EPA/600/R-93/038
February 1993

Report to Congress

Fundamental and Applied Research At The Environmental Protection Agency

Office of Research and Development
U.S. Environmental Protection Agency
Washington, D.C. 20460

Preface

In its FY 1993 House Appropriations Report, the Conference Committee requested a review of the amount of basic and applied research being conducted by EPA.

> "The Committee recognizes the need for both basic and applied environmental research. The Committee believes that, for a number of reasons, EPA has failed to sufficiently address the issue of basic research. Due to the large number of regulatory and statutory mandates, the Agency has focused on short-term applied research. Basic research can be used to identify and assess environmental problems which pose the greatest risk to human health and the environment. The Committee urges the Agency to review both its basic and applied research activities and directs EPA to submit a report outlining the expenditures to date and future proposed budgets for its basic and applied research activities."

Indeed, the difficulty for EPA as well as for other regulatory agencies has been meeting the needs of many research clients. EPA's research program must strike a balance between providing data and technical support for "front-line" regulators solving environmental problems *today* and building a science knowledge base necessary to manage our ecological resources wisely in the coming decades; understand how pollutants affect our health; and prevent or reduce environmental risks in the future.

This report does not attempt to determine whether EPA is doing enough basic research, but rather it contributes to the body of data that is being gathered by Congress to evaluate current Federal science research policy in general, and environmental science policy in particular.

In response to the Congressional request, this report describes the research program of EPA's science arm, the Office of Research and Development (ORD), using FY1993 expenditures. Research projects have been classified by ORD's senior managers according to the terms *fundamental, application directed, demonstration,* and *technical assistance*. The distinctions between fundamental and applied research are often blurred; it is difficult to uniquely classify many research projects. Therefore, the percentages and classifications in this report are more qualitative than quantitative. The data profile the general magnitude of the different types of research being conducted by ORD today.

Contents

Executive Summary

The FY 1993 Appropriations Bill directs EPA to review its basic and applied research activities and to submit a report outlining expenditures to date and future proposed budgets for these research classifications. The Conference Committee Report states, "The Committee believes that, for a number of reasons, EPA has failed to sufficiently address the issue of basic research. Due to the large number of regulatory and statutory mandates, the Agency has focused on short-term applied research. Basic research can be used to identify and assess environmental problems which pose the greatest risk to human health and the environment."

This report classifies research projects as one of the following four types: fundamental research; application directed research; development; and technical assistance. (See page 3 for definitions of these categories.) The term "fundamental research" is used instead of "basic research." Basic research, as commonly defined, is conducted to attain knowledge *without applications towards specific processes or products in mind.* Because ORD's research always has a mission-directed purpose, its work does not fit the traditional definition of basic research.

In FY 1993, a total of $506 million and 1922 full-time equivalents (FTEs) will be devoted to research and development activities within the Office of Research and Development (ORD). These totals reflect ORD's FY1993 Operating Plan prior to the overall reduction in Federal workyears directed by the President. This includes $335 million for extramural research and $171.5 million for intramural expenses. The intramural portion of the budget covers salaries, benefits, and equipment. The extramural portion of the budget covers research funded through contracts, grants, or cooperative agreements. This report provides information on the classification of extramural dollars and in-house (FTEs) resources.

During FY 1993, ORD has allocated $96 million and 494 FTEs for fundamental research, $144 million and 847 FTEs for application directed research, $64 million and 303 FTEs for development activities, and $31 million and 279 FTEs for technical assistance. The largest portion of FY 1993 resources is allocated to application directed research (approximately 43%). Fundamental research accounts for approximately 29%—development, 19%—and technical assistance, 9%. Research exists on a continuum from very basic research to applied research and development, and therefore, some research projects have characteristics of both fundamental and application directed research. Consequently, the above percentages should not be viewed as precise, but rather as estimates of the types of research conducted.

The report concludes that the overall balance of research and development, when distributed over the spectrum from basic to application directed research is the result of competing demands placed on ORD. While budget and program design for fundamental research have increased over the past few years, a significant portion of ORD's budget directly responds to the needs of EPA national programs for developing environmental policies and regulations, the needs of the private sector for technology evaluation, and the needs of State and local governments for technical assistance.

Section 1
Background

Congressional Requirement

The FY 1993 Appropriations Bill directs EPA to review its basic and applied research activities and to submit a report outlining expenditures to date and future proposed budgets for these research classifications. The Conference Committee Report states, "The Committee believes that, for a number of reasons, EPA has failed to sufficiently address the issue of basic research. Due to the large number of regulatory and statutory mandates, the Agency has focused on short-term applied research. Basic research can be used to identify and assess environmental problems which pose the greatest risk to human health and the environment."

The research at EPA is largely performed at laboratories that are part of the Office of Research and Development (ORD). The ORD organizational structure, described in a companion report,[1] includes 12 research laboratories that are organized around scientific disciplines. This organizational approach is typical of most research institutions. It ensures that a sufficient number of scientists and engineers work together to achieve a depth of knowledge in the discipline. It also allows substantial interactions to occur between scientists and engineers in related fields of study. The laboratories will always have this discipline-oriented structure.

New Research Classification Definitions

Fundamental Research: theoretical or experimental investigations to advance scientific knowledge where such knowledge is relevant to understanding pollution, the environment or human health, but immediate practical application is not a direct objective.

Examples include: Mechanisms of chemical carcinogenesis; how ecosystems function; biosensors for pollution monitoring; the use of computers and theoretical understanding to predict a chemical's fate in the environment; understanding and quantifying the reactions that determine the persistence of organic chemicals; pharmacokinetics; mechanisms of bioavailability; clinical and animal studies of the mechanisms of toxicity.

Application Directed Research: research directed to the solution of defined problems, based on existing scientific understanding; the solutions may involve the creation of new processes, procedures, methodologies, or situations that will serve a practical or utilitarian purpose.

Examples include: Construction of pollutant fate models; lab-scale characterization of pollutant degradation processes; formulation of ecological risk assessment frameworks; integration and evaluation of information on pollutant effects and exposure to estimate risks to human populations or ecosystems; creation of new monitoring or measurement methods.

Development: the work required to bring a new process, technique, methodology, or piece of equipment to the production or application stage.

Examples include: Field calibration and testing of models that predict movement of chemical concentrations in the environment; field validation of monitoring methods; pilot/field optimization of sediment and aquifer remediation processes; pilot-scale optimization of control technologies.

Technical Assistance: the application of specialized technical knowledge or services to assist others in accomplishing their mission.

Examples include: Quality assurance/quality control; demonstration of technology or assessment methodology at specific sites; site monitoring; experimental design; expert/peer review and comment; workshops and seminars; expert testimony.

For the purposes of this report, the term "fundamental research" should be equated with the term "basic research" and the term "application directed research" with

[1] U.S. EPA Office of Research and Development, *EPA Organization for Environmental Research: The Third Decade*, Jan. 1993. There are six non-ORD laboratories that provide analytical support to EPA's program offices, and therefore, are not included in the data on fundamental and applied research. A brief description of each of the program office laboratories may be found in the ORD organization report on page 19.

"applied research." The term "fundamental research" is used in lieu of "basic research" because EPA does not conduct "basic research" as that term is generally defined. Basic research is commonly defined as research to attain greater knowledge *without applications towards specific processes or products in mind.* Because ORD research always has a mission-directed or application-specific purpose, it does not fall within the traditional definition of basic research. The term "fundamental research" is therefore used as the classification for the most rudimentary scientific investigations conducted by ORD. Fundamental research will often result in the attainment of knowledge that has application in many EPA environmental programs, and is not directed or formulated to meet shorter-term regulatory needs or narrowly defined program questions.

"Application directed research" includes many research projects that are designed to meet specific regulatory or policy goals. It also includes research, such as the improvement of risk assessment methodologies, that has broad application among EPA regulatory programs and is not driven by short-term regulatory needs. For this reason, application directed research should not be viewed as synonymous with short-term program support.

Development and technical assistance are included to complete the picture of ORD's scientific efforts. They are important components of the Agency's research program in that they provide a link between the knowledge and potential solutions gained through fundamental and application directed research and the societal benefits from such research.

Many research projects have elements of both fundamental and application directed research. For example, to improve a model that will predict the fate and transport of toxic chemicals in the environment, research on basic biological or chemical mechanisms may be conducted. In this sense, the research is fundamental, as it addresses basic mechanisms of action. At the same time, this research may be viewed as application directed because it solves a defined problem. In a similar vein, many research projects logically start out as fundamental and evolve into application directed, then development and finally to technical assistance. The transitions often are not marked by bright lines, but rather by incremental changes in the overall mix of the type of research being conducted under the research project. For these reasons, it is difficult to uniquely classify many research projects. Consequently, the classification data in this report are not precise percentages but more qualitative, indicating the general magnitude of the different types of research being conducted.

Section 2
Organization of ORD Research

Research Implementation

Since the research at EPA is largely performed in the 12 research laboratories of ORD, it is worthwhile to examine the structure of these laboratories and what these new research classifications mean from the research implementation viewpoint.

The laboratories, in general, are discipline-oriented. There are two engineering laboratories that employ principally engineers. The monitoring laboratories are staffed principally with chemists and physicists. Transport and fate laboratories utilize meteorologists, hydrologists, geologists, chemists, and physicists. Health and ecology laboratories are staffed principally with biologists. There are, of course, other disciplines in these laboratories, such as statisticians, computer systems analysts, medical doctors, geographers, etc., that provide other skills to complement the principal ones. Over the last two decades, it has been the staffing practice of these laboratories to ensure that there were sufficient numbers of scientists/engineers of similar training and/or experience to form the critical masses needed to perform the research in the areas mandated to the laboratory. Thus, in each laboratory, there are a number of groups of researchers who maintain a certain depth and breadth of expertise and who cover one of the several areas of the scientific discipline of the laboratory.

Within a laboratory, the scientists/engineers fall into another type of classification, depending on the manner in which they conduct the research. This classification includes five groupings: bench researcher; field and pilot plant researcher; national expert; contract project officer; or collaborating project officer on cooperative agreements.

Laboratories have different mixes of each of these groupings, depending on the research they are conducting and the facilities available. In addition, some scientists/engineers apportion their time to more than one of these groupings, as laboratory workload may demand.

All five groupings of scientists/engineers are capable of performing fundamental research, application directed research, development and technical assistance. However, it is clear that more of the fundamental research is performed by the bench and field researchers and the collaborating project officers on cooperative agreements. Similarly, more development and technical assistance activities are performed by contract project officers and national experts.

This report focuses on a new classification of the research program into four different types of research — fundamental research, application directed research, development, and technical assistance—which are defined in the previous section. The ORD FY 1993 planned expenditures are subdivided into these types.

The report also describes ORD's multidisciplinary research planning process, which is organized around environmental problems and key science questions, and also is used to characterize ORD's overall research activities. Research plans cut across the laboratory structure, and guide the specific research activities at each laboratory. This new planning process ensures strong links across disciplinary line organizations (i.e., ecology, health effects, transport and fate of chemicals, pollutant characterization, engineering, risk assessment, and monitoring).

The Evolution of ORD Research Planning

In the report, *Future Risk: Research Strategies for the 1990s,* September 1988, the Science Advisory Board (SAB) called research "the most fundamental of the tools that promote environmental quality." It recommended that EPA "reshape its strategy for addressing environmental problems for the next decade and beyond" and "plan, implement, and sustain a long-term research program" to support this new strategy. Based on this recommendation, in 1990, ORD began to rethink its research planning and execution as later sections of this report will show.

Recently, there has been a convergence of thinking about the directions science should take in EPA. Two reports, one issued by the Agency's SAB and one by an Expert Panel on the Role of Science at EPA, have

emphasized the importance of the role of science in EPA.[2] Both of these reports recognize science as the foundation for credible environmental decision making. While all parts of EPA continually strive to strengthen the scientific basis for environmental decision making and assessment, ORD, as the research leader in EPA, has the major responsibility.

Seven strategic goals[3] are now providing the long-term future directions for the ORD program:

- *Forge a center of scientific excellence.* ORD will expand its role as a nationally and internationally recognized center of scientific excellence.
- *Ensure that the research program reflects the highest risk areas.* ORD will improve its technical and scientific support for the Regions and national programs that implement statutory mandates to provide the most significant risk reduction.
- *Improve methods for determining relative risks.* Consistent and high-quality risk assessment methodologies will be developed and used for setting priorities for national environmental policy, as well as for controlling exposure to individual pollutants. ORD's risk assessment research will continuously improve the science and knowledge base needed for reducing the uncertainty associated with risk assessments.
- *Place greater emphasis on ecological research and ecological risk assessment.* Currently, we understand relatively little about how pollution affects complex ecosystems over time. ORD's Environmental Monitoring and Assessment Program (EMAP) is gathering information on the nation's ecological condition. This information, our "national ecological report card," is critical for the Agency's efforts of focusing its risk reduction projects on a geographic basis.
- *Examine innovative approaches to risk reduction, both for pollution prevention and pollution control.* Research in this area will improve our understanding of the fundamental mechanisms of pollution control, develop innovative control technologies, and continue ORD's critical support for the Agency's pollution prevention program.
- *Provide information to all segments of society.* As part of the Agency's strategy of education and outreach, ORD will continue sharing technical and research information with all segments of society, including industry, academia, states and local communities, the general public, and other countries.
- *Collaborate with other Federal agencies, industry, academia, and other countries.* In order to use resources most effectively and take advantage of outside expertise, ORD will expand its cooperative research with other research organizations.

Issue-Based Research Planning

To meet these strategic goals, and to improve the ineffective media-based process, ORD has instituted a research planning approach that is organized around environmental problem areas. This approach is designed to more fully address cross-media issues, anticipate future environmental problems, provide continuity for studying particularly difficult environmental problems, and deal with risk-based priorities. At the same time, the new planning approach allows ORD to continue to conduct research on regulatory priorities that are often short-term in nature but crucial to successful implementation of the EPA regulatory programs.

The ORD research program is divided into 38 research issues and grouped by 12 theme areas (see Table 1). Many of the research issues focus on the knowledge gaps identified in ORD's strategic goals - ecological risk assessment methods, environmental monitoring and assessment, human health risk assessment, pollution prevention, and innovative technologies. Other research issues address needs of the regulatory programs, cross-cutting scientific issues, and laboratory infrastructure.

During 1991, research strategies were prepared for each research issue. The issue strategies provide a brief overview of the basic problem to be addressed by the research, strategic goals for the research, status of current efforts, and research topics to be addressed. The issue strategies cover all classifications of research for the issue and together describe EPA's research agenda.

The strategies have guided development of more detailed five-year "research plans." These plans include: detailed descriptions of the scientific questions needing research; the specific areas in which EPA will conduct research; products and schedules; and technology transfer activities. Drafts of the research plans are being completed, and will be widely reviewed within the Agency, by the SAB, and will also undergo review by the broader scientific community.

Historical Perspective on Resources

In addition to the evolution of how research is planned, there have been significant changes in funding levels dictated by changes in policies and environmental priorities. As discussed in the conclusion section of this report, these changes have played a role in the nature of the types of research conducted by ORD.

---

[2] U.S. EPA, Science Advisory Board, *Reducing Risk: Setting Priorities and Strategies for Environmental Protection* (Sept. 1990); and U.S. EPA, *Safeguarding the Future: Credible Science, Credible Decisions* (March 1992).

[3] Office of Research and Development, *Four-Year Strategic Research Plan* (Draft, Nov. 1990)

Over the past decade, the extramural research program has been increasing steadily after reaching a low point in 1983 (see Figure 1—note that figures are in nominal, not constant, dollars). During that time, major areas of growth included the Multimedia and Hazardous Waste programs, and in the past few years, the Air and Radiation, Environmental Monitoring and Assessment, and Global Climate programs. The Multimedia program included exploratory grants, ecological risk assessment, health risk assessment, and pollution prevention. Hazardous Waste research increased significantly following the passage of the Superfund amendments of 1986. The Clean Air Act Amendments of 1990 included many research requirements, and EPA responded with a major increase in Air and Radiation research. On the other hand, Energy research, which was the largest extramural program in 1980, was gradually phased down, and is now a relatively small program that includes research on acid deposition monitoring, modeling, and control technologies.

Table 1. *ORD Research Themes and Issues*

Protecting Ecological Systems

Ecosystems
- Coastal and marine
- Large lakes and rivers
- Wetlands
- Terrestrial systems

Assessments
- Contaminated sediments
- Aquatic ecocriteria
- Nonpoint sources
- Ecorisk assessment methods

Emerging Ecological Issues
- Habitat/Biodiversity
- Environmental releases of biotechnology products

Environmental Monitoring and Assessment
- Environmental Monitoring and Assessment Program

Global Change
- Global warming
- Stratospheric ozone depletion

Air Pollution
- Acid deposition/aerosols
- Air toxics
- Criteria air pollutants
- Pollutants from motor vehicles
- Indoor air pollution

Drinking Water Contamination
- Drinking water pollutants and disinfection
- Groundwater

Waste Management
- Municipal solid waste
- Hazardous waste
- Sludge and wastewater

Environmental Clean-up
- Surface clean-up
- Bioremediation

Human Health Risk Assessment
- Human exposure
- Health effects
- Risk assessment methods

Innovative Technology and Outreach
- Pollution prevention
- Innovative technologies
- Environmental education
- International and national technology transfer

Exploratory Research and Special Environmental Problems
- Environmental review of new chemicals
- Lead and other heavy metals
- Anticipatory research on emerging environmental problems
- Exploratory grants & centers

Infrastructure
- Infrastructure

Cross Program
- Cross program

After a decline in FTEs in the early 1980's, the number of FTEs in ORD has remained fairly stable since 1985. However, there have been some shifts of FTEs between research areas. The number of FTEs involved in Water and Energy research has declined substantially, allowing for an increase in other areas, primarily the Hazardous Waste and Multimedia programs. The FTEs in the Air and Radiation, and Pesticides and Toxics research programs have remained fairly constant.

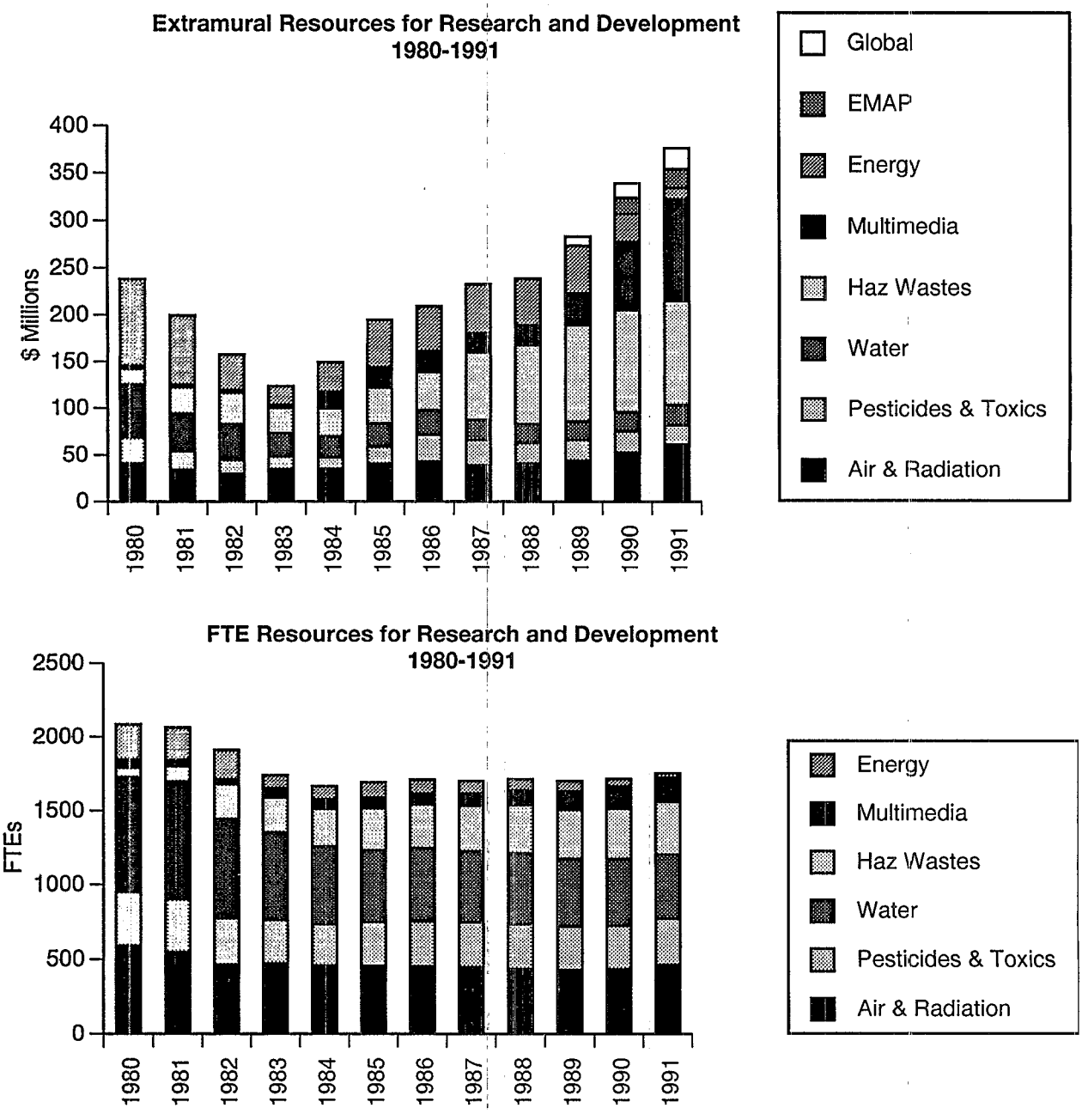


Figure 1. *Resource trends*

Section 3
Classification of EPA Research

Resources

This section provides data concerning the balance of fundamental research, application directed research, development, and technical assistance within ORD. The data are based on the FY 1993 budget enacted by Congress. Data on extramural and in-house resources are provided separately. [4]

In addition to an overall program presentation, data concerning the balance of the different types of research are presented from two other points of view—by research themes and issues and by EPA national program offices (air, water, waste, toxic substances). This approach allows individuals with different interests to view the balance of research in the context that best suits their needs.

Total Research

In FY 1993, a total of $506 million and 1922 FTEs will be devoted to research and development activities within ORD. This includes $335 million for extramural research and $171.5 million for intramural expenses. The intramural portion of the budget covers salaries, benefits, and equipment. The extramural portion of the budget covers research funded through contracts, grants, or cooperative agreements.

This report provides information on the types of research being conducted by in-house researchers (1922 FTEs) and extramural research dollars ($335 million). During FY 1993, ORD, has allocated $96 million and 494 FTEs for fundamental research, $144 million and 847 FTEs for application directed research, $64 million and 303 FTEs for development activities, and $30 million and 279 FTEs for technical assistance.

Figure 2 shows the distribution of extramural resources and in-house resources (FTEs) within the four research classifications discussed in this report. The largest portion of both extramural and in-house resources is allocated to application directed research. Application directed research is organized to support EPA programs and policy formulation. This support includes a wide variety of research products, including monitoring and measurement methods, assessment methodologies and models, technology advancement and evaluations, and risk assessments.

Fundamental research accounts for approximately 30% and 26% of extramural and in-house resources, respectively. This research focuses on more basic scientific inquiries to improve our understanding of mechanisms that cause adverse effects to human health and the environment and the functioning of biological systems. Fundamental research at EPA is directed at specific questions, such as the mechanisms of toxicity of tropospheric ozone, or at broader questions, such as methods to determine priorities for habitat and biodiversity protection.

Development research accounts for approximately 19% of FY 1993 resources. Development research generally focuses on the later stages of refining a process, technology, or method. Development activities often support the overall goal of EPA programs by providing the tools necessary to implement regulatory programs.

Technical assistance accounts for 9% and 14% of extramural and in-house resources, respectively. Technical assistance is provided in many forms, including formal training courses and seminars, technical publications, on-site assistance, and response to requests for specific analyses or information.

Research Themes and Issues

ORD plans research under 38 issues. For simplification, these have been grouped into 12 broad themes. Figure 3 illustrates the allocation of total extramural and in-house resources (FTEs) among the 12 themes. Figure 3a illustrates the distribution of the types of research among the 12 themes.

Fundamental

As shown in Figure 3a, Air Pollution, Exploratory Researach and Special Environmental Problems, EMAP, Global Change, and Human Health Risk Assessment

[4] The classifications of different types of research are based on the judgment of senior ORD scientists and managers responsible for planning and implementing the Agency's research program.

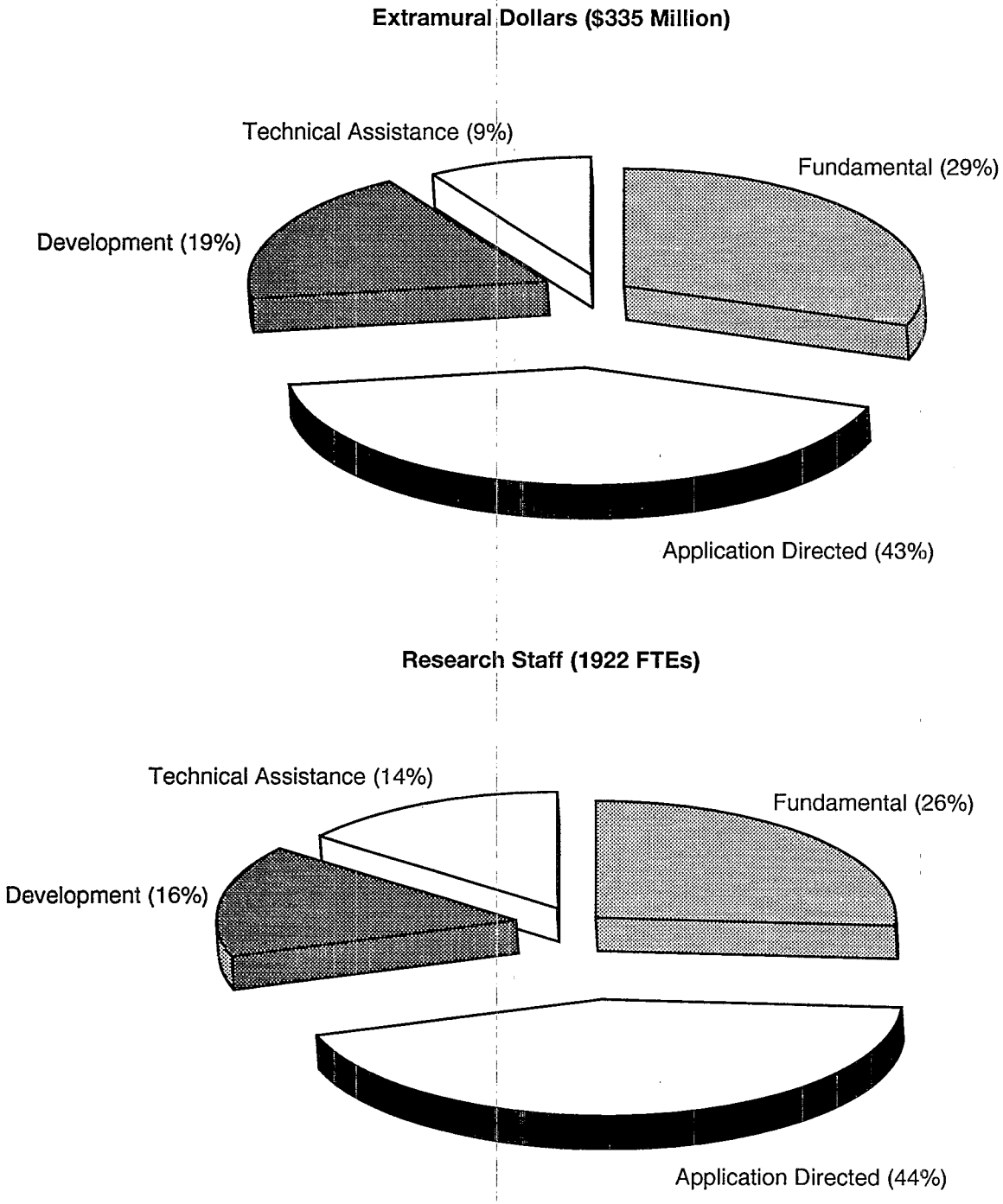


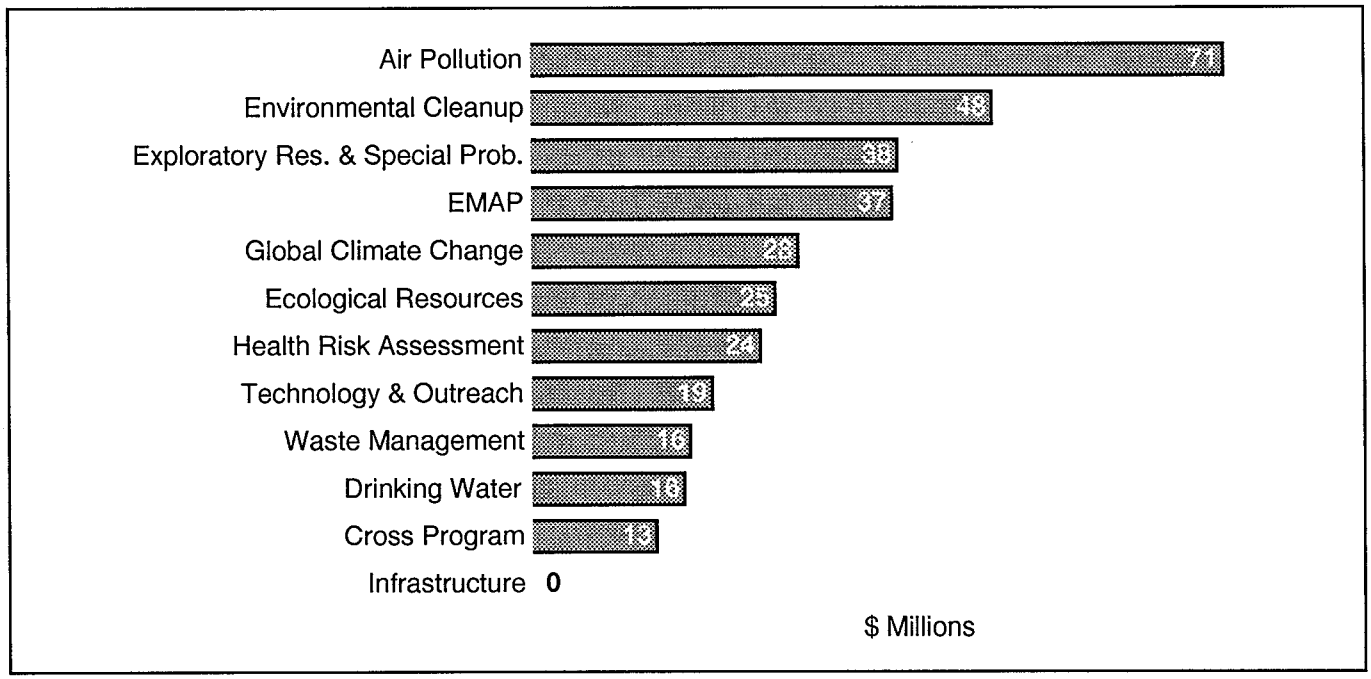
Figure 2. *Classification of ORD research extramural resources and in-house staff*

account for $80 million or 84% of all fundamental research. These research themes also have the highest percentages of resources devoted to fundamental research, ranging from 59% of the Exploratory Research and Special Environmental Problems theme to 29% of the EMAP theme.

Application Directed Research

Application directed research is not as concentrated within a select group of research themes as fundamental research. The Air Pollution, Environmental Cleanup, EMAP, Protecting Ecological Resources, and Exploratory Research and Special Environmental Problems

Extramural Dollars ($335 Million)



Research Staff (1922 FTEs)

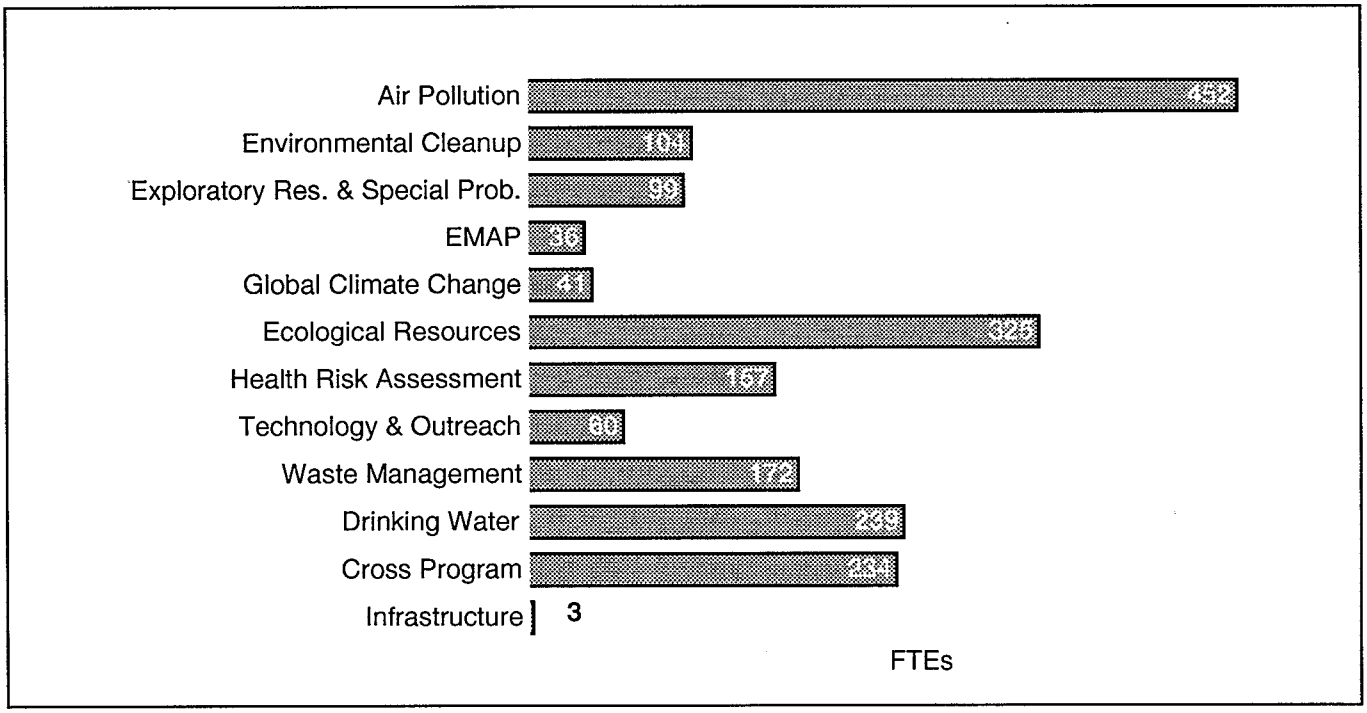


Figure 3. *Total extramural resources and in-house staff FTEs by research theme*

research themes account for 66% of all resources devoted to application directed research. The Waste Management and Protecting Ecological Resources themes have the highest percentage of resources devoted to application directed research with 58% and 57%, respectively. Most other research themes allocate between 40% and 50% of available resources to application directed research.

Development

Research in Environmental Cleanup allocates both the highest proportion of resources (56%) and by far the greatest amount of resources ($26.6 million) to development research. The Innovative Technology and Outreach research theme has both the second highest percentage and amount of resources allocated to development research (43% and $7.9 million, respectively). Air Pollution ranks third in amount of resources allocated to development research. However, due to the large overall amount of resources devoted to the Air Pollution research theme, this is only 10% of the air pollution extramural research budget.

Technical Assistance

The Innovative Technology and Outreach theme allocates the highest amount and percentage of resources to technical assistance ($6.4 million and 40%, respectively). In-house resources devoted to technical assistance generally range from approximately 20 to 40 FTEs for each research theme. ORD scientists and engineers clearly devote significant time to responding to requests for assistance from EPA programs and others.

National Programs

The balance of different types of research can also be arrayed by different national environmental programs under which the research is funded. Figure 4 illustrates the allocation of total extramural and in-house resources (FTEs) by program. Figure 4a, illustrates the balance of the classifications of research within each program.

Air and Radiation, together with Multimedia, allocate a total of $81 million to extramural fundamental research. This is 81% of all extramural resources devoted to fundamental research. These two media also have the highest percentages of resources devoted to fundamental research with 43% and 37%, respectively.

The Water medium allocates $7.5 million or approximately 7% of the total extramural resources devoted to fundamental research. This allocation accounts for 31% of the extramural resources within the Water medium.

The Waste medium allocates almost the same amount of extramural resources to fundamental research as the Water medium, but due to a much larger budget, this accounts for only 7% of the Waste budget. The Pesticides and Toxics medium devotes $4.7 million to fundamental research or 5% of the resources devoted to fundamental research. However, this medium allocates approximately 81 FTEs to fundamental research or 17% of the in-house resources devoted to fundamental research.

The Air and Radiation, Multimedia, and Waste media allocate approximately $110 million to application directed research, accounting for 80% of the total allocation. The Waste medium accounts for 53% of all extramural resources allocated to development research and allocates the highest percentage of its extramural resources to development research (40%.)

Major Research Areas

Following is a brief overview of research that is being conducted within each of the classifications discussed in this report.

Fundamental Research

Research in Air Pollution accounts for almost 29% of the fundamental research conducted by EPA. The major portion of fundamental research in this area is devoted to determining the health effects of ozone and acid aerosols and to understanding the causes/origins of the national photochemical oxidant problem. This research will address major gaps in knowledge that cause difficulties in assessing health benefits associated with control programs and the adequacy of the current National Ambient Air Quality Standards (NAAQS). The research includes human clinical, animal, and epidemiological studies of ozone and acid aerosols for both chronic and acute exposures.

In addition to the health effects of ozone, research concerning the national photochemical oxidant problem will address the important question of whether the mix of chemical precursors that result in photochemical pollution vary by region of the country, or from one major urban area to another. Evidence suggests that the causes/origins may differ in different regions of the country. A true understanding of the nature of this problem is essential to developing effective control measures. Another significant fundamental research project being conducted is the development of methods and data to identify the toxicity, hazards, and dose response curves of mobile source emissions and their transformation products. A long-term effort will address the relative risks of all major fuels options and provide information concerning control technology.

Exploratory Research and Special Environmental Problems is the second largest fundamental research program, accounting for approximately 22% of all fundamental research conducted by EPA. The exploratory grants program funds investigator-initiated fundamental environmental research. While high priority topics have been identified, the program is not intended to be constrained specifically to solving problems that currently occupy EPA's attention. This approach renders the

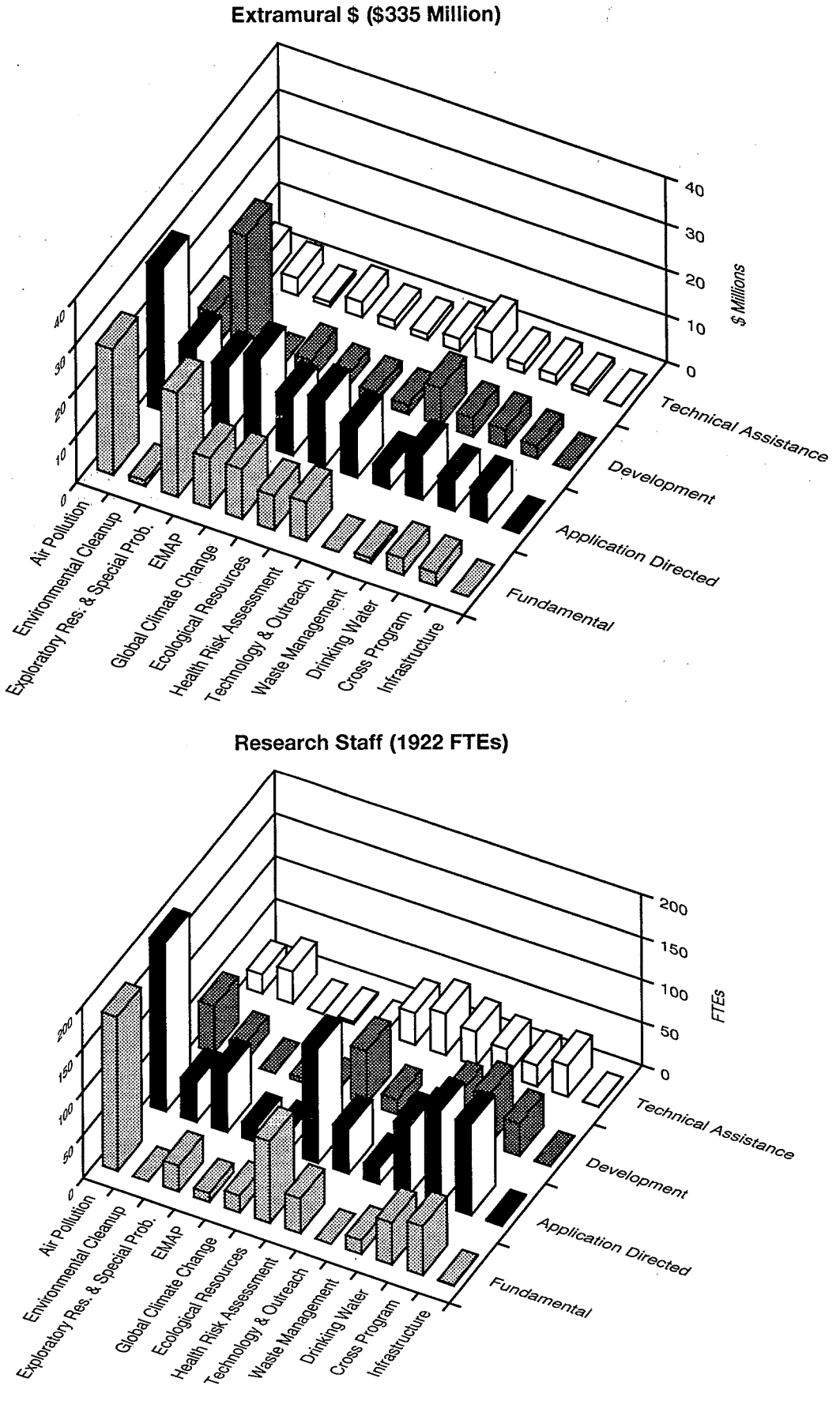


Figure 3a. *Classification of research for ORD research themes*

exploratory grants research program the closest to a traditional basic research program of all the research programs administered by EPA.

ORD has assessed the targeting of resources for exploratory grants. As a result, the first priority of the grants program is to increase the emphasis on research in environmental biology. This includes support for research in areas, such as: biomarkers for the ecological health of freshwater, marine, estuarine, and terrestrial systems; *in situ* bioremediation; and reconstruction of wetlands. Environmental engineering research on innovative methods to prevent pollution, encourage recycling and reuse, and treat wastes is also encouraged. Fundamental research concerning environmental health, and the chemistry and physics of water and air is also supported.

In addition to investigator-initiated grants, a competitive Exploratory Environmental Research Centers (ERC) program is supported. The purpose of this program is to address complex environmental problems that need long-term research. Interdisciplinary and collaborative efforts are encouraged. Four research centers are in place, each with a different research theme that will guide its operations for a decade. The four research themes are: 1) sources, transformation, and control of airborne organic compounds; 2) multiscale experimental ecosystem research; 3) clean manufacturing and pollution prevention; and 4) ecological health research. Fundamental research conducted under this program includes identification of biomarkers for ecological health, ecological assessment studies, fundamental studies on adsorption-desorption processes in sediments, basic studies on the decomposition of chemicals in the environment, material substitution studies that support pollution prevention goals, innovative separation technology for solids and liquids, and bioremediation studies.

EMAP is the fourth largest research area with respect to fundamental research and the second largest for application directed research. EMAP represents a new direction for ORD research. This program will periodically assess and document the condition of the nation's ecological resources on a regional scope appropriate to large-scale environmental problems. Using selected ecological response indicators, EMAP will estimate current status and trends of resource condition, evaluate overall ecosystem health, and make associations between observed responses and selected indicators of natural and anthropogenic stress. Major research efforts are underway with a number of cooperating agencies to implement this program for near-coastal ecosystems, inland aquatic ecosystems, and terrestrial ecosystems. Research in all of these areas will determine the appropriate monitoring scheme, identify indicators, and test monitoring, analysis, and assessment methodologies. EMAP is intended to be a long-term effort, and it will be necessary to gather information over decades to meet the objectives of the program.

EMAP is a difficult program to classify in terms of fundamental and application directed research. On the conceptual level, EMAP will produce base level knowledge about the condition and trends of ecological systems on a scale and in a way that has never been done before. In addition, implementation of EMAP will require that fundamental research be conducted in many areas. For example, to identify indicators of condition or exposure, aggregated indices at the upper level of ecological organization, such as communities and landscapes and integrated assessment methodologies, will be studied. Viewed in this way, EMAP could be classified as fundamental research. Conversely, EMAP also is primarily application directed, as the program uses existing scientific methods and knowledge to deliver data and assessments on ecosystem status and trends. EMAP, in effect, straddles both fundamental and application directed research.

Several major efforts are underway to improve human health risk assessment capabilities. Research is being done to develop data and models that estimate the actual dose that tissues within the human body experience as the result of environmental exposures to toxic chemicals. Environmental concentration is often used as a poor surrogate for human exposure. This effort will improve our ability to determine the environmental concentrations that are harmful to humans. In addition, research to develop and evaluate models that facilitate the extrapolation from animal studies to estimate human risk is being conducted.

Fundamental research being conducted on human exposure will also improve human health risk assessments. A significant effort is underway to design and implement a national exposure monitoring effort known as the National Human Exposure Assessment Survey (NHEXAS). The major product of this long-term research effort is a comprehensive human exposure database, containing monitoring data and information collected during field studies, activity pattern surveys, model development, and data from other sources. This effort will allow EPA to evaluate current assumptions about human exposure levels, compare the relative risk of environmental agents, and identify existing and emerging problems.

Finally, fundamental research is also conducted in the Hazardous Substances Research Centers (HSRC). This program consists of five competitively established multi-university centers. These centers conduct fundamental research in five areas: 1) incineration and *in situ* remediation technology; 2) bioremediation, including engineer-

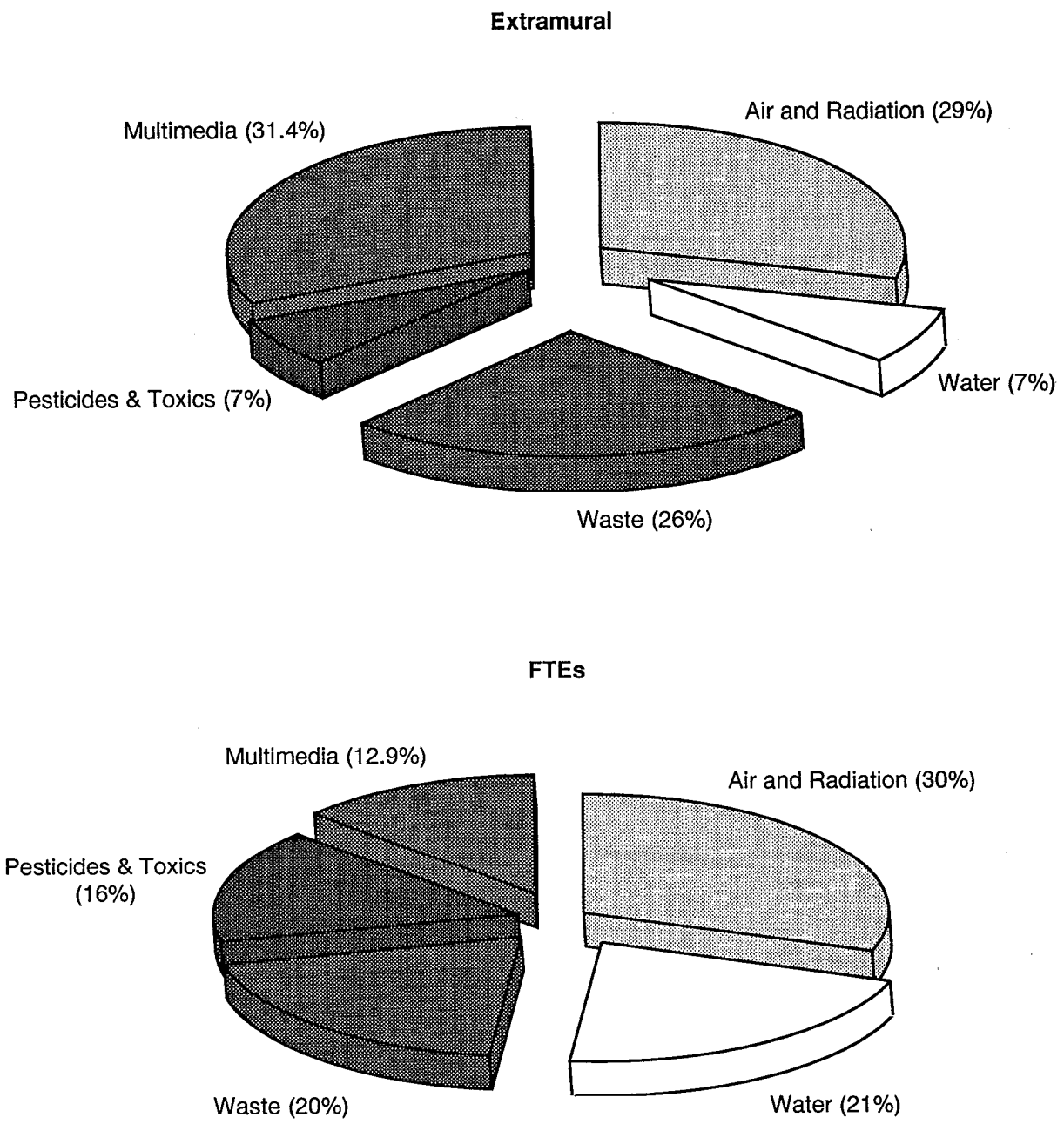


Figure 4. *Total resources by EPA national program*

ing systems; 3) sediment contamination; 4) contamination of soils by metals and non-point sources of organic pollutants; and 5) groundwater cleanup and site remediation.

In addition to the above major areas of fundamental research, many smaller projects are being conducted in a wide variety of areas including: neurotoxicity; pharmacokinetics; environmental risks associated with biotechnology; habitat and biodiversity; threats associated with introduced species; aquatic ecocriteria; bioavailability of metals; and municipal solid waste combustor emissions and toxicology.

Application Directed

Applied research is the largest single classification of research conducted by EPA, accounting for 43% of extramural dollars and 44% of in-house research employees. Two major research components are Air Pollution research and EMAP. Significant application directed research is also conducted in Human Health Risk Assessment, Environmental Cleanup, and Global Change.

In the Air Pollution area, major applied research efforts are underway to improve emission inventories,

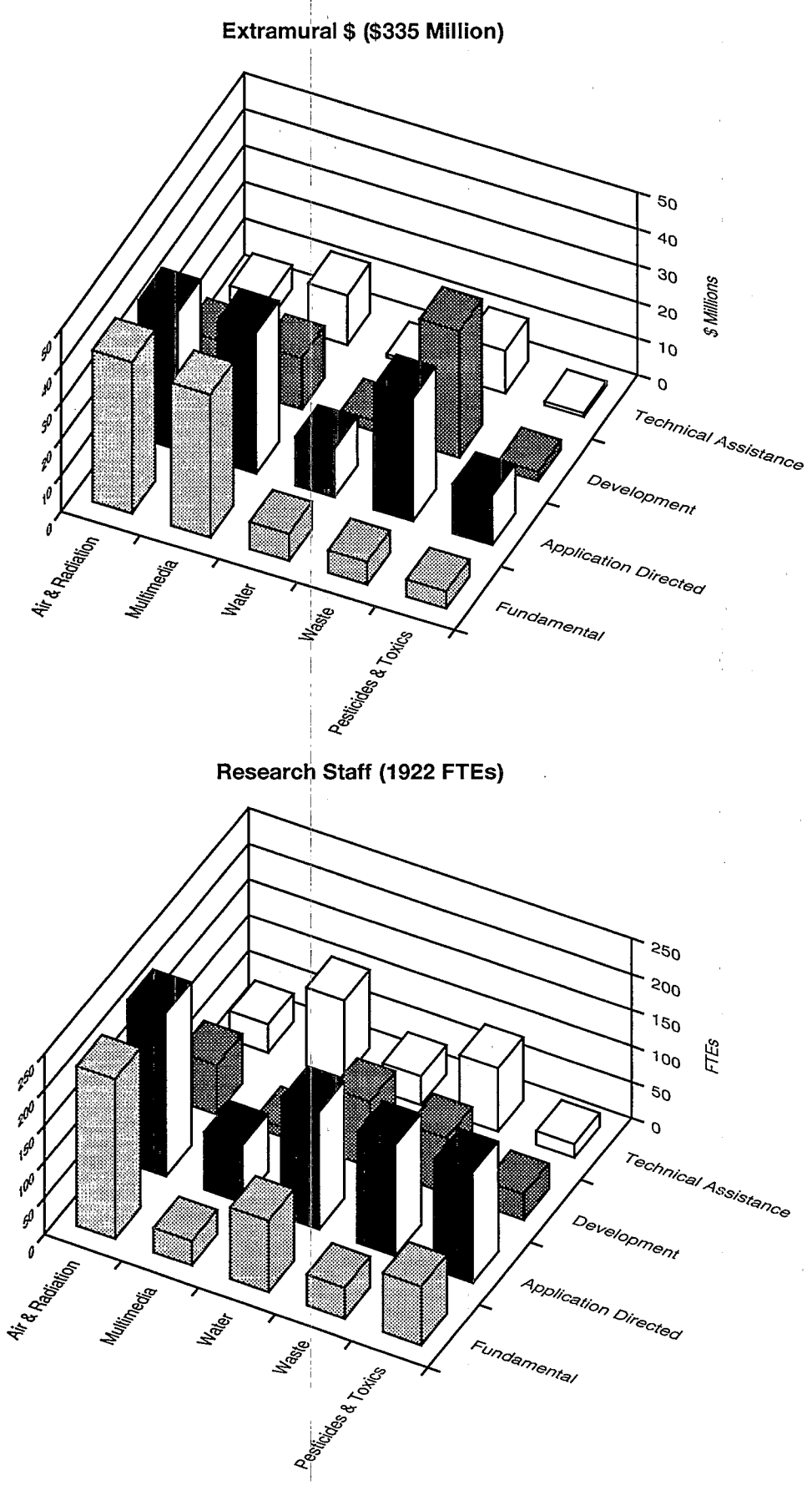


Figure 4a. *Classification of research for EPA national programs*

which form the bases for control strategies to meet NAAQS, monitor acid deposition in accordance with the Clean Air Act Amendments of 1990, and develop source test methods to accurately monitor emissions of toxic air pollutants. These major applied research efforts are in direct support of statutory requirements or high priority research needs of the EPA Air Pollution program.

EMAP is discussed in the fundamental research section of this part. As noted, it is the fourth largest program with respect to fundamental research and the second largest for application directed research. Another significant application directed research project involving resource management is the Midwest Agricultural Surface/ Subsurface Transport and Effects Research (MASTER) program, jointly implemented with USDA and USGS. This program involves research on a watershed-based approach that identifies management systems for sustaining agricultural productivity while protecting ecological and water resources.

In addition to major applied research efforts in Air Pollution and EMAP, significant applied research efforts are underway to address the high national priority of cleaning up hazardous waste sites. One major research program in this area provides support for research on emerging technologies that have potential to significantly improve performance in hazardous waste site remediation. Applied research is also being conducted to develop bioremediation techniques for treating hazardous wastes. Bioremediation research will target five waste types, based on their prevalence on the National Priority List (NPL) of Superfund sites. This research involves the study of microbial action, innovative engineering approaches for field application, and approaches to evaluate the performance of bioremediation.

Applied research concerning Global Climate is also being conducted. One significant research project addresses approaches to controlling large sources of methane emissions from landfills, coal mines, and anaerobic digesters. This research will develop and optimize control approaches and lead to field demonstrations.

In addition to the above, there is research underway on approaches to identify and reduce toxic metal emissions from incineration, risk assessment methodologies, exposure assessment techniques, and improvement and development of subsurface monitoring techniques.

Development

Research involving Environmental Cleanup is by far the largest component in the development area. The Superfund Innovative Technology Evaluation (SITE) program is the largest single development research program. This research promotes the development of promising innovative technologies for cleanup of Superfund sites. During pilot and field demonstrations, innovative technologies are evaluated and are made available to the private sector. The evaluations are documented and made available to the private sector. These evaluations provide an unbiased assessment of performance, thus, fostering the use of successful technologies. A wide variety of technologies are evaluated under this program, including chemical, physical, biological, and thermal technologies. In addition to the SITE program, developmental research concerning new and innovative technologies to prevent or cleanup environmental problems from mining activities is being supported.

In addition to the hazardous waste technologies a smaller research program, known as the Municipal Solid Waste Innovative Technology (MITE) program, supports the development of innovative technologies for municipal solid waste. This program operates much the same as the SITE program. Research is currently focused on recycling strategies and technologies.

Development research is also conducted on innovative technologies under the Small Business Innovative Research Program. This program is based on competitive solicitations of proposals to develop innovative concepts. Research is conducted in a wide variety of areas. Past solicitations include areas such as drinking water treatment, industrial wastewater treatment, *in situ* treatment of hazardous wastes, air pollution control and oil spill prevention.

In addition to the above, other projects include development of the Limestone Injection Multistage Burner (LIMB) global climate mitigation, low NO_x burner development, and underground storage tank monitoring.

Technical Assistance

Technical assistance is provided both through a centralized ORD program and also separately by all components of ORD. As indicated by the resource distribution charts, the resources allocated to technical assistance are the most evenly distributed among the research areas. The centralized effort, conducted under the Innovative Technology and Outreach research theme, involves the preparation and distribution of ORD technical publications and the conduct of numerous technology transfer programs and seminars designed to improve the cost effectiveness of complying with environmental regulation, particularly for small businesses and municipalities.

In addition to the centralized effort, ORD researchers provide technical assistance to many clients. Assistance is provided concerning indoor air pollution, innovative technologies, human health risk assessment, chemical methods, fate and transport modeling, ecological risk assessment methods and biotechnology. In all of these areas, EPA scientists provide expert advice and assistance to EPA, State, and local environmental programs as well as to the private sector.