating, we suggest that it be insulated from more immediate priorities by funding it under provisions of the new research mandate recommended in Chapter 1.

Expertise in analytical chemistry and industrial processes sufficient for accomplishing this inventory program is available to EPA either from within its own laboratories or from other federal, industrial, and academic laboratories. The program would probably be strengthened by cooperation with industrial research and trade associations, with professional societies, and with other federal agencies such as the Departments of Agriculture, Transportation, and Commerce.

ASSESSMENT OF TRENDS IN ENVIRONMENTAL QUALITY

If society is to appreciate what effect it is having on environmental quality, environmental conditions must be continuously monitored, measured, and recorded, and the record must be translated into terms comprehensible to policy makers and the public.

The National Environmental Policy Act of 1969 (NEPA) assigns responsibility for assessing national environmental trends to CEQ. While other agencies, such as the U.S. Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA), monitor environmental parameters, EPA is the line agency whose mission is environmental protection. Therefore EPA has, and must discharge, a responsibility for trend analysis to determine if its programs are effective, and to provide for early detection of future problems.

The results of assessments of environmental trends provide valuable information for legislators and the public to enable them to assess the present benefits and to anticipate future benefits to be obtained from public expenditure on environmental programs.

EPA develops regulations and adopts policies on the basis of predictions of the future effects of such actions. There are always uncertainties, both in the response of the environment to changes in patterns of emissions and in the responses of society to new regulations. Consequently the careful analysis of environmental data (physical, chemical, biological, and health effects) is essential to determine how well the policies are working and to provide the basis for adjustment of policies if there are deficiencies (NRC 1977b).

Raw data gathered through monitoring without analysis often does not give a concise evaluation of developing trends. For example, meteorological or hydrological variations from year to year often produce variations in air or water quality that might obscure changes resulting from reduction of emissions. Research is needed on the techniques of analyzing time series with adjustments for extraneous factors.

Changes in environmental quality are often slow, with subtle redistributions in time and space. Thus there are trends in the patterns of air pollution in time and space as well as trends in single measurements. It is often simplistic to try to answer a question such as "Is the air pollution better or worse?" without being more specific. For example, in the Los Angeles regional air basin, oxidant air quality has been improved over the past decade, while nitrogen dioxide air quality has been deteriorating. And the percentage change in both pollutants has been spatially nonuniform in the airshed (Trijonis et al. 1976).

In some cases the measurement of trends can provide valuable information on the rate of recovery of ecosystems when damaging emissions have been reduced or terminated. Also if the trends do not develop as anticipated, they may be useful in indicating that emissions have not in fact been reduced as much as expected (e.g., toxic chemicals in wastewater discharges).

Finally, analysis of trends is one of the best tools we have for early detection of new problems, particularly those due to trace contaminants. A great deal may be learned about the seriousness of a particular pollutant and the time period in which action is required by a study of the rate at which environmental parameters have been changing in the recent past. There is no use in waiting for damaging levels of pollutant *X* to be reached when several years' data indicate that environmental measures of *X* are steadily rising as a result of some societal activity. The early detection of adverse trends in environmental parameters may also help in establishing research priorities. For example, we now know that the global atmospheric concentration of carbon dioxide is slowly increasing; i.e., there is an unmistakable upward trend in careful measurements of CO_2. We have yet to determine the long-range effects of this change, but we are certainly on notice that the change is steadily occurring.

In summary, assessments of trends (and research on how to do these assessments) are a vital connection between environmental quality and public policy problems already identified and are an invaluable process for early detection of future problems, so that research and policy changes can be undertaken in a timely manner.

Unfortunately, there is as yet no nonarbitrary way to translate the independent, multidimensional measurements needed to assess trends into simple unidimensional indicators of environmental quality. The reduction of an enormous number of dimensions (represented by measurements of different pollutants and other quality indicators at different locations) to a single quality indicator or to a small set of indicators raises the problem of the index number in its most intractable form. For example, there are no natural weights for combining data on

SO_2 at a given set of points with data on oxidants, oxides of nitrogen, or suspended particulates at a different set of points. The many elaborate and superficially impressive weighting schemes that have been devised are all, at root, arbitrary. Changing the weights to another, equally impressive scheme could completely change our perception of the pace and even the direction of the change in environmental quality over time (Inhaber 1976).

Despite the inherent limitations of indices, it is crucial that OR&D undertake research on acceptable index weighting schemes. The principal requirement is a firm grounding in science, but such systems must also be understandable and their rationale clear. Acceptability might best be tested by calculating the implications of different schemes for trends in environmental quality over periods in the recent past and seeing how the results compare with perceptions of change. At the same time, surrogate and inferential measures should be researched, developed, and applied to trend analysis.

DETERMINATION OF THE FATES OF POLLUTANTS

Substances discharged into the environment from point and nonpoint sources undergo physical, chemical, and biological processes that result in their transport, accumulation, and transformation. The objective of research on the fates of pollutants is to identify which processes, at what rates, ultimately determine the ambient concentrations of pollutants in the environment. The scientific and technical tasks needed are a combination of field, laboratory, and analytical studies to determine the dominant processes, measure their rates, model the processes, analyze mass flows, and model the aggregated behavior of a substance or classes of substances in the environment.

The results of research on fates can be used both to support decision making and to anticipate problems. For example, one outcome of fates research should be models that supply the decision maker with reasonably reliable predictions of the levels of exposure likely to result from specific discharges. Such a predictive capability would be useful in regulating the manufacture, distribution, and use of toxic substances. Proposed schemes of environmental management based on effluent charges and designed to maintain specified levels of ambient environmental quality also would depend heavily on predictive modeling of the effects on air or water quality of discharges distributed throughout an airshed or river basin. Finally, understanding the fates of substances may provide guidance on how best to monitor or where best to intervene with controls.

We conclude that EPA should conduct research on fates of pollutants both to support decision making and to anticipate future needs, studying specific pollutants or classes of compounds and developing models of their behavior. The Report of the Panel on Fates of Pollutants (NRC 1977e) contains specific suggestions on how EPA's research in this area might be planned and conducted. That report recommends the study of local or regional biogeochemical cycles (cf. Garrels et al. 1975) as systems for integrating available information, and as a tool for identifying needs for research. The report also concludes that EPA's program would be better balanced if less attention were devoted to physical transport and atmospheric chemistry processes and more to biological processes that determine fates.

In OR&D, research on the fates of pollutants is being conducted in a number of programs. For example, air and water quality models based on the movement and transformation of pollutants are being developed in the Health and Ecological Effects program, while the impacts of certain activities on groundwater quality are being studied in the Public Sector Activities program. Study of the transport and transformation of energy-related pollutants in the air, water, and groundwater is part of the Energy/Environment program (U.S. EPA 1976b).

About a dozen federal agencies are engaged in research on fates, including ERDA, NSF, DOI, and USDA. EPA must take advantage of this research base. The Panel on Fates of Pollutants concluded that federal research on fates of substances in the environment was fractured and dispersed, and that no mechanism exists to oversee and coordinate the federal program. The task of evaluating the program and identifying responsibilities should be included in the development of a national strategy for environmental research that we recommend be conducted by OSTP (see Chapter 1).

DETERMINATION OF THE EFFECTS OF POLLUTANTS AND OTHER MAN-CAUSED ENVIRONMENTAL DISTURBANCES

Study of the effects of pollutants and other man-caused environmental disturbances on living and nonliving receptors includes assessing the hazards of exposure to agents; gathering epidemiological evidence of the results of exposure; investigating biochemical, physiological, and ecological processes; and developing protocols for and conducting a wide range of screening tests, including bioassays.

Information on effects is the impetus for action to protect the environment. For EPA, information on whether, how, and how much a certain level of exposure affects various receptors is essential for setting standards, and is important for predicting future hazards.

Traditionally, environmental policy has particularly emphasized protection of human health. To determine "safe" or "acceptable" levels, knowledge of the relationships between exposure doses and the responses of the population of receptors is needed. In all but a few exceptional cases, it is not yet possible to predict quantitatively the health risks associated with pollution; it is especially difficult to predict the consequences of long-term exposure to low-level pollution. If gross effects are only poorly predictable, more subtle changes, such as behavioral abnormalities in humans or animals, or altered structural or functional features of ecosystems, can barely be sketched, let alone precisely projected.

Research on health effects of environmental exposures is currently being conducted in EPA and in several other agencies, including a number of the National Institutes of Health (NIH), especially the National Institute for Environmental Health Sciences (NIEHS) and the National Cancer Institute (NCI); the National Institute for Occupational Safety and Health (NIOSH); and the National Center for Toxicological Research (NCTR). Federal research programs in environmental health in FY 1978 are reported to be budgeted at a total of $664 million (U.S. OMB 1977, Special Analysis K); the request of OR&D in this category is for $32.1 million (U.S. EPA 1977).

The NIH have substantial programs and a long-standing record of excellence in research related to environmental health, encompassing both basic biomedical investigations and studies of relationships between specific diseases and possible environmental causes. In principle, EPA should neither need nor be expected to duplicate existing environmental health research capabilities; and in practice, it has often proven difficult for EPA to compete with the established, nonregulatory agencies in obtaining health research scientists of outstanding caliber.[1] While EPA does need its own in-house expertise in environmental health (NRC 1977b) we believe that the Agency's own research should focus on immediate regulatory needs, such as the conduct of toxicological tests to screen potential environmental pollutants in order to identify those needing further study.

Most of the fundamental research on environmental health required to

[1]Wilson K. Talley, OR&D, EPA, personal communication, May 2, 1975, recorded in the minutes of the First Meeting of the ERAC, and John Knelson, Health Effects Research Laboratory, Research Triangle Park, North Carolina, OR&D, EPA, personal communication, March 3, 1976, recorded in the minutes of the First Meeting of the Visiting Subcommittee of the ERAC.

meet EPA's needs exists in programs of other agencies. The challenge to EPA is to develop and maintain mechanisms to focus those existing capabilities on problems important to EPA, while using its own research staff to complement and draw upon work done elsewhere. For example, a role appropriate for EPA expertise in epidemiology would be to identify environmental agents that may help cause disease, and to participate in programs to measure and monitor exposures to suspect agents. At the same time, EPA should work closely with agencies such as NIEHS or NCI, and might well contribute funds, through interagency agreements or contracts, to support investigations of the occurrence and etiology of pollutant-related diseases. Some of EPA's programs in epidemiology are moving in this direction (NRC 1977b). A panel of the Agency's Science Advisory Board has examined in detail EPA's needs for epidemiological research, the capabilities that exist within EPA and in other agencies to carry out that research, and mechanisms to bring those capabilities to bear on problems important to EPA in a timely manner (U.S. EPA 1975c).

Research on effects of pollution on ecosystems is performed in relatively uncoordinated programs in EPA, NSF, ERDA, DOI, and USDA (CEQ 1974). A coordinating mechanism for planning and oversight is needed; one such mechanism has been suggested in Chapter 1. EPA has both a demonstrable need for information on ecological effects of environmental agents, and a number of excellent programs of ecological research. In light of EPA's responsibilities under NEPA, we believe that the Agency should play a large part in defining both short-term and long-term objectives of the federal ecological research effort. Because multi-year field studies are often required to detect gradual changes in biological communities and ecosystems, a planning mechanism which will assure long-term continuity of research programs is especially important.

No system of environmental protection is perfect, and occasionally accidents or other circumstances may produce episodes of severe pollution, resulting in heavy damage to humans or to the environment. Examples include many weather-induced air pollution incidents such as the infamous episode at Donora, Pennsylvania; the pollution by Kepone of the area around Hopewell, Virginia; and accidental spills of toxic substances. Such episodes, unfortunate though they are, do provide opportunities for obtaining useful data for research purposes that might not be obtainable from planned experiments. What is learned in one case may help avert or alleviate damage in a future episode. Participation by EPA, along with appropriate local, state, and other federal health and environmental agencies, seems important in order to detect, measure, and describe such episodes and their consequences. Furthermore, data must be obtained quickly, since most episodes tend to be short-lived. We therefore strongly endorse the recommendation of the Panel on Effects of Ambient Environmental Quality that EPA establish mobile, rapid-response teams to gather data while episodes are occurring for use in appropriate follow-up studies (NRC 1977b). Such teams would appropriately be organized in OR&D in the Office of Health and Ecological Effects, but would need to draw on expertise from other elements of the Agency and from outside EPA. EPA has participated in such efforts effectively in the past; for example, the Office of Health and Ecological Effects conducted environmental measurements and sampled human blood in connection with the Kepone incident. The results of such efforts should be sufficiently valuable for the recommended function to be formally organized within EPA along lines similar to the Epidemic Intelligence Service of the Center for Disease Control.

INVESTIGATION OF FUNDAMENTAL PHYSICAL, CHEMICAL, AND BIOLOGICAL PROCESSES

Investigations of fundamental physical, chemical, and biological processes are intended to advance the general state of knowledge by elucidating underlying principles, rather than to describe the specific consequences of those principles in a particular case. Included in this category of research are studies of the transport and reactions of pollutants in air, water, and soils; investigations of the biochemical and physiological mechanisms involved in the effects of contaminants on plants, animals, and humans; studies of mechanisms of corrosion; and investigations of ecological processes that influence the response of a system to stress.

An example of the distinction drawn above may be found in research on chemical carcinogenesis. In studies aimed at discovering general principles, the mechanisms of action of known carcinogens are examined in order to describe the biochemical steps involved in the transformation of cells from a "normal" to a "cancerous" state. In other studies more closely connected with decision making, specific chemicals are tested to determine which are capable of triggering the steps in that transformation process, and substances identified as potential carcinogens are tested further in long-term animal studies from which dose-response data are inferred. Similarly, basic biochemical research can describe the organisms and metabolic pathways through which pesticides and other substances can be broken down or transformed. For policy making, however, studies are needed that measure reaction rates and identify by-products as they occur under different environmental conditions.

Research of the latter kind in each case (i.e., in support of decision making) has been discussed earlier in this chapter.

An example of studies dealing with the biological and physical responses of an ecosystem is research on acid rain. Acid rain harms not only man-made structures but also biophysical processes in natural systems; it influences the availability of nutrients to plants and may damage plant foliage. Such fundamental biological, physical, and chemical processes would be appropriate for EPA to research.

Despite the value of fundamental research for future decision making, in terms of relevance to immediate regulatory needs many other kinds of research, such as the performance of integrated technical analyses, the modeling of the transport and transformation of pollutants, and the measurement of effects of environmental exposures, deserve higher priority in EPA than fundamental investigations. There are nonetheless important advantages to EPA inherent in conducting some "basic" research within the Agency and through extramural researchers. In particular, the inclusion of some basic research in a program that is primarily devoted to more applied work keeps the program vital, tends to speed the process of applying the results of fundamental studies to current problems, and aids in recruitment and retention of high quality personnel. Such work should, however, be secondary to research more directly tied to regulatory programs, and should emphasize problems not adequately pursued in other agencies. In order to insulate fundamental research from the day-to-day demands for support for decision making, we recommend that it be separately organized, planned, and funded within OR&D (see Chapter 4).

Basic research in biological and environmental sciences, much of which may eventually find applications in environmental protection, is broadly supported by the federal government. NSF, NIH, ERDA, NOAA, DOI, and USDA (chiefly through State Agricultural Experiment Stations) are among the foremost agencies conducting such programs. In order to inventory that current work, as well as to identify gaps that EPA might need to fill, development of a national environmental strategy (as described in Chapter 1) appears an essential first step.

ANALYSIS AND MODELING OF ECOSYSTEMS

Research to develop and refine models of ecosystems is aimed at creating tools that can predict the behavior of ecosystems, including responses to environmental stresses. (NRC 1977b). Work on similar models that integrate the ecological and social components of systems promises to be valuable for management of both natural resource systems and the environment (NRC 1977c). Modeling research requires large investments of time and money in interdisciplinary programs, and much of the work now under way is concentrated on advancing the methodology. An adequate theoretical description of all of the structural and functional characteristics of an ecosystem has not yet been achieved; it is possible, however, to model parts of systems (for instance, nutrient cycles) with some degree of assurance (Reichle 1975).

Several research approaches need to be pursued simultaneously. Simulation models can be tested against physical models (such as laboratory microcosms), against controlled studies involving experimental perturbation of portions of ecosystems in the field, and against the results of large-scale empirical research on the structure and functions of various ecosystems such as the biome studies of the International Biological Program (NRC 1977b).

Research on modeling and analysis of ecosystems is being carried on or funded by several federal agencies, notably NSF and ERDA. Several of EPA's laboratories are engaged in ecological research, ranging from developing and testing microcosms to large-scale ecosystem analysis, under both the Ecological Processes and Effects subprogram and the Health and Ecological Effects/Energy subprogram (U.S. EPA 1976b). Under Reorganization Plan No. 3 of 1970, the responsibility for developing and maintaining a program of fundamental ecological research in accordance with the provisions of NEPA was transferred to EPA (5 USC App. 1970; 35 F.R. 15623); however, EPA has yet to receive research appropriations under this authority. While it seems appropriate for EPA to lead in this field, we recommend that the work be closely coordinated with similar programs in NSF and ERDA. Furthermore, the programs EPA itself may mount in this area will require long-term continuity, and should be included in the new and separate research mandate recommended in Chapter 1. As a lead agency, EPA could also provide critical advice and support to other agencies doing ecosystem research.

Several other agencies, including USDA, DOI, and NOAA, are also heavily involved in ecosystem work, as applied to their missions. Because of the diversity of agency interest, the multiplicity and broad geographical distribution of ecosystems studied, and the high cost of the large interdisciplinary programs required, improved coordination of effort in this area of research is imperative. Once again, the initial step should be the development of a national environmental research strategy which we have recommended that OSTP undertake.

INVESTIGATION OF ALTERNATIVE ECONOMIC, SOCIAL, AND LEGAL STRATEGIES FOR ENVIRONMENTAL MANAGEMENT

Research to develop alternative strategies for environmental management contributes to the future capacity of government for continued development of national environmental policy and legislative initiatives.

Two levels of institutional research, as Chapter 1 implies, can usefully be distinguished. One concerns the processes for making fundamental decisions about levels of environmental quality that balance risks with traditional goals of economic welfare. On this level is research into such problems as legislative structure, the changing nature of administrative law, the role of the courts in reviewing actions of executive agencies, and the appropriate jurisdictional level at which to make particular decisions. We believe that EPA, as a central part of the existing system, is not in a position to perform or to fund research on this level.

We therefore recommend that EPA not be responsible for such research. However, the national environmental research program must include such research if future decisions on environmental policy and legislation are to have the full advantage of creative scholarship. The research could be institutionalized in a national policy research institute external to government and supported with private funds (for example, see U.S. Congress, House 1977).

A second level of institutional research relevant to the environment concerns the mechanisms for translating the larger decisions into appropriate management actions. Under this heading would come such questions as: the potential for translating desired levels of ambient environmental quality into limits or incentives for dischargers; possible ways of dealing with short-run dislocations caused by imposition of more stringent environmental policy; and ways of motivating the great innovative forces available within our economy in the search for better technologies. It is possible that research at this level could be done within or supported extramurally by EPA since the questions involved do not really concern the foundations of the system. Currently, however, even such issues as the relative desirability of discharge regulation and economic incentives have taken on highly political overtones and may therefore be difficult for EPA to address.

We realize that there are serious obstacles to the conduct and application of institutional research. The basic problem has already been mentioned: EPA—and other sources of research funds such as NSF—are part of the system and thus not without a stake in things as they are. In addition, it is difficult to show convincingly that some suggested institutional change is an improvement. Short of experimentation, "demonstrations" must be based on *a priori* assumptions and deduction—a somewhat tenuous basis for changes that may have far-reaching effects on society. Furthermore, experimentation in this field is very difficult, perhaps impossible. But the riskiness of institutional innovation is not evidence that institutional research is useless—rather the opposite.

We are therefore inclined to stress opportunities rather than obstacles, and endorse the detailed observations, summarized below, of the Panel on Sources and Control Techniques on the problems and possibilities for institutional research (NRC 1977f).

1. At the theoretical level the field known as "social choice" appears promising (Sen 1970).

2. On the more applied level, an obvious technique is analysis of the performance of existing institutions. There are, of course, limits to this technique, since measures of performance are easier to devise and agree on at the management level where the broader goals have already been stated by some higher authority.

3. Because of possibilities for using sophisticated behavior to influence the outcomes, experiments with institutions do not generally seem very promising. This problem is most acute when the participants are few, well informed, and themselves sophisticated, as they often are in the environmental area.

4. Not all institutional research can or should be conducted extramurally; critical questions of statutory implementation, particularly judgments about the reach of statutory programs, must necessarily be analyzed by the agency staff itself. However, intramural and extramural research in combination can facilitate the search for innovative and reliable institutional devices to bring about more efficient, efficacious, and fair environmental control programs (Kneese and Schultze 1975).

5. EPA has been active in several of these areas. Sometimes, however, the research has been integrated into engineering, economic, and technical studies in a way that results in dilution, underfunding, and reduction in impact.

3 Organizing the Research and Development Program in EPA

Chapter 2 indicated the kinds of research and development activities EPA should conduct and for what purposes. This chapter deals with how the Agency's staff and extramural resources should be organized to perform this work.

RESPONSIBILITY FOR RESEARCH IN EPA

The scientific and technical resources of EPA consist of about 4400 natural and social scientists and engineers (of a total staff of 10,300), 42 laboratories, and numerous personnel and facilities available through interagency agreements, contracts, and grants.

OR&D employs only about one-quarter of EPA's scientists and engineers and maintains 15 laboratories at 26 sites (U.S. EPA 1976b). The rest of the scientific personnel and facilities are organized within the Offices of Water and Hazardous Materials, Air and Waste Management, Planning and Evaluation, and the Offices of the 10 Regional Administrators. The Office of Pesticide Programs operates four laboratories, the Office of Radiation two, the Office of Enforcement one, the Office of

Noise Enforcement one, the Office of Air and Waste Management one, and the Regional Administrators a total of 18.[1] Much of the scientific and technical work of offices other than OR&D is routine, such as analyzing samples; some, although we have no clear measure of how much, is more properly considered research and development as defined broadly in Chapter 2.

There are advantages and disadvantages in assigning responsibility for conducting research programs in EPA to a separate research and development unit rather than to the Program Offices whose activities the research is intended to support. From the viewpoint of the Program Offices, centralization of research under OR&D would have the following disadvantages:

- The resources and personnel of OR&D would inevitably be inadequate to satisfy all the needs considered important by the Program Offices, and each program would be competing for priority against other programs.
- Management and supervision of the research might reflect interests different from those of the Program Offices, with consequent failure to satisfy specific requirements.
- Since transfer of results to potential users is more difficult at one remove, there is a danger that research may be wasted (Fromm et al. 1975, Caplan et al. 1975).

On the other hand, centralization of research under OR&D would have a number of advantages:

- Research conducted in OR&D is less likely to be limited by artificial boundaries established in legislation than work carried out by offices responsible for enforcing that legislation. (Considerations of impacts on air, land, and water, for example, can be more readily integrated into work performed by OR&D than might be expected in research performed to meet the specific interests of, for instance, the Office of Air Programs.)
- Duplication of expertise is minimized. (For example, conducting separate programs in environmental epidemiology for air, water, pesticides, and toxic substances is an inefficient use of a scarce resource—environmental epidemiologists.)
- Because the Agency's ability to perform its missions is affected by its scientific capabilities which, in turn, are colored by the scope of its

[1]Phyllis Daly, Office of Planning and Review, OR&D, EPA, personal communication received October 15, 1976.

research program, centralized planning of the research effort can more effectively reflect Agencywide priorities.

- All research and development activities in the Agency's program are identified and focused so as to facilitate contacts with Congress, other agencies, and the community outside the Agency.

We believe that the disadvantages of centralization in OR&D can be overcome, at least in part. For example, if limited resources actually constrain the research program to the detriment of important needs, the Program Offices have the option of transferring funds from their other activities to OR&D. Whatever the organization of research, limited resources mean that judgments have to be made both on the relative priority of research as a function and in assigning priorities for projects within the research program (see Chapter 4).

Other disadvantages of centralizing research can be overcome by good management practices. For instance, the Program Offices, with the cooperation of OR&D, could monitor and influence research performed to meet their respective needs by temporarily assigning personnel to OR&D for periods of one to two years as program managers for appropriate portions of the extramural research program (see Chapter 4). Furthermore, OR&D methods of information transfer can be more effectively organized wherever the information transferred originates (see Chapter 5).

The major advantages of centralization, conversely, are hard to accomplish without duplication of effort. For instance, ensuring that research conducted by Program Offices recognizes the multimedia nature of environmental problems, in the face of authorizing legislation that generally does not, is likely to mean unnecessary duplication of technical capabilities available elsewhere in the Agency.

We therefore recommend that OR&D be responsible for all the Agency's ongoing, substantial research and development. Our recommendation would apply, for instance, to current programs of economic research and analysis of the Economic Analysis Division of the Office of Planning and Evaluation, and to health effects research of the Office of Pesticides Programs and the Office of Toxic Substances, but not to routine laboratory services, which should continue to be supplied through the existing laboratories in the Program and Regional Offices.

CONSEQUENCES FOR OR&D'S PROGRAM

Implementation of Chapter 2's recommendations of appropriate foci for EPA's research would result in a change in emphasis for the program of

OR&D. There would be less emphasis on the development of control technology and on certain aspects of health research, and more on socioeconomic research, anticipatory programs, and analysis of information for direct support of decision making.

At the same time, the centralization of research in OR&D recommended in the present chapter would entail shifting resources among offices and programs. As research now conducted in Program Offices is transferred to OR&D, commensurate resources should also be transferred.

Some of the activities described in Chapter 2 as primarily anticipatory might be accommodated under current legislation. We believe, however, that a more extensive program of anticipatory studies (e.g., inventories of discharges) and a modest program of research to advance fundamental environmental science should be funded under the new research mandate recommended in Chapter 1. Authorization independent of the Agency's other mandates would allow broader scope and a longer and more stable duration than appears possible under existing legislation. A possible alternative solution for funding fundamental research in ecology would be to use the existing provisions of NEPA (see Chapter 2 on Analysis and Modeling of Ecosystems).

Of special consequence to the program of OR&D is the recommendation in Chapter 2 that an Office of Integrated Technical Analysis be established to perform integrated assessments of available information in direct support of decision making. We envisage an integrated technical analysis group of as many as 100 scientists and engineers supported by a clerical, editorial, and managerial staff. Its ultimate size will, of course, depend on the workload (which is likely to be significantly affected by the Toxic Substances Control Act), but we estimate that minimum disciplinary coverage adequate to begin such a group would require 25–30 scientists and engineers. The professional staff should be organized along traditional disciplinary lines rather than according to program in order to facilitate collection and evaluation of information which ordinarily is produced by discipline-oriented research and development. The traditional disciplines to be represented could be grouped into physical, chemical, and mathematical sciences (e.g., fluid dynamics, mechanics, analytical chemistry, organic chemistry, physical chemistry, and statistics); health and biological sciences (e.g., pathology, biochemistry, epidemiology, toxicology, biostatistics, entomology, plant sciences, and ecology); technology (e.g., sanitary, industrial, process, mechanical, instrumentation, and systems engineering); and economics and social sciences (e.g., applied welfare economics, risk analysis, and behavioral sciences).

Because of the importance to the Agency's decision-making process of the function of this office, its staff should be highly qualified and carefully selected. The office should be directed by a senior scientist or engineer with experience in the Agency's decision-making processes, who should be a Deputy Assistant Administrator. The director might also be responsible for the Technology Transfer and Technical Support Programs, since the program for technical assessment also deals with information transfer (see Chapter 5). Some personnel should be assigned to the assessment office on a temporary basis from other laboratories in OR&D or from other offices of the Agency, as well as from outside EPA. Temporary transfers from EPA's Program Offices would be useful for providing first-hand experience of the use of information. Interagency transfers and the Intergovernmental Personnel Act of 1970 (84 Stat. 1909, PL 91-648) could also be used to attract qualified and interested scientists and engineers from other federal agencies and from nonfederal institutions. We believe the appropriate level of technical expertise is that of a mid-career or junior scientist with at least several years' experience. Rotating assignments for a period of from one to two years would keep the technical expertise of the office up to date and would facilitate communication with the rest of the scientific and technical community, both inside and outside the Agency.

The technical staff would gather, analyze, and assess existing data. Staff members would be responsible for maintaining channels of communication with the general scientific community to facilitate these activities. When data, otherwise not subjected to scientific peer review, are deemed critical to a decision, the staff should organize appropriate reviews in accordance with the principles described in Chapter 4 (see also NRC 1977a). The director of the office should be responsible for integrating the information from the several disciplines and for presenting it in a form suitable for effective use in the decision-making process. To carry out this responsibility, the director might appoint a multidisciplinary committee of staff members, one of whom could also be assigned to membership on the Agency's ad hoc Working Group responsible for developing proposed decisions (see Chapter 5). Thus the analytic resources of an organized multidisciplinary group would be available to the people selected to bring technical expertise to the ad hoc Working Groups.

Because the ultimate purpose of the office is to integrate scientific information for use by decision makers, its work would be enhanced by close interaction among its personnel, and between its staff and the Agency's principal decision makers. Accordingly, we recommend that the office be centrally located at Agency headquarters in Washington, D.C.

THE EXTRAMURAL PROGRAM

Approximately 75 percent of OR&D's research and development program in FY 1975 (U.S. Congress, House 1975), and much of the research and development conducted by Agency Program Offices, was conducted outside the Agency, either through interagency agreements, contracts, or grants.[2] Obviously, the way EPA organizes and manages the extramural program can significantly affect the usefulness of research programs in supporting the Agency's missions.

Contracts and interagency agreements provide for research and development services from nonfederal organizations and individuals and from other federal agencies, respectively; both are ordinarily used to obtain directed or applied research with specified objectives using prescribed procedures. These instruments have advantages in terms of budget control and better specification of work to be performed. Contracts are used when the desired expertise is outside the federal establishment. Interagency agreements are used to transfer funds between agencies. Thus, it is possible to use technical expertise wherever it resides in the government and at the same time permit the funding agency to determine the objectives of the research. For example, under the Energy/Environment Research and Development Program, EPA transferred about $34 million of its FY 1976 appropriation of $100 million to 10 other agencies, including ERDA, DOI, TVA, NBS, NIEHS, NIOSH, and NASA (U.S. EPA 1976c). EPA provides the direction for the research conducted with these "pass-through" funds while the receiving agencies perform the tasks. The receiving agencies may conduct the research in their own laboratories or through contracts with nongovernmental researchers, depending on the terms of the agreement.

Grants, on the other hand, ordinarily provide for research that is less amenable to managerial control of specific objectives, schedules, or procedures, and are most often used to promote the advancement of scientific understanding and encourage the initiative and creativity of the extramural investigator. Research grants to university programs generally have the added benefit of providing research experience to students. Both undirected and applied research that advances the state of the art may be objects of research grants (U.S. Congress, Senate 1962).

Research grants are at present a minor component of EPA programs compared with grants for planning specific environmental management projects and programs, such as state implementation plans for air

[2]Phyllis Daly, Office of Planning and Review, OR&D, EPA, personal communication received October 15, 1976.

pollution control (under the Clean Air Amendments of 1970 [84 Stat. 1677, PL 91-604]) and evaluation of alternative technologies for wastewater treatment facilities (under the Federal Water Pollution Control Act Amendments of 1972 [86 Stat. 842, PL 92-500]). Planning grants generally provide for more careful control of work to meet more highly specific objectives than research grants.

Each of these three instruments, interagency agreements, contracts, and grants, can be applied either to individual projects or to programs into which projects of a specified class might fall. For example, EPA might contract with a private firm or university for a specific project or for a group of related projects by block funding of an umbrella contract. A model for the use of block funding by contract is the federal research and development center, or contract laboratory (U.S. Congress, Joint Committee on Atomic Energy 1960), such as those operated for ERDA (U.S. ERDA 1975b) and for the Department of Defense (U.S. DOD 1975) by both profit-making and nonprofit institutions. Program grants to academic institutions can be used both to obtain needed results and to promote the development of scientific competence, particularly in multidisciplinary activities. Models of such grants to establish and maintain centers of excellence in environmental sciences are those of the NIEHS.[3] Research performed under interagency agreements can also be covered by block funding arrangements.

Block funding of interagency agreements, contracts, and research grants has several advantages over ad hoc arrangements. First, block funding establishes more stable working relationships under which extramural researchers have better opportunities of knowing the Agency's programs and purposes. This arrangement increases the likelihood that their work will conform to the Agency's needs. Thus, extramural programs covered by block funding can become, in essence, an extension of the intramural program. This feature could, of course, become a disadvantage if the extramural researchers become captive to Agency interests and do not maintain some measure of independence. Second, research centers are well suited for work that requires large and expensive facilities. Third, contractor-operated laboratories have flexibility for staffing, organizing, and managing programs and can therefore respond more rapidly to changing needs than is generally possible in Civil Service laboratories. Fourth, when work is initiated under an existing agreement, contract, or grant, delays associated with preparing a Request for Proposals, advertising the request, waiting for proposals to be submitted

[3]NIEHS Data Book, unpublished document, 1976, U.S. National Institutes of Health, Research Triangle Park, N.C.

and reviewed, and preparing the contract are avoided. Basic ordering agreements similarly avoid delay.

While block funding should not be the only means for obtaining extramural research support, we recommend that whenever possible EPA use block funding for interagency agreements, contracts, and grants in its extramural program. An umbrella agreement between EPA and ERDA, for example, could facilitate every aspect of EPA's energy-related program; a contract laboratory or series of laboratories could be established for analysis and development of industrial pollution control technology; and centers of excellence for environmental health (for instance, environmental epidemiology and environmental toxicology) could be established by grants either separate from or in conjunction with those made by other federal agencies. Work performed under block funding, as other research, should be subject to independent review.

A significant impediment to obtaining information for use in decision making through original research is the time required to obtain results. Arranging for the work to be done, particularly extramurally, also requires time. Any mechanisms, such as block funding arrangements described above, that can help reduce the time (and simplify the paperwork) required to initiate extramural work would help to improve the timeliness of this research. But the timeliness of the production of results is not only a function of how long it takes to organize and implement projects. The conduct of research takes time; both intramural and extramural projects must be carefully planned and managed if progress is to be made as quickly as the scientific method allows.

4 Planning and Managing Research and Development in EPA

Planning the research and development program in EPA is itself a form of decision making, involving criteria and constraints that are related to those of regulatory decision making. The terms of reference for research are broadly defined by the demands of the Agency's regulatory function. Within that broad definition, planning of EPA's research program requires decisions on an order of priority for information needs, a ranking necessitated by limitations of budget, personnel, and facilities that make it impossible now and unlikely in the future for the Agency to discharge all the research responsibilities identified by Congress. The ordering of priorities, and the selection of programs to fulfill the needs thus determined, are further constrained by the range of technical abilities of EPA's scientists and engineers, the facilities available, and the ability of the Agency to obtain and monitor extramural research.

While the need to implement legislation and the constraints of funds and capacity thus strongly influence planning, the ability of the Agency to perform its legislated functions in turn depends on the abilities of its scientific staff to analyze and interpret the implications of scientific and technical information for the decision-making process. The range of intramural expertise is determined by the mix of skills of the Agency's staff and by the design and management of the research and development program. Thus, planning the research program is important not only to ensure that public funds are spent effectively, but also to provide direction and scientific competence to the Agency's programs.

IDENTIFYING RESEARCH NEEDS

Research needs will be defined and the research program planned differently for different kinds of activity. EPA at present conducts a "top-down" planning procedure, represented schematically in Figure 4.1, in which the needs for research programs are defined primarily at administrative levels, and responsibilities for satisfying those needs are assigned to laboratories.[1] Laboratory directors and staff scientists then define projects and sometimes recommend addition, deletion, or redefinition of the needs. Figure 4.1 also illustrates an alternative, "bottom-up" procedure, characterized by reliance on the working level scientists and technologists to identify opportunities for research potentially applicable to the mission (Given 1949). Programs are then organized at administrative levels, where judgments on priorities are made in response to the proposals. The latter planning scheme decentralizes the identification of research needs; the former centralizes decision making on both needs and priorities, although decisions may be influenced by the expression of needs from diverse sources, particularly EPA's own Program and Regional Offices. The "top-down" and "bottom-up" schemes described above are, of course, oversimplifications, but they are useful in differentiating between planning philosophies that depend on centralized or decentralized identification of needs respectively. In both schemes, priorities are set by the administrative officers; it is in the location of primary responsibility for identification of need that they differ.

The needs for scientific and technical activities to support Agency decision making may be defined by legislative mandates, by the Regional Offices, the Program Offices, or the Offices of the General Counsel and Enforcement, or by analyses of specific problems based on existing information. Because Agency policies and programs are at stake in decisions on priorities for research, we conclude that the Assistant Administrator for Research and Development should be responsible for planning scientific and technical activities to respond to these diversely identified needs. Such centralization is essential to facilitate the tasks of the working scientists, and to ensure that EPA's research resources are allocated to projects that support the Agency's missions. Accordingly, we recommend that the "top-down" scheme depicted in Figure 4.2 be used in planning the scientific and technical activities in EPA performed to support decision making. The scheme, which is essentially the same as that recommended earlier by the NRC's ad hoc Review Committee on

[1]Phyllis Daly, Office of Planning and Review, OR&D, EPA, personal communication, November 6, 1975, recorded in the minutes of the Fourth Meeting of the ERAC.

the Management of EPA's Research and Development Activities (Appendix C) and currently in use in OR&D, emphasizes the Agency's information needs as expressed through its administrative officers and the assessment of priorities by the Assistant Administrator for Research and Development. In particular, for allocating research funds appropriated under the several programs prescribed by enacting legislation, the research needs of the respective Assistant Administrators for these programs should have highest priority. Thus, conscientious "top-down" planning should help to ensure the responsiveness of the research to the objectives of the Program Offices. The role of the Deputy Assistant Administrator for Information Transfer (see Chapter 5) is to assess the potential value to decision making of the results of proposed research, using the expertise in the Office of Integrated Technical Analysis (see Chapter 3).

Research intended to anticipate future problems or to advance the frontiers of fundamental scientific understanding is harder to define, prescribe, and plan than research needed to support decision making. It is generally accepted that decentralized identification of needs is more likely to be successful in defining an effective program for anticipatory and fundamental research, and for establishing appropriate priorities within it. Scientists themselves are in the best position to detect under-researched areas in their own fields that may become problematic, and to identify opportunities for research that will advance their science. Furthermore, despite the inevitable pitfalls of any system of peer review, scientists are still in a better position than any other group to evaluate the proposals of their peers. This reasoning is as convincing for environmental as for any other science.

Accordingly, we recommend that EPA's research and development designed to anticipate problems or to advance fundamental scientific understanding be planned using the "bottom-up" system represented schematically in Figure 4.3. For anticipatory research in particular, the Office of Integrated Technical Analysis should play a significant part in defining research needs. For fundamental research, the system should rely upon the scientific community inside and outside EPA to identify research needs through such means as unsolicited proposals.

The general scientific community outside the Agency should also be involved in advising on planning research. One technique for achieving this is to establish technical advisory committees for each research laboratory in the Agency (of which there are 15 in OR&D); another is to draw on the advice of committees of the Science Advisory Board for different aspects of the research program. The former technique has three advantages over the latter: decision making is more decentralized, can

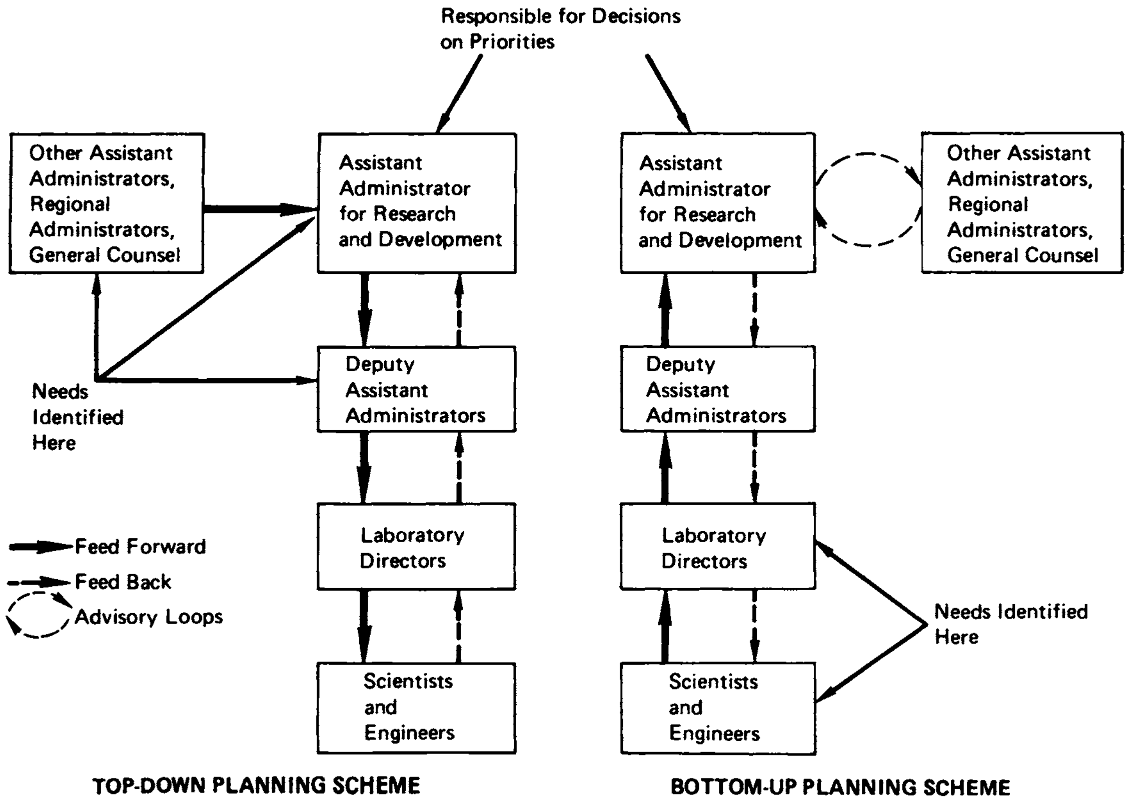


FIGURE 4.1 Simplified schemes for planning research in EPA.

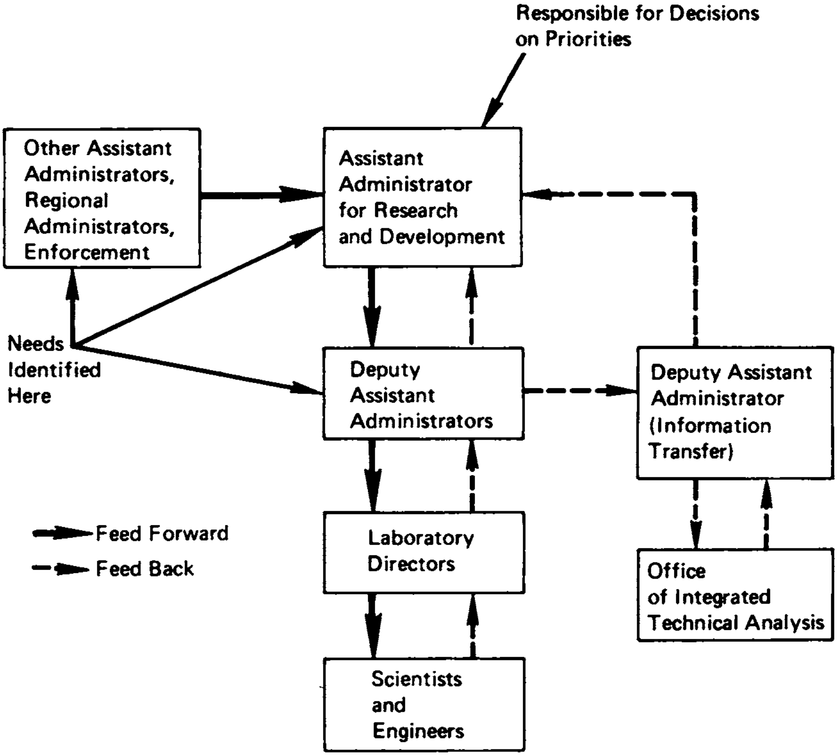


FIGURE 4.2 Recommended scheme for planning research and development in support of decision making.

better reflect regional diversity, and calls for participation of more of the nation's scientific community.

The most significant change entailed in implementing our recommendations for planning the Agency's research would be the elevation in status of activities that directly support decision making through the formal organization of the group responsible for performing integrated technical analyses. The recommended "bottom-up" planning technique for research to anticipate future environmental problems and to advance environmental science would also entail a change in emphasis. This portion of the research agenda should be funded separately from that intended to support immediate needs of regulatory decision making (see Chapter 1). The number of participants in the planning process will need to increase if the intramural technical analysis group and the extramural technical advisory committees or their equivalents are established as

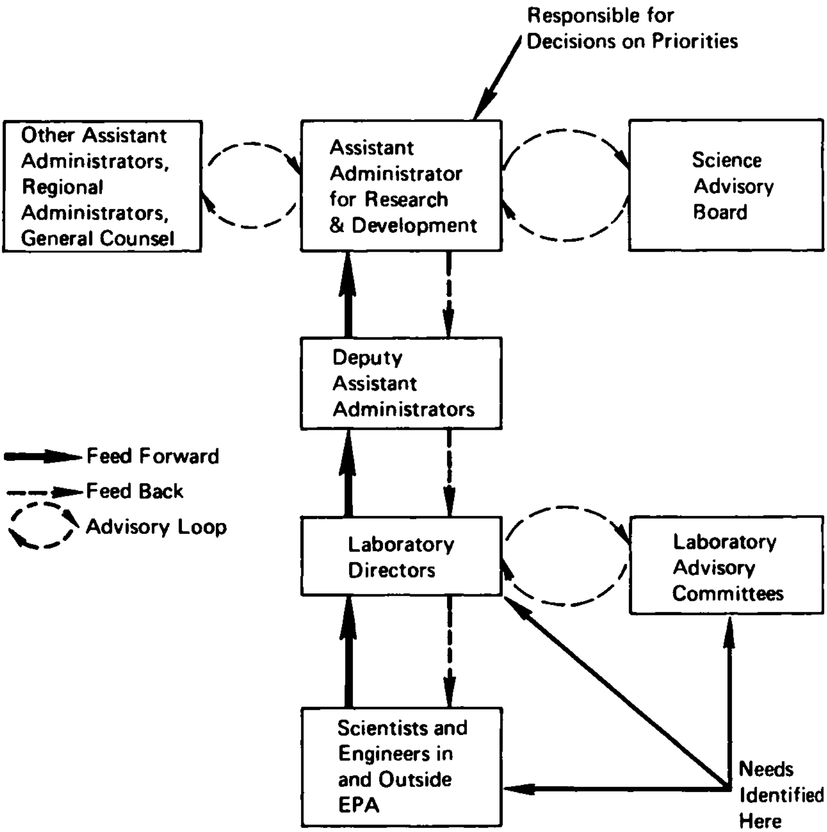


FIGURE 4.3 Recommended scheme for planning research and development for anticipation of problems and advancement of fundamental scientific understanding.

recommended. Not changed by the implementation of our recommendations would be the ultimate responsibility of EPA's administration to determine the contents and priorities of the Agency's scientific and technical programs.

CONSTRAINTS ON RESEARCH PLANNING

In EPA, as elsewhere, research managers operate under a number of constraints. Paramount among the constraints is limited budget, with consequent limitations on manpower and facilities. Another constraint on EPA's research program in particular is a degree of inflexibility in the distribution of disciplinary skills within the Agency, and a set of practical constraints is provided by various Congressional instructions.

BUDGETARY CONSTRAINTS

The budget procedure, as currently practiced, is iterative: budget and personnel ceilings are set for every agency of the government by the Executive Office of the President, and the administrative officers are then responsible for advising OMB how each agency wishes to allocate these resources to its programs. After several iterations, the President's budget is submitted to Congress, which may alter both the ceilings and the specific programs.

The administration of EPA is initially responsible for apportioning the Agency's total budget among its various programs, including its scientific and technical activities. Table 4.1 shows how EPA's appropriations for FY 1972 through FY 1977 have been allocated to research and development. The appropriations for total operations exclude funds granted for construction of wastewater treatment facilities. Appropriations for research are divided between funds especially appropriated to support the program of energy independence initiated in FY 1975 (U.S. Atomic Energy Commission [AEC] 1973) and the base program. Excluding the special appropriations for energy-related research and development, the percentage of the total budget allocated to research has declined steadily, even as the Agency's program responsibilities have steadily increased. Implementation of legislation is usually assigned a higher priority than research.[2] We believe that the President's budget should request and Congress should fund research and development to support legislated programs at a level commensurate with the needs for implementing those programs.

Another aspect of the current budgetary process that affects EPA's research program is that allocations for scientific and technical activities are all authorized under programmatic legislation. EPA has consequently felt unable to sustain certain important research programs, especially those that range beyond the limits of the legislation or that require a stable, long-term commitment of resources. In this category are programs conducted to anticipate future environmental problems or to advance fundamental scientific understanding, as well as some programs that have direct bearing on decision making, but need a long time, such as environmental epidemiology. In Chapter 1 we recommended an addition

[2]John Quarles, Deputy Administrator, EPA, personal communication, May 6, 1976, recorded in the minutes of the Seventh Meeting of the ERAC.

TABLE 4.1 EPA Appropriations for Operations and for Research and Development, FY 1972–FY 1977 (millions of dollars)

Fiscal Year (Appropriations Act)	Total Operations	Base Operations Excluding Energy-Related R&D	Total R&D (% of total operations)	Energy-Related R&D (% of total R&D)	Base R&D Excluding Energy-Related R&D (% of total operations)	Base R&D as % of Base Operations
FY 77 (PL 94-378)	773.4	676.4	259.9 (33.6)	97.0[1] (37.3)	162.9[1] (21.0)	24.1
FY 76 (PL 94-116)	771.5	671.5	270.7 (35.1)	100.0 (36.9)	170.7 (22.1)	25.4
FY 75 (PL 93-563)	646.1	566.1	255.7 (39.6)	80.0 (31.3)	175.7 (27.2)	31
FY 74 (PL 93-135)	541.7	541.7	166.8 (30.8)	Not Applicable	166.8 (30.8)	30.8
FY 73 (PL 92-399)	471.0	471.0	185.2 (39.3)	Not Applicable	185.2 (39.3)	39.3
FY 72 (PL 92-73)	448.4	448.4	Not Separately Appropriated	Not Applicable	Not Separately Appropriated	37.4[2]

[1] Estimate based on President's budget for energy-related R&D (U.S. OMB 1976).
[2] Estimate based on EPA data (P. Daly, Office of Planning and Review, OR&D, EPA, personal communication received October 15, 1976).

to EPA's research mandate to overcome the limitations of the present system.

LIMITATIONS ON AVAILABLE EXPERTISE

EPA must conform to Civil Service personnel procedures and therefore cannot easily adjust the mix of skills of its scientific and technical personnel. The distribution of these skills in EPA today, both geographically and among disciplines, reflects priorities of several years ago because the scientific and technical direction of the Agency has changed more rapidly than the mix of personnel (and facilities). Illustrating this problem is the case of the development of specific technologies, such as in the municipal wastewater research and development program. In such cases, research teams may work for several years until the technology is appropriately developed, after which the technologists involved may require retraining before being able to contribute to the next project, with a consequent reduction in their usefulness to the Agency in the meantime.

Since EPA's technical capabilities are constrained, the Agency's relationships with other research performers, in and out of government, are extremely important. EPA should attempt to use the technical skills it needs wherever they exist; concomitantly, EPA should not unnecessarily duplicate resources that are available elsewhere. To identify available skills and to use them effectively will require full implementation of our recommendation that OSTP define a national environmental research strategy, assess the roles of participating agencies and institutions, and coordinate the federal environmental research and development program (see Chapter 1).

EPA's scientific and technical programs may also be constrained by the lack of sufficient expertise anywhere in the nation. This may be true for enforcement of the Toxic Substances Control Act, enacted in October 1976. Under this legislation EPA will be provided with information on the production and intended use of potentially toxic substances and with the results of tests of their toxicity. The Agency will be asked to determine, very rapidly, (a) the relevance of the laboratory tests to field exposures, and (b) the extent to which the patterns of production and use of the substances will result in harmful concentrations in the ambient environment. Scientific understanding is not yet sufficiently developed to determine either of these things with confidence. Both EPA and OSTP must identify areas where needed understanding and expertise are lacking. The national strategy for environmental research developed by OSTP must include programs to develop such understanding and to train personnel to apply it.

CONGRESSIONAL CONSTRAINTS

Congressional instructions are another constraint on EPA's ability to conduct its scientific and technical activities. Historically, some acts authorizing EPA's research and development program have included very specific instructions on projects that were of local interest only. Performance of this research impedes more pressing work of regional or national importance. We recognize that Congress is responsible for overseeing the national environmental research program, as part of its responsibility for expressing the concerns of the public and for ensuring that public funds are spent effectively. We respectfully suggest, however, that the Agency must be accorded flexibility in the conduct of specific projects if the timetables established by Congress are to be met.

CRITERIA FOR ASSIGNING PRIORITIES

After needs have been defined and weighed against constraints comes the most difficult task in planning research: assigning priorities among competing programs and among competing projects within programs. Decisions on priorities determine how EPA's scientific and technical resources are to be used and these decisions ultimately affect the Agency's ability to perform its mission, since science and technology are integral to that mission. Consequently, we consider EPA's decision making on research priorities almost as important as its decision making on regulations and standards. Both processes must take into account a wide variety of interests and factors, of which scientific and technical considerations are but a part.

Setting priorities is essential if funds and expertise are not to be spread so thinly as to deprive the work of any value. Faced with the demands of a multiplicity of environmental problems, each with an equally valid claim for urgent solution, the planner understandably resorts to compromise. The results, too often, are diluted or fragmented research and a protracted "non-solution."

Priorities must therefore be set even though accepted, quantitative measures of importance are lacking. We have no magic formula for resolving this dilemma, nor do we expect anyone else to have one. Some obvious criteria do exist, however, for providing an initial ordering of priorities.

We recognize two categories of problems as having top priority by definition: those for which research funds have been specifically appropriated by legislation, and those that suddenly threaten public health and well-being, environmental values, and ecosystems, especially when the effects may be irreversible. Problems other than these must then be ranked according to extent (geographic area and population affected) and intensity. Criteria to estimate problem intensity include such crude measures as public health effect (from mild discomfort to death), environmental effect (from mild aesthetic impact to gross nuisance), ecologic effect (from slight shifts in species abundance, as in mild eutrophication, to destruction of vegetation, fish, and wildlife), and economic effect.

Beyond this general ordering, the ranking process is necessarily subjective, and must sometimes be arbitrary. Therefore, mature and experienced judgments must be depended upon, the assumption being that decisions on ranking are more apt to be reliable when they have the benefit of advice from as diverse a group of informed and experienced people as possible.

Two considerations have special application to the assignment of priorities for scientific and technical activities within these mandates and rankings and should be taken into account when forming the criteria for evaluation. First, the potential value of the results of the research should be commensurate with the costs. (In the field of decision analysis, the value of the information developed through research is measured by its potential use.) For example, if research is conducted primarily to support decision making, its potential value should be measured by the amount of influence the results might have on the decision at hand (NRC 1975a,b). If the particular decision is not sensitive to the range of expected results, the research cannot be justified as supporting decision making in that instance, but may be justified for some other purpose. In this respect, the group assigned responsibility for conducting integrated technical analyses should be very helpful in assigning potential value to proposed activities, since its primary function is to assess the implications of existing knowledge, including research results, for specific problems in decision making.

The second consideration particularly applicable to decision making on research priorities is the probability of success. This will depend in part on whether the question is well posed and whether resources are available to solve it. A research question is well posed if its objective is clearly defined and if adequate basic knowledge and methodologies exist for doing the research. The resources needed to accomplish the work include capable trained specialists, appropriate equipment and facilities, and funding for an adequate period of time. All but one of the factors that determine the probability for success can best be estimated by scientists through peer review processes as described in subsequent sections of this chapter. The availability of adequate funding, however, can only be estimated by those making decisions on priorities. If a research program is otherwise deemed to have high priority, research administrators should commit adequate funding to assure that the work will be accomplished. For example, if EPA decides to fund a program in environmental epidemiology, as recommended in Chapter 2, it must recognize that such a program will require a stable level of support over a number of years and take this fact into account when making the decision.

The essence of the two considerations described above is that decision making on research priorities should take into account the costs, benefits, and risks of conducting the scientific and technical activities. These factors can, to some extent, be quantified and, as such, help EPA's decision makers to determine priorities by permitting regular, standardized comparisons between alternative proposals.

PERSONNEL AND FACILITIES

RECRUITMENT AND RETENTION OF STAFF

Constraints on the research program associated with the quality, as opposed to the quantity, of the technical resources available to managers can be more easily circumvented by good management than can the inevitable constraints of the budget. While some of EPA's research scientists and engineers are highly competent and many are highly motivated, the Agency is reported to have difficulties in recruiting and keeping highly qualified researchers.[3] Some of these difficulties result from noncompetitive salary schedules and the lack of career opportunities in research; others from working conditions typified by continual shifts in objectives of research programs in response to newly-perceived environmental threats. New objectives, for example, require renewed justification, or else alteration, of projects and sometimes reallocation of staff and resources. Frequent reorganization of the research program creates insecurity and low morale of Agency scientists, who may be prevented from finishing projects, or be forced to spend what, to them, is an inordinate amount of time rejustifying projects and redirecting contractors. Compounding the insecurity of shifting programs is the fact that the combined research activities of several disparate agencies from

[3]Wilson K. Talley, OR&D, EPA, personal communication, May 2, 1975, recorded in the minutes of the First Meeting of the ERAC; John Knelson, Health Effects Research Laboratory, Research Triangle Park, North Carolina, OR&D, EPA, personal communication, March 3, 1976, recorded in the minutes of the First Meeting of the Visiting Subcommittee of the ERAC; and U.S. EPA (1976a).

which the Agency's research program was formed have not yet been fully integrated. To recruit and keep good research staff, working conditions need to be created in which a stable sense of mission can be maintained.

ACTIVITIES OTHER THAN RESEARCH

In addition to conducting the scientific and technical activities described in Chapter 2, the research staff of EPA provides other offices in EPA and other federal and state agencies with technical assistance and support, serves as liaison to other agencies and organizations, and helps manage the Agency's research program. Recommendations on these functions, though they clearly affect personnel, relate more closely to the management of scientific activities than to personnel procedures, and therefore appear in the section on Managing Scientific Activities, below.

OPPORTUNITIES AND INCENTIVES

To maintain technical capabilities, management must provide scientific and technical staff with opportunities and incentives that will motivate high standards of professional performance. Among the most important incentives are an effective reward system of personal advancement, and working conditions that combine a mix of scientific skills appropriate to the work with suitable services, equipment, and facilities. Nearly as important are opportunities for education, retraining, and exposure to work being done outside the Agency.

Peer Review

Each scientist is personally responsible for the work he or she performs. Each should welcome peer review, and should assume responsibility for disseminating results through publication in appropriate journals. Individuals should seek personal interaction with peers whether at professional meetings or through personal communications. To assist in this interchange, managers can encourage publication in peer-reviewed journals and active participation in professional society activities, particularly by providing the opportunity to attend professional meetings.

Promotion Procedures

The reward for meritorious scientific and technical performance in EPA is usually step advancement within grade or promotion to a higher grade in the Civil Service system. Advancement within a grade means a salary increase; grade promotion adds increased administrative responsibility to a salary increase. Unfortunately, increased administrative responsibility almost always affects a researcher's scientific output. A strongly motivated scientist who refuses advancement through managerial ranks is likely to sacrifice both monetary rewards and career advancement.

We recommend that the reward structure used by EPA include parallel grade advancement systems, one for scientific and one for managerial performance. The grade structure for management should remain as presently constituted, while a parallel grade structure for scientific advancement, including three or four levels covering GS grades 12-18, should be used. Such a dual system can be implemented under current Civil Service regulations.

Location of Facilities and Composition of Laboratory Staffs

The location of facilities and the viability of working groups are also important for recruitment and morale. For a working group to be effective, it must not operate in a vacuum. Members of the group need the stimulus of discussing problems with fellow scientists knowledgeable in the same or related fields. While some existing EPA facilities are near intellectual centers where libraries and an array of scientific competence and interests are easily accessible, others are not. Since research is essentially an activity of scholarship, facilities without these scientific amenities are at a disadvantage in recruiting and holding top quality people though they may have such offsetting advantages as natural beauty, pleasant climate, or small town life.

Altogether, it seems to us that technical capabilities might be improved by eventually consolidating laboratory activities at sites that have both a diversity and intensity of scientific interests.

Education and Training

Opportunities for education can be provided within laboratories or may be available outside. Activities such as continuing seminar programs involving extramural scientists may provide first-hand knowledge of new developments. Special education programs may be designed to enable staff scientists to undertake research in new fields of study.

The frequent shifts in assignments and responsibilities of personnel required by the dynamic nature of EPA's activities occasionally cause mismatches between needs and capabilities. The impact of such mismatches can be lessened by providing specialized study programs for staff scientists, either within the Agency or, when this is impossible, through such means as educational leave or shorter-term assignment to relevant research centers. Exchange of scientists with academic institutions or industry under the auspices of the Intergovernmental Personnel Act, or with other agencies on temporary transfers, is another means of keeping Agency programs up to date, and can be educational and stimulating to both parties. Rotating asssignments of EPA scientists to the proposed integrated analysis group would provide still another opportunity to broaden the research interests of the laboratory scientist and to increase the relevance of his or her work.

Managers in EPA are aware of many of these opportunities and in some instances have taken advantage of them, but much more can be done. We therefore recommend that EPA adopt a policy of providing educational leave where retraining would be useful, and of encouraging the exchange of scientists between EPA's laboratories and those of industry and academia through the Intergovernmental Personnel Act and other programs.

MANAGING SCIENTIFIC ACTIVITIES

To assure that research meets its objectives and is of high technical quality requires both administrative skill and scientific leadership. Administrative skills are needed to obtain and allocate resources, to organize people and programs, and to create and maintain a working climate that stimulates good scientific work. Scientific leadership is important in setting priorities and in exercising judgments on the scientific content of the work being done.

Administrative and leadership styles are highly dependent on personalities. In creative research, latitude of thought and action within the constraints of bureaucratic organization must be provided not only for the laboratory scientists, but also for their leaders. The general perception of the quality of the scientific leadership in EPA is a major factor in the acceptance of the Agency's research output by the scientific and professional communities. Since lack of confidence in the results of research conducted by EPA may be a major obstacle for the Agency, as a regulatory body, to overcome (see Chapters 1 and 5), it is imperative that the leadership within the organization be identified not only as qualified administrators, but also as respected environmental scientists.

REVIEWING PROPOSALS

Ideally, once the needs of a research program have been defined, scientists inside and outside EPA respond with proposals for specific projects. Proposals act as a check on the feasibility of meeting the needs and objectives defined in a "top-down" planning process, since proposals indicate what the researchers can reasonably accomplish. Internally, the preparation of a proposal may be integrated with the formulation of objectives. This integration is helpful where the proposed research is tailored to a specified need, but is a drawback when the objective is manipulated to fit the researcher's independent interests.

Proposals should be reviewed to assure that the research plan is well-formulated, that it has a reasonable chance to meet objectives, and that the researcher or research team has adequate funds, facilities, and expertise to accomplish the work. Reviews also minimize the risk of duplicating work already done elsewhere, and may help to correct a limited or biased perspective.

Current EPA policy requires review of proposals from nonfederal sources, usually by reviewers from both inside and outside EPA. Proposals from inside EPA and from other federal agencies, however, are not generally submitted for external technical review. In our opinion, the scientific merit and the credibility of the Agency's scientific program would be enhanced by submitting all proposals for research, without exception, to peer review by scientists both inside and outside the Agency.

We therefore recommend that each laboratory director establish a consistent procedure for obtaining thorough technical reviews of all proposed research, and that all intramural research be justified by a written proposal that can be reviewed. Appropriate procedures might well include mail review of scientific merit from scientists representing the relevant disciplines, followed by review by standing panels (for instance, the Laboratory Advisory Committees, suggested earlier in this chapter) to evaluate the results of mail reviews and to assess the appropriateness of proposals to programs. Scientific review of Requests for Proposals before they are published might substitute for some aspects of the review of solicited proposals.

TECHNICAL ASSISTANCE AND SUPPORT

Technical assistance and support may take the form of consulting on urgent problems ("fire-fighting"), assessing existing data for use in position papers or decision documents, preparing and delivering expert testimony, and performing laboratory services or operating specialized equipment. Approximately 10 percent of the base budget of OR&D is used for technical assistance and support.[4] The funds appear to be divided roughly equally between short-term responses to immediate needs and longer-term services. These figures are approximate and do not account for the considerable technical advice and assistance informally provided by OR&D personnel based in headquarters.

Providing technical assistance and support to others becomes central when the assistance is provided to the decision-making process. The activity, however, often deflects time and funds from other research pursuits; moreover, to date the burden of funding has fallen on the office providing rather than on the office receiving the service, which may have encouraged more requests than are necessary. To guard against excessive disruption, we recommend that accounting procedures be devised and adopted to transfer funds from the requesting to the performing office for such support functions as the preparation of expert testimony, the provision of laboratory services, and the operation of specialized equipment or facilities.[5] While the organization of an Office of Integrated Technical Analysis should also alleviate some pressure on laboratory scientists for quick analyses and consultations, that pressure will not disappear. In fact, the integrated analysis group itself will need to consult other Agency scientists in the conduct of its work.

EXTRAMURAL AGREEMENTS AND CONTRACTS

Extramural research in EPA can best be managed at the laboratory level since the research is intended to support the scientific and technical programs within each laboratory. Those responsible should have scientific and technical competence appropriate to the disciplines engaged in their respective programs.

Monitoring the extramural program is particularly important because roughly three-quarters of EPA's research budget supports work conducted outside the Agency (one-half to private contractors and grantees and one-quarter to other federal agencies) (U.S. Congress, House 1975). In OR&D at present, laboratory scientists and engineers monitor the extramural program, preparing Requests for Proposals, reviewing solicited and unsolicited proposals, and guiding work as it progresses. Effective

[4]Phyllis Daly, Office of Planning and Review, OR&D, EPA, personal communication, received October 15, 1976.

[5]OR&D has instituted a procedure for reporting requests for technical services and has indicated a willingness to respond to those requests without transfer of funds provided the total resources used for this purpose do not exceed 10 percent of the OR&D base budget.

monitoring requires time and, however valuable it may be for complementing the work of Agency scientists, competes for attention with their own work. We find deficiencies at each stage of the EPA program for monitoring research, an important cause for which is the assignment of monitoring responsibilities as only one of several duties of research personnel.

The monitoring efforts of a laboratory would be greatly improved by the assignment of special extramural program managers who would monitor extramural research. Program management in NSF is a model that we believe should be emulated by EPA. The most important functions of the manager of extramural research would be to monitor and review extramural research activities and act as a liaison with staff researchers, with higher management in the laboratory, and among laboratories with similar programs. The extramural research manager would be the most logical person to evaluate contractors' performance for use in future selection of contractors.

To implement this recommendation requires the assignment of technically competent people to what is essentially an administrative function, but one that deals directly with scientific and technical issues. We believe, however, that the task we have outlined is not unattractive, especially on a temporary basis for scientists in other offices of EPA or outside the Agency. Both NSF and ERDA, for example, augment permanent staff with extramural scientists temporarily assigned to manage their extramural research programs. These "rotators" are attracted by the opportunity to broaden perspectives in their respective fields and to become acquainted with federal science problems and policies. They bring with them ideas and viewpoints that help keep these federal agencies scientifically alert. Rotators from Program Offices in EPA would tighten the links between the researchers and the potential users of their results, thereby overcoming some of the difficulties encountered when OR&D supervises extramural research performed to fill the needs of Program Offices. Interagency transfers may be used to attract personnel from other federal agencies, and the Intergovernmental Personnel Act to attract personnel from nonfederal institutions. We see no reason why EPA cannot use rotators to supplement its permanent staff in monitoring the extramural research program.

Individuals selected for monitoring positions should be scientifically and technically competent in the disciplines appropriate to the work they are monitoring. They should be familiar with the work and the workers of their field, well informed of the substance of the work that the laboratory is conducting internally, and able to interact with extramural researchers. In addition to responsibilities outlined above, extramural program managers, being responsible for an overview of the extramural work of the laboratory, could serve as liaison between the laboratories and their respective advisory committees (see section on Identifying Research Needs).

For those laboratories that do not have extramural programs large enough to warrant a full-time monitoring position, the monitoring function should be distributed among the laboratory staff (as is the practice at present).

EVALUATING PROGRAMS AND PROJECTS

Projects and programs, as well as proposals, must be reviewed periodically to assure their scientific and technical merit, the relevance of projects to the scientific and technical goals of programs, and the relevance of programs to the Agency's missions. Because the credibility of research performed by or for a regulatory agency is sometimes questioned, EPA must take exceptional measures to assure that its results are scientifically valid.

In particular, it is imperative that the final results of all scientific and technical activities performed by or for EPA be submitted for review and evaluation on the merits by scientific peers both inside and outside the Agency, to provide an independent assessment of the scientific validity of each research project. Usually, reviews are obtained in the course of publication of results in professional journals, but because not all research results are submitted for publication, and in view of the normal time lag when they are submitted, laboratory directors should be responsible for obtaining early, independent reviews of completed research. Such reviews should be submitted to the researchers and retained in Agency files for future reference.

Some alternatives that are available to laboratory directors for obtaining extramural peer review of the work of staff researchers include periodic site visits and reviews by Laboratory Advisory Committees, appointment of ad hoc review teams under the auspices of either the Laboratory Advisory Committees or the Science Advisory Board, or the preparation and publication of annual reports detailing the progress of each project. An example is the work of the Ecology Advisory Committee of the Science Advisory Board in providing a critique of the Agency's ecological research programs (U.S. EPA 1976a).

Evaluating the relevance of projects to programs is a means of checking the effectiveness of the way research is being performed at the laboratory level, while judging the relevance of programs to the Agency's missions is important for assessing how much support the scientific and technical staff gives to the rest of the organization. Current formal review procedures conducted by the Office of Planning and Review in OR&D concentrate on evaluating the responsiveness of programs to Agency strategies, but are not intended to judge the scientific validity of the work.[6]

[6]Phyllis Daly, Office of Planning and Review, OR&D, EPA, personal communication, received October 14, 1976.

5 Transferring the Results of Scientific and Technical Activities

We believe that EPA personnel, in addition to conducting scientific and technical activities in research and development, should be responsible for transferring the relevant information, obtained either intramurally or extramurally, to its potential users. To this end, EPA should continue to open and develop channels of communication with the extramural scientific community both directly and through formal advisory mechanisms.

There is a large and varied clientele for the results of the scientific and technical activities of EPA, both inside and outside the Agency. Among the potential users are policy and regulatory decision makers (in Congress, and in EPA and other federal, regional, state, or local governmental agencies), decision makers in regulated activities, research scientists and engineers, practicing design engineers, special interest groups, and the general public. These clients apply the results of research primarily in regulatory decision making and standard setting, responding to regulations, planning research and monitoring programs, designing process technology, and developing policy and legislative alternatives. The planning and management of EPA's scientific and technical activities must take into account these applications, as well as the potential impediments to the use of research results mentioned below.

EPA's formal program of information transfer does not, at present, cover all these applications; its effort is confined for the most part to technology transfer, which serves to inform practicing engineers of advances in control and measurement technology (Federal Council for

Science and Technology [FCST] 1975). A small effort is also devoted to the preparation of Scientific and Technical Assessment Reports, which collect available data and assess their implications for eventual regulatory action. Though most laboratory directors in EPA encourage the transfer of research results to the scientific community at large through publication in the open scientific literature, dissemination of results is, in practice, generally limited to internal reports which are neither subject to external peer review nor widely distributed outside the Agency. OR&D does, however, publish a quarterly bibliographic summary of all reports published, and this summary is widely distributed.[1] Most of the information transfer within the Agency dealing with regulatory decision making, standard setting, and the planning of scientific programs is informal, and relies on personal communication from members of the technical staff.

We recommend that OR&D reassess the planning and management of its scientific and technical program in the light of the potential applications of results. In particular, all information transfer functions, including those of the Office of Integrated Technical Analysis (see Chapter 2 on Assessment and Integration of Available Information), should be organized under one Deputy Assistant Administrator to give proper recognition to this function and coherence to the program.

APPLICATIONS OF THE RESULTS OF R&D

Each of the primary applications of research described above draws on the results of different types of scientific and technical activities. And in each case the potential users may be different people with differing responsibilities. The problems of information transfer vary accordingly.

FOR REGULATORY DECISION MAKING, STANDARD SETTING, AND ANTICIPATION OF PROBLEMS

Most of the scientific and technical activities described in Chapter 2 and recommended for EPA are aimed at supporting the Agency's decision-making functions by furnishing information directly relevant to regulation and standard setting. The principal clients for this information are the administrative officers of EPA charged with interpreting and implementing legislatively mandated programs. In each case the information is channeled through a formal decision-making sequence, passing

[1]Phyllis Daly, Office of Planning and Review, OR&D, EPA, personal communication, received October 15, 1976.

first through a working group specially appointed to examine the regulatory action or standard under consideration, then through the Agency's Steering Committee, and finally to the Administrator. The results of this process may be the promulgation of a regulation or the setting of a standard. (See the report of the Committee on Environmental Decision Making [NRC 1977a] for a description of the use of scientific and technical information in the decision-making process in EPA.)

The same clients use the results of those scientific and technical studies that are aimed at anticipating future environmental problems. Here, however, the process is less formal, and the result may merely be a decision to keep a particular problem under consideration, or perhaps to conduct further studies.

Other users of the results of research performed for these purposes are decision makers outside EPA who must deal with the same problems. Among these are officers of regional, state, and local governmental bodies and of other federal agencies affected by EPA decisions; regulated parties; and special interest groups. Each class has its own particular uses for the information.

The kinds of information transferred to these decision makers range from estimates of the risks of exposure to specifications of the performance of technology. Even if the decision makers involved were all trained scientists—which they neither are nor are likely to be—they would almost certainly lack the breadth of technical experience needed to judge the validity and applicability of such diverse scientific and technical information. We therefore conclude that scientists, informed and up-to-date in their respective fields, should be responsible for gathering, analyzing, transforming, and transferring the information in a form that can be used by nonexperts.

Furthermore, we conclude that it is not reasonable to expect every scientist and technologist working on environmental problems to be proficient in the complicated task of information transfer to regulatory decision makers. Special talents are required: prime among these is the understanding and appreciation of the use to which the information will be put that comes from experience with the decision-making process itself. Another necessary characteristic is the ability to look beyond one's own technical disciplinary experience, to integrate disciplinary knowledge into a multidisciplinary whole. No one scientist can be expected to integrate the broad range of information, making all the uncertainties explicit, and then transfer that information to decision makers. For this reason, we conclude that information transfer to decision makers should be performed by a multidisciplinary integrated technical analysis group, as recommended in Chapter 2 and described in detail in Chapter 3.

The technical analyses to be performed by this multidisciplinary group will be of interest to others outside EPA, and should therefore be made publicly available. Such publication will not only tend to develop the capabilities of the group through a form of peer review; it will also give the interested public more insight into the Agency's decision-making process (NRC 1975b).

FOR PLANNING SCIENTIFIC AND TECHNICAL PROGRAMS

The results of research, whether the research is conducted by EPA or elsewhere, are also used in planning additional research and monitoring programs. For example, new research needs are often identified in the conduct of a particular study. Results of research are also used in designing monitoring systems since they might indicate the appropriate parameters to monitor, the instruments to use, the frequency and location of measurement, and the characteristics of the data handling system.

Planners of research and monitoring programs necessarily have some technical scientific expertise and therefore should be able to use the results of research directly, without need for an intermediate translation.

Assessments of research and monitoring needs should flow naturally from the kinds of analyses that the Office of Integrated Technical Analysis would perform. Therefore, we recommend that the Office be charged with specifying and assessing research and monitoring needs identified in the conduct of its analyses. The information so provided should supplement information from other sources.

For transfer of research results to potential users outside the Agency for use in planning external research and monitoring activities, EPA should employ the traditional means: publication in widely circulated literature, presentation of papers at professional conferences and meetings, and appropriate use of such information systems as the National Technical Information Service. EPA scientists should be encouraged to publish their work not only to obtain peer review to improve credibility, but also to participate in the normal exchange of results that eventually leads to advances in science and technology. As a means of promoting this exchange, EPA should encourage publication of scientific communications without constraints arising from consideration of Agency policy, i.e., requiring internal review for scientific merit but not for policy approval; technical papers should be identified clearly as the sole responsibility of the author or authors to avoid the interpretation that the reported results imply an official position on their implications for environmental protection policy.

FOR ENGINEERING DESIGN

EPA's research, development, and demonstration of control technology, instrumentation, or monitoring system design are conducted primarily to identify technological options and estimate costs. The results are used by engineers, industry, and public agencies.

EPA has a competent program in Technology Transfer designed to inform practicing engineers of advances in control, process, and monitoring technologies and in quality assurance practices. This program uses a variety of mechanisms to achieve transfer, including manuals and guides, films, seminars, and short courses (FCST 1975). Despite the drawbacks described below (see section on Impediments to the Use of Results), this program seems reasonably effective. It would be even more effective if the research results were to treat economic and other costs more consistently and thoroughly (NRC 1977f).

FOR DEVELOPMENT OF POLICY AND LEGISLATION

The results of research are also used in formulating environmental policy and legislation, although the connection between the scientific and technical work and the policy alternatives is usually much less direct than the relationships between the research program and its other applications. Environmental policy and legislative alternatives are developed not only in EPA, but also in other agencies of the Executive Branch, in Congress, in state and local governments, in regional authorities, and in private institutions. We have, however, also recognized a separate need for research specifically on alternative strategies (see Chapter 2 on Investigation of Alternative Economic, Social, and Legal Strategies for Environmental Management). In view of assertions that EPA may be biased in analyzing alternatives to regulations and standards or to other facets of existing legislation, the findings of such research should be transferred directly to the decision makers concerned.

Nonetheless, within the Agency, the integrated technical analysis group should be helpful to EPA's policy analysts in assessing the scientific and technical aspects of specific proposed policies or legislation. In decision making on policies and legislation, as in decision making on regulations and standards, scientific and technical information does not and need not dictate choices, but choices made should be in concert with scientific and technical understanding of the environment and its processes. Man can establish laws at will, but he cannot successfully enforce legal institutions that are not in accord with the laws of nature.

IMPEDIMENTS TO THE USE OF RESULTS

The transfer of the results of research and development is subject to difficulties, only some of which can be overcome by careful management practices. In this section we describe several of these difficulties, and suggest some ways of dealing with them.

DISPARITIES BETWEEN RESULTS AND NEEDS

Because the focus of a research and development office devoted solely to scientific and technical activities is necessarily different from that of a Program Office whose needs it is intended to fulfill, there is always a danger that research will fail to match those needs precisely. The possibilility of divergence is even greater when a third party, a contractor for example, actually performs the work (Fromm et al. 1975, Caplan et al. 1975). A mismatch can occur because the question for study was not carefully described, because the researchers and the administrators may view the objectives differently, or because the research plan did not sufficiently consider the eventual application. Important management tools for overcoming these difficulties would be the reformed systems for reviewing proposals and for monitoring work in progress described in Chapter 4.

CREDIBILITY

Scientific

The credibility of research results depends on a host of factors, some scientific and some institutional. Among the scientific factors are the reputation of the performer and his research unit, the clarity with which the results are presented, and whether both the research plan and the results have been subjected to review by competent scientific peers. Good management practices can turn these factors to advantage: for example, external peer review and publication not only can improve the quality of work, but also can influence the acceptability of the results to both the technical and nontechnical communities. EPA should also insist that reports of work it performs or sponsors should be clearly written and concise; the harm done by vague and obfuscatory writing should never be underestimated. We urge that the selection of extramural research performers recognize the special contributions that may be made by younger scientists whose research presents evidence of fresh ideas and bold innovation. Finally, EPA should not continue to use extramural research performers who do not have a record of satisfactory performance.

Institutional

The problem of institutional credibility is rooted in the legal structure of environmental legislation and the adversary nature of our legal system. Research performed or commissioned by either party to what is likely to become a legal dispute is generally regarded as suspect, at least by the other party. Unfortunately it is prudent to be aware that self-interest may influence the design, conduct, or reporting of research, whether performed on behalf of the regulated or the regulator. Peer review may be able to overcome some of this tendency, but generally only time and the appearance of substantial corroborating evidence will overcome the lack of credibility of research associated with self-interested parties. To make the verified results of research available for timely use in decision making, schemes need to be devised for obtaining scientific peer review and corroborating evidence more quickly.

BUREAUCRATIC OBSTACLES

Sometimes organizations give more credence to the results of their own work than to that of others. One reason for this is the tendency to feel more secure with familiar work; another is the bureaucratic reaction of defending empires. Both undoubtedly influence the attitudes that sometimes exist among federal agencies that have apparently conflicting missions. Such attitudes can have effects that go beyond those associated with the use of results; they create tensions among agencies and impede cooperation and the coordination of research planning.

LACK OF INCENTIVES

Lack of incentives to adopt results is perhaps the most serious barrier to the transfer of results of EPA research to the private and local government sectors. This barrier is very largely created by the existing legislation. We have already mentioned, in Chapter 1, that that legislation has created almost no incentives for private or local government research into pollution control technologies. By the same token, the system gives these sectors no reason to adopt technologies developed by EPA.

In the area of wastewater treatment technology, for example, several features of current law concentrate nearly all construction activity in well-known secondary treatment processes, even though EPA and its predecessors have worked hard for many years to develop advanced waste treatment systems that offer many advantages. One major disincentive to use of new systems lies in 1977 requirements for municipal wastewater treatment plants, as set out in the Federal Water Pollution Control Act Amendments of 1972 (86 Stat. 845, PL 92-500), which specify secondary treatment as the minimum acceptable level, with more stringent requirements where water quality standards will not otherwise be met. Public Law 92-500 specifies that secondary treatment is to be defined by the Administrator, and EPA has promulgated effluent guidelines based on the performance of established biological treatment processes. EPA appears to be inflexible in administering this section, and newer technologies, which might perform the same functions as the customary secondary treatment processes, are apparently not encouraged in issuing permits and grants. In addition, to the extent that the newer processes have higher operating and lower capital costs than those they are designed to replace, the subsidies themselves discourage innovation, since operating costs are not covered, while a high percentage of capital costs are. These two features of the water pollution management system probably reinforce, as well, conservative tendencies of design engineers themselves, who are comfortable with the established, tested technology and who wish to avoid risks associated with the application of newer processes without long operating records.

The report of the Panel on Sources and Control Techniques furnishes further examples of the disincentives to adoption of new technology in current legislation (NRC 1977f).

CONCLUSION

All of which brings us back to where we started. The environmental research effort, as currently structured and operating, cannot be understood in isolation from the broader framework of existing environmental legislation. Existing institutional arrangements largely determine which sectors of society have incentives to monitor environmental quality, to attempt to anticipate future problems, or to develop techniques for dealing with specific threats. EPA's research efforts cannot, as we have stressed, be fairly evaluated, without taking into account the peculiar mix of politics and science and the dependence on detailed, regulatory responses that have characterized the developing body of environmental policy. By the same token, realistic prescriptions for future research strategies cannot be made without dealing with the question of institutional alternatives. Institutional research, therefore, can be seen to be of central importance.

Some changes in EPA's management of research are desirable to overcome the problem of maintaining credibility in an adversary system. As in any large organization, problems of morale and career rewards exist. Along with these are found tensions unique to research—especially how to reconcile the encouragement of imagination and intellectual daring with the necessity for "relevant" and timely results. Certain areas, especially perhaps the social sciences, have been relatively neglected, at least partly because the laws recognize principally the role of the natural sciences, engineering, and medicine. Useful techniques, such as quantitative regional analysis, have languished, perhaps because no regional institutions have existed to make use of the results (NRC 1977f). Even within the existing system, however, EPA might make a much greater contribution to the long-run amelioration of our problems if it were to take a fresh look at the conceptual basis for its research structure. The view schematically represented by Figure 1.1 has been helpful to many of us, both in our committee deliberations and in our work in private life. Some such overview should, it seems to us, suggest a new and, we hope, a better balance of the research activities of EPA.

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APPENDIX

A Biographical Sketches of Committee Members

JOHN M. NEUHOLD is Professor of Wildlife Management and Director of the Ecology Center at Utah State University, where he received a B.S. (1952), M.S. (1954), and Ph.D. (1959) in fisheries biology. He is expert in the fields of pollution limnology, and primary production and population dynamics in aquatic habitats. Dr. Neuhold is a member of the Ecology Panel of the EPA Science Advisory Board. He was Director of the Institute of Ecology from 1975–1976 and a member of the NRC Review Committee on the Management of EPA's Research and Development Activities.

TIMOTHY ATKESON is a partner in the Washington, D.C. office of the law firm of Steptoe & Johnson. He received a B.A. from Haverford College, was a Rhodes Scholar at Oxford University, and received a J.D. from Yale Law School. He has served as General Counsel to the Asian Development Bank in Manila, as General Counsel to the Council on Environmental Quality in the Executive Office of the President, and as General Counsel to the Office of Technology Assessment of the United States Congress. He has taught environmental law courses at Catholic University Law School and Dartmouth College and serves as a Trustee of the Environmental Law Institute.

BERNARD B. BERGER is Director of the Water Resources Research Center and Professor of Civil Engineering at the University of Massachusetts, Amherst. He received a B.S. in public health engineering from M.I.T. in 1935, and an M.S. in sanitary engineering from Harvard University in 1948. Mr. Berger was with the U.S. Public Health Service from 1941–1966, as Chief of Water Supply and Pollution Control Research at the Robert A. Taft Sanitary Engineering Center from 1954–1963. He served as Water Resources Specialist in the Office of Science and Technology and as Chairman of the Federal Committee on Water Resources Research in 1968–1969.

NORMAN H. BROOKS, an environmental and civil engineer, is James Irvine Professor of Environmental Engineering Science and Director of the Environmental Quality Laboratory at California Institute of Technology. A member of the National Academy of Engineering, his field of technical expertise is hydraulics and hydrological aspects of water resources and water pollution control. Dr. Brooks received an A.B. in mathematics from Harvard College in 1949, an M.S. in civil engineering from Harvard University in 1950, and a Ph.D. in civil engineering from California Institute of Technology in 1954. He has done extensive research at Caltech in the area of hydrologic transport processes, and is a special consultant on the design of ocean outfall systems.

A.W. CASTLEMAN, JR. is Professor of Chemistry at the University of Colorado, Boulder. He is also a Fellow of the Cooperative Institute for Research in Environmental Sciences at the University. Dr. Castleman has the following degrees in chemical engineering: B.Ch.E., 1957, Rensselaer Polytechnic Institute; M.S., 1963 and Ph.D., 1969, Polytechnic Institute of Brooklyn. His specialties are chemical physics, nucleation phenomena, molecular properties of small clusters, kinetics of association reactions, statistical methods of aerocolloidal systems, and aerosol and surface chemistry. Before joining the faculty at the University of Colorado he was Leader of the Atmospheric Chemistry Research Group at the Brookhaven National Laboratory.

GEORGE M. HIDY, an expert in physical chemistry, atmospheric chemistry, fluid dynamics, and air–sea interactions, is Vice President and General Manager of the Western Technical Center, Environmental Research and Technology, Inc. He has received degrees from Columbia University (A.B., 1956; B.S., 1957), Princeton University (M.S.E., 1958), and Johns Hopkins University (D.Eng., chemical engineering, 1962). Dr. Hidy was a Senior Research Fellow in Environmental Engineering, California Institute of Technology, from 1969–1976.

WILLIAM B. HOUSE is the Director of the Biological Sciences Division of the Midwest Research Institute, Kansas City, Missouri. His three degrees from the University of Missouri include a B.S. in agriculture (1941), an M.S. in nutrition (1949), and a Ph.D. in nutrition (1958). Dr. House directs the activities of a 90-worker scientific staff in the fields of physiology, pharmacology, toxicology, biodetection, environmental assessment, medicinal chemistry, immunology, microbiology, virology, and biochemistry.

PAUL KOTIN, Senior Vice-President for Health, Safety, and Environment at the Johns-Mansville Corporation, is a specialist in pathology and environmental medicine. Dr. Kotin received a B.S. from the University of Illinois in 1937 and an M.D. from the University of Illinois Medical School in 1940. While working for the National Cancer Institute, he served as Scientific Director for Etiology from 1964–1966. He was the first Director of the National Institute of Environmental Health Sciences (1969–1971), and Vice-President for Health Sciences and Dean of the School of Medicine at Temple University (1971–1974).

JOHN P. MAHLSTEDE, Professor of Horticulture, is Associate Director of the Agriculture and Home Economics Experiment Station at Iowa State University. Dr. Mahlstede received a B.S. in botany in 1947 from Miami University in Ohio, an M.S. in pomology (1948) and a Ph.D. in ornamental horticulture (1951) from Michigan State University. He is Associate Dean of the College of Agriculture, Iowa State University, and a Fellow and Past President of the American Society for Horticultural Sciences. Dr. Mahlstede was selected as the B.Y. Morrison Memorial Lecturer of the Agricultural Research Service in 1973, and served from 1975–1976 as the Chairman of the Experiment Station Committee on Policy for the National Association of State Universities and Land-Grant Colleges. He is currently chairman of Administrative Advisors IR-4 Project "A National Program for Clearences of Pesticides for Minor or Specialty Uses in Agriculture."

DUNCAN T. PATTEN is Chairman of the Department of Botany and Microbiology at Arizona State University, Tempe. A Professor of Botany, Dr. Patten's field of expertise encompasses mountainous and arid land studies: investigations of communities and ecosystems, physiological ecology of organisms, and man's impacts on arid areas. He received a B.A. in biochemistry from Amherst College in 1956, an M.S. in plant ecology from the University of Massachusetts in 1959, and a Ph.D. in plant ecology from Duke University in 1962. Dr. Patten has worked as a consultant on environmental impacts in arid lands and mountains, and was Co-director of RMER-Quest, a study of environmental problems in the Rocky Mountains.

CLIFFORD S. RUSSELL, a research economist, is Director of the Institutions and Public Decisions Division of Resources for the Future, Inc., Washington, D.C. Dr. Russell received a B.A. in mathematics and economics from Dartmouth College in 1960, and a Ph.D. in economics from Harvard University in 1968. He is a specialist in the fields of applied welfare economics, with emphasis on the costs of pollution control at the plant and regional levels; and social choice, especially public decisions about pollution control. Dr. Russell has been a consultant to the Environmental Directorate of the Organization for European Community Development and is Treasurer of the Board of Trustees and member of the Executive Committee of the Environmental Defense Fund.

RICHARD J. SULLIVAN, of Richard J. Sullivan Associates, Hamilton Square, New Jersey, was formerly Commissioner of the New Jersey Department of Environmental Protection. He also served as a member of the Delaware River Basin Commission and was its chairman from 1970–1971. Mr. Sullivan has been a faculty member at the Center for Environmental Studies, Princeton University, and was Director of the Center for Municipal Studies and Services, Stevens Institute of Technology. He holds the degree of mechanical engineer from Stevens Institute of Technology, an M.A. from Seton Hall University, and an M.P.H. from Columbia University (1955).

APPENDIX B People Interviewed by the Committee

Roy Albert, Deputy Assistant Administrator for Health and Ecological Effects, OR&D, EPA

Alvin L. Alm, Assistant Administrator for Planning and Management, EPA

Alfred F. Bartsch, Director, Environmental Research Laboratory, Corvallis, Oregon, OR&D, EPA

Thomas D. Bath, Executive Director, Science Advisory Board, EPA

Andrew W. Breidenbach, Assistant Administrator for Water and Hazardous Materials, EPA

The Honorable George E. Brown, Jr., M.C., Chairman, Subcommittee on the Environment and the Atmosphere, House Committee on Science and Technology, 94th Congress

Cyril L. Comar, Director, Environmental Assessment Department, Electric Power Research Institute

John Convery, Acting Director, Wastewater Research Division, Municipal Environmental Research Laboratory, Cincinnati, Ohio, EPA

Donald E. Crabill, Deputy Associate Director for Natural Resources, Office of Management and Budget

Phyllis A. Daly, Director, Office of Planning and Review, OR&D, EPA

The Honorable Marvin L. Esch, M.C., Ranking Minority Member, Subcommittee on the Environment and the Atmosphere, House Committee on Science and Technology, 94th Congress

John F. Finklea, Director, National Institute of Occupational Safety and Health

Stephen J. Gage, Deputy Assistant Administrator for Energy, Minerals, and Industry, OR&D, EPA

Isaiah Gellman, Technical Director, National Council (of the Paper Industry) for Air and Stream Improvement

Carl R. Gerber, Associate Assistant Administrator for Research and Development, EPA

John V.N. Granger, Executive Secretary, Federal Council for Science and Technology

Stanley M. Greenfield, Formerly Assistant Administrator for Research and Monitoring, EPA

John Knelson, Director, Health Effects Research Laboratory, Research Triangle Park, North Carolina, OR&D, EPA

James L. Liverman, Assistant Administrator for Environment and Safety, Energy Research and Development Administration

Hugh F. Loweth, Deputy Associate Director for Science, Space and Energy, Office of Management and Budget

John Moran, Monitoring Technology Division, Office of Monitoring and Technical Support, OR&D, EPA

Warren R. Muir, Senior staff member, Council on Environmental Quality

Thomas A. Murphy, Deputy Assistant Administrator for Air, Land, and Water Use, OR&D, EPA

The Honorable Russell W. Peterson, Chairman, Council on Environmental Quality

Frank Princiotta, Director, Energy Processes Division, Office of Energy, Minerals, and Industry, OR&D, EPA

John R. Quarles, Deputy Administrator, EPA

David P. Rall, Director, National Institute of Environmental Health Sciences

W. Randall Shobe, Director, Technical Information Division, Office of Monitoring and Technical Support, OR&D, EPA

Glenn R. Schleede, Assistant Director, Domestic Council, Executive Office of the President

David G. Stephan, Director, Industrial Environmental Research Laboratory, Cincinnati, Ohio, OR&D, EPA

Roger Strelow, Assistant Administrator for Air and Waste Management, EPA

Wilson K. Talley, Assistant Administrator for Research and Development, EPA

James Tozzi, Assistant Division Chief for Environmental Programs, Natural Resources, Office of Management and Budget

Albert C. Trakowski, Deputy Assistant Administrator for Monitoring and Technical Support, EPA

David J. Ward, Associate Coordinator of Environmental Quality Activities, Office of Research Planning and Coordination, U.S. Department of Agriculture

APPENDIX C

Report of the Review Commiteee on the Management of EPA's Research and Development Activities

August 27, 1974

Mr. Russell E. Train, Administrator
Environmental Protection Agency
Washington, D.C.

Dear Mr. Train:

This letter is in response to your request of May 31, 1974 that the National Academy of Sciences provide advisory assistance on the management of EPA's Office of Research and Development. Your request posed the following specific questions:

1. What are the mechanisms for establishing research and development priorities that are responsive to program goals?
2. What are the best organizational arrangements to accomplish EPA's goals most effectively and efficiently?
3. What are the most effective mechanisms to assure high quality research and development? What is the best mix between inhouse and contract efforts? What interaction is necessary with outside groups to assure continued scrutiny of the quality of EPA's research and development program?

The Commission on Natural Resources within the National Research Council was assigned responsibility for the study. The Commission assembled experienced research administrators and environmental scientists as a Review Committee on the Management of EPA's Research and Development Activities to conduct the study. The members were: Robert W. Berliner (Chairman), Yale University School of Medicine; Ivan L. Bennett, New York University Medical Center; Hendrick W. Bode, Harvard University; Ralph E. Gomory, International Business Machines Corporation; Milton Harris, retired; John Neuhold, Utah State University. William Robertson IV provided staff assistance.

The opportunity afforded by the appointment of a new Assistant Administrator for the Office of Research and Development governs the timeliness of the inquiry. We agreed to proceed as rapidly as possible to address the first two questions, recognizing that the hazards of recommendations based on a limited study must be balanced against the value of advice available at a time when it can be useful. We understood that the third question could be delayed for a time.

We did not investigate and therefore have no basis for questioning the quality of the scientific work that the Agency has performed or the validity of EPA research results.

Our review did not deal with the performance of the people involved in the research and development effort. This report should not be construed as critical of the work of the many dedicated and competent scientists within the Agency.

Extensive background materials provided by the Agency and assembled by Committee staff were examined and evaluated by the Committee. A briefing meeting was conducted by the Agency during which descriptive background presentations were made by senior officials. The Committee had an opportunity to discuss operations candidly on an individual basis with Office of Research and Development personnel. Views from a number of scientists within the organization were also obtained.

The Committee circulated and discussed tentative findings and recommendations based on the materials and information available to it. The group then met to develop a set of draft findings and recommendations and discuss them with the Commission on Natural Resources. These were communicated to you and your associates at Woods Hole on August 27. Subsequently, this report has been reviewed in accordance with Academy procedures and now stands as an official response.

This statement of the Committee represents the group's judgment of those areas where prompt action can and should be taken and where the needed action is clear. In addition, areas where more investigation is needed are identified.

The questions for the Review Committee had to be narrowly specified on the basis of the appropriate role for the National Research Council and the urgency of the Agency's request. Although the members of the Committee bring their experience and judgment to their deliberations, they were not familiar with the actual internal workings of the Agency and no reasonable amount of briefing could equip the panel to advise on details of future operations. The project was clearly limited to an immediate effort to assist the Agency at an important time. Continued research and development management advice should be arranged for from a panel directly responsible to the Administrator and not under National Research Council auspices. An item for early consideration should be a thorough investigation of the National Environmental Research Centers. This could be accomplished through the Agency's Science Advisory Board. If this approach is adopted a special task group of that Board with extensive successful management experience with large scale research and development organizations would be required.

FINDINGS

The present Office of Research and Development planning and management system fails to meet the need of the Agency. We refer to procedures outlined in the "ORD Program Planning and Reporting Manual" which are not a satisfactory base for management and must be abandoned. We recognize that the establishment of a successful research and development organization takes time. We believe, however, that the present system has started in a wrong direction and that a fresh start is needed.

The reasons for failure fall into two main categories:

1. The nature of the system itself.

a. Planning is separated from responsibility for execution, leading to severe resentment among performing researchers. The assignment of responsibility for specific actions and decisions is difficult.

b. Priorities do not reflect the needs of regulatory offices and regional offices because of the "vacuum cleaner" approach to soliciting ideas, and the system-induced barriers to using common sense in the selection process (see pp 1-18, "ORD Program Planning and Reporting Manual").

c. Inadequate attention has been paid to the possibility for trade-offs, or modifications in budgeted costs, among various projects. This has aided in the development of a situation where there is only a series of discrete projects and no Agency program. This situation is further aggravated by the absence of long-term (3–5-year) planning.

d. The complexity of the system makes it counter-productive. The large amount of paperwork and excessive bureaucratic review is a wasteful consumption of time and energy. The needs of the Agency are complex; however, this does not change—but rather heightens—the need for a simple and understandable planning and reporting system clearly directed by the Assistant Administrator and in which field personnel have a real participatory input.

e. Accountability is made impossible by the parallel but separate management systems—some for housekeeping and the others for program content—and by the hopelessly complex Program Area Manager-Program Element Director-Program Assessment Group-Strategies system which obfuscates management responsibility.

f. Excessive requirements for detail at all planning levels lead to an oversized headquarters staff and to the stifling of innovation in the laboratory.

g. The existing management structure does not allow for the corrective feedback and flexibility which are essential to any successful research and development program.

h. A long-term program designed to meet stated goals is missing and this is vital for any scientific venture.

i. A false sense of control is generated by the highly structured mechanism for planning.

j. Relationships between the headquarters and field are strained at best; a state of frustration in the field staff is apparent.

2. External constraints, as perceived by the Office of Research and Development and communicated to the Review Committee.

a. Enabling legislation is noncoherent and mandates a set of unbalanced and uncoordinated research objectives and timetables.

b. The lack of an integrated approach to environmental pollution control in the Agency as a whole makes an integrated research and development program very difficult to form.

c. Civil Service rules, parochial political pressures, and human nature combine as barriers to the simplification, assembly into "critical masses," and logical organization of the research units which were inherited by EPA when it was created.

d. A level budget (except for the energy "roller coaster" of FY 74, 75, 76) prevents transitions which would be possible in a steady growth situation. An internal "roller coaster" budget appears to be particularly disruptive to individual projects.

The Review Committee finds that although many of the external constraints on the Office of Research and Development are significant, the faults of the planning and management system are the dominant reasons for failure. Thus, it is reasonable to expect that the Agency can look forward to a satisfactory research and development arm by adopting changes in the system. At the same time, efforts should begin to ameliorate some of the external constraints which are amenable to improvement.

RECOMMENDATIONS

1. The Environmental Research Objective Statement-Research Objective Achievement Plan-Program Area Manager-Program Element Director-Program Assessment Group-system should be abolished. Responsibility for carrying out a program designed to meet the goals of the Office of Research and Development should be delegated directly to the National Environmental Research Center directors. Resources of manpower and money should be allocated directly to each National Environmental Research Center.

2. The line reporting within the Office of Research and Development should be from the National Environmental Research Center directors to the Assistant Administrator. The Assistant Administrator should have a small staff to perform only staff functions and not to serve as a filter or layer through which the National Environmental Research Center directors report. This should develop into a simple pyramidal management system through which all direction, supervision, and evaluation is accomplished. This would, in effect, eliminate all layers or parallel management plans and result in a clear chain of authority from the individual researchers to the Assistant Administrator for Research and Development. The pyramid should decentralize quickly from Washington Headquarters to major field units. The Headquarter's staff should be trimmed appropriately and those necessary for "Washington liaison" activities clearly labeled. We did not have sufficient time to evaluate the role and position of the Washington Environmental Research Center. Such an evaluation should be made.

Because of the recent formation of the Agency by coalescence of disparate portions of other agencies, a particular need for intra-agency communication exists. To this end, a planned continuing rotation of field personnel into and back from a small Headquarters staff unit and between other units should be carried out. Short term, non-government talent should also be worked into this rotation system.

3. The function of the Assistant Administrator for Research and Development should be to assemble, analyze, and clearly define Agency research and development needs and objectives with the participation of

the other Assistant Administrators and the National Environmental Research Center directors, subject to approval of the Administrator.

The Assistant Administrator should use participatory discussions with National Environmental Research Center directors as the mechanism to develop goals, programs, and priorities. He should allocate objectives and the resources for their accomplishment to the National Environmental Research Centers. Once allocation is decided upon, the performer of the research or development should be linked directly to the user of the projected output for information exchange.

A performance evaluation system should be set up to include continued inputs from users, and outside visiting committees reporting at a high level should be regularly employed. The system of visiting committees employed by the National Bureau of Standards should be studied for applicability.

A plan for a 3–5-year period to be revised at least annually should be developed.

4. Not only the changing nature of environmental problems but also the exigencies of the economy, suggest that it would be inadvisable to build up a large permanent staff. Rather, maintaining the necessary competence to monitor grant and contract work as needed would appear to be a prudent course.

A careful review of the contract and grant procedures should be undertaken.

The Review Committee wishes to express its appreciation for the cooperation of many EPA personnel, particularly Alvin L. Alm and David L. Jackson.

Sincerely,

GORDON J.F. MACDONALD, *Chairman*
Commission on Natural Resources

ROBERT W. BERLINER, *Chairman*
Chairman
Ivan L. Bennett
Henrick W. Bode
Ralph E. Gomory
Milton Harris
John Neuhold