

SUMMARY OF AWARDS 1975

Division of Advanced Environmental Research and Technology

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CAPITAL SYSTEMS GROUP, INC.
6110 EXECUTIVE BOULEVARD
SUITE 250
ROCKVILLE, MARYLAND 20852

INTRODUCTION

In 1971, the Research Applied to National Needs (RANN) Program was created for the purpose of focusing U.S. scientific and technical resources on selected problems of national importance for the purpose of contributing to and accelerating their solution. RANN serves as a link between basic research and the development, demonstration, and general utilization of research results by industry, State and local governments, and related Federal mission agencies. During the fiscal year 1975, the RANN Program supported interdisciplinary research in both basic and applied areas under the Divisions of Advanced Energy Research and Technology (AERT); Advanced Environmental Research and Technology (AENV); Advanced Productivity Research and Technology (APRT); and Exploratory Research and Problem Assessment (ERPA).

This report presents brief summaries of projects funded by the Division of Advanced Environmental Research and Technology in fiscal year 1975, and projects funded during previous years that were active during that period. The report describes the nature of the Division's seven programs: Environmental Effects of Energy; Trace Contaminants; Regional Environmental

Management; Earthquake Engineering; Fire Research; Socio-Economic Response to Natural Hazards; and Weather Modification.

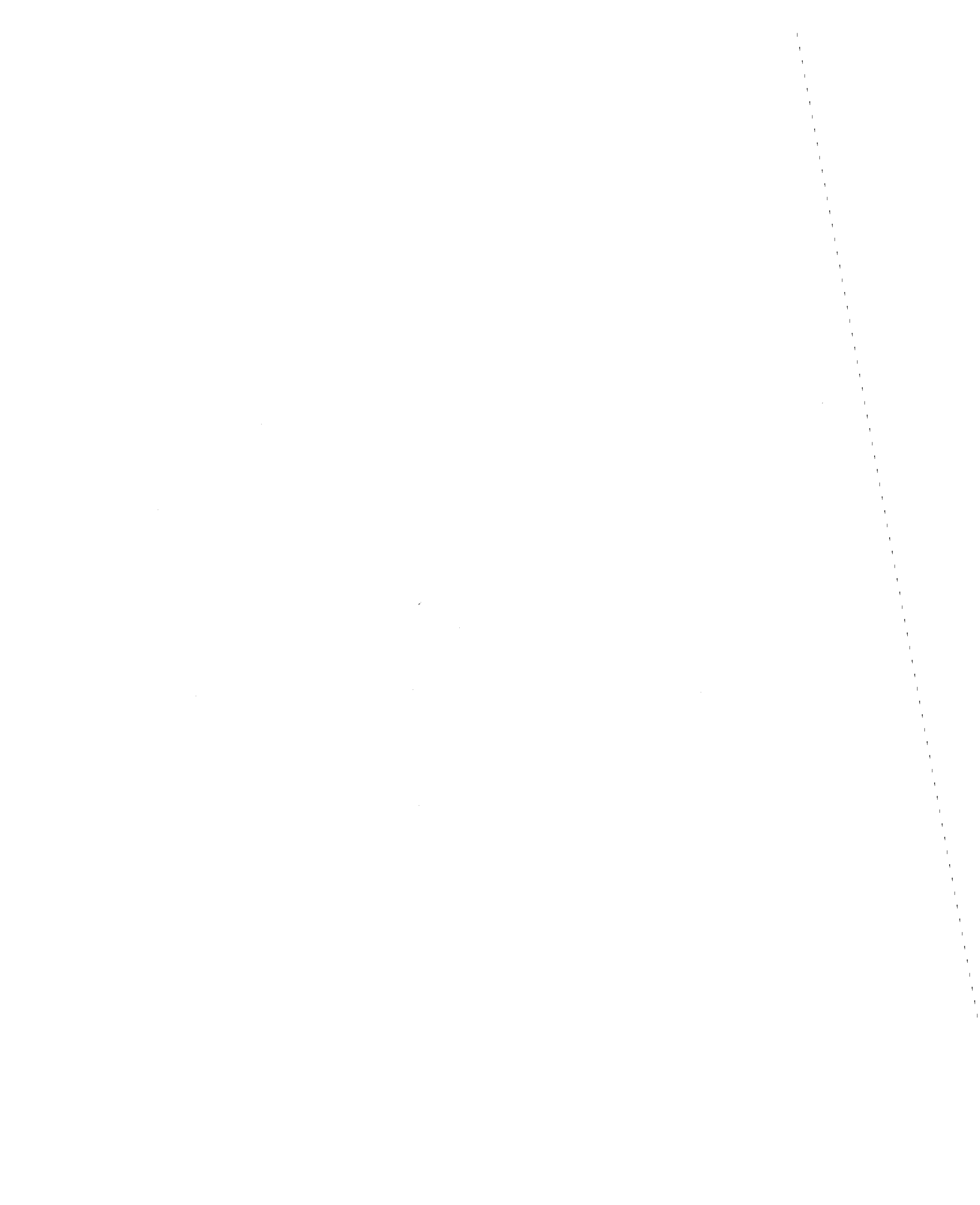
Research projects funded by RANN are reviewed by the scientific community and by representatives of user groups. Eligibility for support under the RANN program hinges not only on scientific merit, but also on the projected impact of the results on government and the private sector in inducing constructive change in policies and practices. A key to the successful application of research results is the strong involvement of user groups during the planning and execution of the research. This involvement helps assure that the scientific activities supported by RANN are being driven by real-world problems.

Interested readers wishing further information on any particular activity described in this report are advised to contact Principal Investigators directly or the Division of Advanced Environmental Research and Technology. Other publications available include RANN Guidelines for Proposal Preparation (NSF 75-21), and the summary of awards for the other RANN Divisions.



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DIVISION OF ADVANCED ENVIRONMENTAL RESEARCH AND TECHNOLOGY

The goal of the RANN Division of Advanced Environmental Research and Technology is to provide a scientific basis for reducing loss of life, property, and the disruption of vital ecological and social relationships from environmental hazards, whether natural or man-caused. There are two program elements within the Division: Managing the Natural Environment, and Disasters and Natural Hazards. Research in the first area is concerned with providing the scientific base to allow improved public decisions about environmental problems. Research in the second area provides information to allow mitigation of the undesirable effects of such natural hazards as weather, earthquakes, and fire. The objectives are to:

- Identify and analyze the nature and extent of man-caused and natural environmental hazards.
- Identify and evaluate innovative methods to reduce the environmental risk and mitigate the impacts of disasters when they occur.
- Evaluate social and technological opportunities for, and constraints to, the adoption of innovative mitigation procedures.
- Synthesize acceptable environmental risk management strategies.

The objectives of the Division are pursued through seven programs:

MANAGING THE NATURAL ENVIRONMENT

- Environment Effects of Energy
- Environmental Aspects of Trace Contaminants
- Regional Environmental Management

DISASTERS AND NATURAL HAZARDS

- Earthquake Engineering
- Fire Research
- Socio-Economic Response to Natural Hazards
- Weather Modification

In fiscal year 1975, a total of \$22,563,000 was awarded by the Division: Environmental Effects of Energy (\$1,147,000); Environmental Aspects of Trace Contaminants (\$3,780,000); Regional Environmental Management (\$7,500,000);

Weather Modification (\$3,937,000); Earthquake Engineering (\$5,309,000); Fire Research (\$650,000); and Socio-Economic Response to Natural Hazards (\$240,000).

The report presents brief descriptions of projects funded in fiscal year 1975 and the projects funded in previous years that were active during that period. The report is organized by program and by objectives within each program. For each project, an attempt has been made to identify the problem area addressed by the research; to indicate how the research may help solve that problem; and to identify the users and potential users of the research results. An alphabetical listing by Principal Investigator is included in Appendix A.

Environmental problem areas presently excluded from support include problems of the open ocean, the upper atmosphere, the occupational environment, applied medicine and drugs, ionizing radiation, pesticides, and issues unique to countries other than the U.S.

DIVISION OF ADVANCED ENVIRONMENTAL RESEARCH AND TECHNOLOGY

Division Director Larry W. Tombaugh
Deputy Division Director Charles C. Thiel
Senior Scientist H. Kenneth Gayer
Administrative Assistant Dorothy F. E. Dooren

Managing the Natural Environment

Environmental Effects of Energy
Program Manager, Ralph M. Perhac

Trace Contaminants
Program Managers:
Marvin E. Stephenson
Richard A. Carrigan
Ronald S. Goor
Glen E. Gordon

Regional Environmental Management
Program Managers:
Edward H. Bryan
Josephine K. Doherty
Gordon H. Jacobs
Terry R. Sopher

Disasters and Natural Hazards

Earthquake Engineering
Program Managers:
John B. Scalzi
Henry J. Lagorio

Fire Research
Program Manager, Ralph H. Long, Jr.

Socio-Economic Response to Natural Hazards
Program Manager, George W. Baker

Weather Modification
Program Managers:
Currie S. Downie
Richard A. Dirks

MANAGING THE NATURAL ENVIRONMENT

The program element Managing the Natural Environment provides a scientific basis for mitigating man-caused environmental threats to the natural environment in ways that are compatible with other social goals. Through its three subelements, the program attempts to assess the environmental consequences of advanced and innovative technologies for processing energy and for storing and transporting energy and fuels; to identify, understand, and contribute to the reduction of contamination problems arising from mining and processing of metal ores, manufacturing and use of chemical products, and disposal of potentially toxic wastes; and to continue research on land use, on rural and urban environmental management, and on waste management.

The programs in this area are:

- Environmental Effects of Energy
- Environmental Aspects of Trace Contaminants
- Regional Environmental Management

ENVIRONMENTAL EFFECTS OF ENERGY

The objective of this program is to develop the scientific knowledge needed to reduce conflicts between increased energy production and environmental quality. Development of major new energy technologies of extraction, storage, transmission, and conversion will likely require massive expenditures of public and private funds as well as several years or decades. The Nation needs an "early warning" capability so that the probability of making such investments only to find that the environmental consequences are unacceptable is minimized.

Specific objectives of the Environmental Effects of Energy program are to:

- Identify major environmental problems associated with advanced energy technologies.
- Identify and assess innovative approaches for overcoming these problems.

An Evaluation of Multi-Purpose Offshore Industrial Port Islands; *Robert B. Biggs;* University of Delaware, College of Marine Studies, Newark, Delaware 19711; \$216,830 for 12 months beginning May 1, 1974

The United States is confronted with a complex situation affecting its industrial development and its ability to maintain a vigorous economy and an adequate national defense posture. On the Atlantic Coast in particular, and on the Gulf Coast to a lesser extent, there are intensive on-shore population pressures and the need to develop basic services and heavy industrial facilities. Industrial activities which are essential to our economy but difficult to construct, expand, and operate are: refineries and directly related petro-chemical plants; petroleum and petroleum product port facilities for deep-draft ships; dry-bulk cargo port facilities for deep-draft ships for import, export, and transfer; electric power generation plants; liquified natural gas unloading and regasification facilities; and solid waste, sludge, and dredge spoil disposal.

This project is evaluating the feasibility of multi-purpose offshore industrial port islands. The economic feasibility is judged through a study which integrates consideration of activity and real estate value for maximum effectiveness, recognizing relative cost differences between natural and created land, and the potential cost differences for pollution management, process development and logistic support. The objectives are to: (1) identify sites for multi-purpose offshore industrial port islands on the Atlantic and Gulf

coasts based on the geography of demand; (2) identify compatible island activities for these sites; (3) identify problems requiring further research and promising research approaches; and (4) make preliminary suggestions of island and process configurations.

Four institutions are involved in this study, each responsible for distinct functions and areas of expertise. The College of Marine Studies, University of Delaware, is responsible for project management, system analysis and optimization, legal and environmental factors; Texas A&M University is involved with economic, social, and market analyses; Gilbert Associates, Inc. covers industrial process and plant technology, master planning, plant installation, and operating costs; and Frederick R. Harris, Inc. is concerned with site selection, island construction methods, access, and cost estimates. Dr. Robert B. Biggs is responsible for overall coordination of the project.

Periodic briefings are held during the course of the study to establish a dialog with potential users. Attending the briefings are the Governors' designees to the Coastal States Organization, and also representatives of key Federal agencies, including the Maritime Administration, Department of Commerce, the U.S. Coast Guard, the Atomic Energy Commission, and the National Oceanic and Atmospheric Administration.

Research on the Effects of Crude Oil Transfer and Upstream Refineries on Delaware Bay; Robert B. Biggs; University of Delaware, College of Marine Studies, Newark, Delaware 19711; \$300,800 for 15 months beginning March 1, 1974

Approximately 70 percent of all the oil that is delivered to the east coast of the United States moves by water up the Delaware Bay and River. This high risk transfer operation, although conducted without incident so far, represents a potential hazard. We are not in a position to predict the movement of a spill from the existing lightering area, nor its environmental consequences, nor the most efficient deployment of cleanup equipment. And it is anticipated that, due in part to the Nation's energy shortage, the transfer activities will increase markedly in the future. The seven refineries located on the Delaware River have a combined throughput of more than 900,000 barrels of crude oil per day, and this capacity could be doubled on property already owned by the oil companies. While volumes and composition of refinery effluents are well documented for the Delaware Valley area, no work has been completed on the effects of refinery residuals in areas remote from the point of discharge. The goal of this research program is to conduct timely studies on refinery residuals and oil transfer operations as these impact on Delaware Bay. The project is broken into three components: (1) a four-month planning study which will yield a four-year

research program designed to provide operational management criteria at the end of the program; (2) a nineteen-month study designed to produce biological baseline data on the ecology of the marine biota prior to the anticipated increase in crude oil transfer, with particular emphasis on the lightering area; (3) a nineteen-month study designed to provide a user-oriented predictive model for oil slick movement in Delaware Bay.

This project is the successor to the eighteen-month exploratory project in which the University of Delaware, Rutgers University, and the Philadelphia Academy of Natural Sciences collaborated in producing an initial assessment of the management problems of the Delaware Bay region and an assessment of various aspects of the environment (see p. 4). Agencies which have indicated an interest in data from this project include: the Council on Environmental Quality; U.S. Army Corps of Engineers; U.S. Coast Guard; the States of Delaware and New Jersey; Delaware River Basin Commission; Delaware River and Bay Authority; the Department of Commerce; and private industry.

The Petroleum Industry in the Delaware Estuary; William Whipple, Jr; Rutgers University, Water Resources Research Institute, New Brunswick, New Jersey 08903; \$450,000 for 12 months beginning March 1, 1975

The Delaware Estuary is one of the most vital industrial estuaries in the country. At the present time close to 900,000 barrels of petroleum per day are produced by a highly developed group of refineries. A recent coastal zone act passed by the State of Delaware prohibits heavy industry on the coast, particularly refinery development. Similarly, the wetlands act passed in New Jersey limits industrial development in marshlands. One particular goal of this study is to study pollution from refineries as compared to other sources, especially urban runoff, so that the true effect of the refineries can be isolated from other sources of pollution.

This research has three main goals: (1) to measure the amounts and types of petroleum pollutants entering the Delaware estuary; (2) evaluate the effects of the pollutants on estuary fauna; and (3) to evaluate the economic impact of the pollution damage in terms of cost-benefit analysis. Eleven individual projects will attempt to accomplish the necessary work. Subjects analyzed under the groups include analysis of oils and refinery wastes; measurements of the amount and nature

of pollutants entering the river from urban runoff; measurement of total petroleum wastes from all industrial and urban sources; specific toxicant distribution analysis; effects on animals; and an assessment of the economics of pollution and pollution control.

Experimental results of this program are being disseminated through oral presentations, scientific meetings and in scientific journals. A yearly progress report and final report will be given to the National Science Foundation as well as the U.S. Geological Survey, Federal Energy Administration, Environmental Protection Agency, Delaware River Basin Committee, the City of Philadelphia, and representatives of the oil companies operating in the Delaware estuary. In addition, semi-annual project reviews, attended by the Advisory Committee, NSF/RANN Program Manager, and all project personnel, are held to maintain coordination between governmental agencies and private industry.

ENVIRONMENTAL ASPECTS OF TRACE CONTAMINANTS

The program is principally committed to determining the levels of potentially or overtly toxic trace substances in the environment; assessing the effects of these levels on man, animal, and plant communities; and relating these findings to methods of control. A close communications relationship exists between investigators, producers of industrial wastes, and officials in the Council of Environmental Quality, National Institute of Environmental Health Sciences, and the Environmental Protection Agency.

The objectives of this program are to:

- Assess the potential for damage to ecosystem communities, populations, and biological species along contaminant paths.
- Identify and quantify the contaminants resulting from the mining and processing of metal ores, manufacturing and use of chemical products, and disposal of potentially toxic wastes.
- Improve existing techniques in analytical chemistry specifically applicable to achieving the above objectives.

The major research elements are:

- Air Quality
- Metals
- Nitrate
- Organic Chemicals of Commerce
- Supporting Methodology
- Program Development and Utilization

AIR QUALITY

The purpose of the Air Quality element is to establish the impact of pollutant sources on the atmospheric chemical reactions that determine air quality.

Chemical Transformations in Photochemical Smog and Their Applications to Air Pollution Control Strategies;
James N. Pitts, Jr.; University of California, Riverside, Statewide Air Pollution Research Center, Riverside, California 92502; \$495,700 for 12 months beginning January 1, 1975

Jointly funded by the Advanced Environmental Research and Technology and the Advanced Energy Research and Technology divisions of NSF, this project's central objective is to develop a model of the chemistry of photochemical smog. The model will be validated by reference to historical air quality data, to current ambient air analyses, and to experimental observations in the Chamber Facility of the Statewide Air Pollution Research Center (SAPRC). The ultimate goal is a chemical model suitable for airshed modeling for developing revised control strategies, for initiating health warning systems, and for providing a key element in the comparison of alternative land-use options.

The basis for model development will be an experimental program on synthetic gas mixtures and ambient air to generate concentration-time profiles for reactants, products, and, where possible, intermediates in smog systems. Experiments will be done in the SAPRC 200-cubic foot smog-reaction chamber, and all will include studies of minor, but potentially important, gases like nitrous oxide and halogen compounds. Also included will be studies of the effects of ultraviolet light on smog chemistry, and investigations of the kinetics and mechanisms by which potential gaseous carcinogens may be formed in polluted air.

The modeling program will include experiments to measure the rates of formation of aerosols in mixtures simulating polluted atmospheres, and to chemically characterize the resulting aerosols. A program to

chemically characterize size-resolved aerosol particulates formed under a variety of meteorological conditions and having different temporal and spatial histories will be jointly carried out with the above effort.

Utilization of this research is a continuing process. The project team is repeatedly called on to prepare briefings or testimonial appearances before Federal and State legislative and administrative authorities. These contacts deal with questions of legislation or administrative decision-making regarding air quality standards and control strategies. Because of the uncertain scientific basis for regulatory standards, the current air quality and emission standards of EPA and the California Air Resources Board are under attack. The Clear Air Act itself is threatened by a proposal that there be a shift in emphasis from health effects to feasible control technology as the basis for standard-setting. As a source of current scientific findings in this controversial area, the project should play a significant role in the evolution of pollution control strategies.

In addition to these connections in the legislative and regulatory arenas, SAPRC maintains a vigorous program of information dissemination through several channels. SAPRC publishes a semi-popular periodical, *California Air Environment*, which is distributed to over 3000 individuals and organizations. Three issues appeared in 1973-74. Articles touch on criteria for air quality standards, research findings, health effects, and related matters.

A Study of Atmospheric Sulfate Pollution from Biological Sources; *David L. Richardson*; Arthur D. Little, Inc., Acorn Park, Cambridge, Massachusetts 02140; \$59,200 for 6 months beginning June 15, 1975

This is a statistical study of relationships between measured atmospheric levels of sulfate in urban and non-urban sites and factors that relate to biological sulfate reduction in surface waters, anthropogenic sulfur dioxide and sulfate emissions, and meteorological factors influencing the atmospheric transport and removal of sulfur compounds. The objective is to test the hypothesis

that biogenic emissions of hydrogen sulfide from natural water bodies contribute significantly to the atmospheric load of hazardous particulate sulfates. The planning and execution of the research are in the hands of Ms. Dian R. Hitchcock.

This is the first phase of a two-phase study. The first

phase includes the examination of seasonal and annual averages of about 20 non-urban sites in the U.S. and approximately 70 urban sites. Data will be drawn from monitoring records. To the extent possible, the urban sites will be geographically matched with non-urban sites. The study sites are located in the north central and northeastern U.S. and in Arizona.

In addition to the seasonal correlations of atmospheric sulfate levels, further correlations will be sought with other species that may help to identify the anthropogenic or biogenic origins of atmospheric pollutants. Meteorological data will be used primarily to estimate space-heating demands, to categorize sampling days with respect to atmospheric stability, and, at sites where

major anthropogenic or biogenic sulfur sources are directionally localized, to identify sampling days on which the monitoring station was downwind of the suspected source.

The research is designed to be used as background for decisions by regulatory authorities on whether or not to impose ambient air standards for particulate sulfate. Phase I will not prove or disprove the hypothesis that natural biogenic sources are significant; rather it is the next logical step that can be taken with existing methodology to provide needed strengthening of the limited circumstantial evidence now available. Staff scientists of both ERDA and EPA have expressed interest in the research.

Atmospheric Impact of Major Sources and Consumers of Energy; *William H. Zoller*; University of Maryland, College Park, Maryland 20742; \$290,000 for 11 months beginning October 1, 1974

A number of chemical elements are found to be markedly enriched in the particulates of urban polluted air. Some of these are known to be toxic, or are suspected of having adverse health effects when they occur in "respirable" particles, i.e. particles falling in the small size range associated with retention in the lungs. Although much information has been gathered by many investigators bearing on atmospheric loadings of trace elements in ambient urban and rural air, conclusions about the sources of these elements are presently based on inadequate data or even in some cases on untested assumptions. A prime objective of this research is to characterize definitively major isolated sources, of types generally present in urban areas, as to their emission to the atmosphere of trace elements in a range of particle sizes, including the respirable size range. This objective includes correlating the emission data with fuel composition and plant design and operating parameters to the extent possible with the necessarily limited number of installations. The problem is to identify

sources accounting for the observed high ambient levels.

The second objective is to determine how the emitted pollutants, including the gaseous pollutants, react with one another and with constituents of the ambient air to form secondary pollutants that act as toxicants or bioirritants. Attainment of these objectives will help to resolve problems faced by regulatory authorities in their efforts to control emissions within limits allowing acceptable levels of pollutants in ambient air, and to harmonize pollution control with energy requirements.

Project results are distributed regularly to key elements of the user community, especially in the U.S. Environmental Protection Agency and the State of Maryland. Close relationships are maintained with the Maryland Power Plant Siting Program and power companies in the area. Some twenty different modeling groups in the U.S. and abroad receive current reports of chemical kinetic data produced on the project.

METALS

The objective of the Metals element is to assess the environmental hazards of metallic contaminants in relation to the characteristics of their sources and the economics of control measures.

Effects and Environmental Indicators of Metallic Pollutants on Vertebrate Embryos; Wesley J. Birge; University of Kentucky, Lexington, Kentucky 40506; \$61,700 for 12 months beginning June 1, 1975

The University of Kentucky is entering a research study whose objectives are to: (1) evaluate the hazards of metallic tract contaminants upon vertebrate embryos, to determine if the developing vertebrate represents the most sensitive stage in the life cycle; and (2) develop a sensitive bioassay system using vertebrate embryos to assess toxic effects of environmental pollutants.

Fish, amphibian, and avian embryos will be exposed to various concentrations of arsenic, cadmium, mercury, lead, and zinc in order to: (1) determine the range of concentrations at which individual metals kill or seriously impair these vertebrate embryos; (2) identify periods of embryogenesis which exhibit greatest susceptibility to metallic poisoning; (3) ascertain the extent to which metals may accumulate in vertebrate

eggs prior to ovulation; (4) consider the possible antagonistic, additive or synergistic effects of combinations of metals upon developmental processes; and (5) construct a sensitive "bioassay system" in which vertebrate embryos may be used to assess toxic effects of environmental pollutants.

The data resulting from this research will be used to establish a "toxicity index" to frequencies of embryonic lethality and/or teratogeny produced by specific concentrations and combinations of test metals, and environmental standards for metallic pollutants will be critiqued from the viewpoint of establishing "safe" or tolerable limits necessary to safeguard embryonic development and reproductive potential in vertebrate organisms.

Geochemistries of Mercury, Arsenic and Other Metals in Puget Sound; Roy Carpenter; University of Washington, Department of Oceanography, Seattle, Washington 98195; \$59,500 for 12 months beginning June 1, 1975

Researchers in the Department of Oceanography at the University of Washington are continuing studies of the source, sinks, routes and rates of transfer of mercury and arsenic between different aquatic reservoirs and between different chemical forms. The main thrust during this phase of research is to identify the chemical forms in which arsenic and mercury are present in the waters, sediments, and organisms of the contaminated areas and the rate of conversion of these metals to toxic and nontoxic forms. In addition, this research will seek to determine the effects of arsenic on the life stages of salmon and shrimp populations native to Puget Sound.

The objectives of this year of activity are concurrently attained by specific efforts in four major areas of research: Mercury Investigations; Arsenic in Water; Arsenic in Sediments; and Arsenic in Salmon and Shrimp.

Results of this study will be shared with regulatory agencies with responsibilities for environmental quality management in the Puget Sound area. Specific agencies include: Puget Sound Air Pollution Control Agency; NOAA/MESA project; EPA-Seattle Regional Office; and the Washington State Department of Ecology.

Transport and the Biological Effects of Molybdenum in the Environment; *Willard R. Chappell*; University of Colorado, Department of Physics and Astrophysics, Boulder, Colorado 80302; \$145,000 for 12 months beginning June 1, 1975

The Molybdenum Project is an interdisciplinary group of scientists which is investigating the transport and biological effects of molybdenum in the environment. At sufficiently high rates of intake, the micronutrient is toxic to living organisms.

This study is a continuation of the current award whose objectives are to: (1) determine the release and transport of molybdenum in natural and disturbed molybdenum source areas; (2) assess the effect of elevated levels of molybdenum in irrigation water on soils, plants and livestock; and (3) investigate physiological effects of chronic levels of molybdenum in

mammals. In addition to focusing on the above efforts, the project group conducted a major conference in Denver during the summer of 1975. Entitled the "Symposium on Molybdenum in the Environment," the conference addressed the current state-of-knowledge of molybdenum in the environment and those future research needs relative to human health and the quality of the environment.

Regulatory agencies have made extensive use of project data and results in developing emission standards for mining and milling operations in Climax, Colorado and Urad, New Mexico.

Heavy Metals as Environmental Hazards to Man; *Thomas W. Clarkson*; University of Rochester, School of Medicine and Dentistry, Rochester, New York 14642; \$241,000 for 12 months beginning June 1, 1975

Now entering its fifth year of support for research on the health effects on organic and inorganic mercury on man and other mammalian populations, this project's major concern is with the following objectives: (1) improve analytical techniques for the identification and quantification of total mercury and mercurial species in tissues; (2) understand how mercurials are absorbed after ingestion, are distributed to organs and organ systems, are mobilized for secretion, and are detoxified; and (3) recognize animal behavioral, physiological and cellular responses to doses of mercurials. Human population studies will center on continuing previously initiated work in Iraq to understand the epidemiology and pathology of mercury poisoning in epidemic proportions, and to evaluate the health effects of diets consisting almost exclusively of predator ocean fish among residents of Malta.

Issues of major concern in this work are: (1) dose-response relationships in adults and children; (2) dose-response relationships in offspring exposed prenatally and early postnatally from breast milk; and (3) the

kinetics of transmission of methylmercury from mother to offspring prenatally and postnatally via milk.

The Food and Drug Administration and the World Health Organization are major users of results from this research, as the information obtained is applied directly to the task of setting standards of purity and safety, both nationally and internationally. Decisions are made as to safe levels of methylmercury in food, especially of concern to the fishery industry in the U.S. The World Health Organization has asked Rochester to prepare a criteria document which will be the basis for official World Health Organization guidelines for safe levels of all forms of mercury in food, water and air. Conference proceedings, reviews and journal articles serve to disseminate research findings through the medium of scientific publications. The research team has participated in the organization and proceedings of the Baghdad Conference on Intoxication Due to Alkyl Mercury Treated Seeds. The project is co-funded by the U.S. Food and Drug Administration.

Environmental Contamination Caused by Lead; *Harry W. Edwards*; Colorado State University, Engineering Research Center, Fort Collins, Colorado; \$223,200 for 12 months beginning July 1, 1975

The Colorado State University environmental lead program is an interdisciplinary study of the environmental flow and effects of lead contamination from automotive sources. The program has been instituted to identify the nature and extent of environmental problems caused by automotive lead, in

the anticipation that possible environmental and/or technological solutions can be determined and specific recommendations be made.

This research is a continuation of the current award involving the following major objectives: (1) correct the

deficiencies in present sampling techniques for atmospheric lead; (2) determine the actual size and distribution of lead-containing particles with distance from the source; (3) determine atmospheric organic lead content variation with distance from the source; (4) recognize the primary effects of city geometry upon contaminant dispersion in city streets; (5) characterize the bioavailability, uptake and effects of lead sulfate and oxysulfate (the principal forms of lead in soil) on plants; and (6) complete the lab and field ice-nucleation studies of lead particulates as related to inadvertent weather modification.

During the past year, an urban sampling network was employed to measure lead dispersion in Fort Collins, Colorado. An urban model was then developed to correlate observed atmospheric lead levels with traffic data and meteorological parameters. A 1:400 scale model of Ft. Collins was employed for wind tunnel studies in an effort to correlate field measurements of urban lead dispersion with concentration profiles obtained using a laboratory simulation.

Ice nucleation characteristics of automotive exhaust are being studied by both laboratory and field tests to determine the nature and extent of inadvertent weather modification effects that may be caused by lead and lead substitutes. Experiments were undertaken to investigate scavenging of lead alkyl vapor by atmospheric particulate

matter as a part of the overall effort to determine the fate of organic lead in the atmosphere. Finally, an apparatus for exposing growing plants to lead aerosols has been designed, constructed, and tested.

In addition to publications and talks given by team members at regional, national and international professional society meetings and speciality conferences, one member arranged symposia on lead for the national meetings of the Air Pollution Control Association (June, 1974) and the AAAS (January, 1975). Members of the CSU team worked closely with representatives of key regulatory agencies on two specific problems during the past twelve months. Several CSU lead project participants worked with Colorado Air Pollution Control Commission personnel on the present regulation governing point-source release of lead and other toxic substances. Members of the team are collaborating with EPA personnel to define deficiencies of air sampling techniques for lead. In addition, CSU lead project participants are collaborating with University of Illinois and University of Missouri researchers in preparation of the *Three University Report on the Status of Environmental Contamination by Lead*. The purpose of this collaborative undertaking is to consolidate and evaluate data from the three complimentary lead research projects.

Ecology and Analysis of Trace Contaminants; William Fulkerson; Oak Ridge National Laboratory, Post Office Box X, Oak Ridge, Tennessee 37830; \$700,000 for 7 months beginning June 1, 1975

This award is for the renewal of a research project jointly funded by the Trace Contaminants and Environmental Effects of Energy programs of AENV. The general purpose of the program is to develop techniques and data useful to government agencies, industry, and the scientific community in assessing potential environmental problems with trace contaminants; and in reducing discharges of certain toxic materials into the environment. To accomplish this objective, the research effort continues to be organized into five areas:

1. Development and validation of a Unified Transport Model (UTM) which simulates trace contaminant transport in a watershed.
2. Ecological Research to identify and measure the natural processes governing trace element behavior in ecological systems and to use these data in developing and validating the UTM.
3. Measurements Research to develop analytical techniques that will increase efficiency of trace contaminant analysis by increased speed or reduced

cost; and extend analytical capability by improving sensitivity and accuracy or by the determination of chemical species.

4. Abatement Technology designed to continue to develop and to conduct proof of concept and economic feasibility studies on two aqueous abatement techniques developed during previous grant periods; solvent extraction using high molecular weight amines; electrochemical reduction using porous or packed bed electrodes for selective recovery of toxic contaminants from industrial aqueous waste streams.

The validation of the United Transport Model will occur at two watersheds in the New Lead Belt in Southeastern Missouri, in collaboration with the University of Missouri; in addition to the watershed at Oak Ridge. Ecological Research finds three new studies undertaken during this year of funding: (1) examine the effects of litter contamination on Crooked Creek microbial populations; (2) study the availability of mercury to fish *in situ* in the Holston River-Cherokee

Reservoir System; and (3) expand the effort made on Walker Branch Watershed to gain further insight into the processes governing the transport and distribution of trace elements in watershed areas.

The Measurements Research now falls into two broad areas: inorganic and organic analysis. There are two projects in each area, and there is some overlap (e.g., organometallic analysis) in one of these (gas chromatography).

Work with industry has expanded as a result of the fourth project theme of characterizing materials from coal conversion pilot plants. The team has visited and is cooperating with the FMC Corporation in Princeton,

New Jersey (COED process), Hydrocarbon Research, Inc., of Trenton, New Jersey (H-coal process), and the Bureau of Mines Pittsburgh Energy Research Center (Synthane and Synthoil process). An extensive set of samples has been received from the COED pilot plant, and a few samples from the H-coal and Synthoil processes. Results will be reported to the respective institutions, and further collaborative research will be developed both with the industries involved and with other research groups (e.g., the Biology Division and the Environmental Science Division at Oak Ridge and other interested laboratories doing biological testing).

Environmental Aspects of Trace Metals on Human Hair; *Adon A. Gordus*; University of Michigan, Department of Chemistry, Ann Arbor, Michigan 48104, \$131,000 for 18 months beginning November 1, 1973

Regulatory agencies, such as the U.S. Environmental Protection Agency, the Food and Drug Administration, and the National Institute of Occupational Safety and Health, are seeking a human tissue assay that can integrate man's environmental experience with metallic compounds and thereby give a picture of exposure over a defined time period. Such an assay would complement blood and urine analyses, which provide only recent exposure data. Hair is an attractive candidate as such an

integrator tissue. It is easy and painless to collect; it loses little if any of its trace chemical constituents; many elements seem to concentrate in hair; hair is readily preserved so that historical samples can be analyzed in order to determine long-term trends; and hair grows at a defined rate so that trace element concentrations at given distances along a strand can be correlated with time of exposure as well as blood and urine data.

Sources of Lead in Children; *Paul B. Hammond*; University of Cincinnati, College of Medicine, Eden & Bethesda Avenues, Cincinnati, Ohio 45219; \$77,800 for 12 months beginning May 1, 1975

Young children are generally considered to be the most vulnerable age group of the populace at risk to the toxic effects of lead. The role of paint containing lead in developing, or contributing to, adverse health effects has been and continues to be of primary concern. However, exposure to lead is derived from a variety of sources of atmospheric (inhalation) and dietary origin. The relative importance and mass amounts culminating in excessive blood lead levels in children from these multiple sources are not sufficiently understood to the point that a definitive course of action can be prescribed for the individual.

eight children have been identified in a community-wide lead screening program and brought into the study. Of these, twenty-two have elevated blood leads and eight have been hospitalized and undergone chelation therapy.

It was found that although these children may have high blood lead values, their fecal lead values are frequently low. This indicates that the pica habit leading to elevated fecal lead excretion is sporadic. It also means each child can serve as its own control.

This award is a renewal of a research project whose objective is to develop techniques for determining the magnitude of sources of excessive lead exposure in young children. Work in the second year will: (1) continue to select and identify children with elevated blood lead; (2) identify markers unique for each environmental source of lead; and (3) determine the degree of absorption of markers and lead in each source. Twenty-

Another finding indicates that inner city children seem to have a high background level of lead excretion upon which is superimposed spikes of high fecal lead concentrations. It is not yet known if this means that inner city children have a consistently high oral lead intake that is a background for sporadic bouts of pica or if previous estimates of fecal lead concentrations for normal children have been too low.

Detailed studies were done on the children of two families in order to try to determine the environmental

sources of lead in their feces. Emission spectroscopy was used to determine elemental profiles of fecal and environmental (paint, dust, soil) samples. The results, although not as conclusive as hoped for, did indicate a multiplicity of sources including a few exterior paint samples and exterior dust samples. Because emission spectroscopy did not generate data sufficient for good correlations to be made, future studies will make use of x-ray fluorescence and neutron activation analysis (NAA). In addition, actual environmental paint, dust and soil samples from homes of lead-poisoned children will be fed to infant rats. Their feces will be examined by x-ray

fluorescence and NAA for the elemental profile and correlated with that of the environmental samples. This will be done in parallel with similar studies on children.

The progress of this research is being closely monitored by the Health Effects Division and the Human Studies Laboratory of EPA; the Bureau of State Service, USPHS, Center for Disease Control; the Office of Policy Development and Research of HUD; and the International Lead Zinc Research Organization. The project is a cooperative venture of NSF/RANN, the HUD and USPHS Center for Disease Control.

Cadmium in an Aquatic Ecosystem — Distribution and Effects; *Theodore J. Kneip*; New York University Medical Center, Institute of Environmental Medicine, New York, New York 10016, \$50,700 for 12 months beginning May 1, 1974

This research project seeks to define and quantify the environmental impact of cadmium-bearing wastes discharged into a near-shore aquatic ecosystem. The study, now in its second year, is examining an area of sediments in Foundry Cove near Cold Springs on the Hudson River that has been heavily contaminated with cadmium and nickel by discharges from a local nickel-cadmium battery manufacturer. Research has been undertaken to determine the distribution, transport mechanisms, and potential effects of these metals in the tidal marsh and cove.

Study efforts are concentrating on the development of data relating to the physical distribution of cadmium in the sediments and water in the cove and within the food web through which cadmium may pass. Also work is being carried out on the definition of toxicities for a number of organisms and the relation to effects on biota present in the system. Preliminary results indicate that the cadmium contamination is continuing to spread to areas previously unaffected. Some of the metal is being transported into the river in both the dissolved and particulate phases. It has been found that cadmium is biologically available and that significant concentrations occur in plants, fish and animals in the affected area.

Continuous flow toxicity studies have been performed in cooperation with the EPA laboratory in Edison, New Jersey, and organisms have been implanted in the cove for uptake studies. Field studies of benthic organisms and toxicity tests on fish eggs and larvae indicate that both aquatic and benthic cadmium concentrations in the cove are of concern in relation to these organisms. A complete listing has been compiled of New York State and United States agencies interested in and responsible for resolution of the existing problem of cadmium contamination.

In addition to the dissemination of research findings through scientific publications, committee reports and participation in hearings, progress reports are sent to a representative of each interested agency as well as a number of groups including the Hudson River Fisherman's Association, the Hudson River Environmental Society, and industrial organizations. Discussions have been held with the battery manufacturer, and corporate information concerning the history of the process, discharges, field studies, and waste management has been made available to the investigators.

Drosophila as Indicators of Environmental Lead and Cadmium; *William R. Lower*; University of Missouri, Columbia, Missouri 65201; \$30,000 for 12 months beginning April 1, 1975

The general objective of this research project is to determine the validity of using fruit fly species (*Drosophila*) as a monitoring device for lead and other heavy metals. More specifically, the research work seeks to:

1. Determine levels of lead, cadmium and other metals

in *Drosophila* trapped at sites near the AMAX and ASARCO lead mines and smelters in the New Lead Belt in Southeastern Missouri.

2. Determine biological effects of exposure to these metals; specifically, this will be check for increased

incidences of anomalies, sex-linked lethal mutations, and for higher genetic load;

3. Coordinate collections and data with the on-going RANN-funded study of environmental pollution by lead and cadmium from industrial development in the New Lead Belt of Southeastern Missouri directed by Dr. Bobby Wixson.

Fruit flies of the genus *Drosophila* will be collected in traps at sites around the AMAX lead mines, smelters, and ore transport routes. In addition, flies will be captured at sites near the ASARCO smelter at Glover, Missouri. ASARCO awarded a grant to Drs. Hemphill and Wixson, of the University of Missouri, to establish

an environmental investigation of the metals pollution around ASARCO. Flies that are trapped will be checked for levels of lead, cadmium, zinc, copper, and mercury by atomic absorption spectrometry and/or by x-ray fluorescence. Twenty isozyme loci will be checked for genetic frequencies of isozymes by electrophoresis. This data is correlated with lead levels with distance from the source, such as a smelter or mine.

This project will provide much-needed data on levels in biota and effects on biota of lead and other metals enter a forest ecosystem from the nearby mines and smelters. The data will be incorporated into the final results of the larger project directed by Dr. Wixson.

Mercury in the Biogeochemical Environment; George A. Parks; Stanford University, Department of Applied Earth Sciences, Stanford, California 94305, \$85,000 for 12 months beginning September 15, 1973

Researchers at Stanford University have sought to establish a basic understanding of the processes by which mercury is released, transported and fixed in the natural environment. It is intended that the development of this information will contribute to the fundamental pool of knowledge of natural geochemical and microbiologically mediated processes controlling mercury translocation in the environment and should assist in the construction of more accurate models of mercury transport processes designed for the purposes of effective pollution prevention and control.

A limited drainage network, originating in the New Almaden Quicksilver Mining Area and leading through creeks and a small river to San Francisco Bay, was selected as the general area for all field work. The drainage system includes the New Almaden reservoir and passes through the City of San Jose. The reservoir, creeks, and river are presently closed to fishing because of mercury contamination. The study area is geochemically very complex but offers the opportunity to study geochemical and biogeochemical processes of release, transport and fixation of mercury in a very wide variety of environments.

Studies on transformations of mercury from one form to another have concentrated on microbiologically mediated changes, with emphasis on oxidation of sulfides of mercury, volatilization of Hg(II), and alkylation. These are all processes that mobilize mercury and enhance its biological availability. It has been found that various forms of the sulfides of mercury are oxidized

at different rates and depend strongly upon the environmental condition, particularly pH. Hg(II) added to biological systems was volatilized, probably through conversion to elemental mercury in varying degrees. Greatest volatilization was observed in aerobic systems, and was brought about by the presence of certain biological growth media, and by sterilized effluents from secondary wastewater treatment plants. In other cases, it was associated directly with the growth of microorganisms. The extent of volatilization was reduced by suspended solids and was insignificant in anaerobic systems where the potential for complex formation was high.

This project is providing important information on processes of mercury transport and fixation for the modeling efforts in the Ecology and Analysis of Trace Contaminants Program at Oak Ridge National Laboratory. However, the most direct involvement has occurred between the project staff and the Santa Clara County Water District which has responsibility for the management of three Hg-contaminated reservoirs and a system of contaminated streams. Project staff has also maintained contact with a number of user groups including Battelle Pacific Northwest Laboratories, The Division of Biological Science-National Research Council of Canada, USEPA-Southeast Research Laboratory, the U.S. Geological Survey and the San Francisco Bay Region Study sponsored by the U.S. Geological Survey and the U.S. Department of Housing and Urban Development.

An Interdisciplinary Study of Environmental Pollution by Lead and other Metals; Gary L. Rolfe; University of Illinois, Urbana, Illinois 61801; \$509,700 for 12 months beginning October 1, 1974

This award is for the continuation of a comprehensive research program centered on the environmental impacts of lead emissions from combustion of leaded gasoline. This terminal phase of the project will include studies of effects of soil and atmospheric lead on crop yield of corn and soybeans. In addition, plant burdens of lead as a function of various soil lead levels will be studied. The distribution of lead in an urban area, including building interiors, will be determined in an effort to identify the hot spots of exposure of the population to lead. The lead will be characterized as to its physical and chemical forms as a first step toward identifying the environmental transport pathways and transformations of lead.

More specifically, the project objectives are to: (1) determine the soil, plant and microbial factors controlling lead availability to the plant from the soil system; (2) identify the particulate deposition and reentrainment and movement of lead into plants from aerosol sources; (3) determine and quantitate the effects of lead on plant processes such as root growth, seed

germination, photosynthesis, respiration, and overall plant production and yield; (4) collect and characterize urban particulates in aerosols, street dusts, house dusts, etc. in order to determine their urban distribution and physico-chemical composition; and (5) apply/risk/benefit methodology to both the crop productivity and human health problem areas in order to weigh the risks versus the energy-economic benefits of the continued use of lead in gasoline.

Direct utilization of much of the University of Illinois data will be with the State, EPA and HUD. The Air Pollution Control Agency of Anderson, Indiana has contacted the research team for permission and assistance in using the air transport model developed by the project. The Illinois Department of Transportation is using data from the project on traffic volume effects on lead content along roadsides. The project will include the preparation of a book that will integrate the conclusions of this and other RANN-supported lead research at Colorado State University, the University of Missouri, and Purdue University.

A Search for Non-Biogenic Photochemical Mercury Methylation Processes Involving Suspended Water Drops; B. A. Soldano; Furman University, Division of Science and Mathematics, Greenville, South Carolina 29613, \$30,600 for 12 months beginning July 1, 1973

The project is designed to test the hypothesis that mercury is methylated by an inorganic mechanism operating in fogs exposed to sunlight in the neighborhood of mercury sources. The hypothesis

suggests that the currently recognized biological conversion of inorganic mercury to the more toxic methylmercury may account for only a portion of the methylmercury found in environmental media.

Human Lead Metabolism; George W. Wetherill; University of California, Department of Planetary & Space Science, Los Angeles, California 90024, \$66,000 for 12 months beginning April 15, 1974

The natural distribution of many elements has been greatly perturbed as a result of industrialization. In the case of lead, its use in gasoline additives, paint, insecticides, storage batteries, solder, piping, and utensils has exposed some humans as well as other living organisms to quantities of lead sufficient to cause severe lead intoxication and sometimes death. It has also been suggested that more prevalent disabilities with more obscure causes, such as hyperkinesia in children, are associated with low levels of lead intoxication.

Initiated through RANN support in April 1973, this project has sought to develop basic information that can be used to evaluate the margin of safety between those

persons apparently free of ill effects attributable to lead, those marginally affected, and those clinically ill. Research is continuing on the establishment of the principles governing the incorporation, internal distribution, and excretion of lead at typical environmental concentrations in normal adult males. During the period of the current award, studies are being expanded to include both sexes and other age groups. These studies use stable lead isotopes added to low lead diets to:

(1) determine the metabolic pools, pathways and residence time of lead; (2) assess the physiological regulation of lead concentration in tissue; (3) conduct

short-term studies on a wide range of individuals to evaluate factors influencing gastrointestinal absorption; (4) determine short-term response to blood components and urine; and (5) validate a multi-compartment physiological model of lead distribution in the body.

Recent project results indicate that the concentration of lead in the blood of adult male subjects can be simply related to such measurements as the fraction of food lead absorbed in the gut, the daily quantity of internal lead excreted in the urine and incorporated in the hair, and the characteristic residence time of lead in the metabolic pool that exchanges rapidly with the blood.

An Interdisciplinary Investigation of Environmental Pollution by Lead and Other Heavy Metals from Industrial Development in the New Lead Belt of Southeastern Missouri; *Bobby Wixson*; University of Missouri, Rolla, Missouri 65401; \$240,600 for 12 months beginning September 1, 1974

This award provides support for the continuation of an existing research plan to examine the extent, causes, and effects of heavy metal contamination in the forest environment, so that corrective action, if required, can be designed to minimize ecological effects; and so that the distribution and intensity of effects in a forested area can be compared with effects that might be expected in alternative sitings. More specifically, the objectives of this research are to: (1) evaluate the source intensities of various industrial operations in the area to identify what controls would be most likely to ameliorate environmental contamination; (2) evaluate the extent and intensity of the pattern of contamination in air, water, soils, and biota extending from the source to the surrounding uncontaminated areas; (3) describe mechanisms of transport and accumulation of heavy metals through environmental media; i.e., to determine the importance of sediment versus solution transport in water courses; evaluate the apparently significant transport of soluble humic acid complexes of lead by leaching or runoff from soils; assess the effects of particle size distribution on short-range versus long-range transport of particulates; and determine effects of stream vegetation on local processes of accumulation; (4) describe effects of heavy metals on the surrounding ecosystem; and (5) supply data needed by Oak Ridge National Laboratory for describing the transport of

Approximately one-third of the average daily lead intake for the typical urban male is derived from atmospheric sources through inspiration. The remainder is ingested in the diet.

Direct contact has been maintained by the project staff with representatives of the U.S. Environmental Protection Agency, the Food and Drug Administration and the Ethyl Corporation. Project reports and papers are distributed to several organizations including the California State Air Resources Board, several industrial corporations and environmental groups, and to private citizens.

pollutants through environmental compartments.

During the remaining two years of the project, the air transport, geochemical, and soil studies will be completed by extending heavy metals deposition and suspended particulate measurements out to a 10 mile radius from the smelter stack. In addition, extensive efforts will be made to elucidate the role of humic acids from decaying leaf litter in mobilizing lead and other metals. Studies of the toxicity of heavy metals, organic milling reagents, and combinations of these on common fish species of the area will be continued, along with studies on long-term toxicity effects of heavy metals on aquatic vegetation.

Lead industry officials and operators in the study area, the AMAX Lead Company of Missouri, for example, are the most regular users of research results from this program. The St. Joe Minerals Corporation has used project data to guide the construction of a mill waste recycling system, while the Missouri Air Conservation Commission is using project data to establish improved state standards and guidelines. Other users include: The Missouri Clean Water Commission, Missouri Department of Conservation, Missouri Geological Survey, U.S. Forest Service, Environmental Protection Agency, Bureau of Mines, and the Geological Survey.

Environmental Flow of Cadmium and Other Trace Metals; Kenneth J. Yost; Purdue University, Institute of Environmental Health, Pharmacy Building, Purdue University, West Lafayette, Indiana 47907; \$372,000 for 12 months beginning January 1, 1975

This award funds the second phase of a research project concerned with the environmental problems attributable to the steelmaking, zinc smelting, and metal finishing industries responsible for major releases of cadmium, zinc and other heavy metals from their plant emission/effluent systems. The overall objective of this project is to provide data which will contribute to the formulation of source standards which not only protect the environment, but also do not "over regulate" industry, thereby creating excessive control costs which must be passed on to the consumer of the product.

During this award period, Phase II, objectives are:

1. *Source Factors* — For the steelmaking, electroplating and zinc smelting operations detailed emission/effluent sampling programs will be completed to determine the characteristics of these releases in terms of the metal content, particle size distribution and variability in mass emission rate. Studies of measures for the effective control of these emissions which were initiated in the current year of activity are to be continued.

2. *Environmental Behavior and Effects* — Field research is to continue on designated terrestrial and aquatic sites to define metal flow patterns in each ecosystem and identify "target organisms" which are structurally important to the system and are principal accumulators of metals. These target organisms are to

be examined further during the final phase of this project.

The research plan will continue to focus on: (1) collaborative research with industrial concerns whose process streams contain significant amounts of cadmium, zinc, and other heavy metals; and (2) environmental studies on terrestrial and aquatic sites where regulatory agencies have expressed concern over the extent of the metal pollution problem attributable to the steel, zinc, and metal finishing industries. During this period, accumulation of extensive sample collections of water, soil and airborne materials, in addition to plant and animal tissue samples, will be analyzed for specific metals and the chemical structures in which they are incorporated. This information and data on industrial process performance and meteorological measurements will serve as the basis for calculations of rates of metal translocation, loss and accumulation; environment-organism metal equilibria, and evaluations of biological community structure and function.

The user community for this data and the conclusions derived from it consists of regulatory agencies who must set source and environmental standards (USEPA, Illinois EPA), groups representing sources on which standards will be imposed (Inland Steel Co., Warsaw Plating Co., and New Jersey Zinc Co.), and a larger, non-specific community of individuals interested by reason of profession and/or concern.

NITRATE

The objective of the Nitrate element is to provide the scientific and technological information which will assist in the resolution of the conflict between acceptable environmental levels of nitrate emanating from agricultural lands and maximum agricultural productivity.

A Study of Certain Ecological and Economic Consequences of the Use of Inorganic Nitrogen Fertilizer; *Daniel H. Kobl, Barry Commoner, and Georgia Shearer*; Washington University, Center for the Biology of Natural Systems, Saint Louis, Missouri 63130; \$300,000 for 12 months beginning June 1, 1975

This award makes possible the completion of a project, now in its fifth year of activity, designed to: (1) define the limits of usefulness of nitrogen isotope ratio measurements for tracing nitrate sources in the field without using isotopically enriched nitrogen fertilizer; (2) while developing the necessary observational data base, to derive and test mathematical models capable of predicting the effects of varying natural conditions and agronomic practices on the entry of nitrate into surface waters; and (3) to produce quantitative estimates of the effects of different rates of fertilizer nitrogen application on the economics of Corn Belt farming, and to relate the economic effects to variations in the quality of surface waters.

The research plan calls for extensive laboratory measurements of $^{15}\text{N}/^{14}\text{N}$ ratios of nitrogen produced in individual steps of the soil nitrogen cycle. These experiments are designed to show what conditions allow natural soil processes to affect the identification of fertilizer-derived nitrate by $^{15}\text{N}/^{14}\text{N}$ measurements. The project has demonstrated a correlation between high nitrate in surface waters and low values of the $^{15}\text{N}/^{14}\text{N}$ ratio in the nitrate, but the correlation, although significant, is imperfect. A second part of the research plan is therefore directed toward identifying what factors account for the residual variance.

Nitrate in Effluents from Irrigated Lands; *Parker F. Pratt*; University of California, Kearney Foundation of Soil Science, Davis, California 95616; \$490,100 for 12 months beginning August 4, 1975

Now entering its fourth year of activity, this project has continued to develop the capability to predict and regulate the amount of nitrate entering surface and

A mathematical model for simulating the movement of nitrate through Corn-Belt soils, developed on the project, will be further tested and refined, and extended to apply to an entire watershed. Nitrogen transformation rates, patterns of water movement in soils as influenced by rainfall variability, and the rate of evapotranspiration are input parameters that will be used to test the sensitivity of the model.

The economic phase of the program will be the completion of a two-year detailed study of agronomic practices and motivations on up to 100 farms representing sub-watersheds. This phase of the study ties together the observations of nitrate levels in drainage waters with corresponding data on the economic impact on farmers that would result if fertilizer applications were restricted.

The Illinois Pollution Control Board held hearings in 1972 to determine whether fertilizer application rates should be restricted in order to control the quality of public water supplies. Recognizing that nitrate pollution of waters may grow as the demand for food and feed increases, the Board concluded that it should not promulgate regulations until more is known about the problem. The project at Washington University should help to clarify the issue for the midwestern corn belt as a whole.

underground water supplies from irrigated croplands in relation to controllable practices of irrigation, fertilization, cropping, and soil management. A closely

correlated goal has been to test the hypothesis that important amounts of excess nitrate not used by crops are lost from soils by microbial conversion to gaseous nitrogen and nitrous oxide (denitrification), and to examine how controllable variables could be adjusted to promote denitrification as a factor ameliorating leakage of surplus nitrate into water supplies.

At a variety of irrigated sites, the volume of tile drainage water and its nitrate content have been correlated with observations of soil characteristics, cropping practices, fertilizer input, and time with respect to water applications. The same factors are being correlated with nitrate in the vadose water moving by free drainage at various levels below the root zone toward underlying aquifers. The foregoing direct correlations are being related to standard soil cartographic units to produce interpretive maps useful for characterizing soil areas as to their tendencies to release excess nitrate to drainage pathways, or, conversely, to eliminate nitrate excess by denitrification.

Isotopically pure nitrogen-14 has been applied as ammonium sulfate fertilizer to cropped experimental plots totaling several acres each at locations near Davis and Fresno, California. Fertilization and irrigation are varied to create a wide range of conditions affecting the dynamics of nitrogen transformations, nitrate leaching, and plant uptake. Periodic determinations of nitrogen chemical species and isotopic ratios are made at various depths within and below the root zone.

The Davis plots are instrumented on a closely spaced grid in x-y coordinates down to 300 cm. for measurements of soil water content and tension, and for withdrawal of soil solution through implanted suction cups. Smaller field plots and lysimeters receive nitrogen-15 applications. These isotopic tracer experiments permit interpretation in terms of the fate of fertilizer

nitrogen, turnover rates of nitrogen in the soil organic pool, the degree of correlation of effluent nitrate with recently applied nitrogen, and options available for regulating nitrate effluent by managing the soil/crop system.

Laboratory and field plot studies of the kinetics of nitrogen transformations in solutions percolating through soil columns provide rate data for constructing a mathematical model of nitrification and denitrification. This model, along with data on water and nitrate movement from the instrumented plots at Davis, supports the development of a more comprehensive model to predict the downward movement of nitrate beyond the root zone in relation to variable fertilization and irrigation practices.

The research is designed to serve the needs of public health officials, members of Congress and state legislatures, the U.S. Environmental Protection Agency, and indeed any persons or agencies that must consider proposals to regulate the use of fertilizer. In the present climate of public concern about water pollution, such proposals have been seriously advanced.

In September 1974, the Kearney Foundation and the California Department of Water Resources co-sponsored a two-day "Symposium on Nitrogen, Especially as Related to Agricultural Production and Water Quality" in Sacramento. This project contributed about a fourth of the content of the symposium, which was attended by 188 attendees representing State and regional water quality officials, the California irrigation districts, the USDA, the EPA, the U.S. Bureau of Reclamation, the California Farm Bureau Federation, various industrial organizations, and other agencies.

The project holds annual conferences with user groups to convey research data and interim conclusions.

ORGANIC CHEMICALS OF COMMERCE

The objective of the Organic Chemicals of Commerce element is to develop the hazard prediction capability for organic chemicals based on chemical structure, physical properties, and other parameters; and to determine the environmental and human health effects of toxic organic chemicals.

Identification of Mutagenic Organic Compounds in Environmental Samples; *Barry Commoner*; Washington University, Center for the Biology of Natural Systems, St. Louis, Missouri 63130; \$180,200 for 12 months beginning April 1, 1975

In recent years, man has become environmentally exposed to a wide and increasing variety of chemicals, some of which are mutagens. The so-called "Ames test" (a reverse mutation test on bacteria) has shown that there exists a strong correlation between bacterial mutagenesis and carcinogenic behavior of compounds in animal tests. At the present time a direct one-to-one relation between a positive Ames test and carcinogenicity is unclear. This project will apply the Ames test to a number of compounds and attempt to improve the test itself by adding a series of steps to it.

Specific objectives of this project are to; (1) perfect a bacterial mutagenesis test for the rapid, systematic screening of mixed effluents and chromatographic fractions of these effluents from chemical industries; (2) determine the presence of coordinated interactions and interference among the substances present in mixed effluents; (3) identify individual active organic chemicals in the effluents; and (4) perfect methods of organic chemical identification by means of hyperfine labelling electron spin resonance based on the production of free radicals by radiation of caged compounds with X-rays.

Experimental activities include the determination of mutagenic activity for 75-100 pure compounds that are suspect because of structural considerations, i.e., relationships to known mutagens or carcinogens and

which are known to be present in the environment or are produced in large tonnage. In addition, effluents from chemical industries in Harris County, Texas will be provided by the Harris County Pollution Control Department and analyzed for mutagenesis. Harris County is the site of many large chemical companies. The water samples will be fractionated and the fractions tested individually and in combinations. Active fractions will be analyzed by gas chromatography/mass spectrometry and by electron spin resonance in order to identify the active chemical species.

In effect, the utilization of research results is largely built into the research program itself. The investigators will collect samples of effluents from chemical plants in collaboration with government agencies that are responsible for monitoring these sources. The Harris County (Texas) Pollution Control Department has agreed to provide aliquots of the samples of chemical plant effluents that the Department regularly collects in the Houston ship channel, and to collaborate by comparing their analytical methods and results with those of the team at Washington University. The Ames test will be applied to organic materials found in the channel. Should such tests prove positive an attempt will be made to do chemical separations on the samples to determine the compound giving the positive test.

Fates of Industrial Synthetic Organic Chemicals: A Case Study; *Ronald A. Hites*; Massachusetts Institute of Technology, Cambridge, Massachusetts 02139; \$107,900 for 12 months beginning June 1, 1975

Pesticides, polychlorinated biphenyls, chlorofluoromethanes, tetrachloro-dibenzodioxane, and phthalate esters are a few of the many industrial organic compounds which have been found to have deleterious

environmental effects. One of the most straight-forward and effective points at which controls of these compounds could be initiated is the industrial site where they are either produced or used. Before regulations can

be established, however, it is necessary to know the identities (and abundances) of the organic compounds in wastewater from such industrial sites and to know what happens to these chemicals once they have entered the environment.

The purpose of this research is to conduct an initial survey of several types of industrial plants to determine the identities and amounts of organic compounds in their effluents. Two sites selected from this group will be studied to determine in detail the fates of the effluent compounds in the various receiving waters. The study will be carried out in close cooperation with the Environmental Protection Agency — Southeast

Environmental Research Laboratory. The heart of this program is the qualitative and semi-quantitative analysis of complex mixtures of organic compounds isolated from water, sediment, and organisms. Such analyses will be performed using mass spectrometry both in combination with gas chromatography and under high resolution conditions.

The industrial community will benefit from detailed characterization of their effluent streams and from studies of the effectiveness of their water treatment systems. The methods developed in this study will be transferrable to chemical industries other than those studied.

SUPPORTING METHODOLOGY

The purpose of the Supporting Methodology element is to develop methods and instrumentation needed to implement the research objectives of the Trace Contaminants Program.

A Water Pollution Monitoring Laser Optical System; *Silverio P. Almeida;* Virginia Polytechnic Institute and State University, Department of Physics, Blacksburg, Virginia 24061; \$73,600 for 12 months beginning July 1, 1975

This award continues research that is concerned with the automation of biological monitoring of water quality using laser holography. The development of a laser optical system is being carried out in a new approach to monitoring biological indexes of water pollution. Knowledge of the concentration and types of algae (diatoms) in water has been shown to be an important parameter in determining the biological condition of a given body of water. The laser optical system is designed to automatically scan and select, in a given sample, the types and numbers of various diatoms through the use of coherent spatial filtering techniques. The collected data are digitized and read into a computer that has semi-automatic control over the monitor system. Preliminary results indicate that the rate of counting and identifying diatoms with such a system is far greater than can presently be done by humans.

Management of aquatic ecosystems depends upon frequent information feedback. In current practice, techniques for measuring the responses of aquatic organisms and communities require days or weeks. These techniques, however, are not suitable for meaningful quality control of aquatic ecosystems and

crisis prevention that require response times of hours or minutes. The purpose of this work is to try to shorten the time lag in biological information generation through development of a laser optical system. An additional benefit is that such a development should increase the objectivity of the analysis. It is expected that this research will result in a prototype coherent optical spatial filtering device. Such an instrument would appear to have a great potential as an automated instream biological monitoring system in the waterways of the Nation.

The investigators are in close touch with potential users of the water pollution monitor currently under development. Seminars for users have been presented and papers have been published on results to date. EPA and DOD both funded a one-time supplement to last year's award and have expressed continuing interest in the development of this instrument. They both see applications by their agencies and contractors. Dr. Cairns, co-principal investigator on this grant, is an advisor to the Ohio River Valley Water Sanitation Commission.

An Environmental Study of Selected Trace Elements; *Robert S. Braman;* University of South Florida, Tampa, Florida 33620; \$44,000 for 12 months beginning June 1, 1975

This award renewal enables the continuation of research to: (1) devise new methods for analyzing environmental samples (especially air, soil, and water) for minute traces of specific molecular forms of antimony, selenium, tellurium, germanium, thallium, and tin; (2) determine the full range of elements biomethylated in the environment, with identification of the compounds so formed and verification of their presence in the

environment; (3) determine the rates of translocation of the biomethylated elements from their sources into the environment; and (4) develop of preliminary hazard assessments where possible.

Analytical studies will explore techniques already successfully applied by the principal investigator to the measurement of methylated forms of arsenic and

mercury. Methylated forms of the several elements will be sought in air, water, and soil in and around Tampa Bay, as well as in the air of homes and buildings. Confirmation of the identity of each detected form will be sought by combined gas chromatography and mass spectroscopy. In locations (lakes, rivers, bays) where biomethylation is suspected because of polluted conditions, studies will be conducted to determine relationships between concentrations in sediments and water of the several forms of methylated elements.

Research findings have been presented at the fall 1974 meeting of the American Chemical Society; the

International Symposium on Recent Advances in the Assessment of Health Effects of Environmental Pollution, Paris, June 1974; the Fifth Annual Symposium on Recent Advances in the Analytical Chemistry of Pollutants, Jekyll Island, Georgia, May, 1975; and an EPA hearing on mercury pesticides, January, 1975. Representatives of several laboratories from this country and abroad have visited the project to become familiar with the new techniques. The EPA environmental research laboratory at Las Vegas is using these methods in research on environmental transformations of mercury species.

Application of Alpha Scattering and X-Ray Fluorescence to Real-Time Analysis of Trace Elements; T. A. Cabill; University of California, Davis, Crocker Nuclear Laboratory, Davis, California 95616; \$15,000 for 12 months beginning January 15, 1975

The primary objectives of this grant renewal are: (1) to complete the testing of elastic scattering of alpha particles for the real-time analysis of elements of low atomic number in atmospheric particulate samples; and (2) to complete the research on an optimum computer coding for the developed X-ray fluorescence method.

Utilization is fully developed at this late stage in the

project. The California Air Resources Board (ARB) has concluded that the analytical system developed under this program is the most efficient available for ARB purposes. The ARB makes routine use of the system on a contract basis for analyzing air particulate samples collected in the ARB sampling network. Thousands of samples have already been analyzed.

Investigation of the Use of the Resonance Raman Effect as an Environmental Monitor; Owen Chamberlain; Lawrence Berkeley Laboratory, Berkeley, California 94720, \$78,500 for 12 months beginning November 1, 1973

The intention of this work has been to assess the feasibility of developing instrumentation which can exploit the resonance Raman effect for ranging and remotely sensing trace atmospheric contaminant gases. Whereas the ordinary Raman effect is weak, and Raman backscattering excited in a remote (kilometer range) volume of air is likely to be too faint for detection against sky background, the use of a finely tuned laser wavelength, very close to an absorption line of the pollutant gas, should permit enhancement of the return signal by 4 orders of magnitude or more. The objective of

the project is to determine in the laboratory the numerical parameters necessary for an assessment of the feasibility of developing a usable field instrument based on this effect.

A tunable pulsed dye laser system has been constructed for operation with or without frequency-doubling crystals so as to permit operation over a wide range of visible and ultraviolet wavelengths. The gaseous species that are being examined include SO_2 , O_3 , NO_2 , and acetone.

Application of Cryogenic Techniques to Problems in Air Pollution; Russell J. Donnelly; University of Oregon, Department of Physics, Eugene, Oregon 97403, \$95,100 for 13 months beginning February 1, 1974

Many of the hydrocarbon contaminants in the normal atmosphere take part in the photochemical reactions that form smog, but methane, which occurs naturally at relatively high levels, is less reactive. Studies have shown that methane is typically present at levels above 940 micrograms per cubic meter (1.4 ppm) and constitutes perhaps half of the total hydrocarbon level in an urban

atmosphere. The ratio of methane to non-methane hydrocarbons varies so widely, however, that total hydrocarbon measurements do not accurately reflect the smog-generating potential. For this reason the U.S. Environmental Protection Agency has set a national primary and secondary ambient air standard for hydrocarbons, specifying non-methane hydrocarbons.

Researchers at the University of Oregon are developing a method for measurement of non-methane hydrocarbons in ambient air that differentiates methane from the heavier hydrocarbons by cryogenic separation using liquid nitrogen. The basic methane separation device is a cooled tube through which the sample air stream flows prior to entering a conventional total hydrocarbon analyzer. Activities during the current period of support center around the development of an instrument for field conditions that will meet the equivalency tests for the EPA reference method for the determination of non-methane hydrocarbons. Improvements over the current instrument will include; (1) a simplified or automatic cooling system in order to make the final instrument more attractive for use under typical field conditions; (2) modifications to improve signal averaging for methane and total hydrocarbon

levels in order to allow nearly simultaneous, real-time measurements of both methane and total hydrocarbons; and (3) electronics to provide records of both of these signals and their difference.

The anticipated result of this project is an acceptable, relatively simple and low-cost system for the measurement of non-methane hydrocarbons, that could be produced commercially for use by local air pollution authorities for routine monitoring to determine compliance with ambient air standards. The Air Quality Measurement Methods Branch of EPA follows the progress of this work and provides advice to the project staff. Preliminary contact has been made with potential manufacturers of the cryogenic methane separator and further consideration will be dependent on the results of the current phase of the project.

Seminar on Early Warning Systems for Toxic Substances; James E. Flinn; Battelle Memorial Institute, Columbus, Ohio 43201, \$4,900 for 12 months beginning March 1, 1974

Considerable progress has been made on identifying, characterizing and controlling pollutants resulting from man's current activities. Efforts are now being placed on projecting into the future the identity of pollutants that may prove to be directly or indirectly toxic or hazardous to man or the environment. The number of candidate substances is large and there is a need for methods of selecting and prioritizing those substances that represent the more significant hazards, and thus to permit the allocation of usually limited resources for study and control. Such methods must be; (1) thorough or comprehensive with respect to potential sources; (2) discriminating through reference to indicators of potential hazards; (3) adaptable to current usage; i.e.,

within the framework of existing technology and societal systems; and (4) amenable to the establishment of priorities for the identified substances.

The aim of the seminar held January 30 thru February 5, 1974 was to critically examine the tools that exist for identifying and assessing, *a priori*, toxic or hazardous substances and to assess their practicality with respect to current early warning needs. Participants were drawn from government and nongovernmental expert sources. The proceedings of the seminar are to be published and distributed to a large number of governmental agencies and industrial firms, particularly chemical manufacturers.

Plan for a National Environmental Monitoring Specimen Bank; George M. Goldstein; U.S. Environmental Protection Agency, National Environmental Research Center Research Triangle Park, North Carolina 27711, \$100,000 for 24 months beginning June 1, 1974

Sample collections of air, soil, water, and plant and animal tissues, collected and preserved under standardized, controlled conditions serve as reference libraries to the condition of the environment at the time and place the samples were taken. If new patterns of morbidity or mortality appear in humans or other animals and seem to be associated with high concentrations of toxic substances or persistent residues in the environment or in living tissues, a back-check with similar tissues collected in earlier years may corroborate or deny the presumed cause of these patterns. Many

collections of samples already exist, but their location and type are not widely known and their usefulness to science may be more accidental than planned.

The objective of this project is to study the feasibility of a national environmental monitoring specimen bank. To this end a four-task approach is proposed which includes; (1) a survey of existing specimen banks; (2) the evaluation of the survey data to determine applicability of existing banks to a national system for environmental monitoring; (3) the production of a 5-year plan for the

organization, management and resource needs for such a banking system; and (4) the initiation of research to establish criteria for collection, preparation, storage and chemical analysis of various types of specimens.

Responsibility for organizing and managing

Extention of IZAA Technique to Multiple Elements; *Tetsuo Hadeishi*; Energy Research and Development Administration, San Francisco Operations Office; Lawrence Berkeley Laboratory, Berkeley, California 94720; \$99,200 for 12 months beginning April 1, 1975

The isotope-shift Zeeman-effect atomic absorption spectrometer is being evaluated for the determination in a variety of materials of minute amounts of mercury, cadmium, lead, and other elements without prior chemical preparation.

Project work has been mainly devoted to: (1) the development of electrodeless source lamps that are capable of stable, long-life performance within the configuration of the Zeeman magnet; (2) the development of one or more furnace designs suited to the quick and complete decomposition of various sample materials with minimum smoke production and no retention of trace metals; (3) the suppression of zero and calibration drifts by electronic means and the computerization of readout circuitry; and (4) the development and refinement of the optical and mechanical systems and the Zeeman magnet.

Present research plans during this continuation period are: (1) the development of lamps for additional

Diode Laser Multi-Pollutant Ambient Air Monitoring; *E. D. Hinkley*; Massachusetts Institute of Technology, Lincoln Laboratory, 244 Wood Street, Lexington, Massachusetts 02137; \$116,800 for 12 months beginning March 1, 1975

The objective of this research is to deliver to the Environmental Protection Agency a mobile laboratory facility instrumented for diode laser monitoring of gaseous pollutants in connection with the EPA Regional Air Pollution Study (RAPS) in St. Louis. This will enable measurements integrated over a kilometer path between the mobile van and a fixed retroreflector. The pollutant gases to be studied are carbon monoxide, nitric oxide, ozone, ammonia, and, of lower priority, sulfuric acid vapor, vinyl chloride, and sulfur dioxide. The EPA is co-funding the project.

Research planned for this year of study includes: (1) experiments to devise a system for the detection of ozone and ammonia in the laboratory, and a test of the system

this project is with the Bioenvironmental Laboratory Branch, Human Studies Laboratory, EPA, NERC-North Carolina. The project is co-funded by the EPA and the National Bureau of Standards.

elements of interest in environmental studies or product control; (2) further investigation of a new two-chamber furnace using three alternative designs for covering the full volatility range of the chemical elements; and (3) the comparison of the isotope-shift Zeeman-effect atomic absorption (IZAA) method with conventional atomic absorption spectroscopy (AA) as to superiority of background correction, relative sensitivity and sensitivities relative to those needed in critical environmental measurements.

Commercial interest in the IZAA spectrometer has been expressed by Nissei Sangyo Instrument, Inc., Mountain View, California, who exhibited the instrument at the national meeting of the Federation of Analytical Chemistry and Spectroscopy Societies at Atlantic City. The National Environmental Research Center of the U.S. Environmental Protection Agency at Las Vegas is using such an instrument on EPA research programs.

at the field site; (2) an examination of the spectra of sulfuric acid vapor and vinyl chloride to evaluate the possibility of extending the methodology to these substances; and (3) a study of the possibility of extending the laser path to 10 kilometers by improving signal processing techniques in the hope of increasing the detection sensitivity for sulfur dioxide.

The prime user of the system and of the associated techniques is the Environmental Protection Agency. The RAPS measurements in St. Louis will be carried out in part by EPA personnel as part of their indoctrination by Lincoln Laboratory staff in the use of the instrumented van.

Evaluation of a Laboratory Microcosm for Study of Toxic Substances in the Environment; *Robert L. Metcalf*; University of Illinois, Department of Entomology, Urban, Illinois 61801; \$61,600 for 12 months beginning July 15, 1974

This grant enables the continuation of research by the University of Illinois into toxic environmental substances. The major objectives of the research are to: (1) relate laboratory results from model ecosystem study to evaluate the environmental significance of a given range of ecological magnification (E. M.) and biodegradability index (B. I.) in terms of practical pollution problems; (2) characterize the environmental micropollutant characteristics of a variety of synthetic organic compounds for which little appreciation of environmental toxicology exists; and (3) develop knowledge about the principles of biodegradability of organic compounds so that laboratory screening by model ecosystem technology can be used to design chemicals for optimum compatibility with environmental quality.

The first objective is being met by literature survey of

Tunable Lasers for Application to Air Pollution Measurements; *Aram Mooradian*; Massachusetts Institute of Technology, Lincoln Laboratory, 244 Wood Street, Lexington, Massachusetts 02137; \$80,800 for 12 months beginning May 1, 1975

Lincoln Laboratory at MIT has recently developed a tunable near-infrared source that operates by generating the difference in frequency between two lasers. Because of its tunability, and the exceedingly narrow width of its spectrum lines, this system functions as a spectrometer capable of better than Doppler-limited resolution over the 2.2 to 4.2 micrometer spectral range. This development is a great step forward in spectroscopic capability needed for research on the chemistry of atmospheric pollutants.

The objective of this research is to apply the new technique to the search for new spectral signatures of important pollutant and transient species by cataloging their high resolution spectra. In the before-mentioned spectral range, there occur many characteristic

data on environmental pollution by a variety of organo-chlorine pesticides, phthalate esters, which have or will be evaluated in the model ecosystem. In addition, Lake Decatur, a reservoir impoundment in the heart of rich farmland heavily treated with pesticides, and surrounded by an industrial urban area, will be used as a real life situation. Objective two is well illustrated by data now being obtained on compounds reported in the Progress Report. Finally, objective three is met through a detailed study of the DDT-type molecule with the incorporation of various degradophores.

Dr. Metcalf has been asked by the EPA, NERC Corvallis, to design a model terrestrial ecosystem. The research team has evaluated candidate compounds for: Zoecon, Stauffer Chemical Company, Mobil Chemical Company, Monsanto Chemical, Thompson Hayward Company, and Eli Lilly.

absorptions of light hydrocarbons and other simple pollutant molecules. Also in this region, spectral signatures are expected for the important radicals OH and HO₂. This information will assist in devising instrumental methods for measuring their concentrations and for following the dynamics of their participation in the formation of secondary pollutants and in the reactions of primary pollutants in the stratosphere.

The project serves the needs of research workers who require extremely detailed molecular spectroscopic data in a variety of research activities on ground-level atmospheric pollution, stratospheric chemistry modeling, and in planning remote monitoring systems.

Study of the Chemistry of Atmospheric Particulates by Electron Spectroscopy for Chemical Analysis (ESCA); *T. Novakov*; University of California Lawrence Berkeley Laboratory, Berkeley, California 94720; \$210,000 for 12 months beginning July 1, 1974

Whereas most analytical studies of atmospheric particulates are restricted to the identification and measurement of chemical elements without regard to their forms of chemical combination, this project has the objective of characterizing molecular and surface-chemical forms of combination. Ambient aerosols, and aerosols emitted by primary sources, are being described

in this fashion. A second objective is to determine the nature of surface-chemical and catalytic reactions on aerosols. The ultimate goal is to establish links between the nature of the primary particulates, the chemistry of gas-particulate reactions, and the chemical properties of the final aerosols.

The first approach being taken is to prepare an inventory of the chemical species characteristic of ambient and source aerosols. The inventory is made up by analyzing samples collected in diverse locations in California and in other parts of the U.S. Available for this purpose is the extensive collection of samples taken in the Aerosol Characterization Study (ACHEX, 1972) sponsored by the California Air Resources Board. The concentrations of various chemical species are being correlated among themselves and with other measurables, including particle size, time of day, and photochemical agents. The principal observables in the laboratory study are the ESCA chemical shift and temperature-dependent ESCA measurements. The latter observations facilitate interpretation of the ESCA spectra by characterizing chemical species by their volatility or pyrolytic behavior.

The second approach has been to conduct experiments

to elucidate various gas-particle reactions and to assess the role and significance of these processes in atmospheric pollution. Results of the first two years of work have shown the importance of soot particles for the catalytic conversion of sulfur dioxide to the production of sulfate-bearing particulate, and for the production of characteristic nitrogen-bearing aerosols. Further experiments are being done with particulates collected from ambient air in locations suspected of containing large concentrations of carbonaceous particles.

The relationship to the ACHEX project of the California Air Resources Board has provided a close tie with a major State agency responsible for elucidating the nature of atmospheric pollutants in its area. A similar close relationship exists with the Air and Industrial Hygiene Laboratory of the California Department of Health. The EPA National Environmental Research Center at Research Triangle Park, North Carolina, is also interested in the results of this project.

Continuing Support of the Subcommittee on the Geochemical Environment in Relation to Health and Disease;
William L. Petrie; National Academy of Sciences, National Research Council, Washington, D.C. 20418, \$10,000 for 12 months beginning January 17, 1974

The Subcommittee on the Geochemical Environment in Relation to Health and Disease is a branch of the U.S. National Committee for Geochemistry, Division of Earth Sciences, NAS/NRC. During the past three years the Committee has been concerned with an assessment of what is known about biologically significant chemical elements, the identification of the most significant gaps in present knowledge, and other lines for future research.

An early accomplishment of this project was the planning and partial support of the three-day Conference on Geochemical Environment in Relation to Health and Disease held October 4-6, 1971, under auspices of the New York Academy of Sciences. The principal activities were the workshops held at the Asilomar Conference Grounds in Pacific Grove, California, and at Capon Springs, West Virginia. The book stemming from the first workshop is now available.

Major activities of the Subcommittee during the current interval are to: (1) complete and submit for publication the report of the second workshop at Capon Springs; (2) conduct the third workshop of the planned series with appropriate biomedical data and to identify

and define patterns of spatial coincidence through the use of maps, computers and other data handling devices; (3) prepare a full report on the activities of the third workshop with illustrative data, and with recommendations for future work; (4) plan and prepare a concise, descriptive report on the overall field along with estimates of their relative present and future importance; (5) provide advice and guidance, primarily on request, to supporting organizations on geochemical factors involved in health and disease; and (6) continue to work cooperatively with the International Association of Geochemistry and Cosmochemistry Working Group on the Geochemistry of Health and Disease, and other groups, such as the Society for Environmental Geochemistry and Health, toward the development of both national and international programs and exchanges in the study of geochemistry and health, emphasizing the multidisciplinary approach.

The project is co-funded by the U.S. Environmental Protection Agency and the Energy Research and Development Administration.

Remote Measurement of Air Pollutants; *Edward K. Proctor, Jr.*; Stanford Research Institute, Menlo Park, California 94025; and Robert L. Byer, Stanford University, Stanford, California 94305; \$164,500 for 12 months beginning May 1, 1975

The differential-absorption lidar (DIAL) scheme, is a means through which light from a transmit-receiver laser optical system is reflected back to the system by dust particles in the air at arbitrarily selected range distances, the distance being controlled by gating circuitry. The concentration of the pollutant gas is correlated with the absorption of light from the beam at a characteristic molecular wavelength, correction for variations in dust back-scattering and background absorption being made by reference to absorption at a nearby wavelength just off the peak of the pollutant spectrum line. Jointly funded by the Trace Contaminants and Environmental Effects of Energy programs of AENV, this project seeks to achieve the capability to design, construct and deploy lidar instruments suitable for remote range-resolved measurements of air pollutants under field conditions.

The research plan calls for the following steps to be pursued simultaneously, or in some cases sequentially: (1) achieve tunable sources for the infrared bands of interest; (2) obtain high-resolution spectral data on gaseous pollutants and atmospheric constituents; (3) carry out experiments to show whether the DIAL technique is as effective and sensitive as indicated by theory; (4) determine the effects on this measurement technique of atmospheric scintillation; and (5) determine the wavelength dependence in the infrared region of back scattering by typical atmospheric aerosols.

The Electric Power Research Institute has drawn on the results of the work in a project to test its feasibility for application in the Institute's own research program on remote monitoring.

Research on Analytical Methods for the Determination of Trace Elements; *Philip W. West*; Louisiana State University, Baton Rouge, Louisiana 70803; \$78,200 for 12 months beginning August 1, 1974

This award continues research being carried out on the development of analytical methods appropriate for the evaluation of environmental quality along four general lines of investigation:

1. Achieve a general method for producing standard toxic dusts having known particle size and pre-determined and accurately adjustable chemical composition. This is necessary so as to make it possible to prepare standard samples representative of ambient airborne dusts that would serve as reference standards in the chemical analysis of atmospheric particulates, and as precisely defined experimental materials for toxicological research.
2. Extend the application of the inexpensive ring-oven method, used to determine various trace metals in water, to the analysis of waters and sewage so as to permit screening of water supplies by numerous environmental control laboratories not equipped or staffed for more sophisticated methodology.
3. Advance in the application of chelating agents to the extraction of toxic metals from exposed air-sampling filters so as to shorten the ensuing atomic

absorption procedure and avoid interference from matrix elements in the collected dust sample.

4. Combine the simplified chelating extraction with the ultra-sensitive heated graphite atomizer technique of atomic absorption analysis, so as to increase the sensitivity of both air and water analysis.

An important outlet for the results of this research is the Air Pollution Training Program of the U.S. Environmental Protection Agency (EPA) in the Office of Manpower Development at the National Environmental Research Center in North Carolina. Earlier work has been utilized in the preparation of two manuals to be used by EPA: one for training analytical personnel, and another for describing actual test protocols for regulatory monitoring. The program for extending the ring-oven technique to water analysis is designed for use by water treatment plant operators inexperienced in chemical analysis, serving thousands of population centers. The goal is to provide an inexpensive technique that will allow routine checking for compliance with U.S. Public Health guidelines on metallic contaminants in water supplies.

Fluorescence Immunoassay Methods for the Detection of Organic Environmental Contaminants; *Colin B. Williams*; IRT Corporation, P.O. Box 80817, San Diego, California 92138; \$76,400 for 12 months beginning March 1, 1975

A serious obstacle in the field study of organic environmental contamination is the lack of a rapid, simple, sensitive and accurate method for quantitatively detecting the presence of a specific organic chemical in a variety of environmental samples. This project is aimed at developing an assay methodology that would be simple, rapid and portable enough for a technician to measure a specific contaminant in a variety of environmental samples directly in the field. The method is intended for use by those agencies in government and industry with responsibility for environmental monitoring.

During the current year of RANN support, the

application of fluorescence polarization immunoassay (FPI) methods to the detection of organic contaminants in trace amounts has been successfully demonstrated in the laboratory. The next three steps remaining to be taken to establish the value of this technique under practical operation conditions are: (1) the development of reagents which will enable a multi-residue analysis to be undertaken; (2) the production of reagents which will be stable under the normal environmental conditions associated with their use; and (3) the design, fabrication, and testing of a prototype wideband fluorescence polarimeter will be undertaken for use under field assay conditions.

PROGRAM DEVELOPMENT AND UTILIZATION

The objectives of Program Development and Utilization are to assist the Trace Contaminants Program in the: (1) development and assessment of Program initiatives and priorities; (2) promotion of cohesiveness in the overall Program effort by supporting interproject communication; and (3) implementation of effective utilization of Program outputs.

Program on Ranking Manufactured Organic Chemicals for Research Priorities; Fred Y. Chan; Stanford Research Institute, Menlo Park, California 94025; \$145,400 for 12 months beginning May 1, 1974

This project is providing supportive information to the "Workshop to Select Organic Chemicals for Environmental Research," which is described in an accompanying summary. Data are being compiled in a useful format on the production, use, disposal,

properties, and toxicity of certain organic chemicals in commercial production. The data are then reviewed by the workshop to select a small number of priority compounds for in-depth research on their environmental and health impacts.

The Restoration and Recovery of Damaged Ecosystems — A Symposium; Kenneth L. Dickson; Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061; \$8,000 for 12 months beginning January 1, 1974

Although much research and regulatory resources are aimed at preventing environmental damage, it is nonetheless a fact that many ecosystems have been and are still being degraded by various human activities. Federal requirements for protection and restoration of the environment are becoming increasingly common.

An international symposium, funded by NSF, was held at VPI&SU on March 23-25, 1975, on the Restoration and Recovery of Damaged Ecosystems. The objective of this symposium was to develop an understanding of the mechanisms (both natural and man directed) by which ecosystems are to: (1) study the nature of the recovery process for various representative types of ecosystems (freshwater, marine, and terrestrial) and to identify the elements common to the recovery process for all ecosystems, as well as the unique attributes of different

types of ecosystems in the recovery process; and (2) to determine whether the recovery and restoration process can be accelerated by human intervention and management.

The most tangible product of the symposium is a book which will be published containing the symposium results as well as discussions on goals, commonalities, and significant differences of recovery of various damaged ecosystems. In addition, the book will reveal research gaps and establish research and management priorities. The symposium was attended by Federal and State regulatory personnel, environmental policy makers, Federal agencies with resource responsibilities (Interior, Agriculture, Energy) Public action groups (Sierra Club, etc.), ecologists, industrialist environmental planners, etc.

Planning and Management of Problem Oriented Interdisciplinary Research: A Case Study; Robert H. Ellis; Rensselaer Polytechnic Institute of Connecticut, Inc., Hartford Graduate Center, 275 Windsor Street, Hartford, Connecticut 06120; \$600 for 3 months beginning December 1, 1974

This is a supplementary award for an original research project whose objectives are: (1) to identify and evaluate management and operations analysis methods which can

improve the effectiveness of the RANN-funded Heavy Metals Task Force Program, at the Institute of Environmental Studies, University of Illinois; (2) recommend

specific objectives, priorities, plans, program designs and methods to improve the effectiveness of the University of Illinois program; and (3) generalize the results of the project in the form of guidelines and recommendations

for application to other projects with similar attributes. The purpose of the supplement is to publish 250 extra copies of the final report requested by the Trace Contaminants Program.

Ninth Annual Conference on Trace Substances in Environmental Health; *Delbert D. Hemphill*; University of Missouri, Columbia, Missouri 65201; \$15,000 for 12 months beginning June 1, 1975

This award funds the Ninth Annual Conference on Trace Substances in Environmental Health held on June 10, 11, and 12, 1975 at the University of Missouri. The purpose of these conferences are to explore the biological, ecological and health-related effects of trace amounts of organic and inorganic chemical substances in the environment on man and the total ecosystem. The occurrence of these substances in the water, food, and air, and the means of transport to the biological systems and their effects are examined. The conferences form part of an overall interdisciplinary approach necessary to

understand the complexity of environmental and ecological problems and methods for their control. Since the interdisciplinary fields involved in recognition, evaluation and control of effects of trace substances are too broad to include all areas for each meeting, some specific areas of interest are chosen by the Committee. The general areas for the Ninth Annual Conference include: Epidemiology of Trace Substances, Environmental Pollution, Environmental Geochemistry, and Health, Analytical Methodology, and the Metabolic and Health Effects of these Chemical Substances.

Workshop to Select Organic Chemicals for Environmental Research; *Norton Nelson*; New York University, Institute of Environmental Medicine, New York, New York 10016, \$15,000 for 12 months beginning May 1, 1974

About two million chemical compounds are known to date. Although most of the thousands of new compounds synthesized each year remain laboratory items, several hundred of them are added to the growing list of marketed compounds. The synthetic and natural organics, metals and metallic compounds are of particular concern because of their rapidly increasing numbers and uses.

This grant supports the organization and management of a workshop to review data on production, use, disposal, properties, and toxicity of certain organic compounds in commercial production. On the basis of these data, other information, and the expertise of the members, the panel will select and rank compounds as candidates for research to determine their effects on environmental and human health. The workshop members have been drawn from industry, government, public interest groups, academic institutions, national laboratories, and non-profit research organizations. Successful completion of this project will aid government agencies and industry in anticipating potential problems before they reach crisis proportions and thus allow for more orderly processing and marketing of chemical compounds and products.

Several government agencies, including the National Science Foundation, the Environmental Protection Agency, the National Institute of Occupational Safety and Health, the National Cancer Institute, the Food and Drug Administration, and the Department of Interior, need to know which compounds pose serious threats to man and his environment. Since monitoring and research resources are limited, it is imperative that these agencies concentrate their money and activities on compounds most likely to be hazardous.

Ecosystem Processes and Organic Contamination: A Workshop; *John Neuhold*; The Institute of Ecology, Post Office Box A, Logan, Utah 84321; \$59,900 for 12 months beginning January 15, 1975

This award funded a multidisciplinary workshop which was held in early April, 1975, in order to: (1) identify and evaluate those ecosystem processes most vulnerable to organic contamination; (2) assess the effects of organic contamination on ecosystem processes; and (3) exchange information respecting future research needs, including improvements of research techniques for a better

understanding and prevention of ecosystem damage from organic contaminants.

A final report summarizing the workshop findings will be prepared primarily as input to the program planning of the Trace Contaminants program.

NSF/RANN Trace Contaminants Program Information Service; *John R. Trotter*; Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830, \$10,200 for 18 months beginning April 1, 1973

This award provides for complete documentation of research results achieved under the Environmental Aspects of Trace Contaminants Program, compiled by the Toxic Materials Information Center of the Environmental Information System Office at Oak Ridge National Laboratory. Summary information on these

results is distributed to all program participants and other interested persons on a bimonthly and annual basis. In addition, a continuously updated directory of Trace Contaminants personnel is provided to the Trace Contaminants Program. The publication is entitled "Trace Contaminants Abstracts."

REGIONAL ENVIRONMENTAL MANAGEMENT

Research on Regional Environmental Management is designed to enhance man's ability to deal effectively with regional environmental problems. The program is focused on specific regional environments within the context of overall societal goals. Research in this program is user-oriented and is designed to produce information of value to the planning and management of regions or natural resources with maximum benefit and minimal environmental disruption. Accordingly, there is a substantial continuing coordination effort and information exchange between investigators and Federal agencies, State and local governments, and industry.

The objectives of the Program are to:

- Provide an improved economic and ecological basis for environmental decisionmaking.
- Investigate methods for predicting land use and other secondary consequences of environmental control.
- Synthesize and test regional environmental management strategies.
- Examine the applicability of selected technologies to regional environmental management problems.

The Program directed its supported research toward problems relating to:

- Land-Use Allocation
- Residuals Management
- Urban-Rural Environments

LAND USE ALLOCATION

Land use research in the Division is concerned specifically with land use allocation and the relation between land use and environmental quality. These projects were directed toward the following objectives:

- Develop and demonstrate the capability for determining the impact of selected public programs and private activities on land use.
- Determine the effectiveness and implications of particular land use control techniques.
- Develop methods of identification and definition for addressing the problems associated with and caused by evolving State and regional land use legislation.
- Evaluate and demonstrate the capability of selected technologies for improving land use planning and management.

Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region; \$746,782 for 12 months beginning June 1, 1975; *Orson Anderson and Gordon Jacoby*; University of California, Institute of Geophysics and Planetary Physics, Los Angeles, California 90024; (\$147,900). *Helen M. Ingram*; University of Arizona, Tucson, Arizona 85721; (\$16,400). *Michael D. Williams and Shaul Ben-David*; John Muir Institute, 2118-C Vine Street, Berkeley, California 94709; (\$106,200). *Dean E. Mann*; University of California, Santa Barbara, California 93106; (\$20,000). *David E. Kidd and Loren D. Potter*; University of New Mexico, Department of Biology, Albuquerque, New Mexico 87106; (\$175,800). *Jerrold E. Levy*; University of Arizona, Department of Anthropology, Tucson, Arizona 05721; (\$102,500). *Stephen J. Kunitz*; University of Rochester, Department of Preventive Medicine and Community Health, Rochester, New York 14627; (\$9,600). *Monroe Price*; University of California, School of Law, Los Angeles, California 90024; (\$26,300). *Eric G. Walther*; Northern Arizona Society of Science and Art, Inc. Flagstaff, Arizona 86001; (\$27,800). *Ronald L. Little*; Arizona State University, Department of Anthropology, Tucson, Arizona 85721; (\$40,800). *Charles L. Drake*, Dartmouth College, Department of Earth Sciences, Hanover, New Hampshire 03755; (\$78,700).

This project is a continuation of an interdisciplinary program concerned with the consequences of water and energy development in the arid Southwest. Lake Powell is a major storage and hydroelectric reservoir on the Colorado River in northern Arizona and southern Utah. The region around the Lake is currently experiencing converging demands for water and energy resource development, preservation of unique national scenic features, expansion of recreation facilities, and economic growth and modernization in previously rural areas.

Specific goals of the overall project are: (1) predict the level and distribution of income and wealth generated by resource development; (2) identify the institutional framework for environmental assessment and planning; (3) identify alternative institutional mechanisms for resource allocation; (4) assess the implications for Federal Indian policies of accelerated economic development of the Navajo Indian Reservation; (5) assess the impact of development on demographic structures in the region; (6) assess existing and future

consumptive water use in the region, (7) predict future significant changes in the Lake Powell ecosystem; (8) determine the recreational carrying capacity of the Glen Canyon National Recreation Area; (9) assess the impact of energy development around Lake Powell; and (10) identify the consequences of fluctuating elevations of Lake Powell waters.

Involved in this project are 17 subprojects and 9 different institutions, coordinated by Orson L. Anderson at UCLA. Interdisciplinary studies include such topics as biological limnology, shoreline ecology, heavy metals, hydrology, sedimentation, lake geochemistry, physical limnology, air quality, plume analysis, Kaiparowits resources, political science, law, epidemiology, anthropology, sociology and economics.

This study is proving to be increasingly important as pressures to develop energy resources in the region intensify. Information is regularly exchanged with the National Park Service, Environmental Protection

Agency, Bureau of Reclamation, and members of the Navajo Tribe. Communications have also been maintained with industrial concerns such as Dames & Moore where overlapping areas of interest lie. Reports are prepared in response to requests made by user groups in reference to particular problems. One such report, "Air Quality in the Lake Powell Region," describes much of the gathered data and analysis of atmospheric characteristics around the Lake Powell system. "Mercury in the Lake Powell Ecosystem" presents an analysis of the phenomenon of biomagnification whereby non-lethal levels of mercury in water become concentrated to hazardous concentrations in animals by virtue of natural food chains. In response to a Congressional report, a project report entitled "Some Consequences of Restricting the Maximum Elevation of Lake Powell," was released by the research group. To date, 61 research reports have either been produced or are presently in preparation by the project group.

Coordination of Environmental and Land Use Controls; *Fred P. Bosselman*; Ross, Hardies, O'Keefe, Babcock, and Parsons, One IBM Plaza, Chicago, Illinois 60611; \$324,800 for 18 months beginning June 1, 1974

A wide variety of separate and independent systems of land use and environmental control have evolved in the United States at Federal, State and local levels. Most of these systems operate independently, each in search of the goals of a particular system without regard to the goals of other control systems. Frequently independent control systems work at cross purposes, producing land use decisions that are environmentally and economically unsound.

The objective of this study is to investigate and evaluate methods by which existing systems of land use and environmental control can be coordinated, using as test regions, five Standard Metropolitan Statistical Areas (SMSA's), including the Honolulu SMSA in Hawaii, the Minneapolis-St. Paul SMSA in Minnesota, the Salinas-Monterey SMSA in California, the Philadelphia-Camden SMSA in Pennsylvania and New Jersey, and the San Antonio SMSA in Texas.

The study plan is divided into four phases. Phase I, the analytical phase, involves the analysis of land use and environmental control systems and potential coordination methods. "Control systems" include all of the various separate systems of land use and environmental control. Coordination methods include A-95 budget coordination procedures, interstate planning compacts, and local comprehensive planning

laws. Phase I is divided into three parts: (1) an analysis of all Federal, State, regional and local control systems that are currently in effect in each of the test regions, and an examination of how the control systems are directed to operate by law, and any variations found in actual practice; (2) an analysis of coordination methods; and (3) publication of selected aspects of Phase I by the Conservation Foundation and Urban Land Institute.

In Phase II, coordination methods that have promise for improving the operation of the existing land use and environmental control systems are defined and reviewed by an advisory group.

Phase II, the testing phase, involves a study of the feasibility and effectiveness of each of the potential coordination methods as applied to the various test regions.

In Phase IV, all the work undertaken in the first three phases will be synthesized, published and disseminated.

Eventual utilization of the study results will come from Federal, State and local government agencies engaged in the land use and environmental control process. Control system officials in the test areas are involved in the initial analysis of existing control systems and, with Federal officials, in evaluating potential coordination methods.

Land Use, Energy Flow and Decision Making in Human Society; *John W. Brewer;* University of California, Department of Mechanical Engineering, Davis, California 95616; \$147,000 for 6 months beginning February 1, 1975

Population growth combined with technological advances are increasingly affecting resource demands, ecological cycles, and the quality of life. The rapidity of these changes is reducing allowable response time to each new crisis. The general purpose of this project is to provide a tool which will assist decision makers in the prediction of land use and energy flow given certain population levels, resource availability, and economic and technological development. More specifically, a hierarchical systems model must be developed in regards to land use and energy flow which will have the capability to evaluate policy or to quantify the effects of alternative policies available. During this phase, the project will focus on modeling the impacts of the decreasing availability and increasing costs of energy at several levels, from local impacts on transportation systems to national impacts on agricultural production for exports to pay for crude oil imports.

The simulation model which has been developed simulates interactions between certain international, national and local level phenomena. Unlike other large-

scale models of this kind, considerable data are used to "tune" the model to historical trends. The model is currently being used in large systems effects analysis of U.S. crude oil import policy on agricultural land prices, urban transportation systems and the density characteristics of urbanized areas.

A second task confronting the program is to develop and document a set of simulations to analyze the effects of certain federal policy options such as the price of imported crude oil and gasoline.

A technical documentation of the model will be produced along with a user's manual at the termination of the project. An additional report will deal with a description of the model. Various user groups include the Pacific Gas and Electric Company, the California Assembly Natural Resources Committee, and the Environmental Protection Agency, Office of Categorical Programs. In addition, the research group has been working with the Office of Technology Assessment on energy/agriculture related problems.

Equity Considerations and Compensation Techniques as Related to Increased Public Control of Land Use; *Emery N. Castle and Herbert H. Stoevener;* Oregon State University, Corvallis, Oregon 97331; \$98,700 for 18 months beginning July 1, 1974

The fundamental social problem of land use control involves the restructuring of property rights between the private and public sectors. To address this problem, one needs to know those attributes of private property rights which must be subject to public control if land use is to conform to group objectives. The application of social constraints on the use of private land and the equity problems which result requires careful study in order to calculate political feasibility of these growth control schemes, and to understand the relationship to the societal objective of distributive justice.

This project is concerned with the investigation of techniques, including compensation, which hold promise of addressing the equity problems that would result from

greater social control of land use. The project scope includes: an analysis of functions performed by the real property institutions, a study of distributional characteristics of real property ownership, and finally, an examination of the equity consequences of land development and control.

Under the research plan, nontechnical reports will be presented at a regional conference on regional economic development held annually in the Pacific Northwest. The conference is attended by State and Federal government officials as well as representatives of the private sector of the economy. A special workshop will be developed and run for those interested in land use control at the state level.

Regional Interaction of Resource Utilization, Environmental Quality and Economic Development; *Harold Chatland;* Association of Monterey Bay Area Governments, Monterey, California 93940; \$14,800 for 8 months beginning May 1, 1974

Regional decision-makers and planners, facing increasing pressures from citizens and special interest groups, are seeking better procedures to assist them in

defining problems facing the region and in assessing the consequences of the various alternatives open to them. This award continues a project to evaluate gaming as a

means of increasing understanding of issues among citizens, elected officials and planners.

The need for the project was perceived by the Association of Monterey Bay Area Government (AMBAG), the official regional planning body, organized to establish a permanent forum for planning, discussion and study of problems of mutual interest and concern to the Counties of Monterey, San Benito, Santa Cruz, and incorporated cities within these counties. The area is endowed with rich agricultural land and is known for its rare scenic beauty. The area is also economically depressed, has a low population density and a high rate of unemployment, and thus faces the classical conflicts between environmental preservation and economic development.

The first phase of this research project included an analysis of planning and decision-making in the region and the creation of a set of games to be used by planners,

elected officials, and citizen groups. One of the games was used by the Monterey County Board of Supervisors to help determine the impact of a road planned for construction. The results were so revealing as to the related factors, that even though construction was budgeted, the project has been delayed indefinitely.

The second phase is designed to refine and further implement techniques developed in the first phase. Specific objectives are to: (1) complete and test the game "AT ISSUE" with participation by the Carmel Valley Property Owners Association, supervisors and planners of the County of Monterey, and citizens, elected officials and planners in the City of Watsonville; (2) integrate the games "IMPASSE" and "AT ISSUE" during the tests listed above to prepare them for use in locations outside the test area; and (3) prepare a handbook on the games for use by citizen groups and elected officials.

Regional Environmental System Analysis; Clyde W. Craven, Jr.; Oak Ridge National Laboratory, Oak Ridge, Tennessee; \$745,000 for 18 months beginning June 1, 1973

The National Science Board of NSF has concluded that, "Environmental science today is unable to match the needs of society for definitive information, predictive capability, and the analysis of environmental systems as systems. Because existing data and current theoretical models are inadequate, environmental science remains unable in virtually all areas of application to offer more than qualitative interpretations or suggestions of environmental change that may occur in response to specific actions."

The Oak Ridge effort, started in 1972, is an attempt to help overcome this problem by developing models for assessing the socio-economic, land use, ecological, and political consequences of particular actions of specific regional management agencies. Up to this point emphasis has been on the development of a socio-economic model and a land use model, with exploratory attention being given to ecological and socio-political

models. This award calls for an acceleration of effort on the latter two models and for development of linkages among submodels.

The research team has established working relationships with user groups and maintains frequent communication by serving on advisory committees, providing data and software, and seeking users' guidance in structuring the research program. Organizations which have utilized research findings include the East Tennessee Development District, the First Tennessee Development District, the Atomic Energy Commission, the U.S. Forest Service, the Tennessee Valley Authority, and the Soil Conservation Service (SCS). Members of the research team provided help and leadership in developing computer-generated interpretive soil maps of Hamilton County and Henry County, Tennessee for the SCS.

Control of Land Subsidence in the Texas Gulf Coast Area; Andre P. Delflache; Lamar University, Department of Civil Engineering, Beaumont, Texas 77710; \$68,700 for 24 months beginning June 1, 1973

Land subsidence due to groundwater withdrawal is a worldwide phenomenon. Subsidence causes damage to buildings, pavement, utility lines and drainage, and subsidence of lowlands causes the loss of property due to permanent inundation, and it increases the risk of flooding during hurricanes. In the Texas Houston-Galveston area some of the consequences are well

documented and publicized, and the State is now considering legislation to create a Texas Water Rights Commission that will have authority to regulate the private withdrawal of groundwater. A technically satisfactory means of estimating the relation of rate of withdrawal to subsidence effects is needed to provide a basis for action by this Commission.

The objective of this research is to develop a technique which, when incorporated in groundwater management programs, will permit an optimum utilization of water resources, consonant with acceptable minimal subsidence. Specifically, the proposed technique will assist in the determination of the areal distribution of water wells, and in the selection of aquifer intervals to be exploited and the tolerable rates of depletion. The technique is being developed by correlating data obtained from several U.S. Geological Survey observation and test wells located in the Houston-Galveston area, with laboratory consolidation characteristics of clay samples taken from the aquifer systems underlying the subsidence field under investigation. The laboratory equipment simulates field conditions. The clay specimens are being subjected to the effect of slow fluid

pressure decline. A computer program is being developed to facilitate the calculation of the anticipated amount and rate of land subsidence associated with a given rate of fluid pressure decline over a given area.

As the problem of land subsidence is a topic of critical interest and extensive press coverage in southeastern Texas, many organizations are holding meetings on this subject. The results of this research are presented through briefings to the following organizations: Harris County Mayors' and Councilmen's Association, Citizens' Environmental Coalition Educational Fund, Inc. (Houston), Houston Engineering and Scientific Society, and Coastal Industrial Water and many other public and private organizations.

Methodology to Evaluate Alternative Coastal Zone Management Policies: Application in the Texas Coastal Zone;
E. Gus Frub; University of Texas, Division of Natural Resources and Environment, Austin, Texas 78712; \$328,000 for 12 months beginning June 1, 1975

The major developmental land users along the Texas coastline are the residential homesite and tourist-commercial development industries. Many activities of these Gulfshore community developments involve environmental and resource conflicts. State agencies responsible for implementing the State coastal management act of 1972, which deals with the public lands and private land uses affecting such lands, are faced with a deluge of permit applications for which they have no methodology or criteria to apply in a rational manner.

The objective of this project is to: (1) develop an interdisciplinary methodology for assessment of economic and environmental impacts of alternative coastal zone management policies; and (2) demonstrate transferability of the methodology to various areas of the Texas coastal zone and the applicability on a national basis.

During the previous 12 months' grant, the research team refined and tested the methodology through a study of the Mustang Island-North Padre Island area of the Coastal area to demonstrate transferability to other

segments of the Texas coast and to evaluate and demonstrate applicability to other States. This phase also develops a conceptual methodology for evaluating social impacts. The general approach will be to determine environmental and economic impacts related to three scenarios: (1) an economic policy aimed at developing a future regional growth picture to attract new industry to the Rio Grande Valley; (2) a social-institutional policy aimed at securing a modified regional growth picture developed by State agency people primarily involved in government programs to improve regional social services and welfare; (3) an environmental policy similar in scope with scenario two but having an increased freshwater supply.

The question of transfer and utilization beyond Texas will be fully integrated into the research. A utilization and transfer plan will be developed with the assistance of an advisory group, including the U.S. Office of Coastal Zone Management. Primary users include State personnel involved in coastal zone management as well as those at the Federal level.

Ecological and Sociological Determinants of Land Use Decisions; *Dr. John E. Gannon*; University of Michigan, Biological Station, Pellston, Michigan 49769; \$375,000 for 18 months beginning March 1, 1975

Rapid increase in leisure time and mobility of an affluent population have caused increased recreational pressure on inland lakes and their watersheds throughout the United States. Haphazard development responding to market demands has often resulted in the destruction of

the very resource the people come to enjoy — inland lakes. Northern Michigan is just now beginning to feel this pressure of development. In general, laws and practices which allowed lakes in Southern Michigan to decline are still in existence. The objectives of this study

are to provide scientific information on natural and social systems which are essential to effective land-use planning and management. By extensive personal contact and carefully planned public communication with regional decision makers the utilization of research reports aimed at this audience is encouraged.

The research plan calls for a detailed natural resource inventory of lakes and their watersheds in the study area, and the design of a lake ranking system based upon the relative sensitivity to human impact. Terrestrial research will augment aquatic studies by determining the contribution of soil nutrients to lake water quality. Included in the overall research work is an analysis of interests of inhabitants which may be affected by a variety of resource planning and management strategies.

Land use classification data will be obtained by remote sensing techniques using ERTS-B satellite imagery. Lake ranking will receive major emphasis in the aquatic component of the project with lakes of similar characteristics being grouped by multivariate cluster analysis. Soils are classified, in coordination with the Soil Conservation Service, in terms of nutrient holding capacity.

Defining the Constitutional Issues of Growth Management; *David R. Godschalk*; University of North Carolina, Center for Urban and Regional Studies, 108 Battle Lane, Chapel Hill, North Carolina 27514; \$64,800 for 12 months beginning May 1, 1975

In recent years, numerous rural and urban U.S. communities have become increasingly concerned with the environmental, social and economic consequences of very rapid growth which they were experiencing due to either expanding metropolitan populations or pressures for development of recreational or natural resources. As these communities began to formulate growth management objectives, they discovered that traditional governmental controls were inadequate to manage growth. Accordingly, they attempted to implement growth objectives by adoption of programs to control the rate, volume, character or location of growth. These programs consist of complex mixes of old and new incentive, regulatory, and planning techniques; e.g., moratoria, public investment policies, tax policies, and timed development ordinances. Although traditional planning and zoning have undergone sufficient legal challenge to establish their legality, many law suits have been filed challenging the authority of localities to adopt comprehensive growth control. Due to varying court decisions and incomplete analysis and transfer of information, there is need for clear guidance regarding legality of growth management programs. Although to

Social research studies include the collection of data from people in the study area whose properties are not associated with inland lakes and rivers for comparison with residents near water; and an intensification of communications with user groups to achieve a high level of understanding on the part of various user groups of the data and implications. Finally, an assessment will be made of people's perceptions and assessments of the quality of the environment within which they live.

With the aid of the Center for Research on Utilization of Scientific Knowledge (CRUSK) of the Institute of Social Research at the University of Michigan, the project's Public Information Specialist will head a program aimed at introducing information to "user" groups in such a way as to have demonstrable effects on the activities of decision makers. Since the project's initiation, close communication has been maintained with township and county planning boards, citizen groups, the Michigan Department of Natural Resources, and commercial developers. A User Manual, containing a systematic account of the program's utilization efforts will be used to describe a model which may be followed by those working to undertake a similar program.

date not all court decisions are consistent, there is evolving a series of basic Constitutional principles for judging growth management efforts.

The purpose of this research is to analyze growth management Constitutional issues and develop planning guidelines to promote conformity of growth management programs with Constitutional principles. Questions of major concern include: (1) major growth management approaches; (2) unique factors in different approaches; (3) Constitutional challenges; (4) major planning approaches used; (5) strengths and weaknesses of major approaches in terms of Constitutional principles; and (6) probable future trends.

Categories of major users include elected and appointed officials, attorneys, planners, and citizens. Customized reports will be prepared for each user group and plans will be developed for transfer of results through media and meetings of various user groups. A users' advisory panel will be active throughout the project to review all major aspects of research and advise on dissemination processes.

Environmental Management Research in the Lake Tahoe Basin; Charles R. Goldman; University of California, Davis, Division of Environmental Studies, Davis, California 95616; \$425,000 for 12 months beginning November 1, 1974

This award is a continuation of an interdisciplinary research program aimed at the environmental problems of the Lake Tahoe Basin. The project objectives of this study are to: (1) determine the most important of man's activities in accelerating lake eutrophication; (2) determine natural and accelerating rates of eutrophication; (3) evaluate the technical feasibility for man to control his activities in order to approach more closely the natural rate of eutrophication; (4) assess man's willingness and effectiveness in applying his technical capabilities in the control of environmental degradation through social-political action; and (5) ascertain the ability of the various political institutions to cope with environmental problems on a regional basis.

Involved in the research are disciplines in two major branches of science: biological-physical and socio-political science. Within the biological-physical science division, the aquatic-terrestrial section is continuing to concentrate its work on the Ward Valley watershed. This program will provide a continuous record of qualitative and quantitative data on water arriving as snow or rain and flowing through the watershed into the lake. As tributaries of Ward Creek are representative of different kinds of disturbances (parking lots, skislopes, condominiums, etc.) the effect of man's activities on the water quality of the lake can be assessed. Within the lake

proper, the impact of nutrients is being characterized with respect to their circulation within the lake, the biochemical transformations they undergo, and how they influence lake water quality. In order to predict the effect of watershed development on lake water quality a mathematical model is being developed. Included in the social science component is a study of economics of land use, beginning aspects of a socio-economic simulation model of population growth and land use, and analysis of the interrelationships between scientists and policy makers in the Lake Tahoe Basin. The Tahoe Research Group has many excellent contacts with concerned groups in the Basin, notably the Tahoe Regional Planning Agency, mandated to control the development of the area.

By working with the major private, state and Federal groups in the basin, the results of the research are immediately available to assist in the solutions to problems of resource management in the basin. The Tahoe Research Group maintains communication with a number of groups who use the research findings. Among these are: the U.S. Forest Service, U.S. Geological Survey, Soil Conservation Service Scripps Oceanographic Institute, U.S. Environmental Protection Agency, Lake Tahoe Environmental Education Consortium, and the Tahoe Regional Planning Agency.

Multiobjective Analysis in the Maumee River Basin; Yacov Y. Haimes; Case Western Reserve University, Systems Engineering Department, Case Institute of Technology, Cleveland, Ohio 44106; \$55,000 for 16 months beginning April 1, 1975

The objective of this project is to test and refine a procedural model for determining alternative decision strategies and policies in planning situations that deal explicitly with multiple non-commensurable objectives. The case selected for study here is the Maumee River Basin. More specifically, the tasks are:

1. To formulate a planning and management model of the Maumee River Basin system that simultaneously considers a variety of non-commensurable objectives utilizing recent research results in the comprehensive planning of regional water resources systems supported by NSF/RANN, Office of Water Research and Technology (OWRT), the Rockefeller Foundation, and Case Western Reserve University.
2. To formulate the case study in coordination and cooperation with the Water Resources Council, the Great Lakes Basin Commission, the Maumee River

Basin Commission, and OWRT utilizing Surrogate Worth Tradeoff (SWT) methodology.

3. Integrate within the larger framework relevant submodels dealing with capacity expansion for water supply and wastewater treatment projects, groundwater models, and models for the control of phosphorus pollution. (These have been developed, in part, by previous RANN grants.)
4. Use of the case study as a vehicle to uncover and resolve the problems that may be encountered in the implementation of multiobjective function analyses.

The research plan follows a two level hierarchical structure. The first level considers the planning phase, while the second level is concerned with the decision-making phase. Within the first level are two lines of thought: (1) an information layer representing the

physical environment and the economic system in the river basin, (2) and an optimization layer which strives to choose the best combination of control measures for a given set of benefits at minimum cost, subject to various constraints.

The second level of research finds the decision makers evaluating the required trade-offs, comparing them to their subjective preferences among the objectives. A satisfactory multiobjective solution is secured after new desired benefit levels are specified, essentially using the SWT methodology.

National Environmental Models of Agricultural Policy, Land Use, and Water Quality; Earl O. Heady; Iowa State University, Department of Economics, Ames, Iowa 50010; \$486,700 for 24 months beginning June 1, 1974

The growing impact of agriculture on the quality of natural resources and environmental conditions results from technological advances, economic development, and particular public policies. In light of continuing environmental concerns, there is a need to look at the degree certain public policies are meeting environmental objectives along with other societal goals.

This project is a continuation of a past effort to develop and apply mathematical models which incorporate all major commodities and land and water resources for U.S. agriculture. The purpose is to provide the capability for evaluating the effect of alternative policies of environmental restraints, land use, water quality and allocation, farm programs and trade on: (1) agricultural productivity, (2) food supplies and prices, (3) farm income and structure, (4) interregional redistributions of income and wealth, and (5) environmental parameters. The study is measuring impacts at both the national and the regional level and is evaluating the interaction among regions as different environmental goals are examined. It will explicitly determine the extent of the trade-offs involved in imposing environmental controls on the agricultural sector.

The core linear programming model developed under prior funding is being simplified by reducing it from a 223 region basis to a 99 region basis. It is also being tailored for specific users, such as the United States

Regional Analysis and Management of Environmental Systems; Donald A. Jameson; Colorado State University, Fort Collins, Colorado; \$320,900 for 12 months beginning September 1, 1974

Recreational activities in the great grasslands of the United States and exploitation of their natural resources are rapidly coming into conflict with the more traditional use of these areas for production of plant and animal

Utilization of research is the focus of the Maumee effort, but the processes and results will be applicable to a large number of other comprehensive regional planning efforts across the nation. National utilization is visualized also. An advisory board with both national and regional representation has been established to facilitate broader potential applications. Such membership includes U.S. Army Corps of Engineers, U.S. Water Resources Council, U.S. Geological Survey and others.

Water Resource Council. New capabilities to be developed include an energy sector, an attempt to approximate limitations on water availability imposed by water laws, effects on agriculture, and land use of climate changes, and non-linear programming of certain agricultural/environmental interrelationships.

A specific application of the core model was performed for the Environmental Protection Agency last year. Other organizations seeking specific applications to their problems include: the Midwest Governor's Conference, the Soil Conservation Service, the Commodities Division of the USDA, the Tennessee Valley Authority, and the National Commission on Water Quality.

An important utilization activity has been associated with the need of the U.S. Water Resources Council in conducting the 1975 National Assessment of Water and Related Land Resources. A formal agreement has been worked out in which NSF will support certain modifications in the Iowa State models that will bring them to the point at which they can be applied in the National Assessment. Upon completion of these modifications, the Water Resources Council, U.S. Department of Agriculture, and Bureau of Reclamation will support specific applications of the technology to the National Assessment.

products. These pressures and the current controversy over beef prices has pointed up a need for increased efficiency in management of range lands.

Essential to the land use planning problem is the need to provide some indication about the status of the existing ecological-economic systems and projections about probable changes in the system given various alternative courses of action. In this project, projections are made through simulation models of ecological, monetary, demographic and industrial systems. The simulation models are designed to show the interaction between these components. The models are based on concepts of ecosystem dynamics widely used in biome research for the ecological components, dynamic nonlinear input/output analysis for the economic component, and survival-migration models for the demographic component. This project places emphasis on those industries which are based on natural resources.

The following models are under development: COPLAN — an interactive, dynamic individual firm (ranch) planning model; RANGES — a verified and validated grassland ecological simulation model; PUBLIC — a model of attitudes and involvement of the public in grassland utilization and management; and REACT — a regional managerial planning procedure. Field testing of COPLAN by the Soil Conservation Service and development of a refinement of the model will occur during this twelve month period. In addition, final validation of RANGES and final documentation of

the monetary and livestock components of the REFLOW model development, verification of the demographic component, and field testing will also occur. Development of the interactive mode of the REACT model, and analysis of meaningful input and output data forms for regional planners is planned for the period of this grant renewal.

The research group has had excellent continuing cooperation with appropriate users of the results of the project which include: Individual ranchers, grazing and livestock associations, and federal agencies. In the next year, the Soil Conservation Service will participate in a full scale field test of COPLAN involving some 20 SCS ranch planners; a field test of PUBLIC procedures on 5 ranger districts of the National Forest System; an in-depth analysis of the procedures developed in this program by a member of the California Extension Service to determine the applicability of the procedure to both the Colorado and California Extension Service; a survey and interview of county and state planning activities. End point products of the research will be procedure manuals which will describe the models including the basic theoretical concepts, an example case, and a microfiche copy of the current computer programs used in the model. It will be distributed to landuse decision makers.

Cooperative Evaluation and Analysis of Cost Effectiveness of Applications of Controlled Environmental Facilities; \$190,900 for 12 months beginning July 1, 1975; *Paul J. Kramer*; Department of Botany, Durham, North Carolina 17706; (\$89,400). *C. David Raper*; Department of Soils, North Carolina State University, Raleigh, North Carolina 27607; (\$101,500).

Faced with continued demands for feeding and housing its increased population in an era of unprecedented urban growth, the United States expends hundreds of millions of dollars for plant research. Although the pressure of expanding needs for plant resources for food and fiber is likely to increase the expenditures for research on plants, few studies have been made of the economics of research in plant science.

One of the most important new developments in research methodology is the increased use of controlled environment equipment such as plant growth chambers and phytotrons. The use of such equipment has been productive in isolating and evaluating the effects of various environmental factors on plant growth. The importance of controlled environment facilities was recognized by a panel summoned by the National Science Foundation some ten years ago. As a result of the deliberations of that group, two controlled environment facilities were developed, with NSF funds, at Duke University and North Carolina State University.

The first experimental objective is to make careful measurements of the quantity and quality of growth made by plants of several species growing in field plots and phytotrons. The following species have been selected: cotton, because we already know something about its growth pattern in growth chambers and in the field and because it is an important crop plant; soybean, because it is interesting physiologically and very important agronomically; tobacco, because of its economic importance and physiological interest; and loblolly pine, an important woody species which was also used in an International Biological Program project in the Research Triangle Area.

The second objective is to make careful comparisons of the cost efficiency of research in phytotrons and in field plots. The economic data from field and phytotron experimentation is used to build a model for cost-benefit evaluation of proposed environmental research.

Some results from the first year's research already

have been presented at meetings of the Southern Section of the American Society of Plant Physiologists, at the national meeting of the A.S.P.P., at the annual meetings of the Ecological Society of America, the American Society of Agricultural Engineers, the American Society of Agronomy and the Tobacco Worker's Conference. In February 1974, an advisory group of investigators from Southeastern universities and agricultural experiment stations were brought to NCSU and Duke and told about this project and other phytotron research. This committee is now being enlarged and in March 1975 a group of 30 investigators and administrators were invited to NCSU-Duke to discuss phytotron research and will be told about the RANN project. Some information concerning this project is to appear in the Phytotronic Newsletter distributed by the phytotron at Gif, France,

Assessment of Selected Environmental Modelling Projects; *Brian W. Mar*; University of Washington, Seattle, Washington 98195; \$6,200 for 6 months beginning May 1, 1975

A panel of modelling experts from engineering, economic and environmental disciplines are evaluating the progress of mathematical modelling in selected research projects supported by the Division of Advanced Environmental Research and Technology. Specifically, the program seeks to evaluate the effectiveness and applicability of environmental simulation models. Site teams drawn from the original panel visited each project

which goes to several hundred scientists all over the world. As the project nears completion, a summary in the form of a bulletin which can be widely distributed among agricultural experiment stations and other agencies and industries which can carry on plant research will be prepared.

Some users of research results found in this study include scientists and administrators in federal organizations which support plant research, such as the Department of Agriculture, the Environmental Protection Agency, and the National Science Foundation, the state agricultural experiment stations, and private groups such as Cotton Incorporated, representing the cotton industry, and the tobacco industry.

to evaluate the direction, type and rate of progress in modelling activities as well as limitations. Reconvening at the end of the year, the panel prepared a report to NSF on the environmental modelling status.

The principle users of this information are AENV staff. Bimonthly meetings with the project manager ensured close coupling with RANN goals and programs.

Natural Resources Availability and Policy Implications in the United States; *Dennis L. Meadows*; Dartmouth College, Thayer School of Engineering, Hanover, New Hampshire 03755; \$133,300 for 12 months beginning September 15, 1973

The objectives of this research project initiated in 1972 is to provide U.S. policy makers with a dynamic policy analysis framework capable of integrating the general effects of economic, geological, political, and technological factors on the availability of nonrenewable resources to the U.S. economy over the next 50 years. Coal and copper were selected to force consideration of minerals that differ along several important dimensions, including domestic reserve positions, recycleability and import-export characteristics.

The goal of the coal project has been the development of an integrated set of models that incorporate the major factors influencing the fraction of U.S. energy that will be satisfied by coal over the next 30-50 years. Factors such as declining domestic gas and oil availability, increased balance of payment problems, delays in nuclear power development, and the development of coal gasification technologies tend to increase this fraction. The prospects

of increased environmental damage from strip mining and SO emissions and increased labor, health and safety problems tend to decrease this fraction over the long term. Depending on U.S. energy policies, this fraction could either continue its secular decline or rise sharply in the future. The models will be used to identify a set of policies that could be enacted at the national level to expand coal production costs.

Reports from the project are being disseminated through the distribution of project working papers and publication in appropriate technical journals. The two major reports on coal and copper will be prepared in book form for use by government policymakers and other research groups. Research seminars on long-term resource availability are held at Dartmouth College. The first, conducted April 2-3, 1973, drew together a selected group of analysts and policymakers from industry and government in the United States and Canada to study the

basis of system dynamics methodology and its application to analysis of nonrenewable resource issues. In addition, a seminar was held in Washington, D.C. on November 12, 1973, and provided the opportunity for

the research team to discuss the project with its Advisory Committee and representatives from U.S. Government agencies, and to identify areas of common interest.

Regional Environment Systems Analysis; *Michael M. McCarthy*; Atomic Energy Commission, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830; \$193,400 for 10 months beginning January 1, 1975

This project is the final stage of the regional environmental systems analysis program funded by the National Science Foundation. The objective of this research is to thoroughly document all of the work completed under the RANN-supported Regional Environmental Systems Analysis program at the Oak Ridge National Laboratory. The overall goal has been to contribute to the comprehensive appraisal and hence the solution of regional environmental problems by improving the scientific basis for examining the consequences of alternative courses of action. This goal has been undertaken through a developed set of linked models.

Specifically, all past work will be documented and a package of technical reports will be prepared concerning work on: (1) information and data management systems; (2) socioeconomic models; (3) socio-

political/policy analysis and social impact; (4) land-use allocation; and (5) ecological/natural systems.

The Atomic Energy Commission and the Tennessee Valley Authority are primary users of the results of the project to date. The Atomic Energy Commission has assumed an increased share of the project cost. Members of the research team provided help and leadership in developing computer-generated interpretive soil maps of Hamilton County and Henry County, Tennessee for the Soil Conservation Service. The maps provide basic information upon which sound decisions on land use can be made. Wider applications are expected as the documentation is completed. The techniques developed under the research are applicable to a wide range of situations in which the need is to predict the second-order consequences of major development decisions.

National Symposium on Data Requirements and Special Information Systems for Identifying, Planning and Regulating Geographical Areas of Critical Environmental Concern; *Bernard J. Niemann*; University of Wisconsin, Institute for Environmental Studies, Madison, Wisconsin 53706; \$4,000 for 4 months beginning May 1, 1975

This award continues research designed to: (1) assist states and local units of government in the planning of inventory and management programs for geographical areas of "critical environmental concern," i.e., floodplains, natural hazard areas, aquifer recharge zones, and areas of scientific interest. In addition, this project strives to provide a basis for Federal agencies to design cost-effective guidelines for data systems to be implemented at State or local levels of government. The project is proceeding in four steps. A workshop, was held in February, 1975, and addressed the question: "What are the issues associated with identification, inventory, planning and management of critical land areas and how do these define land use data needs?" Based on this workshop, a report was prepared which summarized data needed to identify, inventory, plan and manage critical areas. The report circulated to selected participants and the project review group for recommendations. The revised report has provided the

basis for a second workshop which was held in April, 1975. This workshop addressed the question: "What data and data manipulation techniques are now available or reasonably anticipated in the near future to meet critical area data needs as defined in the first workshop?" A report will be prepared which will summarize data sources and evaluate data manipulation techniques for meeting State and local critical area management needs. The report will be specifically written for technically trained persons in State and local government who are responsible for critical area management.

Technically trained individuals from State agencies are involved in the design and execution of the workshops, and all reports are written to meet their needs. With the implementation across the country of State land use legislation emphasizing critical areas, there is a high level of interest generated in the reports.

The Impact of Economic Development and Land Utilization Policies on the Quality of the Environment; *Gaylor M. Northrop*; The Center for the Environment and Man, Inc. 275 Windsor St., Hartford, Connecticut 06120; \$35,500 for 6 months beginning May 1, 1975

The Center for the Environment and Man, Inc. is developing a cohesive, comprehensive methodology to evaluate the environmental impact of alternative activities which can be applied to any region, and can be used by local, state, or Federal agencies. During Phase I of this study, a methodology and computer programs were developed for assessing the environmental and selected energy consumption consequences of alternative land use plans, environmental control policies that affect regional economic development, population growth, and the quality of the environment. Phase II involved the application of the methodology to the industrial development of Westover Air Force Base in the Springfield-Chicopeeholyoke (S-C-H) Standard Metropolitan Statistical Area. The investigation focussed on the conversion of "excess property" portions of Westover to new industrial, commercial and regional activity, with the objective of identifying mixes of proposed development that have economic potential for the region, and acceptable environmental impact.

The objective of the work to be accomplished under this continuation proposal is to adequately document and describe the work performed under this grant in order to

achieve effective information and technology transfer to those seeking to evaluate, modify, or use these efforts. The Center for the Environment and Man, CEM, believes the information and technology transfer associated with the models it has developed and applied under this grant will benefit greatly from development and documentation procedures recommended by Brian Mar as a result of recent RANN support. Mar's paper cites the problems encountered by natural resource and environmental researchers in effecting technology transfer to user organizations and agencies and suggests a series of documentation remedies. Where it is feasible, CEM proposes to develop the necessary documentation based on Mar's guidelines. CEM will also develop clear, terse guidelines for application of the CEM models to other regions.

The research group interacts with the Westover Task Force and the Massachusetts Executive Office of Environmental Affairs to assure utilization of the products of the project, and to effect transfer of the technology developed. CEM efforts are aimed at increasing the overall usefulness of their work to recognize potential environmental decision makers.

Impact of a Large Recreational Development Upon a Semi-Primitive Environment: A Case Study; *John W. Reuss*; Montana State University, Bozeman, Montana 59715; \$261,000 for 18 months beginning July 1, 1973

Recreational developments such as ski areas and second home communities are becoming increasingly prevalent in parts of the country that were previously undeveloped. Some of these developments are ill-planned and lead directly to environmental degradation. Others are very well-planned and, conceptually, should result in minimal on-site environmental insult. Even well-planned developments, however, may have considerable indirect environmental impact as they attract other kinds of development. Little is known of the dynamics of recreational developments and of the degree to which they can maintain a high level of on-site environmental quality in light of perturbations such as difficult financial situations.

This study is an extension of past research on the environmental, social, and economic effects in the region of one particular development, the "Big Sky" recreation complex of southwestern Montana. It is seeking to provide information to agencies within the State of Montana and to Federal land management agencies concerning the types of problems and the benefits likely

to arise from such facilities. The effort to date has consisted of gathering baseline data and monitoring early changes in selected environmental and socio-economic variables as the Big Sky complex develops and as visitor use increases. Monitoring and assessment of changes is continuing over the next eighteen months. Attention is focused on air quality, water quality, wildlife, site suitability, economic impacts, political impacts, sociological impacts, and traffic safety. Parallel attention is given to the management system for the project.

A thorough baseline analysis of the Gallatin Canyon region prior to construction of the Big Sky development has been completed. This information has been used by the Forest Service in an environmental impact statement concerning land exchanges and by the Montana Department of Highways in another environmental impact statement. Geological research has provided a basis for avoiding costly errors in locating ski facilities and a reservoir. A number of specific problem areas have been identified and are serving to guide the study.

Assessment of Programs for Public Participation in State Land Use Decision-Making; *Nelson Rosenbaum*; Urban Institute, Land Use Center, 2100 M Street N.W., Washington, D.C. 20037; \$72,900 for 9 months beginning June 1, 1975

Over the past decade, there has developed a major and widespread concern over the problems of fiscal strain, environmental degradation and social inequity resulting from current patterns of land allocation and development. Strong pressure for change in both the structure and processes of land use decision-making has been a result of such concern. A major structural change has been for higher levels of government to assume a role in certain land use decisions which were previously made solely by local government. In conjunction with this change in the structure of land use decisions, there has been an emphasis on ensuring that the decision process provided meaningful opportunities for all affected elements of the public to be informed and involved in land use decisions. This combination of changes presents a significant challenge to public officials faced with developing and implementing land use policies and programs.

The initial objective of this research is to fully organize a conceptual framework for planning and evaluating public participation programs. The framework is designed to: (1) distinguish between problems and opportunities in large-scale vs. small-scale jurisdictions and in policy-planning vs. policy implementation

Forest Land-Use Allocation and Environmental Systems Evaluation; *Gerard F. Schreuder*; University of Washington, College of Forest Resources, Seattle, Washington 98195; \$249,900 for 18 months beginning June 1, 1974

This award is to complete a project to develop a general methodology for evaluating the physical, economic and environmental consequences of alternative decisions concerning the management and use of forested environments. It is designed to address a number of important issues surrounding forest management practices, such as clearcutting of timber, which are being called into question because of the presumed environmental impact. At the same time, forest resources are in short supply. A conflict is raging between environmentalists and timber producers, particularly in the Douglas-fir regions of the Pacific Northwest where both timber values and amenity values are very great. Cost-effective, systematic ways to help decision-makers assess the true environmental effects of major forest land management decisions are badly needed.

The research plan is to develop a set of interrelated mathematical simulation models that are capable of

processes; (2) clarify different components of participation programs; and (3) identify specific techniques and mechanisms of participation which may be more effective or appropriate in certain situations. The second objective is to conduct a comparative empirical evaluation of the relative effectiveness of different public participation programs in selected large-scale jurisdictions which have been developing and implementing land use related programs.

The intent of the research is to provide guidance that will enable public officials and others to select, adopt and implement public participation processes and programs that appear most appropriate for their own unique setting and circumstance.

The four major user groups include: (1) State, regional and county government officials; (2) State and national legislators; (3) citizens and citizen groups; (4) professional groups and researchers. A Users' Advisory Committee will function throughout the study to provide advice on the research plan and progress, content and format of draft documents, and other dissemination mechanisms.

simulating tree growth, tree harvesting and road construction, forest residues, recreation use, stream-flow, and atmospheric conditions. Specific objectives are to: (1) utilize the project technology developed in Phase I to evaluate the environmental consequences of alternative wildland use allocations in the Snohomish River Basin, (2) test the utility of the methodology when transferred to other forest ecosystems, and (3) document the models so that they can be of maximum utility to natural resource agencies in the States of Washington and Oregon.

The Washington Department of Natural Resources and the U.S. Forest Service have been the primary users of research results. A Northwest Forest Resources Environmental Quality Control Council has been formed to help increase user awareness of the research project and to provide a forum for discussion for regulatory and land management agencies.

Seminars on Cellulose Conversion and Leaf Protein Production; *John Stone*; Mitre Corporation, Westgate Research Park, McLean, Virginia 22101; \$6,600 for 3 months beginning March 1, 1975

This award funds a series of seminars, the first of which will concern the research problems involved in the production of protein from leaf sources. Forage crops, grasses, water hyacinths, etc. will be considered as sources of proteins. The factors affecting the growth of the plant, methods of extraction from the plant, and problems of obtaining human consumable protein will be discussed.

The second seminar will be on the conversion of polysaccharides in plants and trees to fermentable sugars. Sources of cellulosic material will be discussed, as well as factors controlling the rate of acid and enzymatic conversion. Problems associated with the preparation of feed stocks and recovery of the enzymes from the process system will be discussed.

Impact of a Large Recreational Development Upon a Semi-Primitive Environment; *David G. Stuart*; Montana State University, Institute of Applied Research, Bozeman, Montana 59715; \$43,000 for 12 months beginning January 1, 1975

Recreational developments such as ski areas and second home communities are becoming increasingly prevalent in parts of the country that were previously undeveloped. Some of these developments are ill-planned and lead directly to environmental degradation. Others are very well-planned and, conceptually, should result in minimal on-site environmental insult. Even well-planned developments, however, may have considerable indirect environmental impact as they attract other kinds of development. Little is known of the dynamics of recreational developments and of the degree to which they can maintain a high level of on-site environmental quality in light of perturbations such as difficult financial situations.

This study is an extension of past research on the regional environmental, social and economic effects of one particular development, the "Big Sky" recreation complex of southwestern Montana. Essentially unchanged from the previous research, the project objectives include: (1) the establishment of a pre-development data base, observation of trends, and

identification of the on-site and off-site economic, social and environmental impacts of the development; (2) presentation of research results in a form of maximum use to public and private decision makers; and (3) to the extent appropriate, a restatement of project data and experience for broader application.

Primary target users of research findings in this project include the Forest Service and Montana State and local government officials, but it is anticipated that such research would be of great value and interest to other State and local officials concerned with evaluating impacts of large-scale recreational developments on semi-primitive environments. Project-generated data and knowledge has been utilized in U.S. Forest Service environmental impact statements for units of the Gallatin National Forest; development of a waste allocation management plan for the Gallatin River Basin; state-wide workshops discussing land use problems in Montana; and by many other interested groups.

Analysis of a New Approach for Environmental Policy Evaluation; *Harold A. Thomas, Jr.*; Harvard University, Division of Engineering and Applied Physics, Cambridge, Massachusetts 02138; \$212,900 for 12 months beginning July 1, 1974

This award continues a research effort to develop the Paretian Environmental Analysis as a practical operational tool for examining and solving environmental control problems. The method is constructed on the thesis that an environmental control agency tends to be responsible to the wishes of a number of different interest groups, each of which as a fairly well-defined framework for evaluating the impact of possible agency decisions from its own point of view. The central concept is that decisions will be "Pareto admissible." A

decision is defined as "Pareto admissible" if there exists no possible alternative decision that some groups regard as superior and no group regards as inferior. Where two decisions, A and B, are compared, A is called "Pareto-superior" to B if one or more of the groups prefers A and none of the other prefers B. In this case, decision A dominates decision B.

The project is evaluating environmental policy issues related to five problem areas, in order to attempt the

development of general methods for using Pareto Analysis as a means of evaluating the political feasibility of various decisions. These problem areas are: (1) control of air pollution-stationary sources; (2) control of air pollution mobile sources; (3) environmental aspects of electric power plant siting; (4) residuals management in land use planning; and (5) urban solid waste management.

The work to date has focused on the problems of a local or regional agency for environmental control.

National Economic Models of Industrial Water Use and Waste Treatment; *Russell G. Thompson*; University of Houston, Department of Quantitative Management Science, Houston, Texas 77004; \$404,200 for 16 months beginning May 1, 1974

New water pollution control legislation and regulations are being generated at an extraordinary rate. The cumulative effect of these activities on industrial efficiency and productivity is as yet unknown, but could be very great. There is a need to develop an analytical capability for assessing the economic impact of these environmental control regulations and for predicting industry response in order to avoid future economic and environmental problems.

This project is a continuation of an earlier study to develop production functions for the five most important water-using industries: chemicals, pulp and paper, primary metals, petroleum refining, and electric power generation. The following costs are being estimated: (1) total cost of production; (2) costs of important inputs used in production; (3) input water treatment costs; (4) wastewater treatment costs; (5) air emission control costs; (6) solid waste and brine disposal costs; and (7) costs of treating water for reuse. Adjustments for size and age of plants provide a comprehensive microeconomic basis for each industry modeled.

Analysis of the models of water and waste treatment that have been developed for representative ethelene plants with naphtha feedstocks indicate that:

Several specific recent decisions were examined in detail to determine if the choice from among the known alternative was in fact "Pareto admissible." These cases relate to air pollution in the Boston and Syracuse area, regional solid waste management in southern Massachusetts, electric power plant siting in New England, and residuals management in land use planning in the Syracuse area. Current research efforts are focused on model reformulation and refinement.

1. A level of removal of the total dissolved solids discharge approximating a zero-discharge policy increases per unit product cost by 8 percent.

2. A level of removal of total dissolved carbon discharge approximating a zero-discharge policy increases per unit product cost less than one percent with no reuse of the water and 4.8 percent with reuse of waste water.

3. A level of removal of oil and suspended solid discharges approximating a zero-discharge policy has an insignificant effect on per unit product cost.

4. A level of removal of oil, total suspended solids, total dissolved carbon, and total dissolved solids discharges approximating a zero-discharge policy increases the cost of producing one billion pounds per year of ethelene by 9 percent.

Similar economic studies have been completed for ammonia and caustic soda-chlorine. The effect of restrictive wastewater discharge policies of per unit product cost for these materials was found to be relatively small.

RESIDUALS MANAGEMENT

Solid and liquid residuals from municipal and industrial sources are both a threat to regional environmental quality and a potential solution to its security as a viable ecosystem. The goal of the Residuals Management Program is to synthesize residuals management strategies for minimizing environmental risk. Research directed toward solution to problems of residuals management is coupled with the recovery of potential resource values of waste constituents.

Continued research is being carried out investigating the injection of municipal sludges into soils; utilization of wetlands for advanced treatment of municipal effluent; and application of high energy electrons for disinfection of both sludge and effluent.

Objectives of the program are to:

- Identify the limitations of present management practices.
- Evaluate new approaches for processing and management.
- Reconcile processing economies of scale with collection system diseconomies to better define appropriate levels of regionalization.
- Seek processes for conversion of residuals into products or forms that minimize or eliminate environmental risk.

Solid and liquid residuals from municipal and industrial sources are both a threat to regional environmental quality and a potential solution to its security as a viable ecosystem. Program development strategy is to couple research directed toward solutions to problems of residuals management with recovery of their potential resource value. Objective is to maximize potential for utilization of research-results.

Utilization of Waste Heat in a System for Management of Animal Residuals to Recover and Recycle Nutrients; L. Boersma; Oregon State University, Corvallis, Oregon 97331; \$71,500 for 12 months beginning July 1, 1975

The technical and economic feasibility of combining the utilization of animal metabolic residuals and waste heat from generation of power in a closed system for the purpose of unicellular plant culture is the continued concern of L. Boersma under this research grant. Specific objectives under this program include determination of: (1) the quality and quantity of single cell protein produced; (2) potential problems of algae production, for extended periods, in open-air basins; (3) effect and value of power plant waste heat on the performance of the system; (4) the economic constraints of the system; and (5) potential benefits to society.

The animal waste management system consists of a livestock confinement building from which animal

wastes are hydraulically transported first to a sump, and then to a solid-liquid separator. The solid-rich fraction is subjected to anaerobic digestion. The separator overflow is pumped into nutrient-recovery basins. Algae cultivated in the basins and separated centrifugally will be evaluated for their potential as a constituent of animal feed. The algal growth medium concentrate is returned to storage to be used as the animal waste-transport fluid.

Experimental work carried on while design and construction of the facility continues includes evaluation of clarification, effect of animal residual concentration on algal growth rate, evaluation of protein-quality of algal extract, estimation of potential harvest rate, determination of optimal culture tank depth, effect of

addition of carbon dioxide on production of algae, pond-nitrogen balance, and assessment of algal-culture stability.

The concept of an integrated system for warm water use was developed at Oregon State in response to requests from local utilities like Pacific Power and Light and the Portland General Electric Company. The research team maintains contact with livestock producer

groups at national meetings and will be particularly effective locally with emphasis on participation during regularly scheduled Animal Waste Management Field Days. Recommendations gathered at the workshop on "Future Developments in Waste Heat Utilization and Power Plant Operation for Maximum Energy Use Efficiency," December 16-17, are being prepared for publication.

Research on the Chesapeake Bay to Provide the Knowledge Base for Waste Outfall Management; *Theodore Chamberlain*; Chesapeake Research Consortium Inc., Baltimore, Maryland 21218; \$160,000 for 2 months beginning October 1, 1974

The Chesapeake Research Consortium, Inc. (CRC), whose membership includes the Johns Hopkins University, the University of Maryland, the Smithsonian Institution, and the Virginia Institute of Marine Science, has been conducting research relating to the problem of wastewater outfall management. The research strategy is to analyze one relatively unpolluted system (Rhode River) and two comparatively polluted river estuaries (Back and Elizabeth Rivers). The issues being addressed include environmental standards, ineffective septic systems, behavior and effects of effluents, inadequate planning, increasing population density, flushing, extreme flooding, advanced waste treatment, inadequate or outdated facilities, definition of optimal water quality, divided authority and public attitudes toward environmental control. This research is a continuation of previous scientific studies and is expected to provide workable means through which waste outfalls can be managed. A secondary objective of this project has been to improve the analysis of the present conditions on the edges of the Bay and the effects of various developmental pressures. Particular emphasis has been directed toward incremental effects of small scale modifications to the shore-line.

The Consortium continues its close working relationship with agencies of the Federal Government

and in Virginia and Maryland. The output of this study is timed to coincide with a study by the Baltimore Districts Corps of Engineers, which is responsible for providing a management plan for the Bay area by 1976. Recommendations based on this project were submitted by the research team to the Virginia Division of State Planning and Community affairs and were the primary source of data enabling definition and location of critical wetlands areas for the Department's "Critical Areas Management Proposal." Recommendations provided by researchers were also used in developing legislative proposals which led to the Virginia Wetlands Management Act of 1972. Another action was the use by the Virginia Marine Resource Commission and the Corps of Engineers of a report by CRC on erosion characteristics and shoreline uses. This information was used in the preparation of proposed shorelines defenses at Silver Beach, North Hampton County. The Consortium was selected by the State of Maryland Department of Natural Resources to undertake survey work and conduct additional research relating to effects of a recent 200,000 gallon oil spill on Chesapeake Bay. Background data and analytical techniques synthesized during this research will be utilized to estimate ecological effects on affected areas of Chesapeake Bay.

Process Selection for Optimum Management of Regional Wastewater Treatment Residuals; *Richard I. Dick*; University of Delaware, Department of Civil Engineering, Newark, Delaware 19711; \$59,100 for 14 months beginning July 1, 1975

Approximately 40-50% of the total costs of wastewater treatment are attributable to management of treatment residuals (sludges). Critical analysis of current practice indicates a relatively large number of systems that are illogical. Major shortcomings include: failure to integrate sludge treatment and subsequent management with the wastewater treatment processes which generate the

sludges; failure to control inputs at the source which adversely affects its quality, lack of optimal integration of treatment, transport, "disposal" and reclamation processes, lack of a regionalized approach to residuals management, and among others, a tendency toward management procedures that do not consider the total impact of the management system used on either the

process itself or on regional environmental quality.

The research objective of this program is to synthesize a procedure for analysis of cost and performance of sludge treatment processes and integration into procedures for selection of regional residuals management concepts to minimize environmental impact and achieve public acceptance. Interactions between process elements for treatment and management of sludge generated in treatment of wastewater are being evaluated to characterize optimal sludge management systems. Mathematical models of the performance and cost of individual processes are being constructed and optimal combinations of processes and operating conditions are being identified by integrating combinations of processes into systems for residuals management. Fundamental sludge properties which influence performance of treatment and subsequent management procedures are being used as input

variables in performance models and operational and economic variables are being used to build cost and performance models. Others are being noted as traits of particular systems for residuals management.

Principal users expected to utilize results include: municipalities, industries, consulting engineers, governmental agencies, equipment manufactures, and various public interest groups. A Project workshop group will initialize contact with users seeking project guidance by ensuring a better orientation of project results to user needs. In addition to the coordination with the Project Workshop Group, the utilization plan for the first phase of the project involves presentation and publication of pertinent project results through participation in professional meetings and submission of papers to professional journals.

The Role of Microorganisms in the Decomposition of Deep Well Injected Liquid Industrial Wastes; Gerald H. Elkan; North Carolina State University, Department of Microbiology, Raleigh, North Carolina 27607; \$73,300 for 24 months beginning July 1, 1973

Storage and disposal of industrial chemical wastes by injection into deep aquifers is a practice with little base of knowledge as to the biological implications of such a system. This research is sited at an experimental deep well located in Wilmington, North Carolina designed for injection of 300,000 gallons per day of industrial wastewater from production of dimethyl terephthalate into formations 850 to 1025 feet deep. The experimental system includes an injection well and observation well, operated under a permit issued in 1968 by the State of North Carolina, which included provisions for study of the feasibility and effects. Objectives of this study are to develop techniques for sampling and isolating microorganisms indigenous to deep aquifers as a necessary prerequisite to determining changes that may occur in microbial population resulting from wastewater injection. The roles of indigenous organisms and the wastewater injection procedure in causing dispersal of

microorganisms in the aquifer are also being studied. Inoculation of wastewater with selected microorganisms to accelerate wastewater constituent degradation is being explored to determine the feasibility of utilizing deep well systems for treatment of industrial wastewaters.

This program is being coordinated with groups having prime interest in the data obtained, namely: Environmental Protection Agency, Research Triangle Park, North Carolina; the U.S. Geological Survey, District Office, Raleigh, North Carolina; and the North Carolina State Department of Natural Resources, Ground Water Division, Raleigh, North Carolina. A number of private companies and consulting firms, including Hercules, Monsanto, and Celanese, have utilized research results.

Integration of Thermal and Food-processing Residuals into a System for Commercial Culture of Fresh-water Shrimp; Carlos R. Guerra; Public Service Electric and Gas Company, Research and Development Department, 80 Park Place, Newark, New Jersey 07101; \$127,900 for 16 months beginning July 1, 1975

Now in its second year of research, this program's objective is to determine the technical and economic feasibility of utilizing residual heat from electric power generation and residuals from food-processing to culture the freshwater shrimp, *Macrobrachium rosenbergii*, and

a secondary species, the rainbow trout, *Salmo gairdneri*, in a controlled environmental system of tanks and ponds. Results to date indicate that both species are suited to this environment and that dual crop aquaculture operations appear viable in temperature zones.

Specific objectives are: (1) improved management of low grade thermal energy discharged in power plant cooling water; (2) optimization of the conversion ratios of weight of food to weight of shrimp or trout using selected feeds including organic wastes (fish and shellfish scrap) under constant optimal culture conditions; (3) optimization of the stocking density of shrimp and trout per water volume; (4) optimization of conditions for each growth phase of shrimp including feeding and general behavior; (5) specification for commercial operation of species' physiological constraints of the culturing system including optimum temperature, optimum dissolved oxygen and dissolved oxygen-temperature interactions; (6) determination for design specification of operational methods, equipment, and systems to minimize manual labor and increase the potential productivity of the culturing system; (7) further characterization of the quality of the discharge canal water and untreated Delaware River water with respect to constituents of significance to culturing and/or environmental impact of culturing; and

(8) technical/economic analysis of feasibility of utilization of waste heat in the culturing system.

This research is the result of cooperation between two potential users of the research results, the Public Service Electric and Gas Company (utilization of waste heat), and the Long Island Oyster Farms (commercial aquatic food producer and processor). The communication channels and working relationships that have already developed will serve as a basis for the utilization of the results from the research. Trenton State College and Rutgers, the State University, participated in planning the research and are carrying out the biological testing under subcontract with Public Service Electric and Gas Company. In April, 1975 two thousand trout were successfully raised under this program and distributed throughout the state by the Department of Environmental Protection; 500 being given to the Chatham Fire Department for a fishing outing and 500 used to stock Branch Brook Park in Newark.

Feasibility of Utilization of Wetland Ecosystem for Nutrient Removal from Secondary Municipal Wastewater Treatment Plant Effluent; Robert H. Kadlec; University of Michigan, Ann Arbor, Michigan 48104; \$140,000 for 12 months beginning July 1, 1975

Treatment of municipal wastewater has as its primary and secondary objectives the removal of suspended solids and carbonaceous material that would exert, indirectly, a demand upon oxygen resources of the receiving water ecosystem. Nutrients (nitrogen and phosphorus) remaining in the effluent from secondary treatment can stimulate the growth of algae and other aquatic vegetation which, upon death and decay, can also exert a demand for oxygen. Nutrient removal is therefore an objective of advanced treatment. Although phosphorus can be removed from effluent by chemical precipitation, an alternative is the potential use of natural wetlands into which secondary effluent can be directed and within which nutrient removal can be achieved simultaneously with a potentially desirable increase in the productivity of the wetland ecosystem.

The project goal, determination of the feasibility of utilizing wetlands as a receiving system for domestic wastewater treatment plant effluents, has five specific objectives: (1) evaluation of immediate impact of an effluent on the wetland ecosystem; (2) determination of the effectiveness of the ecosystem as a treatment concept for the effluent; (3) projection of long term effects and changes in the wetland ecosystem and changes in its "normal" response; (4) acquisition of a means of understanding any changes that take place to provide a

basis for extrapolation to other wetland ecosystems; and (5) development of a systematic analysis scheme to permit extrapolation of results to other wetland ecosystems.

The objective of this continuation period is to validate a dynamic modeling approach synthesized during the 3-year period of prior support by field application and monitoring on a sufficiently large scale to provide significance and confidence in utilizing the model for long-range projections and utilization of the results to other locations. The research plan includes acquisition of additional information on wetland ecosystems, evaluation of initial irrigation systems, refinement of models, and exchange of information between user agencies and researchers.

Regular communication is maintained with the two users appropriate at this state of research, Williams and Works and the Houghton Lake Sewage Authority. A major conference and user workshop is planned for the week of May 10, 1976 at Ann Arbor, Michigan. Research and utilization is being coordinated with the cypress wetlands project at the University of Florida under the direction of Dr. H. T. Odum.

Separation of Cellulose Fiber From Mixed Municipal, Industrial and Agricultural Residuals for Utilization as a Constituent of Animal Feed; *William McIlroy*; Grumman Ecosystems Corporation, 1111 Stewart Avenue, Bethpage, New York 11714; \$44,800 for 6 months beginning March 1, 1975

Quantities of residuals from municipal, industrial and agricultural activities have been increasing, presenting a regional management problem of increasing magnitude for municipalities as land for fill-sites becomes less available and environmental air quality standards progressively foreclose the incineration-option for the "light-fraction" of the residuals for which no economically viable demand has yet been developed. The lightfraction (65% by weight of current mixed, municipal residuals) contains cellulose fiber (50%-70%) from which value can be extracted by direct pyrolysis or indirectly after first being converted to methane by anaerobic digestion. However, indications are that fiber contained in these residuals has an inherently greater value for potential utilization as an animal-feed constituent. If possible, adoption on a large scale would reduce the demand on grain and grain products used for cattle feed and thus provide a potential source revenue to offset processing costs. Viability of resource recovery from mixed residuals will be improved if the recovery process provides a method for utilization of the bulk of material remaining after metals, glass and plastics have been separated. This will, in turn, reduce the volume of unusable material for which disposal sites must be located in rural areas near municipal sources of residuals with improvement in the region's environmental quality.

The initial phase objective is to evaluate a concept of separation of cellulose fibers from mixed municipal, industrial, and agricultural residuals and assessment of the feasibility of utilizing the separated fraction as a constituent of feed for dairy cows and beef cattle.

Objectives of the second phase will be to conduct feeding studies and refine economic cost and benefit data for determination of commercial feasibility of this concept for management of regional solid residuals. Research is conducted at St. Louis, Missouri research facility. The program will include verification of requirements for blends of potential feed components in cooperation with those commercially available, including identification of undesirable or harmful constituents. Feeding studies will be conducted to assess palatability, effects upon animal productivity and product quality, and to provide data for estimation of residuals-processing plant costs and commercial viability of this concept for regional management of mixed, solid residuals.

This research is jointly conducted by Grumman Ecosystems Corporation and the Department of Dairy Husbandry, College of Agriculture of the University of Missouri, Columbia. The Ralston Purina Company, St. Louis District Dairy Council and the Allied Market Interests, a livestock feeding and marketing group, will provide access to extensive channels of information dissemination to potential users. The primary channel for formal dissemination will be by publication and distribution of reports to key feed produce companies and dairy cattle raising associations as well as to the scientific community active in agriculture and animal husbandry research. Research personnel will participate in seminars and conferences sponsored by the solid waste industry, Public Works Association, League of Cities, City Management Association, and dairy and cattle raising associations.

Improvement and Evaluation of Techniques for the Mechanical Removal and Utilization of Excess Aquatic Vegetation; *Richard Koegel*; University of Wisconsin, Department of Mechanical Engineering, Madison, Wisconsin 53706; \$160,200 for 36 months beginning July 1, 1973

Excessive growth of aquatic vegetation is a problem encompassing approximately 270,000 acres of inland waters in the United States. Mechanical harvesting of nuisance-causing vegetation is more acceptable than the use of herbicides, but the adoption of mechanical harvesting as an environmentally preferred concept will depend on development of acceptable methods of handling the harvested vegetation. An integral part of this research project is to investigate processing of harvested vegetation to provide components of animal

feed and to continue search for fractionated components of higher value.

The project takes advantage of an existing Dane County, Wisconsin aquatic plant management program to obtain data on the cost, effect, and effectiveness of large-scale harvesting operations. Researchers have been providing designs and fabrication of hardware and data analysis. Results have already proven that significant reductions can be made in the cost of

managing excess aquatic vegetation through improvements in the mechanical equipment, development of cost productivity data for potential users, and the utilization of harvested vegetation for soil conditioning. Productivity of harvesting has increased 50 percent from 0.63 acres per hour to 0.94 acres per hour. Costs have been reduced 27 percent from \$94 per acre to

\$68 per acre. Results are being communicated continuously to the Dane County Aquatic Management Program, and to manufacturers of harvesting equipment, including Aquamarine Corporation, Clark Equipment Company, and Outboard Marine Corporation.

Regional Sewerage Planning by Mixed Integer Programming; *Donald T. Lauria*; University of North Carolina, Department of Environmental Sciences and Engineering, Chapel Hill, North Carolina 27517; \$17,000 for 18 months beginning April 1, 1973

This research is addressed to the planning of municipal sewerage systems and is directed toward developing a practical analytical procedure for use by consulting engineers to achieve optimum solutions for wastewater management problems on behalf of their clients (municipalities, counties, regional planning commission, etc.).

Regionalization provides a potential for achievement of "economics of scale" when treatment of wastewater is necessary to meet receiving-water objectives. This project is further investigating a mathematical approach that accommodates the type of cost function associated with economies of scale characteristic of construction and operation costs of wastewater collection, transmission and treatment facilities. An existing mixed integer programming model (MIP) is being adapted and

modified to indicate the optimum degree of treatment required at each treatment plant location to meet regional wastewater objectives. An optimal process for each treatment plant in the total regional collection-treatment system is the objective of the project.

The model developed as a result will be applied to an actual planning problem involving 14 alternative plant sites for which extensive cost and other data are available. This problem was analyzed by a consulting engineering firm and the solution developed by the firm will be directly compared to that provided by the MIP model. Further implementation of a utilization plan is contingent upon success in achieving the project objective, viz. an improved approach to optimizing public expenditures for regional wastewater facilities.

Control of Virus Pathogens in Municipal Wastewater and Treatment Residuals by Irradiation with High-Energy Electrons; *Theodore G. Metcalf*; University of New Hampshire, Department of Microbiology, Durham, New Hampshire 03824; \$43,000 for 12 months beginning July 1, 1975

This project, coordinated with research underway at the Massachusetts Institute of Technology High Voltage Research Laboratory, is designed to investigate the potential role of high energy electrons for disinfection of wastewater treatment plant residuals, as well as human enteric viruses contained in the municipal wastewater. Objectives of the research include comparison of concentration, adsorption, and magnetic separation virus assay techniques for accuracy and reliability in enumeration of enteric viruses in aqueous media, and application of viral assay procedures to determine the effectiveness of electron irradiation for inactivation of viruses. Investigations include determination of radiation dose for inactivation of viruses in the presence and absence of oxygen and under variations in pH, temperature and pressure.

Being closely linked to the MIT research, this work is integrated with the MIT-utilization plan, an important component of which is the location of the research unit at a potential user-site (Boston MDC — Deer Island) and coordinated with both the Commonwealth's Department of Natural Resources and the Regional U.S. E.P.A. office which also provides direct coordination with the U.S. E.P.A., Cincinnati NERC. Previous findings by the Virology Laboratory, Department of Microbiology, have been utilized in recent research by other groups to assess public health problems associated with the use of wastewater and wastewater liquid residuals for their nutrient value, including virologic studies of an aquaculture system at Woods Hole Oceanographic Institution.

Feasibility of Utilizing Cypress Wetlands for Conservation of Water and Nutrients in Effluent from Municipal Wastewater Treatment Plants; Howard T. Odum; University of Florida, Center for Wetlands, Gainesville, Florida 32601; \$223,600 for 12 months beginning May 1, 1975

Cypress domes are being studied for a determination of their potential utilization for management of effluent for secondary treatment of municipal wastewater, simultaneously providing regional greenbelts for esthetic enhancement and protection of wildlife. Project objectives are to assess the feasibility of utilizing cypress wetlands for management of wastewater to achieve conservation of both nutrients and water while simultaneously providing enhancement of regional environmental quality. The goal of the continuation period of research is to produce a handbook of cypress wetland management for use by planning agencies for potential utilization of wetlands in management concepts for regional wastewater.

Continuation of research is expected to result in the achievement of the following objectives:

1. Determination of the limits of wastewater loading on cypress wetlands and drafting of suggested guidelines for use of wetlands in management of wastewater treatment plant effluents.
2. Description of the cypress wetland ecosystem resulting from adaptation to optimum wastewater effluent loadings.
3. Acquisition of sufficient data and analytical capability to predict consequences of wetland utilization for wastewater management for regions other than those directly subjected to evaluation in this research.
4. Determination of the relative value of wetlands for quantitative and qualitative management of water resources, forest products, insect control, residential microclimate buffers and wastewater management.

The research was originally structured to include

studies of site management, hydrology, systems ecology and modeling, air quality, aquatic microbiology, water quality and heavy metals, forest growth, seedlings and fertility, soils, mosquitoes, ecosystem metabolism and microclimate, corkscrew swamp control characterization, regional wetlands management and utilization.

Potential direct users include the Florida Division of Planning, Florida Coastal Coordinating Council, South Florida Flood Control District, and the County Board from Alchua, Collier and Lee Counties. Strong support from the State of Florida in this research has resulted in coordinate funding of the phase directed toward the "Forested Wetlands Use Manual." Results of this research are being incorporated into the Division of State Planning proposals to the State Legislature for land use regulation and into the Department of Pollution Control plans for regulation of wastewater discharges. Presentations are planned for county commissioners of the five counties as part of the responsibilities of the South Florida Environmental Study Project. Special presentations have been made to a Florida State Legislative committee on Big cypress and staffs of the U.S. Department of Interior. A Users Steering Committee with state and county representatives has been active in providing advice to investigators.

This research is being coordinated with wetlands-utilization work currently underway at the University of Michigan under the direction of Dr. Robert Kadlec. Substantial coordinate funding for the University of Florida project is being supplied by the Rockefeller Foundation which, in addition, is supporting virus-fate studies with a grant to the State of Florida Department of Health (Dr. Flora Mae Wellings).

Western Water Needs for Energy Conversion and Processing with Environmental Quality Constraints (Phase I); Ronald F. Probstein; Water Purification Associates, 53 Jordan Road, Brookline, Massachusetts 02146; \$36,900 for 4 months beginning June 1, 1974

The primary objective of this project is to assess the ability of advanced water treatment systems to help satisfy the water needs and environmental constraints for fossil fuel energy processing and conversion, concentrating on the semi-arid western States. Estimates of water requirements and discharges (quantity and quality) are being obtained, for producing low Btu clean gas from coal, high Btu gas from coal, oil from coal, oil

from shale, and generating electric energy from steam. For each, optimum water treatment systems will be suggested. Assessment is being made of the environmental effects as a function of site and conversion system expected from inclusion of the water treatment consideration, as well as the determination of the incremental cost effects on the energy product which results from this inclusion. The final effort is to correlate

all the technical information derived for potential use in determination of policy.

The significance of the results bears directly on national needs affecting the economy and environment of vast regions of the country. In relation to fossil fuel conversion these results will provide necessary information to develop guidelines concerning water use and effluent discharges, the most appropriate plant sitings, more precise estimates of water requirements, and more detailed specifications on the types of water resource surveys needed.

The study will suggest specific technological means for inclusion of advanced water purification equipment in specific energy conversion processes, and as such is of vital concern to those industries involved in the development of these processes and environmental

standards, to the Environmental Protection Agency in drawing up guidelines for effluent discharge, and to the Department of Interior in developing leasing requirements for Federal lands. It will define optimum locations for energy conversion plants and thereby assist the Bureau of Land Management, Office of Coal Research and the Atomic Energy Commission. It will also enable more precise estimates to be made of water needs thus enabling State agencies and the Bureau of Reclamation to define conservation and allocation measures.

The dissemination of the results of the program will be made through distribution of interim and final reports and publications in technical journals with widespread distribution.

Management of Physical Alteration to the Edges of Chesapeake Bay and Their Effects on Environmental Quality;
W. H. Queen; Chesapeake Research Consortium Inc., Room 111, Whitehead Hall, Johns Hopkins University,
Baltimore, Maryland 21218; \$280,800 for 7 months, beginning December 1, 1974

The objectives of this program are to: (1) identify the principle patterns, trends and rates of physical alterations of the edges of the Chesapeake Bay and evaluate their environmental significance; and (2) to develop a better understanding of the decision process pertaining to physical alterations of the Bay and application of this better understanding to the evaluation of policies and programs affecting environmental quality of the region.

Primary issues being addressed include: 1) cumulative impacts resulting from incremental alterations; 2) the capability of the regulatory agency permit process to address the problem of cumulative impacts; and 3) the informational needs of regulatory agency personnel pursuant to their responsibilities for making decisions on physical alterations involving the coastline. Procedures being utilized are: (1) selective analysis of permit applications that have been submitted to the Baltimore and Norfolk Offices of the U.S. Army Corps of Engineers; (2) case studies of a representative set of permit applications; and (3) shoreline studies of selected Bay counties. The permit analysis is being undertaken to

identify patterns, trends and rates of shoreline alterations. Case studies of permit applications are being used: (1) identify ecologic, social, economic and legal issues that are presented by the permit applications; (2) to provide a basis for assembly and evaluation of existing literature that can be used to address these issues; and (3) develop a better understanding of the current "decision process." The shoreline studies are being conducted to provide a characterization of the shoreline that is necessary to assess the impacts of alteration activities within the shore zone.

The project has been structured in such a way that each major activity will close with a report for use by local, state and Federal regulatory agency personnel, state and federal legislators and the general public. Regulatory agency personnel have been invited to participate actively in case study group meetings. Program investigators will meet with appropriate agency personnel to review project reports as they are compiled. In addition, a series of public conferences and seminars are held.

Socioeconomic Correlates of Household Food Residuals; *William J. Rathje;* University of Arizona, Department of Anthropology, Tucson, Arizona 85721; \$15,200 for 5 months beginning April 1, 1975

Data collected since 1973 in Tucson, Arizona, indicates that approximately nine percent of the food that was purchased by 600 sample households was discarded. If

sample households were representative of all households in Tucson, an estimated 9,500 tons of food valued at \$9-10 million were discarded into sanitary land fills in 1974.

The presence of food resources as a constituent of mixed household refuse adds to the problem of resource recovery from residuals and to the problem of their management to achieve adequate standards of regional environmental quality. Objective of this research is to continue collection and analysis of data from a comparable sample of households to determine whether changes in food price have influenced the efficiency of food utilization and thus changed the relative composition of mixed refuse. A preliminary observation that households below the poverty level appear to be more efficient consumers will be further studied to identify behaviors and their socioeconomic correlates which result in more or less efficiency in utilization of resources.

Achievement of the project objective of collecting, analyzing and comparing data obtained during the research period with results of prior work will address issues such as: (1) the magnitude of food waste in sample households; (2) types of food wasted; (3) socio-

economic correlates of efficiency and inefficiency as measured by food waste; and (4) changes resulting from economic stresses produced in food utilization patterns.

Data from the pilot phases of this project has been supplied to several divisions of the U.S. Department of Agriculture, state and local health and consumer information agencies. The Smithsonian Institution and the Office of Naval Research invited research personnel to a conference on "Survey Alternatives." Papers have been given at seven professional meetings during the last year, including the American Public Health Association, American Anthropological Association, and The Society for Nutrition Education. Major articles have appeared in such publications as the *Journal of Nutrition* and the *American Journal of Public Health*. In addition, data on food waste from the Project's pilot phases are being disseminated to the general public. In addition, information from the Project is being circulated in response to requests from primary and secondary school systems.

Research on Management of Effluent from Secondary Wastewater Treatment Utilizing a Marine-Aquaculture System for Removal of Inorganic Nutrients; John H. Ryther; Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543; \$250,000 for 12 months beginning May 15, 1974

For the past two years, NSF/RANN has been supporting the development of a waste management system at WHOI to achieve the objectives of a tertiary-stage (inorganic nutrient removal), culminating in the harvesting of shellfish (oysters). The objectives of this award are to continue evaluation of an integrated system of marine plants and animals capable of removing inorganic nutrients from a mixture of treatment municipal wastewater (secondary-level effluent) and to assess the technical and economic feasibility of such a system.

Specific objectives include; (1) plant and animal species selection; (2) rates of production, their economic and nutritional value, and (3) acceptability and marketability of products. The research program is divided into 5 components. The *phytoplankton* component is directed toward investigation and determination of optimal mixtures of secondary-effluent and seawater, harvest rate and yield, nutrient removal efficiency, control of species as a good source for shellfish, prevention and control of algal clumping and methods of circulation, and effects of solar radiation and temperature on growth, nutrient removal and predator and competitor control. The *shellfish component* is directed toward species selection and evaluation, effect of food species on growth and yield, culture methods, feeding methods, oxygen requirements, waste removal, water dilution requirements, solid and dissolved waste

production, effects of temperature on growth and yield, fouling and control of reproduction and sexual maturation. The *seaweed component* is directed toward species selection and evaluation, nutrient removal efficiency, effects of nutrient concentration on growth and yield, effects of temperature and solar radiation on nutrient removal, growth and yield, fouling control, culture methods, circulation technology, and control of reproduction. The *ancillary component* is investigating a detritus feeder system, a scavenger feeder system, and a herbivore-browser feeder system to determine their effectiveness in converting system waste products into "marketable" protein. The *nutrient monitoring component* is directed toward assessment of performance of the total system.

The potential for utilization of results for this research is contingent upon technical feasibility of the process, economic viability of the system, and acceptability, a function of both technical and economic factors. Potential user interest has been developed with: the town of Marion, Mass. Marine Resource Commission; the town of Falmouth, Mass.; Camp, Dresser and McKee, Boston, Mass., consulting engineering firm; Marine Colloids, Inc. (seaweed production potential of the system); Mariculture, Ltd. (interest in oyster culture as a secondary crop to sea turtles); and Kramer, Chin and Mayo, consulting engineering firm.

Human Enteric Viruses in a Waste-Recycling Aquaculture System; John H. Ryther and Theodore G. Metcalf; Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543; \$104,000 for 24 months beginning July 1, 1973

This project applies viral monitoring techniques recently developed at the Baylor University School of Medicine to determine the fate of human enteric viruses entering a shellfish aquaculture system for tertiary treatment of municipal wastewater. The potential benefit of conserving nutrients remaining in wastewater is accompanied by potential concentration of deleterious substances. Prior studies of viruses in secondary effluents and their concentration within components of a subsequent food chain have been difficult to accomplish

because a suitable procedure did not exist for concentration of viruses. This study utilizes a new procedure for viral concentration to: (1) determine whether viruses are concentrated by oysters and marine life serving as nutrient concentrators; (2) determine possible solutions to the viral-concentration problem if one is determined to exist; and (3) apply information obtained to gain useful insights into the fate of human viruses in marine environments subjected to pollution by human wastes.

Virus Survival in Soils Injected with Municipal Wastewater Treatment Residuals; Bernark P. Sagik; University of Texas at San Antonio, College of Science and Mathematics, San Antonio, Texas 78285; \$58,900 for 12 months beginning February 1, 1975

Management of residual sludges from wastewater treatment is a major problem of municipalities and regional wastewater management districts accounting for roughly one-half of the capital and operating costs. Intensive application to land has emerged as an attractive alternative despite questions of long term effects on soils, and potentially adverse effects on health and technical limitations of process. Of the various application systems, direct injection appears to provide the advantages of economy, technical superiority, and more acceptable esthetic and environmental impact. However, viruses efficiently removed from the wastewater are concentrated in residual sludges as are ova, cysts, and spores of bacteria of potential significance toward ultimate acceptability of soil-application as a regional management procedure for these residuals.

Objectives of this research are to evaluate the potential contamination significance by viruses on soils into which residuals have been injected utilizing procedures developed by the principal investigator in recently completed research at the Govalle treatment plant in Austin, Texas. These models will be applied to the evaluation of sludge-injection for its virus disease

potential (via contamination of ground and surface runoff waters). The specific objectives of the program are: (1) Determination of virus level of treatment plant sludges at Boulder, Ft. Collins and Hampton Roads treatment plants; (2) Determination of sludge virus level at time of injection into soils; (3) Concentration and enumeration of viruses from irrigation tailing water and groundwater after varying periods of injection and soil resting; (4) Mapping of viruses movement in waste effluents through soils and quantification of this flow; (5) Determine the efficiency of recovery of infectious and physical particles using parallel laboratory studies of biologically-occluded isotopically-labelled poliovirus injected into natural soil cores; (6) To quantify the survival of poliovirus as an indicator of other enteric viruses in soil systems; (7) To evaluate sludges being injected for evidence of ova, cysts and parasites and assess their significance in potential contamination of soil.

Research will be coordinated with Colorado State personnel who are formulating an analytical model of subsurface injection.

Management of Mining Residuals by Placement Into Underground Voids; Theodore M. Schad; National Academy of Sciences/National Academy of Engineering, Environmental Studies Board, 810 Joseph Henry Building, Washington, D.C. 20418; \$12,300 for 2 months beginning February 1, 1975

The National Academy of Sciences/National Academy of Engineering studied underground placement of mining residuals and feasibility of underground solid waste storage resulting from deep mining of coal. Needs for additional lines of investigation were evaluated.

The objective of this research is to complete the assessment of the state of knowledge relative to underground placement of solid residuals from coal mining and beneficiation, and the feasibility of current research and technology needs. The research plan calls

for completion of a thorough critical review and revision of the report with publication expected upon award period termination.

The completion of the Final Report will occur during this continuation period and will be published and distributed by the National Academy of Science and Engineering. Parties interested in a summary of the research to guide their efforts in drafting and introducing

environmental legislation include congressional members from West Virginia and Pennsylvania, Pennsylvania legislators. The Deputy for Environmental Protection and Regulation in Pennsylvania's Department of Environmental Resources has asked for guidance from the study in promulgating regulations on mining.

Characterization of Contaminants in Oil Shale Residuals and the Potential for Their Management to Meet Environmental Quality Standards; Josef J. Schmidt-Collerus; Denver Research Institute, University Park, Denver, Colorado 80210; \$40,000 for 12 months beginning March 15, 1975

This project is a continuation of work initiated in September 1972 and is being jointly funded by the Environmental Protection Agency, Federal Energy Administration, and the National Science Foundation with the objective of providing information needed for management of residual spent shale to minimize environmental impact. Specific objectives include: (1) determination of the amount and kind of organic components in carbonaceous spent shale and in the process water from retorting operations; (2) isolation and identification of the structure and composition of those compounds that are of known or suspected blastomogenic activity; and (3) investigation of the changes compounds may undergo in large storage sites and investigation of their impact on environmental quality including solubilization and leaching by ground and runoff water, volatilization of potential air pollutants, identification of polycondensed organic matter present in airborne carbonaceous particulates emitted from oil shale processing operations, and effect of possible autooxidation on volatilization of organic compounds from the waste and their transfer into air.

Research to date has involved base-line investigations of possible leasing and spent-shale storage sites and has included study of their physiography and hydrological aspects, collection of water, soil and vegetation samples

from these areas and sampling of spent shale ash from pilot areas. A major effort was spent in the development of appropriate and efficient extraction, separation and qualitative and quantitative analytical identification methods for organic substances extracted.

Research during the continuation period, in addition to following through with investigations already initiated, will address: (1) solubilization of organic matter by runoff, subsurface, and groundwater; (2) the influence of the organic matter on the stabilization of processing residues; (3) the influence of soluble inorganic salts on the solubilization of residual organic matter; and (4) the possible function of the soluble organic matter as a carrier vehicle for inorganic trace elements.

A National Conference on Environmental Effects of Synthetic Fuels Production is scheduled for April or May of 1976. Its content will be directed toward consolidation of current knowledge, identification of research needs and their prioritization. Publication and dissemination of the proceedings of the conference is expected to provide the major utilization action following the initial year of this project. Advisory committee membership includes representation from federal and state agencies, local interests, environmental interest groups and industry.

Assessment of Impact on Estuarine Ecosystems Resulting From Residuals Management by Dredging; Larry S. Slotta; Oregon State University, School of Engineering, Corvallis, Oregon 97331; \$276,000 for 12 months beginning July 1, 1975

This award continues research designed to provide recommended criteria for guidelines to minimize the estuarine impacts of dredging to acceptable levels. Acute impacts of dredging involve such things as significant continuous sediment removal, changes in sedimentary overturn rates, changes in sediment organic composition, and alteration of biological seed areas.

The specific objectives of the continuation period are: (1) to identify important system properties of estuarine benthic deposits; (2) originate and evaluate methods for assessing dredging and related impacts; (3) identify means to implement research results into decision processes; (4) and originate and evaluate techniques for monitoring impacts of dredging and related activities on

estuaries. Principal tasks within the continuation period include:

1. Refinement of characterization of sediments at 10 Coos Bay stations by seasonal sampling of sediment physical properties.
2. Quantitative adjustment of existing disturbance-sediment reaction model for dependent physical responses.
3. Sub-tidal biological seed areas will be sampled seasonally to characterized biologically preferred physical properties.
4. Several estuaries at various stages of development will be sampled using broad perspective, low detail methods to map characteristic physical properties for assessment of chronic impacts.
5. Results will be synthesized so that potential users can be advised on how results of this research can be utilized in considering alternatives for management of estuarine environments.

Field research is sited at Coos Bay, Oregon and includes studies on sulfate-reduction processes in sediments, rates-of-decay and ratios-of-formation of refractory organic carbon, pyrite formation, and the rate of ferrous sulfide oxidation in overturned sediments. Seasonal biological, physical and biochemical investigations are being directed toward the significance of subtidal hardshell clam beds as potential seed areas for exploited intertidal clam populations. Bacterial degradation of iron, sulfur and carbon is being analyzed by an estuarine sediment model.

Land Management of Subsurface — Injected Wastewater Liquid Residuals; *James L. Smith*; Colorado State University, Department of Agricultural Engineering, Fort Collins, Colorado 80521; \$68,900 for 12 months beginning May 1, 1975

This research is a continuation of work coordinated with the University of Texas, San Antonio, to devise and evaluate alternatives for disposal of urban, industrial and agricultural residuals with least insult to urban/rural ecology; provide evaluations of the capability of selected technologies, and analyze the impact on the environment of various activities relating to urbanization.

Objectives of the research are to formulate an analytical model of subsurface injection; calibration of the model by practical-scale injection at two climatically different locations; and development of procedures that will enable communities to evaluate soil injection as an alternative method for managing residuals from wastewater treatment operations. The analytical model

A proposed conceptual model has been improved and tested to allow analysis of the benthic ecosystem by plots of unifying parameters; primarily, sediment organic content and turnover. A rapid particle size analysis procedure has been designed combining electroresistive sensing of fine fractions with settling tube measurements of coarse fractions.

Project personnel have maintained contacts with various agencies including the Oregon Coastal Conservation and Development Commission, the U.S. Corps of Engineers, the Oregon Department of Environmental Quality and the Environmental Protection Agency and Oregon Fish Commission.

A major symposium on the subject of estuarine systems and dredging impacts was sponsored by the research personnel and held during November, 1974 at Mt. Angel, Oregon. Participants included representation from the estuarine research community, state resource agencies, the dredging industry, U.S. Environmental Protection Agency, Sea Grant Marine Advisory Committee, U.S. Army Corps of Engineers and private consulting firms. Project personnel cooperated with the U.S. Environmental Protection Agency in sponsoring a workshop jointly sponsored by the National Council on "Ocean Dumping Criteria," at the Woods Hole Oceanographic Institution. A program will be developed to disseminate research through a series of specific brochures, summaries of technical papers and a 16 mm film. Sufficient progress is expected during this continuation period to draft a handbook of shoreline dredging to minimize environmental effects of residuals management by dredging.

of the subsurface injection process will enable prediction of land requirements (specific to soil-type and climate) expected benefits and potential problems. In addition, research will be directed toward identification of methods for utilization of sludge injected enriched soils and evaluation of the environmental, economic and social constraints inherent in adoption of this concept.

A simulation model is being formulated to describe the ability of soil to remove pollutants from wastewater residues. The model will be modified based on field results from operations in Boulder, Colorado and Williamsburg, Virginia. Laboratory-scale research is being conducted in a soil-bin facility at Colorado State University which has been adapted to permit use of injectors similar to those used in the field. The

environmental, economic, energy requirements, and social consequences of recycling municipal sewage sludge within the generation community are being evaluated by defining potential methods of utilizing sludge-treated soils within a community, assessing economic environmental, energy, and social factors, and defining optimum alternatives for specific community priorities.

Utilization has been an integral part of this research since its inception. Colorado State University has worked closely with a manufacturer of agricultural implements and machinery to insure practicability of the concept of direct soil injection. Field evaluation, a significant step in utilization, is a component part of this research. Arrangements for agricultural evaluation of soil enrichment in Colorado and with the Hampton Roads

Sanitary District of Virginia in cooperation with the Kingsmill development in Williamsburg, assures ability to obtain essential inputs from ultimate users of the concept to determine its acceptability and therefore ultimate utilization.

Emphasis will continue to be on regional seminars with participation largely drawn from local, residuals management and operating personnel, consulting engineering firms, state pollution regulatory agencies, the U.S. Environmental Protection Agency, educators and industrial personnel. Colorado State has negotiated an agreement with Briscoe-Maphis, Inc., of Boulder, Colorado, for manufacture and sale of the injection equipment.

Immobilization of Hazardous Residuals by Encapsulation; R. V. Subramanian; Washington State University, Pullman, Washington 99163; \$37,400 for 18 months beginning March 1, 1975

Liquid residuals that contain toxic or otherwise hazardous substances must be managed in such a way as to minimize danger of their subsequent contamination of the environment at the management sites. With increasingly stringent regulations applied by the government to air and water quality, proper land disposal is the most suitable method. The problem of safe disposal of hazardous metals and their salts thus reduces to one of solidifying them in an impermeable matrix.

The overall objective of this research is the investigation of methods for the dispersion and solidification of hazardous waste materials in a polymer matrix. Initial effort will concentrate specifically on four, model, low-level radioactive wastes, viz., evaporator bottoms, spent ion exchange resin beads, ion exchange resin power and precoat filters. Extended research will include mercury salts, nickel selenide and sodium arsenate which have been identified as hazardous wastes, best managed by chemical solidification followed by burial in land sites. It is also planned to identify problem areas and suggest application of these laboratory, bench-scale results to larger-scale operations.

The essential factor of concern in the research plan is the compatibility of residuals with the delicately balanced resin-redox catalyst system. Studies will seek to determine the kinds of polyester resin, catalyst, and promoter such that polymerization will not be inhibited by the residuals. In addition, such things as: optimum conditions for the emulsification and curing steps, and the strength properties of the solidified product will be analyzed. It is hoped that during the second phase of this project a semi-continuous pilot plant will be developed from laboratory studies with the purpose of identifying and solving problems anticipated in the scale-up to a full-size plant, and for insights into additional laboratory and bench-scale experiments.

User groups expected to receive benefit from the results of this study include both the public and private sectors. United Nuclear Industries, Richland, Washington, for example, has expressed interest in being considered a specific user of information gathered in this research in hopes that they could develop a market for the process. In addition to normal publication channels, the researchers utilize the Washington State University Extension Service for publication and distribution of research reports.

Relative Impact of Selected Pollutants from Diffuse and Discrete Sources on Quality of Water in the Chesapeake Bay; J. Kevin Sullivan; Chesapeake Research Consortium, Inc. Johns Hopkins University, Baltimore, Maryland 21218; \$192,600 for 7 months beginning December 1, 1974

The primary purpose of this program is to assess the relative magnitude and impact of point and non-point pollutants to Chesapeake Bay in order to recommend

management concepts for minimizing effects of these pollutants on water in the Chesapeake Bay region.

Specific objectives include:

1. To develop recommendations for coastal zone land use and development policies and sewerage strategies for dealing with non-point source pollutants. This will be accomplished by determining relative impacts of diffuse sources of pollutants on environmental benefits expected from the construction and upgrading of wastewater treatment plants.

2. To determine the need for standards and procedures for wastewater treatment to minimize acutely toxic effects of residual chlorine on estuarine organisms.

3. To complete assessment of the effects of nutrients from point sources on the biota of certain areas of the Bay and also provide for continuing research management and planning activities which are intended to apply CRC research results of wastewater management issues in the Chesapeake Bay.

The Rockefeller Foundation of New York has requested that the Chesapeake Research Consortium participate in the development of a Rockefeller Foundation postdoctoral educational program in environmental management. Various programs are being developed with citizen groups in the Chesapeake Bay area to familiarize them with the research findings.

High Energy Electron Irradiation of Wastewater Liquid Residuals; John G. Trump; Massachusetts, Institute of Technology, Department of Electrical Engineering, 77 Massachusetts Avenue, Cambridge, Massachusetts 02139; \$198,000 for 12 months beginning May 1, 1975

Application of high energy electrons to achieve disinfection objectives is soundly based on evidence that ionizing radiation can perform this function if the dose is sufficient. High energy electrons have advantages of availability, flexibility, and safety over alternative sources of ionizing energy but their penetrating ability is limited. This research is a continuation of studies in batch-type irradiation to investigate disinfection and other chemical, physical and biological effects to guide operation of a continuous irradiation facility at the Metropolitan District Commission's (Boston) Deer Island Wastewater Treatment Plant, planned for installation in the second quarter of the continuation period. Systematic measurements of performance would continue to obtain engineering and economic data for determination and feasibility. Research utilizing the pilot-scale unit at MSC-Deer Island will be guided by continued operation of an existing 3 MeV electron accelerator at the MIT High Voltage Laboratory.

Since realistic dose rate and flow studies must eventually be made at a community plant, under dynamic conditions, the proposed continuation phase location for the research unit is not only essential for conducting the research but constitutes an important step toward utilization. Direct financial and/or in-kind contributions

from the local level (Metropolitan District Commission) and state level (Water Pollution Control Agency — Commonwealth of Massachusetts) assure user-communication at these levels of the potential user-community. The Advisory Committee will have membership from Federal mission agencies as well as the consulting engineering community, a significant factor in obtaining consideration of new concepts for adoption at the municipal level. The research plan gives highest priority to municipal sludge as the target material for electron treatment. Design of the system for evaluation of Deer Island will include flexibility to investigate irradiation of wastewater treatment plant effluent.

In addition to providing directly useful design information for proof-of-concept scale evaluation, the research will be of value in considering its application to problems presented by special systems, such as hospital wastes, shipboard waste waters and the control of organisms and parasites in aquaculture systems. The utilization program, in addition to review meetings and visits for the purpose of coupling to related work and requirements of others, anticipates that a conference on irradiation of sludge and contaminated waters will be held during the continuation year.

URBAN-RURAL ENVIRONMENTS

The Urban-Rural Environments Program is addressed to environmental problems of rapidly urbanizing areas and to the development of new management techniques for their solution. Research included:

- Analysis of the urbanization process in order to specify adequate environmental data and monitoring needs.
- Assessment of environmental consequences of development alternatives for transportation networks, distribution of utilities, residential and industrial siting, and open spaces.
- Methods for improvement of planning processes in order to accommodate the mixture of human activities within a suitable environment.
- Evaluation of regional planning and implementation approaches.

Study of the Economic, Environmental, Natural Resource and Social Effects Associated with Alternative Metropolitan Development Patterns; *Edwin Clark*; Council on Environmental Quality, 722 Jackson Place, N. W., Washington, D.C. 20006; \$25,000 for 18 months beginning July 1, 1975.

This grant is to contribute to support of an 18 month study managed by the Council on Environmental Quality (CEQ), and jointly funded by CEQ, Environmental Protection Agency, Department of Transportation, Department of Housing and Urban Development, Federal Energy Administration, and the National Science Foundation. The study is conducted by the Urban Institute, Washington, D.C.

The objective is to aggregate and analyze, in a comprehensive and consistent manner, existing knowledge about (1) how development patterns at a metropolitan area scale affect economic costs, environmental quality, natural resource consumption, and social and personal considerations; and (2) how these development patterns are affected by varying transportation policies and programs and by other

Federal, State and local programs, policies, and regulations. The study will identify key factors determining what patterns are feasible for American metropolitan areas and the key decisions which will influence those patterns. It will also identify a complete set of commensurable effects for the alternative development patterns which are feasible over the short and medium term. Finally, the study report will provide the user with guidelines on how the study information can be applied and on what its limitations are. The purpose is not to develop new urban models or decision tools, or to collect original information; the focus is on summarizing and interpreting available information in the most useful and readily accessible manner, as well as identifying knowledge gaps and research needs.

Environmental, Political and Economic Basis for Decision Making in Land Use Management; *Ralph W. Conant*; Southwest Center for Urban Research, Houston, Texas 77004; \$225,900 for 12 months beginning December 1, 1974

Unplanned industrial development in urbanizing areas surrounding urban cores has resulted in many environmental problems and sprawling growth of attendant residential and commercial development. As

these developments usually occur as a part of the general movement at the urban fringe, observation on the effects of any one developmental entity is difficult. Initially, this project focused on the impending large-scale

industrialization and accompanying urbanization in a rural agricultural area of Chambers County, Texas. In general, the research seeks to develop the tools and instruments which may be used by developers and public officials to make environmentally and fiscally sound land use decisions in rapidly urbanizing areas where large scale industrial development, and associated residential and commercial development, are taking place.

Specific goals under this program are as follows:

1. To develop an environmental analysis system which can be used as a tool for environmental planning by developers and public officials.
2. To analyze the economic factors determining or constraining growth and explore various fiscal strategies to be used in guiding or directing growth.
3. To identify national, state, and local institutions which affect land use in order to develop strategies which when coupled with the environmental analysis component and economic information can be used as a basis for formulation of land use guidelines for private developers and public officials responsible for environmental management.

Up to the present time, the project has been focused on the following interrelated, simultaneous investigations: (1) a scientific analysis of the land and environment of the research site; (2) a thorough analysis of existing and pending land use laws and policies which, when coupled with environmental analysis, formulate explicit land use guidelines; and (3) a qualitative investigation of the capacity of responsible

governmental units to adopt and implement a land management program.

For the next 12 month period, the environmental component of the research will focus on testing the effectiveness of the environmental analysis techniques developed during the initial phase of research on several actual decision-making problems of public agencies and private corporations. Groups currently interested in the project include the Houston-Gavelston Area Council, the Chambers County Commissioners Court, The State General Land Office, and U. S. Steel. The law and governmental institutions component will be concerned with monitoring and evaluating an innovative mechanism which develops a coordinated approach to land use planning evolving from existing state regulatory programs. Finally, an analysis of economic factors that determine or constrain growth will be undertaken, as well as an exploration into various fiscal strategies and policy tools which public officials may be able to utilize in guiding or directing growth.

Immediate utilization is envisioned through the application of environmental analysis techniques on development plans of the Chambers County Commissioners Court, the State General Land Office, a large private developer, and a large industry. An incremental change system is to be worked out with the Interagency Council for Natural Resources and the Environment which has as its mandate the coordination of all Texas agencies whose activities affect land resource management.

Hawaiian Environmental Simulation Model; Doak C. Cox; University of Hawaii, Honolulu, Hawaii 96822; \$225,200 for 12 months beginning October 1, 1974

In an attempt to deal with environmental planning problems on a comprehensive basis, the State of Hawaii's Land Use Law was established. The Hawaiian Environmental Simulation Laboratory (HESL) was instituted to assist in providing tools to assess the impacts of technological and economic development. The prime focus of HESL is in stimulating the development of methods of analysis and predictive capabilities and their use in policy making and implementation.

Jointly funded by both the National Science Foundation and the Ford Foundation, HESL is entering its third year of research. Progress up to this time has included an analysis of individual substantive areas (e.g. water, transportation) and a major integrated effort leading to the production of a report for the State Office

of Environmental Quality Control entitled "Kaneohe Alternatives: An Application of Impact Methodology."

Specific objectives for this award are aimed at developing or translating models on inter-related aspects of transportation, land use, public facilities, flooding, and surface water quality in the Kaneohe Bay area. Application oriented research for this year will be focused on: analysis of carrying capacity; watershed and flood plain management; coastal zone management and the production of an information system prototype. The development of this research will involve interaction with state and county agencies and continued association with these agencies on the future environmental consequences of several policy decisions. The results of these simulations will be transmitted to official planning bodies. HESL will also seek to demonstrate the

applicability of its work in the Kaneohe Bay area to other areas of the State. The extension of such a framework will enable HESL to: validate and further demonstrate the application of routines and models initially developed in Kaneohe; deal with topics on an island or state-wide basis; and test techniques on a larger scale for a broader base audience.

HESL has undertaken a number of projects relating to community problems. Among these are: (1) a map of state-owned vacant lands in Kaneohe used by the Governor's office to locate areas for low income housing; (2) a review of sedimentation effects of construction of

H-3 Interstate Highway on erosion and sedimentation yield in the Kaneohe Basin and Bay; and (3) a contract with the State Office of Environmental Quality Control to test alternative growth control policies and their long-range environmental effects in the Kaneohe region. The passage of Senate Concurrent Resolution #53 requests that HESL consider how its new and innovative approaches to understanding environmental relationships and managing environmental systems in the Kaneohe Bay region may be applicable to the entire state.

Applicability of Selected European Laws, Institutions and Policies to Environmental Problems in the United States; *Ralph W. Johnson*; University of Washington, Department of Law and Economics, Seattle, Washington 98105; \$85,900 for 18 months beginning June 1, 1973

Numerous descriptive writings about European environmental management innovations have appeared in the past three or four years, primarily under the auspices of the United Nations and specialized agencies of various European organizations. Little has been incorporated into the standard legal, economic, environmental, and planning journals of the United States concerning either the efficacy of Europe's environmental management programs or their applicability to situations in the United States.

The investigators are studying selected environmental management laws, economic policies and institutions in four western European countries, the United Kingdom, France, and Federal Republic of Germany, and Sweden. Hungarian experiences are being examined as representative of those of East Europe. Individual environmental programs are described, their effectiveness evaluated, and their degree of applicability determined.

The primary purpose is to provide the Regional Environmental Management Program with a thorough analysis of environmental management strategies which have been successfully adopted in other countries and which demonstrate potential for the United States. In addition, the project will provide legislatures, courts, and political, industrial and environmental leaders in this country with useful ideas for environmental management by the documentation of experiments which have been reasonably successful elsewhere. The results of the research will be communicated to potential users in this country through the distribution of a major report on the project, by publications in standard legal, economic and environmental outlets, and by other appropriate means. The investigators serve as advisers to a variety of Federal and State environmental management agencies and will utilize the research results in these advisory capacities.

Design and Management of Rural Ecosystems; *Herman E. Koenig*; Michigan State University, Department of Electrical Engineering, East Lansing, Michigan 48823; \$178,500 for 12 months beginning July 1, 1975

In association with the Office of Land Use of the Department of Natural Resources, State of Michigan, this research team is studying a means of developing basic analytical procedures and modeling tools to provide a systematic approach for land use planning and management in the rural landscape. The research includes the development of analytical procedures (computer based) through which trade-offs in the physical and human resources requirements and the economic costs of food production and processing at the

firm and regional level can be evaluated. Trade-off analyses will center upon alternative regional, ecological features of rural areas, particularly as they relate to alternative uses such as agricultural and forestry production, recreation and wastewater treatment, and alternative physical and technological organizations for carrying out those functions.

The objectives will be developed in two ecologically dissimilar prototype regions within the State of

Michigan with particular emphasis on two alternative scenarios for the future: (1) continuation of the historical trends toward increased scale of operation, product specialization, and increased energy consumption; and (2) a transition to reduced scale, increased diversification, and nutrient recycling.

In this, the last year of the project, models of chemical and caloric input and outflow will be coupled to the hydrology of the region in order to identify tolerance levels for land areas in relationship to their unique physical and ecological features. For large areas, models will be developed which can aggregate tolerance levels to environmental perturbations on a regional basis. Trade-off analyses and models will be developed for evaluation of the physical and human resource

Urban Ecosystems Applied — A Case Study Workshop; *Jack Linville;* American Institute of Planners, Washington, D.C. 20036; \$39,100 for 18 months beginning July 11, 1974

Until recently, elements such as soils, slopes, floodplains, and other physiographic features affecting the urban environment were considered only insofar as they affected the suitability of land for development. Single sector approaches to planning have frequently resulted in development of new environmental problems. Transportation networks, for example, have frequently been developed in the past with little consideration for other plans in the area, thus forcing inadequate readjustment and after-the-fact planning in other sectors. Relatively little understanding or concern for the interaction of urbanization on natural environmental systems has been expressed in urban planning. This workshop, developed by the American Institute of Planners (AIP), is designed to capitalize on existing practical expertise in urban environmental management and discover ways to incorporate advanced technologies into the environmental analysis taking place in urban communities. This national, interdisciplinary workshop is designed to bring together planners and decision makers (elected and appointed), researchers, land developers, engineers, and architects to examine emerging systems of urban environmental analysis.

For the case studies selected, the workshop tasks will include: a survey of environmental problems of urban

Survey of Instrumentation for Environmental Monitoring; *Dick A. Mack;* Atomic Energy Commission, Lawrence Berkeley Laboratory, Berkeley, California 94720; \$113,900 for 12 months beginning June 1, 1975.

It is basic to the maintenance and improvement of environmental quality that efficient and adequate

requirements and economic costs at both the firm and regional levels.

This effort is completely circumscribed by the political, societal and economic realities of concern to the Office of Land Use of the Department of Natural Resources in the State of Michigan. Products developing out of this research include: a monograph for land-use policy makers and professional planners; technical documentation of computer analysis procedures developed for the project components; a compilation of technical papers dealing with the specific technical aspects of the effort; and non-technical manuals and handbooks dealing with problem issues and policy alternatives of concern to particular agencies, institutions and interest groups.

areas and the policies which have been formulated to resolve such problems; review current environmental research in the areas; evaluate the effectiveness of the research results in implementing existing environmental policies; identify those problems which do not lend themselves to solution through research, and conversely; identify those areas of decision making that are in need of research in order to develop more effective techniques to solve environmental problems; evaluate the potential transferability of the results within the selected urban areas to other regions; and propose additional research projects to fill the gap areas identified.

Involvement of the appropriate user group in the formulation of this conference enables important channels for dissemination to be established. A document on the findings, proceedings and recommendations of the seminar will be printed in a limited edition. In addition, the case studies and resulting analysis of potential transferability may be developed into issues of the *Planner's Notebook*, an AIP publication distributed to planners throughout government agencies, universities, and private consultant and research firms.

instrumental systems be used for pollution monitoring. In order to comply with legal requirements, reliable

instrumentation is essential. A national goal is the development of a nationwide system of environmental quality monitoring stations. In addition, there is a need for a practical nationwide set of applicable environmental standards. This can only be accomplished if instrumentation is accurate and precise. This in turn, depends on a practical means of instrumental calibration. Now entering its fifth year of funding, this project is concerned with the present state-of-the-art in air quality monitoring, water quality monitoring, radiation monitoring, and the analysis of biomedical samples damaged by environmental causes. The specific goals of this study include: (1) a comprehensive study of calibration means and procedures; (2) a study of sampling techniques in the instrument fields surveyed; and (3) a comprehensive review of new developments in instruments and techniques in areas previously covered by the survey, with particular emphasis on environmental monitoring instrumentation relevant to energy systems.

The final year of the project will be concerned with a survey of sampling systems for air and water monitoring. For air monitoring, the following general concepts will be applied to all sampling systems: sampling location and frequency, gas flow characteristics, removal of interferences, sample conditioning, sample dilution,

sample train materials, and sampling system components. The water monitoring parameters to be surveyed include: site selection and frequency of sampling for surface water, groundwater, and sewer and sewer flow systems; sampler equipment; identification and records; collection and preservation; statistical design; and homogeneous and non-homogeneous matrices.

The results of the survey are being released in five loose-leaf volumes aimed at four types of potential users: the person using instrumentation who wishes to compare performance of his instrument with others on the market; the person who must purchase instrumentation for environmental monitoring; the person in a position to encourage instrument development by granting financial support; and the individual who is training for work in environmental monitoring. User groups include private, Federal, State and local agencies and colleges and universities. The survey results are disseminated by direct visits and contacts with user groups; news releases mailed to instrument manufacturers; laboratory and medical supply houses, government agencies, and private concerns; publication in journals and presentation of papers at professional meetings; as well as reviews and advertisements of the published survey in technical journals.

Development of a San Francisco Bay Area Air Pollution Model; R. C. Maninger; University of California, Lawrence Livermore Laboratory, Livermore, California 94550; \$30,000 for 6 months beginning February 15, 1975.

This project is concerned with the development and verification of a numerical model for conventional and photochemical air pollution in the San Francisco Bay Area. Work to date has emphasized the development and verification of a multi-box air pollution model by the Lawrence Livermore Laboratory, photochemistry and *in situ* atmospheric measurements by the NASA-Ames Research Center, and ground-based observations made by stations of the San Francisco Bay Area Air Pollution Control District, the potential user of the model. The model is designed to assist in evaluating land use plans, to study consistency of local air quality with the Federal ambient air quality standards, and assessing the effect of

various postulated emission control strategies on local air quality. This extension of the project is used to facilitate use of the model by the District through simplification of the procedures necessary to use the model, creation of a detailed user's guide, and transfer of the model to the District's computer.

The utilization plan hinges on the inclusion of the San Francisco Bay Area Air Pollution Control District as a participant. The Environmental Protection Agency is considering the use of the model in conjunction with their Regional Air Pollution Study in St. Louis.

Evaluation of Alternative Approaches to Control Odors from Animal Feed Lots; J. Ronald Miner; Idaho Research Foundation, Inc., Moscow, Idaho 83843; \$13,650 for 6 months beginning January 1, 1975

Adequate management of residuals from production of animal protein is already a serious and growing problem. Changing management practices over time have seen situations where thousands of animals are contained

continuously on a few acres of land resulting in large quantities of animal waste on small areas. The capacity of the local environment to dilute, stabilize, and dissipate the large accumulation of wastes from these systems is

being greatly exceeded. Proximity of feed lots to market for protein from these concentrated factories creates an environmental quality problem with regard to orders produced.

The current overall objective of this research is to evaluate and assess alternative approaches to control odor in the proximity of animal feed-lots. Such things as feed composition, management practices relating to lot-surface and potential for use of natural vegetation screens augmented by water-spray are being evaluated and assessed with regard to cost and effectiveness.

This research study is tied directly to utilization of

procedures at a fullscale feedlot and their evaluation. At the conclusion of the study, a report will be prepared and distributed to the supporting agencies. This report will include a full description of alternatives evaluated, observations and conclusions. Close contact with livestock association trade publications will be maintained and utilized to disseminate results. A technical paper will be prepared by the principal investigator at the conclusion of the study for publication by the American Society of Agricultural Engineers or an alternate professional journal.

Applicability of Reorganization of Water Management in England to Wastewater Management in the United States; Daniel A. Okun; University of North Carolina, Department of Environmental Sciences and Engineering, Chapel Hill, North Carolina 27514; \$19,100 for 18 months beginning July 1, 1973

The comprehensive program of water management reorganization under way in England and Wales, provides an opportunity for critical analysis and preliminary assessment of its implications for regionalization of wastewater collection, treatment and disposal in the United States. Approximately 1,200 sewerage agencies, 200 water supply and 25 river basin authorities will be reconstituted into 10 Regional Water Authorities, each with complete responsibility for all aspects of water management. The effectiveness of public participation in the development of policy will be particularly evidenced during the transitional period of reorganization when the Region Water Authorities are organized and programs of implementation are initiated.

The British Government has issued an extensive

series of "position papers" on every aspect of the reorganization. These position papers describe the various alternatives and the advantages and disadvantages of all elements of the reorganization. The principal investigator of this project is examining the position papers and the submissions made in relation to them. Where issues are of special significance, officials of the organizations are interviewed, and a study made of the deliberative process that is used in resolving the controversies around each issue. Emphasis in this study is on how the reorganization may provide elements of a sound wastewater management strategy and the extent to which these elements may be applicable and appropriate for implementation in the United States.

Techniques for Increasing Project Scale and Improving Land Use Balance in the Urbanization Process; Donald E. Priest; Urban Land Institute, Research Division, 1200 18th Street, N.W., Washington, D.C. 20036; \$58,000 for 08 months beginning May 15, 1975.

Project scale and land-use balance, the processes by which rural land is brought into urban use, are prime determinants of the quality of the urban and suburban environment. Many of the existing mechanisms used by local government to control growth appear to discourage project scale and land-use balance and are therefore counterproductive in terms of environmental quality of urbanization. This project is designed to analyze the benefits and costs of project scale and land-use balance, with emphasis on environmental quality, for use by land-use decision makers. Existing mechanisms used by local government to control growth will be reviewed to identify those elements that encourage adequate scale

and balance in land development projects and those elements which do not. Identification of alternative strategies for large scale developments including specifications for legislation and administrative programs and education of public and private groups will receive careful consideration.

The report produced at the termination of this study will address itself to the following concerns: (1) benefits and costs of project scale and balance; (2) the impact of existing growth management on scale and balance; (3) an evaluation of proposed alternative mechanisms tied to objectives of increased scale and balance;

(4) recommendations for legislative and administrative action by state and local governments; (5) a model implementation strategy covering public and private education and information programs concerning the need for legislative and administrative action; and (6) a strategy for future research for RANN. Primary users of this study will be state and local officials. Secondary users

include national, state, and local interest groups and citizens groups concerned with demonstrating the need for large scale balanced development and formulating and promoting appropriate programs to meet this need. A summary of the report will appear in *Urban Land*, a monthly magazine published by The Urban Land Institute.

Development of an Acoustic Sounder Network for Air Pollution and Land Use Applications; Philip B. Russell;
Stanford Research Institute, Menlo Park, California 94025; \$44,900 for 12 months beginning April 1, 1975.

Two of the most important atmospheric parameters in determining the transport and dispersion of air pollution are winds and the "mixing depth"—the depth of the mixed layer of the atmosphere through which surface-generated pollutants can freely mix. The influence of mixing depth in determining ambient pollution concentration is especially strong in urban areas of the West Coast where the characteristic marine inversion restricts the mixing depth to lower altitudes. Pronounced topographic and demographic variations within West Coast urban regions also cause both the inversion height and wind to vary considerably on small scales in space and in time. As a result, climatological data on both mixing depth and winds must be provided on rather fine spatial and temporal scales in order to be useful to West Coast planning.

This project is evaluating the application of a network of acoustic sounders for reliable, unattended and continuous observations of mixing depth over the San Francisco Bay Area. This project will: (1) acquire climatological data on mixing depth behavior at a number of Bay Area locations; (2) develop analysis and interpretation techniques for deriving mixing depths and other information; (3) evaluate the utility of the

acoustic sounder for measuring mixing depths; (4) investigate techniques for transmitting sounder data to a common location for operational use; (5) and disseminate data and methodology to appropriate land use planning agencies and air pollution monitors.

A number of agencies in the San Francisco Bay Area have an interest in land use planning for the future. Of these, at least two, the Bay Area Air Pollution Control District (BAAPCD) and the Metropolitan Transportation Commission (MTC), are cognizant of the air quality impact of land utilization and intend to use air quality models in future decisions. The SRI research group has been cooperating with the above groups in the development of the acoustic sounder network, the data from which will be fed into air pollution models. After the field measurement program, all suitable data on spatial and temporal variation of Bay Area mixing depths will be compiled into a readily usable form and made available to the modelers and those planning agencies that have indicated an interest in the data. A user's manual and technical publications will be distributed to other west coast and Federal land-use planners and air quality modelers.

A Comprehensive Analysis of Protein Resources: Present Status, Future Requirements, and Research Needs;
Nevin S. Scrimshaw, Daniel Wang; Massachusetts Institute of Technology, Cambridge, Massachusetts 02139;
\$181,900 for 6 months beginning January 15, 1975

World food needs are increasing rapidly and will continue to increase rapidly for at least the rest of the century. The population of the earth has already doubled since 1940 by adding 2 billion people, but today's numbers will double again within the professional lifetime of many of us. While world per capita protein supplies are still adequate, the maldistribution of protein-rich foods among countries, and among families, makes the protein problem a serious one.

The objective of this project is to perform a comprehensive analysis of protein resources: present

status, future requirements, and research areas for the development of nonconventional protein sources in the years ahead. The report will identify and recommend a limited number of program projects which have the highest probability of making a significant contribution to future protein supplies with respect to different time scales.

NSF/RANN will be the primary user of the product. The other major potential users will be the U. S. Department of Agriculture and the food industry. USDA has been involved in the planning of the study, in

reviewing it, and USDA representatives will be active participants. Copies of the report will be sent to major USDA research offices, to industrial research and

development units, and to interested Congressional staffs and offices.

Environmental Geology Applied to Rural/Urban Needs; *Arthur A. Socolow*; Commonwealth of Pennsylvania, Bureau of Topographic and Geologic Survey, Harrisburg, Pennsylvania 17120; \$55,800 for 6 months beginning June 1, 1975

With the advent of highspeed interstate highway systems and population growth, many rural areas of the nation are faced with pressures of increasing urbanization. Local and regional planning authorities throughout the nation are being presented with problems related to the physical capabilities of the land. In the Great Lakes Basin, local and regional planning authorities are concerned with problems such as landslides, valley floodings, and shoreline erosion. This project is designed to obtain basic environmental geologic data for a rapidly urbanizing area in Pennsylvania — the Oil City quadrangle. The data base will include: bedrock geologic maps at a scale of 1:24,000, and glacial materials distribution maps at a scale of 1:24,000. Interpretive maps will include: oil and gas well frequency, engineering rock characteristics, and an

economic aggregate resource map. Finally, a series of user-group manuals will be prepared on field methods, local building codes and ordinances related to land use, and each of the geological, glacial materials, and interpretive maps.

A Citizens Advisory Committee will review the user manual to determine its suitability. This committee will be composed of interested citizens from such state-wide groups as the Pennsylvania League of Women Voters and the Western Pennsylvania Conservancy. Manuals are to be reviewed to ensure that they accomplish the objectives set forth. One or more members of the Advisory Committee will meet with the research team during their bi-weekly meetings.

Urban Ecosystem Studies; *Forest Stearns*; The Institute of Ecology, University of Wisconsin, Milwaukee, Wisconsin 53201; \$10,000 for 8 months beginning May 15, 1974

Urban ecosystem approaches which focus on both biological and physical systems characteristics of urban regions are becoming a major subject of concern to ecologists and urbanists. In an effort to promote communication among various disciplines concerned with the city as a system, The Institute of Ecology held a workshop in March 1973 in Austin, Texas. Participating in the workshop were architects, planners, ecologists, sociologists, economists, geologists, hydrologists, and engineers. The workshop formed into the following working groups: Goals for the Urban Ecosystem; Institutional Structures; Physical Structure and Function; Resources: Water, Energy and Materials; Population Processes; Indicators of Urban Ecosystem Function and Health; Case Studies of Cities and Urbanized Regions; and Systems Capacities, Limits and Intersystem

Linkages. Reports of each of the task groups were prepared and edited.

This award provides supplemental funds to complete editing and publication of a report of the Urban Ecosystem Workshop. The report will be useful to individuals in universities covering a wide range of disciplines from environmental sciences to urbanologists, decision-makers in cities and regional planning groups, and professional consultants who assist in planning for the urban area. In addition, interest in the document has been expressed by United Nations groups concerned with the development of the UN Conference-Exposition on Human Settlements (Habitat 76) to be held in Vancouver, Canada in June, 1976.

The Interaction between Urbanization and Land: Quality and Quantity in Environmental Planning and Design; *Carl Steinitz and Peter Rogers*; Harvard University, Department of City Planning, Room 201, Gund Hall, 220 Harvard Street, Cambridge, Massachusetts 02138; \$375,100 for 12 months beginning February 1, 1975

This award is a continuation of a program designed to provide a tool to assist State, regional, and local planning

officers in appropriate land use planning in urban fringe areas. Design and development of models of land use

location decision and analysis of their environmental, fiscal, and social impacts have been initiated. A data base necessary to link the component models into a series of analysis frameworks, or modes, to be applied to later urbanization issues has been organized. During the second and third years of research, the component models were implemented and tested and then applied in a planning/simulation mode which could respond to a series of demonstration issues. A series of demonstration studies and experiments related to urbanization policy issues and the impacts of change, using other modes or organization, were completed.

During this year of funding, the research group will work toward the period of formal transfer of the model. Consultation is currently in progress with various state and local agencies. Demonstration issues which will test

the capability of the various models in the several modes will be identified. Tests relating to the planning mode will be undertaken early, to be followed by various experiments using the models in gaming and suboptimization modes. The tests will be carried out in a workshop with evaluation by the participants, associate members, and advisory committees.

A major effort will be the full technical documentation of the component models. A major documentation of the various "modes of organization" for the models will be completed. In addition a series of case study reports which will document the issues, their analysis, approaches, and results will be produced. These summary publications will demonstrate the feasibility and utility of the concepts to which this research has been directed.

Collaborative Workshop for Testing a Regional Model of the Boston Southeast Sector; Carl Steinitz; President and Fellows of Harvard College, Office of Research Contracts, 1350 Massachusetts Avenue, Cambridge, Massachusetts 02138; \$23,000 for 09 months beginning September 1, 1974

For the last 2-1/2 years, the Harvard Graduate School of Design, under a grant directed by Professor Carl Steinitz, has been developing a model that will provide detailed information on the environmental, economic, and legal consequences of various land-use decisions. The model consists of a series of approximately 20 linked submodels concerned with such elements as commercial development, housing, transportation, water, air quality, visual quality, legal constraints, regulatory practice, public expenditure, vegetation, land value, energy consumption, and wildlife, among others. The project is being developed for a rapidly urbanizing area that includes nine towns approximately 15 to 25 miles southeast of Boston. This is referred to as the "study area."

The workshop is the logical culmination of a carefully developed plan to interest the Commonwealth of Massachusetts in the products of the grant. Procedures are being developed to make possible the transfer of the research to appropriate users, should it prove to be a useful and economic tool. On the utilization side, an academic-year, credit-bearing workshop has been

established at the Harvard Graduate School of Design. During each semester a major issue which has recently been considered or is being considered in the study area by state and/or local officials will be examined using the models developed under the basic grant. The results will be compared with those arrived at using conventional techniques, and some judgement made as to which are preferable and why. The results will then be presented to the Massachusetts Resources Management Policy Council, the state-level interagency coordinating group responsible for land-use issues. The major emphasis placed here is that all work will be in a "controlled" environment with a standard against which to check, compare, and argue its answers, as the same issue will have to be considered by the appropriate governmental body using conventional techniques.

This proposed activity is essentially a utilization project in that it will test the model and train people to operate it, maintain it, and use. Thus, if it works, and if it is economically attractive, basic elements for transfer to state operation and maintenance will have been developed.

Environmental Control and Land Use Interactions in the Chicago Region; \$987,000 for 24 months beginning September 1, 1973; George S. Tolley; University of Chicago, Department of Economics, Chicago, Illinois 60637; (\$597,000). *Kevin G. Croke,* Argonne National Laboratory, Argonne, Illinois 60439; (\$390,000)

This study is a continuation of a grant to the Argonne National Laboratory and the University of Chicago, directed toward improving knowledge useful in policy formation to improve air quality in a metropolitan area.

Research includes studies on air pollution emission patterns in the Chicago area which would follow adoption of various emission control programs, on costs of emission control techniques, on the waste interface

implications of alternative air pollution control strategies, and on external costs of pollution and spatial responses to alternative control strategies.

The objective is to develop a set of four physical and economic models for predicting effects of environmental actions. Emissions models will estimate effects of various environmental regulations on emissions as well as the cost of emission control. Dispersion models will estimate the air quality effects of emission changes. Damage models will estimate physical effects and dollar values of improvements in air quality. Finally, spatial models will predict locational adjustments by industries, households, and commercial establishments to pollution and environmental control policies.

Special efforts are made to coordinate the design of the research project with the needs of decision-makers. The models analyze problems of interest to policy-makers; city, county, State and Federal agencies are represented on the project's advisory board; reports and conferences on the use of models and policy implications of research findings are designed for user agencies; and technical expertise is made available for agencies to adopt the models. Results of analyses of residential heating and urban transportation have been used by the Illinois Environmental Protection Agency and the Federal EPA. Partly based on these analyses, a coal ban was retained and changes in transportation regulations were instituted, resulting in considerable cost savings.

Development of an Acoustic Sounder Network in the San Francisco Bay Area; *Edward E. Utbe*; Stanford Research Institute, Menlo Park, California 94025; \$46,100 for 9 months beginning June 1, 1974

This project is designed to determine the capabilities and limitations of a prospective operational network of acoustic sounders to monitor the atmospheric mixing depth in the South Coast Air Basin. Mixing depth, frequently the height of the base of the ambient temperature inversion, is a basic variable controlling atmospheric dilution of pollutants, and thus is a key

parameter needed for all air pollution predictions and air quality simulation models. At the present time, the unavailability of routine detailed data on vertical atmospheric structure, such as mixing depth, is probably the most serious limitation to the improvement of air quality predictions.

On Optimum Meteorological and Air Pollution Sampling Network Selection in Urban Areas: Phase II Test and Evaluation; *Fred M. Vukovich*; Research Triangle Institute, Post Office Box 12194, Research Triangle Park, North Carolina 27709; \$75,000 for 12 months beginning December 1, 1974.

This research project's primary objective is to develop a tool for environmental managers to be used to measure air quality as it is affected by urban growth and technological development. (1) testing an optimum meteorological and air pollution sampling network in order to determine whether a particular pollutant concentration has exceeded the standard; (2) providing a data base for short and long term predictions of the concentration of a particular pollutant over the urban region; and (3) determining the feasibility of using historical wind data together with wind fields to predict wind distributions.

Research field test and verification of the optimum sampling network, (OSN), which will be set up in St.

Louis. Each station will obtain wind data and concentrations of carbon monoxide, methane, and total hydrocarbon data for all stations.

The end product of this research is a technique which develops an optimum meteorological and air pollution sampling network for urban areas. There does not presently exist any objective technique to yield an OSN for urban regions despite the fact that the requirement for air quality networks in urban regions was designated in 1969 by the Federal government. Many urban regions have already developed air quality networks without the benefit of an objective technique for site selection. The results of this study may provide a tool to assist in responding to EPA requirements.

An Investigation of the Potential for Resource Recovery from Demolition Residuals; *David G. Wilson*; Massachusetts Institute of Technology, Cambridge, Massachusetts 02139; \$39,000 for 8 months beginning January 15, 1975

The objectives of this research project are to determine the approximate annual quantities of various categories

of materials contained in buildings which are demolished in the United States; to identify the economic and

technical factors that help to decide whether or not materials in demolition wastes will be reused; and to study the technological developments which would have the potential of highly positive benefit-cost ratios when applied to resource recovery from demolition wastes.

A model of urban material flow will be constructed. The input will include data on materials used in construction by area and year. Data on the age of buildings when demolished will be obtained from contractors and from city building departments. Architectural and engineering drawings will be used where possible to make as precise an assessment as possible of the materials content of appropriate buildings when new. Estimates of the changes in building contents because of renovations, the addition of air-conditioning, fire escapes and so forth will be made. The data will be correlated with contractors' estimates to calibrate other

methods of estimation.

Feasibility and economic studies of possible technological developments will be made. Short-term, critical laboratory studies will be carried out if data on particular areas are unavailable and if the payoff justifies the effort. As an example, the infrared signatures of concrete and plaster could be rapidly determined in the laboratory and would so provide critical data for a feasibility study of a sorting system.

In late July or early August a two-day workshop on resource recovery from construction and demolition debris will be held at MIT. Experts will be invited to attend and make presentations. The workshop proceedings will be a full report of the data-gathering, material-flow modeling, and technological design studies of the project.

Study of Changing Climatic and Weather Patterns and Their Effects on Agricultural and Renewable Resource Productivity; *Sylvan Wittwer and Philip Ross*; National Academy of Sciences, 201 Constitution Avenue, Washington, D.C. 20418; \$150,000 for 12 months beginning May 1, 1975

The earth's current erratic weather is of concern to more and more scientists who foresee troublesome changes in global temperatures and rainfall patterns that could seriously jeopardize the earth's ability to feed itself. The Board on Agriculture and Renewable Resources is developing a study of the changing climate and weather fluctuations and their impact on agriculture and renewable resources; and the technology and research strategies that may be necessary to offset the stresses of these changes in order to optimize agricultural and renewable resource production.

The Board on Agriculture and Renewable Resources appointed a Task Force whose purpose it was to study the feasibility of a study on changing climatic and weather patterns on agriculture and renewable resource productivity. The Task Force recommended that a committee of 12-15 leading specialists in the agri-climatology and meteorology fields be assembled to oversee the study. Seven panels of 5-8 persons reflecting the seven areas of concentrated research will prepare a report on their respective areas. These reports would become the basic documents for synthesis by the committee.

This study will assess and evaluate the following areas: (1) the probability of occurrence of weather fluctuations

and climate changes over the next 5, 10, 25, 50 and 100 years, and their impact on agriculture and renewable resource productivity; (2) research strategies to improve soil, water, and plant management technology; (3) the potentialities and research strategies for developing improved cultivars of food and fiber crops that would have better resistance to the effects of adverse weather conditions; (4) the effect of adverse weather conditions on the proliferation of plant pests; (5) the relationship of increased weather instability to soil erosion by wind and water; (6) the necessary adjustment in agriculture technology of developing countries to improve their production under expected climatic fluctuations; and (7) weather modification technology and its potential impact on agricultural production.

The final report generated from this study will be addressed to policy decisionmakers involved in establishing technical, social, and political reserves to meet climatic changes and weather fluctuations that may have far-reaching impacts on our agriculture and renewable resource productivity. The research recommendations will be disseminated throughout the research community including the agricultural research centers, agricultural experiment stations and the National Science Foundation.

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DISASTERS AND NATURAL HAZARDS

Destruction of property and casualties caused by natural hazards, such as earthquakes and fires, cost billions of dollars and thousands of lives each year. In addition, extensive damage is attributed to certain weather hazards such as hail, drought, lightening, and highway fog. The Disasters and Natural Hazards Program seeks to contribute to reducing these losses by providing improved methods of controlling consequences by means of a thorough understanding of the hazard and its effects. The Program also seeks to study the impact of inadvertent weather modification caused by pollution and energy use in metropolitan areas as well as the socio-economic effects of natural hazards and disasters.

The four Program elements are:

- Earthquake Engineering
- Fire Research
- Socio-Economic Response to Natural Hazards
- Weather Modification

EARTHQUAKE ENGINEERING

Earthquakes are potentially the most devastating of natural disasters. Therefore, the Earthquake Engineering Program's major thrust is to conduct research into the probable intensity of earthquakes that may occur, the response of new and existing buildings, and the behavior of other engineered man-made structures in order to investigate the losses due to earthquake events. In response to the need to assess the likelihood of such losses and to weigh these against the increased costs of planning and designing structures to avoid them, the Earthquake Engineering Program is directed toward the following objectives:

- Develop economically feasible design and construction methods for building earthquake resistant structures.
- Develop procedures for integrating information pertaining to seismic risk with on-going land use planning processes.
- Present information in a form suitable for use by all communities seeking to reduce their vulnerability to earthquake forces.

Partial Support of the Committee on Seismology; Joseph W. Berg; National Academy of Sciences, Washington, D.C.;
\$15,800 for 24 months beginning July 1, 1973

This award provides partial support to the Committee on Seismology of the National Research Council. Among their activities will be an evaluation of the status and requirements of the World-Wide Network of

Standardized Seismographs, ascertaining the adequacy of strong-motion instrumentation, and studying the importance and needs for ocean-bottom seismology.

Evaluation of Seismic Safety of Buildings; John M. Biggs, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139; \$236,500 for 24 months beginning September 1, 1974

The ultimate objective of seismic design is to protect the structure and to provide safety for its occupants and contents with a sufficient degree of reliability. The evaluation of safety involves both the specification of ground motion and the criteria used for proportioning the structure. In common practice, these two essential elements of the safety equation are treated almost independently.

The objectives of this research are:

1. Evaluate and compare the possible ways of representing the predicted ground motion and investigate three methods of seismic analysis, random vibration analysis, time-history analysis, and response spectrum approach. In each case an investigation will be made of the proper criteria for both the definition of input and the evaluation of response. Although the

emphasis will be on linear analysis, non-linear systems will also be considered.

2. Establish procedures and to investigate the overall safety provided by seismic design, considering the variability in both the prediction of ground motion and in structural analysis and design.

This research will evaluate the actual structural safety provided by seismic design and the degree of safety which could be provided by improved methods. Five tasks to be researched include: (1) representation of ground motions; (2) alternative methods of elastic dynamic analysis; (3) response of inelastic systems; (4) seismic safety analysis; and (5) case studies of actual buildings.

Because there is a lack of information concerning the nature of earthquake ground motion which can be expected at a particular site, the different methods of representing the predicted motion need to be analyzed. Three techniques: (1) Time-history analysis; (2) Random Vibration; and (3) Response Spectrum Analysis will be compared and evaluated for accuracy and dependability.

The overall safety of earthquake-designed structures will be evaluated as a function of the techniques used to

define the design level earthquake motions and to predict the structural response in terms of the load factors used in the design of the structural components. To check and illustrate the methods of safety evaluation developed during this study, the investigators will relate their findings to a number of real-world low, middle height and high-rise buildings.

The results may be expressed as new seismic building provisions and will provide design criteria for the professionals.

Seismic Resistance of Fossil-Fuel Power Plants; *John L. Bogdanoff*, Purdue University, Lafayette, Indiana; \$372,100 for 24 months beginning January 1, 1974

This project will concentrate upon the determination of the dynamic behavior of large fossil-fuel steam power generating plants when subjected to earthquake forces. The results of the research will be used to establish design guidelines and procedures for the principal components of a power plant for earthquake resistance. These guidelines and procedures will form the basis for the development of seismic code provisions and recommendations for the design and construction of fossil-fuel steam power generating plants. At the present time there are no such generally accepted design procedures similar to that for the design of buildings

available to the industry and professional engineers engaged in the design of these power plants.

This research will study, as a start, the behavior of the principal components such as the furnace-boiler, steam and feedwater piping system, coal handling equipment and conveyor system, cooling towers, and stack.

The results of the research, in addition to code recommendations, will be used to recommend improvements in design for earthquake resistance for old and new plants, and a recommendation for a policy on spare parts to be available in the event of a disaster.

Design Earthquake Parameters; *Bruce A. Bolt*; University of California, Berkeley, California 94720; \$65,500 for 24 months beginning July 1, 1975

It is becoming common in earthquake engineering to use an estimate of the maximum duration and the maximum acceleration likely to be sustained by a site in constructing and designing earthquake spectra, and developing time histories. A gap exists between the seismological activities and the manner in which engineering design is approached. A method by which the differences in philosophy can be improved is to have critical work performed on the stability and optimization of design earthquake parameters which are useful for engineering purposes.

The engineering design earthquake parameters, especially as the parameters relate to northern and central California, will be studied under this award. The major objective of the project is to relate duration of strong motion to frequency and geology, and acceleration peaks to magnitude of an earthquake. An effort will be made to relate sustained peak accelerations, now used by the Atomic Energy Commission, Veterans Administration, and other agencies as a basis for design,

to the strength of the earthquake at a site in a more consistent manner. The following will be studied in detail: (1) the attenuation and duration of strong ground motion as estimated from available records and theoretical models; (2) the correlation between maximum accelerations of various frequencies and other earthquake parameters such as magnitude and fault length; (3) an enhanced instrumental and field observational program of strong ground motion; (4) a finite element analysis will be carried out on the theory for the propagation of seismic body waves (including SV and SH waves) on various surface conditions including ridges and alluvial valleys; (5) development of the earthquake intensity and historical record in northern California.

Recorded strong-ground motion accelerograms will be analyzed to achieve an observational base for a number of these questions and response spectra and filtered time-series records will be obtained.

Laboratory and Numerical Simulation of Nearfield Earthquake Ground Motion; *James Brune*; University of California, San Diego, La Jolla, California 92037; \$93,200 for 24 months beginning June 1, 1975

Displacement, velocity, and acceleration fields associated with ground motion are of prime concern when considering the effect of an earthquake on any type of structure near the epicenter. Unfortunately, because the number of earthquakes whose epicenters are within a couple of fault lengths of a seismograph is small, the parameters which characterize the response of the near field are not well known. Except for a few earthquakes of magnitude 6 or greater these parameters have not been directly measured. Thus, very little has been determined about the distribution of earthquake strong motion in the region near a fault.

This project will research the question of microzonation using foam rubber models and associated numerical calculations. The foam rubber experiments can serve to test numerical computer schemes for treating the rupture process, as well as provide direct

information pertaining to near field motion. Special problems to be studied include: the effects of rupture propagation; vector displacement field around various types of faults; the effect of depth, distance attenuation of strong motion; and the effect of different types of rupture initiation and stopping. Numerical computer code calculations (3D-dynamic codes) will be compared with the model results. This will permit a check of various aspects of computer modeling including: rupture criteria, grid size, crack tip singularities, and focusing of high frequency energy due to rupture propagation.

The data will be used to predict earthquake motions emanating from a fault in order to establish microzonation limits for certain community activities of construction, and serve as a guide to determine the best type of construction in a particular area.

Earthquake Response of Dams Including Hydrodynamic and Foundation Interaction; *A. K. Chopra*; University of California, Berkeley, California 94720; \$89,400 for 24 months beginning August 30, 1974

As a result of the failure of the lower San Fernando Dam, an earth embankment, during the San Fernando earthquake, the Los Angeles County Flood Control District has embarked upon a program to evaluate the earthquake resistance of their existing dams. The capability to evaluate the dynamic deformations and stresses in a dam subjected to prescribed ground motion is essential in order to assess the safety of existing dams and develop rational procedures for design of earthquake resistant dams in the future.

The research program will: (1) develop reliable and effective techniques for analysis of response of dams to

earthquake motions including effects of hydrodynamic and foundation interaction; and (2) understanding the effects of interaction and the significance in the dynamic response of dams. The research will include studies on concrete gravity dams, arch dams, and earth dams.

The results from the research program are beneficial to organizations responsible for evaluating safety of existing dams and designing future dams to be located in seismic areas.

A High Speed Data Acquisition System for Earthquake Engineering Research in Davis Hall; *Ray W. Clough*, University of California, Berkeley, California; \$152,500 for 12 months beginning March 1, 1974

This award provides for the design and installation of a data acquisition system for use by several earthquake engineering research projects. The high-speed system is specifically designed for structural tests using simulated earthquake loadings. These tests are quasi-dynamic and require the recording of stresses and deflections at many

locations of the specimen during the entire loading history. Several simultaneous experiments are normally underway. A low-speed system is incorporated in the design to monitor those data which do not require rapid measurement.

Energy Absorption Characteristics of Structural Systems Subject to Earthquake Excitation; Ray W. Clough, University of California, Berkeley, California; \$994,500 for 12 months beginning November 1, 1974

This is a continuation and expansion of work initiated under previous NSF grants. The program of activities includes testing of structural components such as reinforced concrete beams and beam-columns, reinforced concrete beam and column subassemblies and reinforced concrete frames with spandrel walls. The moderate-size earthquake simulator will be used to verify, extend and modify analytic understanding of the earthquake response of steel rigid and braced frames, reinforced concrete bare frames, reinforced concrete

frames with shear or infilled walls and masonry structures. The results of these experimental activities will be correlated with theory and compared with results of a separate field test program. Concurrent analytic research will be directed toward developing computational procedures with which engineers can predict the inelastic response of real structures under strong earthquakes, the amount of damage likely to be inflicted, and the possibility of complete collapse, with sufficient accuracy and economy for practical purposes.

National Information Service in Earthquake Engineering; Ray W. Clough; University of California, Earthquake Engineering Research Center, Richmond, California 94804; \$137,200 for 12 months beginning April 1, 1975

The Earthquake Engineering Research Center is entering its fifth year of NSF/RANN support in the collection and organization of all the research information currently available on earthquake engineering and related areas. This award will provide for the continuation of the national center for information on earthquake engineering which is available to all researchers and practitioners. Specific functions of the center are to: develop a library of technical data, reports, papers; publish an *Abstract Journal in Earthquake Engineering*; maintain, verify and

disseminate computer programs; publish an International Journal; and provide educational opportunities for professional practitioners.

The National Information Service in Earthquake Engineering is of significant value in fostering the implementation of the results of research programs in earthquake engineering. Special emphasis is placed in making available to the engineering professions the full extent of knowledge developed in the research community.

Structural Loads Analysis and Specification; C. Allin Cornell, Massachusetts Institute of Technology, Cambridge, Massachusetts; \$303,000 for 24 months beginning September 1, 1973

The purpose of this award is to develop a practical unified approach to the analysis and specification of structural loadings, including extreme value loads (e.g., earthquake) and continuous loads (e.g., live load, wind). This study will entail three purposes: 1) to develop a relatively simple, unified set of representations of the random characteristics of loads (in gross magnitude and macro-scale time); 2) to develop and study alternative codifiable treatments of loading and load combination specifications; and 3) to carry out the supplementary basic research that these developments require. The way in which loads can be combined to achieve a design load will be investigated. The effectiveness of alternative deterministic code formats (e.g., a common load factor,

split factors, partial factors, etc., applied to characteristic values or mean load values) will be examined. Effectiveness is measured in terms of simplicity in application versus success in meeting particular stated objectives (e.g., equal risk of exceeding the design values). A common set of probabilistic load models will be developed. The feasibility of new loading specification formats based more directly on these probabilistic models will also be investigated. With a common load model, it may be possible to develop some relatively simple unified scheme of formulas or charts to provide more accurate assessments of the risk of a given combination of values on the design combination for a given risk.

Pacific Tsunami Catalog; Doak C. Cox, University of Hawaii, Honolulu, Hawaii; \$17,200 for 12 months beginning July 1, 1973

A catalog of tsunamis that have occurred in the Pacific Ocean will be prepared that collects all recorded and observed data available. The catalog and subsequent analysis will be completed with the cooperation of Japanese and Russian collaborators. The data base will be analyzed for the following: frequency distributions of

tsunami effects by maximum run-up heights for selected subregions and localities; regional check lists of tsunamis by date; geographic distribution of major tsunami origins; geographic distribution of major tsunami effects.

Workshop on Earthquake Resistant Masonry Construction; Robert A. Crist; National Bureau of Standards, Washington, D.C. 20234; \$20,800 for 4 months beginning June 1, 1975

Because of worldwide studies on earthquake resistant masonry construction and the need for masonry design criteria, a workshop will be conducted in the United States. The goals of this workshop are to: (1) establish liaison between the various research groups; (2) assess the accomplishments and scope of the various research projects, and provide feedback to the researchers in the form of a critical review of their plans and accomplishments by a professional panel; (3) assess the accomplishments of the research as it applies to the

development of improved or new masonry design criteria by the professional panel; (4) review needs and priorities for future research.

The proceedings of the workshop will be published, and will include the technical papers on current practice, current research, and recommendations for future research accompanied by summaries of the panel discussions.

A Minimax Procedure for Specifying Earthquake Motions; R. F. Drenick; Polytechnic Institute of Brooklyn, Brooklyn, New York 11201; \$32,500 for 24 months beginning April 1, 1975

This supplementary award provides for an extension of a Minimax method which has been developed to generate possible design earthquakes that take into account the physical properties of both the site and the structure that occupies the site. Based on a linear method which has been developed, the current award will extend the method to non-linear yielding structures, and subject the linear and non-linear methods to design tests. Investigations will also be made of the extension from one dimensional to three dimensional excitations. Extensive structures may require the modeling of input

motions applied to several points in the structure. This will require the representation of the input as a possible multi-dimensional function. Typical structures under consideration are bridges, elevators, and other building systems that receive their excitation from disjointed supports. The minimax approach concentrates on deterministic functions selected from a normed class. A segment of the research will investigate the possibility of making this a class of probabilistic functions characterized by their maximum value distribution.

Effects of Site and Source on Earthquake Ground Motions; C. Martin Duke, University of California, Los Angeles, California; \$366,200 for 36 months beginning July 1, 1973

The objective of this activity is to develop a set of design procedures that characterize with confidence the earthquake-induced ground motion at any site. The models of the site effects will include both body and surface wave effects in terms of earthquake source and site measurements.

The total model will include the source function expressing the motion near the earthquake origin, the incoming body wave, earthquake motion in bedrock beneath the site, the incoming surface wave motion from

the source region, free field surface ground motion at the site composed of body and surface wave components, the motion of the base of the structure, and the motion of the instrument site in the structure.

Records of ground acceleration (main shock) or velocity (aftershock) are available for a number of sites and earthquakes, principally in the San Fernando sequence. These data will be used to calibrate and validate the engineering design models.

Architect's Role in Reducing Earthquake Damage to Buildings; John P. Eberhard; American Institute of Architects Research Corporation; \$20,000 for 7 months beginning April 1, 1975

The objective of this project is to synthesize current architectural practice in earthquake design and develop a methodology for architects to become aware of the effects of earthquakes on building design. Emphasis will be placed upon those features which the architect can influence during the initial stages of design conception and planning combined with the detail drawings and project specifications. Specifically, this project's task is to collect, organize, synthesize, and categorize the nature of damages which are influenced by architectural considerations; define and enlarge the architect's role to

reduce damages; and develop an understanding of the forces produced by earthquakes, and the response of the total building.

The present award is an amendment to an existing award to add several consultants who are actively engaged in architectural design for earthquake considerations, and who are at present participating in the development of performance criteria for architectural systems subjected to earthquake conditions.

Shear Walls in Earthquake Resistant Structures; Mark Fintel, Portland Cement Association, Skokie, Illinois; \$744,800 for 18 months beginning June 1, 1974

The investigations in this award will develop design data for reinforced concrete shear walls used as lateral bracing in earthquake resistant multi-story buildings. The behavior of multi-story structures during recent earthquakes clearly indicates that both protection of human life and superior damage control can be attained in buildings stiffened by properly proportioned and detailed shear walls. Verification and extension of this significant field observation, both analytically and experimentally, can lead to more efficient and better-performing structures.

Specifically, deformation requirements of shear wall structures subjected to strong ground motions will be determined by analytical means. Stiffness required of a structure to achieve a desired level of response to earthquakes will also be determined. Simultaneously, an experimental program will be presented at technical meetings and published in technical journals. The findings and recommendations will be presented to code writing groups.

Feasibility Study of Dynamic Tests on Full Scale Eleven Story Building — In Pruitt-IGOE Housing Project; T. V. Galambos; Washington University, St. Louis, Missouri 63130, \$20,000 for 3 months beginning April 1, 1975

The specific objective of this project is to determine the feasibility of conducting a full size dynamic testing program on an eleven story apartment building in the Pruitt-IGOE Housing Project, which has been condemned and will be demolished within 18 months. Ultimately, the test program objectives are to develop data and information which will be helpful to determine the structural behavior of a reinforced concrete apartment building under dynamic loads. Other benefits are: (1) data on the dynamic behavior of a large building will be made available to other researchers; (2) behavior of non-structural elements will be observed for design development; (3) inelastic behavior of the structure will

be recorded and compared to theory; (4) in-place properties of materials will be compared with planned properties.

The feasibility study will determine the advisability of proceeding with the large testing program to mechanically shake full size buildings and obtain data for the experiments. Should this study indicate an economically justifiable program to develop information and data which will be useful to the total earthquake engineering program, a complete testing program will evolve.

Inelastic Hysteresis Behavior of Structural Members Subjected to Combined Cyclic Bending and Axial Forces for Use in Studying the Behavior of Braced Frame Structures During Earthquakes; *Subhash C. Goel*; University of Michigan, Ann Arbor, Michigan; \$125,800 for 24 months beginning January 15, 1975

This study will analytically and experimentally investigate the hysteresis behavior of steel members subjected to cyclic axial loading combined with restraining end moments. The data developed from the analysis of the individual member behavior will be used to compute the response of several multistory braced frames subjected to strong earthquake forces. The results obtained will be analyzed for general application of the concepts to the earthquake resistance of structures whose

components have been proportioned by different design philosophies. The two principal philosophies are: (1) in order to avoid extensive repairs, the structure is designed to withstand earthquakes of moderate intensity with little damage throughout its structural life; and (2) that in the event of a severe earthquake catastrophic failure or collapse of the structure must be prevented although the structure may undergo several excursions of reversed yielding.

Century City: Full Scale Seismic Laboratory; *Gary C. Hart*, University of California, Los Angeles, California; \$295,100 for 36 months beginning April 1, 1974

The actual dynamic structural response of low- and high-rise buildings subjected to seismic or wind excitations has not been well substantiated by experiments or full scale observations. This is especially true for structures on various types of foundations. Therefore, data on the effect of the interaction of soil, foundation, and structure are desirable in order to improve the current methods of calculating the dynamic behavior of structures.

Instruments will be installed at the surface and subsurface levels, foundations and throughout a few selected buildings to record the motions which occur during excessive wind and/or seismic action. The data from wind action will provide a basis for understanding the structural behavior during a seismic event.

Data to be obtained are: ground motion amplitudes and spectral content for surface and subsurface layers in built-up and undeveloped environments; dynamic characteristics of selected structures; influence of water table level; torsional effects of foundations; phase relationship between soil, foundations, and building motions; and effect of amplitude of the excitations. From the data obtained during wind and/or seismic action, analytical models will be developed for the low- and high-rise buildings to predict the structural behavior during a future earthquake event.

Socioeconomic and Political Consequences of Earthquake Prediction; *J. E. Haas*; University of Colorado, Boulder, Colorado 80302; \$114,110 for 7 months beginning February 1, 1975

Earthquake forecasts may be one mechanism to reduce potential loss and disruption from earthquakes. With extended lead times, action could be taken to inspect and strengthen buildings; upgrade the seismic component of building code requirements so all new structures would be less susceptible to damage; improve land use zoning regulations so as to limit or prohibit construction in especially hazardous areas and; as the forecasted event day approaches, plans for partial or complete evacuation could be carried out. Earthquake forecasts, on the other hand, could present negative consequences in the event that an extended period of uncertainty followed a forecast for a damaging earthquake.

This research is directed toward providing the broad based empirical knowledge which is needed to mount effective prediction programs. The objectives of this

program are to: (1) develop and interpret a comprehensive set of empirically based findings regarding the probable response of organizations and individual citizens to early credible earthquake forecasts; (2) develop and apply an effective means of informing organizations and the public of the findings and their implications; (3) test in a rigorous fashion the impact of the findings on organizations that participated actively in the research process; (4) prepare recommendations for legislative and administrative action to the extent that the findings so justify.

Four specific tasks will be undertaken during subsequent phases of the program including:

1. After the collection and summary of all initial organization data and the Citizen Response Data, the

research team will compile all findings and the implications thereof of value and interest to local, state, regional, national, and international level organizations. Before dissemination begins however, the results will be tested by going back to all organizations having participated and assessing what impact that feedback for utilization will have.

2. A series of post-briefing measures will be applied some four to six months after the briefings. This interval will provide the time required for organizations to carry out or at least initiate any actions which they deem

appropriate as a result of the briefings workshop.

3. Group meetings with interested citizens and individual meetings with principal officials of organizations having especially broad and significant responsibilities for public health, safety and welfare at the state, regional and national level will be held.

4. Recommendations from the study will be distributed to state, local and Federal officials and follow-up briefings will be held.

Earthquake Induced Bond of Reinforced Concrete; *Neil M. Hawkins*, University of Washington, Seattle, Washington; \$84,600 for 12 months beginning September 1, 1974

The immediate objective of the study is to quantify for simulated earthquake loading, the relative importance of the various factors influencing bond deterioration. This will be studied using stub cantilever specimens subjected to cyclic reversed loadings. Holographic interferometry will be utilized to monitor surface deformations on the specimen and from this to infer the degree of bond deterioration. Simultaneously, acoustic emission measurements will be made and both sets of data will be correlated with visual observation of the cracking pattern in

a dissected specimen and the variation in strains measured by electrical resistance gages placed along the axis of the bar. The long-range goals of this project are: 1) the development of practical techniques and instrumentation permitting assessment of the residual strength and stiffness characteristics of a structure surviving an earthquake and, 2) the development of design recommendations for calculations of the effect of bond deterioration on the strength and stiffness of reinforced concrete structures in an earthquake.

Seismic Resistance of Concrete Slab to Column and Wall Connections; *Neil M. Hawkins*; University of Washington, Civil Engineering Department, Seattle, Washington 98195; \$115,300 for 12 months beginning February 1, 1975

A continuation award, this research addresses several objectives and tasks as follows:

1. Study the effects of reversed cyclic loadings on the strength and energy absorption of connections between concrete flat slabs (plates) and concrete columns and walls.

2. Determine the reinforcement details necessary to ensure ductility and the maintenance of adequate ultimate capacity for these connections during seismic type loadings.

3. Develop recommendations for the seismic design of structures in which flat plates are used as framing members in ductile moment-resistant space frames or structures in which flat plates act in combination with shear walls to resist lateral loads.

During the next period, the research will be divided into three phases: (1) experiments on slab-column specimens; (2) analytical studies for prediction of experimental results; and (3) analytical studies for development of non-elastic and dynamic models for flat slab structures subject to seismic forces.

Earthquake Response and Damage Prediction of Reinforced Concrete Masonry Multi-Story Buildings; *G. A. Hegemier*, University of California, San Diego, California; \$718,000 for 18 months beginning March 1, 1974

This project is a balanced, experimental, analytical, and numerical research investigation of load bearing reinforced concrete masonry (block) structural elements and multi-story shear walls. The research effort will develop the basis for a rational analysis, design and response of the structures to earthquake forces and a

prediction of the extent of damage due to an earthquake event. Experimental data will develop the linear and nonlinear behavior of unreinforced and reinforced concrete masonry units, elements, assemblages, components, and typical connections when subjected to static, quasi-static, and dynamic cyclic loading

applications. The analytical portion of the program will develop the analysis and design methods and the computer programs, including the constitutive properties of the material. The computer program will be user-oriented for simple and rapid design office application to determine structural response and extent of damage due to earthquake forces.

Results of the research will be expressed in the development of recommendations for code provisions, methods for analysis and design of structures, construction techniques, material behavior, connection types, and geometrical arrangements.

Effects of Damage from Strong Earthquakes; *George W. Housner*; California Institute of Technology, Pasadena, California 91109; \$436,800 for 24 months beginning September 13, 1974

During ground shaking, buildings are usually deformed well beyond the range of cracking and damage to structural and nonstructural components. The behavior is nonlinear, an area of structural design for which theories are not too well established or known. There is a great lack of experimental data to guide the development of the required non-linear vibration theories.

earthquakes and related excitations, and ultimately to develop practical methods for the control of damage related to structural response beyond the elastic range. The research is undertaken in three areas: (1) theoretical analyses of the vibration of nonlinear structures; (2) analysis of the behavior of structures and structural elements subjected to earthquake loads; and (3) the development of practical methods of design.

The goal of this research is to develop useful techniques for the analysis of non-linear structural response and to use these techniques to obtain an understanding of the actual behavior of structures during

Results of this program will be disseminated to engineering practitioners in the form of criteria for the design of better earthquake resistant structures.

Earthquake Engineering Instrumentation; *Donald E. Hudson*, California Institute of Technology, Pasadena, California; \$245,300 for 12 months beginning June 1, 1974

This program provides for the placement of a series of strong-motion instruments at selected sites in Southern California. Instruments will be placed at sites that augment existing placements in order to increase the usefulness of existent networks. In addition, an instrument package will be designed for placement in a well. This down hole instrumentation will monitor

strong motion in different geological layers from the basement complex to the surface. Improved instruments will be placed in selected buildings to record three-dimensional behavior of the building. Efforts will be continued to design improved and/or strong-motion instruments.

National Information Service for Earthquake Engineering; *Donald Hudson*; California Institute of Technology, Pasadena, California 91109; \$104,000 for 12 months beginning May 1, 1975

This award, a companion grant to the University of California-Berkeley, provides the fifth year of support of continuing research at CIT. The objective of the project in this year of study is to establish a national center of information on earthquake engineering and related areas. The center will be geared to meet the needs of both academic researchers and design engineers. Reports, (both published and unpublished), site visit records, data collected from various seismic regions, and abstracting services as a basis for technical data directed to the needs

of earthquake engineers will be stored here. The primary area of interest will concern ground motion records and related data.

NISEE is a major thrust by the Earthquake Engineering Program in its utilization scheme, and is of significant value to achieving the goals of the program as established by RANN. Those goals stress the need to foster the implementation of the results of research programs in earthquake engineering.

Tsunami Research and Engineering Applications; *Li-San Hwang*, Tetra Tech, Inc., Pasadena, California; \$95,700 for 12 months beginning June 1, 1974

This project will undertake the development of techniques to appraise the potential tsunami risk of coastal regions. A model and computational methodology will be developed that is capable of describing: 1) tsunami generation by arbitrary sea floor displacement; 2) wave behavior in the immediate region of generation; 3) features of transoceanic propagation including directivity, transformations in variable depth, dispersion, and so forth; 4) coastline interactions

including development of bores and edge-bores, harbor and bay response features, and inundation of near shore regions.

Particular attention will be devoted to modeling of tsunami generated by fault movements near the shoreline, and propagation of the wave parallel to the shoreline.

Mini Technology Assessment of Earthquake Prediction Techniques and Their Applications; *Martin V. Jones*, New England Bureau, Inc., Boston, Massachusetts; \$21,000 for 6 months beginning June 1, 1974

The objective of the project is to present a summary estimate of the total set of consequences — technological and nontechnological, economic and noneconomic, bad as well as good, direct as well as indirect, delayed as well as immediate — that are likely to arise from the development of relatively reliable methods for predicting the occurrence of earthquakes. Ten topics

would be covered: Statement of Problem; Background; The Status of Earthquake Prediction Technology; Relevant Exogenous Factors; Potential Impact Areas; Preliminary Impact Analysis; Action Options; Revised Impact Analysis; Information Sources; and Lessons Learned.

Regional Analysis for Development Planning in Disaster Areas; *Barclay G. Jones*, Cornell University, Ithaca, New York; \$91,200 for 24 months beginning November 17, 1972

This study will develop a methodology for the spatial planning of rural regions, particularly those subjected to periodic disasters. A general abstract study developing this methodology will be carried out. The methodology will be tested using data derived from the Banja Luka region of Bosnia which was subjected to an earthquake in late 1969. It is currently in the process of reconstruction and redevelopment. Socio-economic information will be gathered which will describe the current status of development of the region around Banja Luka. Time

series data will allow recording of the trace of the development path and will permit comparison of the socio-economic structure with selected comparable regions in Yugoslavia. Then the data will be analyzed to arrive at mid-range development objectives for the socio-economic structure of the sub region that seem appropriate and realizable in terms of the previous pace of development and the levels achieved in comparable nearby regions. Comparisons to possible U.S. experience will be continuously pursued.

Stochastic Seismology; *Leon Knopoff*, University of California, Los Angeles, California; \$112,500 for 24 months beginning October 15, 1973

This project will undertake four basic objectives: (1) the reduction of data in the earthquake catalogs in order to establish more clearly the principal statistical features of main-sequence earthquakes and aftershocks; (2) develop a mechanical model for rupture events as a spring-mass system with a suitable refinement in state descriptions (such as specifying the maximum energy density); (3) undertake a theoretical study to test the compatibility of the Kolmogoroff and Poisson Properties in Stochastic

processes, in particular, the solutions to the Kolmogoroff equation that are Poissonian, or nearly so, for certain models of the event probability distribution functions, then to explore whether the subset of large events in such a series of shocks exhibit Poissonian or periodic behavior; and (4) to develop a stochastic fault model with friction, pre-stress and external driving forces. These models will be numerically studied for a large variety of initial conditions.

Optimal Filtering Techniques Applied to Analysis and Modeling of Earthquake Data; *Frank Kozin*, Polytechnic Institute of Brooklyn, New York; \$174,700 for 24 months beginning June 1, 1973

The objective of this award is to characterize earthquake accelerograms as a random process accounting for its nonstationarity as well as the noisy character of the record. The approach is to bring modern estimation of filtering techniques to bear on the earthquake modeling problem. The immediate product besides new techniques and approaches that will result from the investigation will be computer programs that will accept raw earthquake time series data and generate the "best" nonstationary filter equation whose solution is the earthquake process model generated from the given sample. Furthermore, useful statistics, such as moments,

first passage properties and nonstationary spectral properties, will be directly obtained by digital methods as well. The optimal estimation program will be used to analyze records from past earthquakes with emphasis placed on the San Fernando earthquake. The proposed procedure for obtaining the best estimate is based on an approximate nonlinear filter and several possible evaluative norms. Convergence of the estimate will be analyzed using various tests; the proposed run test; trend test; Gaussian test; correlation techniques; variance and mean confidence intervals.

Development of Comprehensive Seismic Design Provisions; *Samuel Kramer*; National Bureau of Standards, Washington, D.C. 20234; \$415,000 for 20 months beginning September 9, 1974

This award provides funds for the second phase of a research project aimed at developing a new set of seismic design provisions and commentary which will be applicable to all regions of the country in order to bring the minimum level of practice up-to-date with the currently available state of knowledge of the seismological data, analytical techniques, computer methods, experimental verifications, and practical experience in design and construction. The ultimate purpose of the design provisions is to provide model code writing bodies and professionals in all phases of construction with an up-to-date document on the design of buildings to minimize loss of life, and concurrently, to reduce property damage, while at the same time, maintaining vital operational functions.

During the first phase of this project, the research philosophy and plan for the achievement of new seismic code provisions and design practices was developed. Expert representatives of the earthquake engineering community in the United States consisting of practitioners, researchers, model code agencies, and local building officials, formulated the detailed program.

An initial project completed by the Applied

Technology Council will serve as background material for the new code provisions and design practices. The project, entitled "An Evaluation of Seismic Codes," investigated eleven buildings of various types for the application of a response spectrum approach to seismic design of these buildings. The new provisions and design practice commentary are based on the technique thus evaluated.

Design maps indicating levels of seismic design required in different areas of the United States shall be developed, with definitions of the levels of design. Provisions to determine which buildings require special consideration will be specified. Three dimensional aspects of seismic response of buildings will be evaluated as well as consideration of: inspection and evaluation of damage; methods of repair; evaluation of existing buildings; and methods of strengthening existing buildings. Categories of structures and their components include: non-engineered buildings based on current practices; high rise and other unusual or major structures; other building types; and appurtenant structures such as elevated tanks, retaining walls, and other special types of structures.

Reducing Losses from Selected Natural Hazards; *Howard C. Kunreuther*, University of Pennsylvania, Philadelphia, Pennsylvania; \$429,600 for 18 months beginning July 1, 1973

This research examines alternative policies for allocating the cost burdens of selected natural disasters; in particular, whether the costs of repairing damage to private residential property disasters should be treated primarily as a public or a private responsibility.

Specifically, research will be accomplished on the following tasks: (1) Evaluation of the performance of alternative insurance and Federal disaster assistance programs through testing of completed models of individual behavior in response to low probability errors.

The models to be tested are the expected utility model and the bounded rationality model. This task will be carried out through a stratified random sample of 3000 individuals in 6 high-risk areas; (2) Estimation of tradeoff between insurance and direct means of

mitigating disasters such as zoning and land-use controls. This task will be accomplished by melding the survey responses with experimental simulation models of disaster effects upon particular communities.

Instrumentation for Seismic Earth Pressure Measurement; *Kenneth L. Lee*, University of California, Los Angeles, California; \$8,500 for 12 months beginning April 1, 1974

An earlier award to the investigator was made to purchase seismic earth pressure recording equipment. Most of this equipment has now been installed to measure earth pressures on the basement walls of a new tall building in Los Angeles. Data on the installation and backfilling procedures are available along with readings of static pressures at various stages of construction. Connection to the seismic recording system will be completed in 1974, at which time the project will lie dormant until a strong motion earthquake makes a

record. For maximum benefit to future users of the anticipated seismic data while the information and facilities are readily available, the static earth pressure readings obtained during construction will be collected and analyzed. This information, along with a small amount of seismic modulus testing data from the backfill, will be recorded in a final report that should be of considerable value in interpreting the anticipated seismic earth pressure data.

Strong Motion Instrumentation Program; *R. B. Matthiesen*; Seismic Engineering Branch, U.S. Geological Survey, San Francisco, California; \$700,000 for 12 months beginning October 1, 1974

The measurement of destructive ground motions in the epicentral region of damaging earthquakes, and the associated response of structures, is achieved by placing a network of instruments at a variety of sites where earthquakes are likely to occur. Because it is fundamental to many projects in earthquake engineering, the collection of strong motion data has been centralized in a core activity under the Seismic Engineering Branch of the USGS. The functions of the Strong Motion Instrumentation Program are to develop a national network of strong motion instrumentation, to maintain this network, and to process, manage, and disseminate the strong-motion data. Specific tasks to be performed in this grant renewal include: (1) development of criteria for design of a national strong-motion instrument network; (2) begin network development by new installations and adjustments of existing networks; (3) develop and place specialized instrument arrays to answer specific research needs; (4) evaluate and develop new instrumentation; and (5) centralize the strong-

motion record files and establish a system for standard processing, management, and dissemination of the strong-motion data. Data management and dissemination are the central activities of this service program. In addition to the well established reporting mechanisms such as *U.S. Earthquakes*, the *Strong Motion Station Listing*, and *Earthquake Notes*, a "Quarterly Strong Motion Information Newsletter," is being established with the first issue to be mailed in October 1975. The report will contain such things as lists of new stations, summaries of preliminary reports on significant records, lists of all new records and analyses of the strong motion collection for noteworthy groupings of records. This publication will be supplemented by an annual Catalogue of Strong Motion Records in which copies of the records are reproduced. Investigations are currently underway to determine the needs for a computer accessible file containing strong motion record characteristics.

Building Enclosure and Finish Systems: Their Interaction with the Primary Structure During Seismic Action; *Gerald M. McCue*; McCue Boone Tomsick, San Francisco, California 94111; \$70,300 for 9 months beginning November 7, 1974

The primary structure of a building, its beams, columns, and shear walls, has traditionally been separated from the so-called "architectural systems" — the nonstructural enclosure and finish subsystems of a

building. Greater attention, however, is needed to focus on the safety considerations of the entire enclosure, finish, and service systems. During most earthquakes, the building structure is not stressed to a point of

collapse, but may deflect enough to create severe hazards through failure of the nonstructural subsystems. The hazard to the building's occupants and to persons nearby is primarily from the failure of the enclosure, finish and service systems.

This award provides for initial research to develop earthquake resistant design guidelines and provisions to minimize life safety related damage to enclosure and finish systems. The objectives of the project are to: (1) define the physical conditions which may exist in these subsystems, and to develop an approach for understanding how these conditions interact with the primary structure. Based upon this definition, it is proposed to (2) develop conceptual models for the degree that the subsystem and the primary structure may

Design for Protection Against Natural Hazards; *N. M. Newmark*; University of Illinois, Urbana, Illinois 61805; \$476,500 for 24 months beginning May 1, 1975

A need exists for new and improved methods of design to provide protection against such hazards as earthquakes, wind, wave forces, land slides, floods, ice, and explosions. The need can be met through a problem-oriented but integrated approach to research and education; the research needed to develop new and improved approaches to design for protection against the hazards noted is not one of developing separate and distinct techniques for each type of hazard; instead, there is a commonality of approach threaded through the technology that presently exists and that needs to be exploited.

This research work is aimed at the development of simplified and improved methods of design to resist dynamic hazards with emphasis on one of the most pressing national problems, namely, protection against earthquakes. The four areas in which work initially is planned are as follows: (1) Response of Subsystems to Dynamic Forces and Motions; (2) Simplified General Methods of Analysis and Design for Earthquakes and Wind; (3) Inelastic Behavior of Multi-Degree-of-

A Study of Tsunamis: Their Generation, Propagation and Coastal Effects; *Fredric Raichlen*; California Institute of Technology, Pasadena, California 91109; \$108,600 for 18 months beginning May 15, 1975

This award provides for completion of research initiated under a previous grant. Experimental studies will be undertaken in three essential areas of tsunami propagation utilizing wave tank and coastal modeling studies. The theoretical and experimental activities are divided into four phases; (1) incorporation of the previous studies of generation and propagation of

be mutually dependent, and of the ways in which they interact during seismic motion. Based on these models, (3) preliminary guidelines for design criteria to minimize life safety related damage will be developed for both the secondary systems and the primary structure. The investigation will be limited to buildings with "regular" configurations. Specific tasks to be undertaken include: categorization of damage characteristics for subsystems; identification of types of interacting subsystems and primary structures; functional requirements for performance of subsystems and primary structures; interaction of subsystems with primary structures; problem areas; conceptual models; preliminary guidelines based on available data; program for future phase II and III investigations; and a report of accomplishments.

Freedom Systems Subjected to Dynamic Loads and Motions; and (4) Simplified Approaches to Dynamic Soil-Structure Interaction.

In-depth research will be conducted to improve knowledge in these areas with the goal of developing improved design approaches of a simple form that will lead to economies in design. During the past decade the attention of designers has been devoted to developing individual methods for approaching the analysis and design of structures and equipment subjected to earthquakes, winds, and other types of dynamic forces. This project hopes to coordinate and relate these methods to one another.

It is anticipated that the results of this research will find their way into practice most rapidly because of the influence the principal investigators have on design criteria, and because of their membership on and activities in various code and specification writing bodies.

tsunamis in order to simulate a few typical earthquake motions that occur in nature; (2) exploration of three-dimensional weakly nonlinear waves of the Kdv class; (3) studies of the refraction of tsunamis by islands and coastal topography; and (4) an investigation of the problem of tsunamis climbing up a continental shelf, progressing along a sloping beach, wave breaking and

the final run up at the beach head.

The several research projects currently underway in Tsunamis are being structured to lay the basis for coastal zone land use studies to control community and individual risk to damage. Close coordination will be maintained with the NOAA and COE programs. A workshop is planned to tie these programs together and

make initial assessments of the form of a land use program. A proposed reactor site on an artificial island off the New Jersey shore has offered the opportunity to utilize findings from this research to estimate breakwater height settings for anti-tsunamis or surge waves.

Behavior of Fine Grained Soil Under Earthquake and Other Repeated Loading; D. A. Sangrey; Cornell University, Ithaca, New York 14850; \$97,400 for 24 months beginning June 1, 1975

Unsatisfactory performance of soils during earthquakes is a major contributor to damage and loss of life and property. For both earth gravity structures (slopes, dams and retaining walls) and foundations, there is clear evidence that failures can be attributed not only to increased stress due to the inertial effects of earthquake acceleration, but also to deterioration of soil strength or shearing resistance.

The overall objective of this research is to understand the behavior of fine grained soils when loading or deformation of the soils is repetitive. Of particular concern is the response to higher frequency loading, especially in the frequency range experienced during earthquakes, and how this response can be related to the better understood response at lower frequencies.

Specific objectives of this research are to:

1. Describe a fundamental theoretical model for strength change of fine grained saturated soils subjected to earthquake and other repeated loading.
2. Evaluate particularly the response of more sensitive fine grained soils. Experimental studies will be conducted using material from formations which historically have experienced catastrophic failures during earthquake loadings.

3. Evaluate the influence of loading frequency on the behavior of undrained fine grained soils. Previous work has been done on the response of natural fine grained soil under the action of long and intermediate period loading. The degree to which the theory applicable to the low frequency range can be applied at other frequencies is a major project objective.

4. Describe a theoretical model for the long-term effects of load repetition on fine grained soils. Specific topics to be included in this objective are long term settlements of structures following load repetition, strength increase and strength decrease resulting from drainage after an interval of load repetition.

Results of this research will be disseminated by way of professional literature and in the Geotechnical Engineering Research Reports series of Cornell University. The principal investigator is also a member of technical committees of several national societies including several working committees of the Transportation Research Board. Transfer of information for use in the design of transportation facilities will be enhanced as a result of these activities.

Project Rio Blanco Low-Rise Motion Damage Study; Roger E. Scholl; John A. Blume and Associates, San Francisco, California; \$19,400 for 9 months beginning July 1, 1974

This research project is a continuation of research on ground motion and building damage data available from Rio Blanco underground nuclear explosion, Plowshare experiment conducted in northwestern Colorado provide an excellent basis for improving present day damage prediction technology for low-rise structures. Specifically, analyses will be made of the available data to obtain a statistical description of the relationship between response spectrum motion amplitude and consequent damage. Project Rio Blanco data will permit evaluation in the important damage threshold range from 0.01 g to 0.1 g. Study results are therefore expected

to allow formulation of comprehensive damage prediction procedures for the entire range of significant ground motion amplitudes, when combined with earlier studies. Because damage to low-rise structures makes up a large part of earthquake losses, a reliable prediction methodology will be extremely valuable for seismic zoning studies, hazard correction measures, disaster relief planning, and building code improvement. Results from earlier studies are already being put to use in upgrading general plans for some California cities, to include a required seismic planning element for mitigation of seismic hazards.

Feasibility Study: Dynamic Soil Testing by Centrifuge; *Ronald F. Scott and G. W. Housner*; California Institute of Technology, Pasadena, California 91109; \$82,200 for 12 months beginning October 15, 1974

During earthquakes, soils behave in a nonlinear, hysteretic manner which can directly affect what happens to an overlying structure, such as a multi-story building or an earth dam. Controlled tests of the performance of such structures are no longer possible at loads of the magnitude of those developed by the inertia of the material under lateral accelerations. As a consequence, attention has been turned to dynamic tests of soil models. Because of soil behavior, the results of such tests carried out under each gravity conditions cannot duplicate or be scaled to the behavior of full-size structures. A centrifuge method, through which gravitational stresses can be suitably increased is presently under investigation as a possible dynamic test which can avoid conventional dynamic testing problems.

This study will be conducted to determine the feasibility of using centrifuge testing to obtain the dynamic response of soils and will include: (1) a study of kinds of tests that are feasible; (2) a preliminary dynamic investigation of existing centrifuges; (3) the identification of problems that may arise in the design,

construction, and use of a centrifuge facility for soil and possibly other material testing purposes; and (4) the preliminary design and analysis of the construction and operating costs of such a facility. In the feasibility study, tests involving soil will be designed and carried out in existing centrifuge facilities.

Such investigations will be directed towards identifying and obtaining preliminary solutions to the problems of the generation of vibrations and the extraction of data from the test structure during the centrifugal motion. If the preliminary tests indicate that the method has promise, a design study will follow, with the object of determining the possible arrangement of a centrifuge design for both static and dynamic soil testing, and estimating the construction costs. As a tentative goal, the feasibility study will be directed toward consideration of equipment to produce maximum centrifugal accelerations on the order of 100 to 300 g on samples with a maximum weight of at least a few hundred pounds at a radius of at least 5 meters.

Analysis of Soil Structure Interaction Effects for Massive Embedded Structures During Earthquakes; *H. Bolton Seed*; University of California, Berkeley, California; \$109,600 for 24 months beginning July 1, 1974

An important aspect of the seismic design of deeply embedded massive structures, such as nuclear power plants and pumping plants, is the evaluation of the dynamic interaction between the structure and the surrounding soil. A new finite-element method for analyzing this effect will be used to determine the lateral extent of interaction effects adjacent to massive structures, the extent to which high-frequency motions are propagated in deeply embedded structures and

adjacent support structures, the applicability of two-dimensional analyses for evaluating the response of three-dimensional systems, the interaction effects between adjacent buildings in a three-dimensional building layout and the stresses developed on the sides of buried structures during earthquakes. Simplified methods will be developed, wherever possible, to evaluate these effects for design purposes.

Measurements and Evaluation of Dynamic Characteristics of Structures; *Hareesh C. Shab*; Stanford University, Stanford, California; \$39,100 for 12 months beginning June 1, 1974

This project will examine the applicability of a new instrument to measure dynamic characteristics of buildings, such as response acceleration spectrum due to ambient vibrations, natural frequencies, damping characteristics, the RMS response acceleration of the building, structural transfer functions, displacements, and the coherence function. The studies will permit a comparison of calculated values with actual ambient conditions. Several buildings in San Francisco, Los Angeles, Palo Alto, and Managua will be studied. A suspension bridge in Sacramento and electrical switch

yard equipment have also been studied.

The current phase will study the correlation between ambient vibration measurements and strong motion measurements on buildings which have experienced a severe earthquake event and for which strong motion data are available. The studies will develop a relationship between frequency and damping values, a method to determine the extent of damage to a building following an earthquake, and a procedure for microzoning a region on the basis of measured micro tremors.

Effects of Earthquake Motions on Reinforced Concrete Buildings; Mete A. Sozen; University of Illinois, Urbana, Illinois 61801; \$316,100 for 24 months beginning September 16, 1974

A series of earthquake simulation tests have been carried out on small-scale reinforced concrete structures at the University of Illinois, Urbana. One of the conclusions of this work is the indication that the maximum inelastic earthquake response of reinforced concrete structures can be estimated closely using a linearly elastic model with appropriate modifications of its stiffness and damping properties. This conclusion has formed the basis of the "substitute-damping method" for determining design forces in reinforced concrete buildings.

The objective of this program is to identify and explain the mechanisms of energy dissipation in slender reinforced concrete structures subjected to strong ground motion, with a view to the development of simple but realistic design methods for earthquake resistance. The

method of investigation is to test structural models using the University of Illinois Earthquake Simulator in an effort to: (1) investigate experimentally the mechanisms of energy dissipation in slender wall and frame systems subjected to strong earthquake motions; (2) develop analytical models to reproduce the response-history of slender reinforced concrete structural systems related explicitly to hysteretic properties of steel and concrete; (3) test the applicability of the substitute-damping method of slender structures; and (4) use the analytical models to extend the range of application of the experimental information. Since the ultimate aim of the research is to develop improved structural design methods, the test structures are physical models of idealized structural concepts, rather than models of a particular or even of a class of buildings.

Seismic Resistant Design of Mechanical and Electrical Systems; T. R. Simonson; G. M. Simonson and T. R. Simonson Consulting Engineers, San Francisco, California 94105; \$70,200 for 9 months beginning March 1, 1975

Recent earthquakes have shown that the mechanical and electrical systems in buildings are inadequately protected and installed to resist seismic effects. This project is aimed at developing design procedures, guidelines, provisions, and criteria to improve the seismic resistance of mechanical and electrical systems in buildings. This first phase of the study will review literature; categorize types of damages; compile and analyze current design procedures, codes and regulations; develop functional requirements for performance of systems and components; study the building to equipment interaction and response of the equipment to seismic forces; and develop design guidelines, provisions and criteria based on currently available data. A plan for validating the

design provisions by actual tests will be developed which will include laboratory and field tests, and analytical analysis to carry out the intent of the design provisions.

The results of Phase I will be published as a technical report and distributed to interested agencies, societies, and organizations to stimulate interest and action. It will serve as background material for the Development of Comprehensive Seismic Design Provisions. The data and design provisions combined with material from other sources will eventually be developed into a manual of design for architects, engineers, and the industry as a whole.

Nonlinear Saturated Soil Motions Resulting from Earthquakes; Victor L. Streeter; University of Michigan, Ann Arbor, Michigan; \$144,900 for 24 months beginning June 15, 1974

This research is concerned with the development of analytical procedures for the prediction of potential liquefaction and nonlinear behavior of soil masses. The equations for transient motions in the saturated soils are solved by the application of the method of characteristics. A distributed parameter description of the material properties is used in the model. A nonlinear shear and pressure wave model that includes permanent

deformations, and therefore void space reductions as a function of strain levels, will be used. Additionally, the maximum shearing strength of the material will be allowed to vary with transient pore pressure, vis-a-vis, effective stress. The criteria for failure due to liquefaction of slope instability will be excessive permanent deformation.

A Technology Assessment of Earthquake Prediction; *L. W. Weisbacker*; Stanford Research Institute, Palo Alto, California; \$283,500 for 12 months beginning June 1, 1974

The specific objectives of this project are: (1) to assess the state-of-the-art and project the future development of earthquake prediction technology; (2) to assess the socio-economic impacts; (3) to determine the

implications for institutions responsible for the development and implementation of the technology; and (4) to evaluate public policy alternatives for developing and implementing earthquake prediction technology.

Shear Transfer in Thick-Walled Reinforced Concrete Structures under Seismic Loading; *Richard N. White*; Cornell University, Ithaca, New York; \$71,300 for 12 months beginning June 1, 1975

Now in its second year of a two year award, this project's overall objective is to develop an improved understanding of the shear transfer mechanism in thick-walled reinforced concrete structures subjected to a seismic shearing force. The relative amounts of shear carried by the longitudinal steel, stirrup steel, concrete cracked section and compressive zone will be determined for cyclical shear loadings.

Current research activities and work planned include: (1) continuation of large scale tests on combined IST (interface shear transfer); (2) formulation of physical and analytical models of the shear transfer mechanism; (3) extension of dynamic analysis; and (4) dynamic load tests.

The results of this investigation will be useful in the development of information for the seismic design of thick-walled concrete structures. It will greatly advance our understanding of the cyclic behavior of shear across cracks in all types of concrete members. The primary application of the results will be in the design of nuclear reactor containment vessels for the combined effects of pressurization and earthquake loading. Current practice requires that nearly all seismic shear be carried by diagonal steel; typical vessels now use over 2 million pounds of diagonal reinforcing in addition to the horizontal and vertical reinforcement.

Seismic Design Analysis for Eastern Metropolitan Areas; *R. V. Whitman*; Massachusetts Institute of Technology, Cambridge, Massachusetts; \$648,500 for 30 months beginning June 5, 1974

The overall objective of this award is to develop a systematic methodology for making decisions concerning the proper level of seismic resistance in buildings and other engineered facilities. In principle, such decisions involve a balancing of the initial costs of increased seismic resistance against expected reductions in human suffering and economic loss during future earthquakes. Working within the constraints imposed by realistic public and private policy, the award will

specifically seek: (1) to develop reliable data concerning the tangible costs and benefits of designing for increased seismic resistance; (2) to develop probabilistic models for analyzing and comparing the costs and benefits of various strategies for mitigating the consequences of future earthquakes; (3) to work with engineers, building officials and public bodies to learn how such data and results can be used as a basis for making decisions about seismic design requirements.

Cost-Benefit Risk Analysis of Research Budgeting for Selected Natural Hazards; *John H. Wiggins*; J. H. Wiggins Company, Redondo Beach, California 90277; \$41,500 for 9 months beginning June 30, 1975

This project will investigate the possible effects of tsunami, storm surge, flood and wind engineering research expenditures on life and property loss from future U.S. occurrences. Four specific times in the next 30 years will be examined and the effects of each disaster agent obtained. For each agent at least one specific event effect will be examined. The annualized expected loss for each disaster agent will be obtained. Each possible event will be investigated for each date, assuming the

availability of research results. The potential for damage mitigation will be accomplished by: (1) estimating the expected damages to the U.S. during each event; (2) estimating the costs of reducing those damages as a function of research dollars available and the types of research performed, and; (3) estimating the damage-ability reduction algorithms associated with the expenditure of research funds and their effectiveness. The research plan calls for each disaster agent to be

separated into three categories: Exposure and Resistance Capacity; Site Modification and Forcing Functions.

This study is in support of the Disaster and Natural

Summer Institute on Protective Design; Bernard Wobbeking; American Society for Engineering Education, Washington, D.C. 20036; \$18,300 for 12 months beginning March 15, 1975

The objectives of the Summer Institute program are to orient and qualify selected architectural and engineering faculty participants to teach college and university students, as well as practicing architects and engineers, the technical aspects of, and the analysis and design methods concerned with, protection against natural hazards such as violent storms, earthquakes, fires, and

Hazards program planning activity for new initiative in disaster mitigation.

nuclear attack effects.

Following the Summer Institute, the faculty will be available to present the technical material in short courses to practicing engineers and architects in all regions of the country.

Theoretical Studies of Tsunamis: Their Generation, Propagation and Coastal Effects; Theodore Y. Wu; California Institute of Technology, Pasadena, California 91109; \$92,500 for 18 months beginning May 15, 1975

This award supports a continuing effort by Caltech to study tsunamis.* One of two such studies presently underway at Caltech, this project award is principally theoretical. The theoretical and experimental activities are divided into four phases.

1. Incorporation of the previous studies of generation and propagation of tsunamis in order to simulate a few typical earthquake motions that occur in nature.
2. Exploration of three-dimensionally weak nonlinear waves of the kdv class. The effort will be concentrated primarily on theoretical development supported by specific experimental investigations with the hope of assessing the validity of the theory.
3. The earlier development of three-dimensional long-wave theory with variable water depth will be applied to study the refraction of tsunamis by islands and coastal topography.

4. The problem of tsunamis climbing up a continental shelf, progressing along a sloping beach, wave breaking and the final run-up at the beach head will be investigated.

These several research projects in Tsunamis are being structured to lay the basis for coastal zone land use studies to control community and individual risk to damage. Close coordination will be maintained with the NOAA and COE programs. A workshop is planned to tie these programs together and make initial assessments of the form of a land use program.

*The research activities of the program will be devoted to three principal areas: (1) generation of tsunamis in the source region — the early stage; (2) propagation of tsunamis in open ocean — the middle stage; and (3) their coastal effects — the final stage.

FIRE RESEARCH

The purpose of the Fire Research Program is to increase the basic knowledge available concerning the ways in which fires can be prevented or controlled in order to reduce the Nation's losses due to hostile fires. Research supported under this program addresses the need for a broad comprehensive effort to apply modern science and technology for a better understanding of the mechanisms of ignition, fire spread, smoke movement, firefighting systems, and human behavior in fires. The potential hazards of the combustion products to humans and to the structure itself are also important areas of research. Because of the new responsibilities for fire prevention and control in the Department of Commerce, it is anticipated that the RANN Fire Research Program will soon be transferred to that agency.

Architectural Approaches to Fire Safety; *Richard Bender*; University of California, Berkeley, California 94720; \$33,500 for 8 months beginning November 1, 1974

This award provides funding to extend research that was started as a part of award GI-43 "Fire Safety in Urban Housing." The project has two major tasks: (1) architectural approaches to the elimination of multiple-death fires in urban housing and (2) simulation of performance of complex elevator configurations. The first task will examine prototypical examples of urban housing, design fire safety systems for adequate protection, estimate the costs of various approaches, and investigate those changes in codes, practice, and equipment which will make improved designs possible.

A secondary task seeks to complete the research on the elevator simulation model (an interactive man-machine system) and document its usefulness in regard to the

performance of elevators in crisis situations. Experiments have been designed for possible validation of the central hypotheses: (1) that elevator configurations can be used as effective means of redistribution, rather than total evacuation of the building population in case of emergency and (2) that the capacity of a crippled elevator configuration can be increased through dynamic allocation of service. Results are disseminated through publications, presentations at scientific and technical meetings, and articles prepared for the popular press. Special seminars will also be held. Local fire and building officials have indicated interest and desire to cooperate in the study.

Mechanics of Wildland Fire Suppression; *Richard C. Corlett*; University of Washington, Seattle, Washington 98195; \$5,000 for 3 months beginning June 1, 1975

This continuation provides for completion of an existing award that is directed toward wildland fire response to fire suppression measures for use in the development of proper equipment, attack strategies, and management techniques that will minimize costs. Specifically, the research will delineate controlling suppression mechanisms for a set of fire situations and formulate meaningful field experiments through analysis and laboratory experiments in cooperation with the U.S. Forest Service.

Specific tasks of the program include: (1) define response of fuel elements of thermal environment of fire and to suppressive action; (2) study analytically and experimentally gas-phase extinction phenomena; (3) determine requirements for extinction with water and other suppressants; (4) evaluate innovative instrumentation techniques for field tests; (5) prepare detailed plan for field-scale experimentation to validate and complete the models. The project is a tri-university effort with overall fire suppression modeling at

University of California, San Diego; design of field-scale experiments at Washington State University; and laboratory-scale experiments coupled with analysis to define fuelbed response as a function of fire thermal environment and suppression variables at the University of Washington.

The experimentation taking place during this extension period consists of further computer calculations and experimental runs to verify the accuracy of some existing, but difficult to interpret, information and

to fill some gaps. These experiments will concentrate on the basic process of char buildup as thermally thick fuel elements are exposed to radiation typical of wildland fires for periods on the order of one minute. To assist in the process of phenomenologically fitting kinetic parameters to experimental data, hopefully eliminating the need for a large matrix of finite difference computer runs, a relatively simple integral type analysis developed within the last few months will be used to obtain first approximations.

Prediction of Fire Hazard in Buildings; *P. Durbetaki*; Georgia Institute of Technology, Atlanta, Georgia; \$64,400 for 12 months beginning April 1, 1974

The experimental and analytical research program will relate building fire hazards to laboratory and field test results. Rational relationships between fire hazard and test methods are indispensable for the assessment of fire hazards, development of fire codes, and evolution of fire safety design criteria.

The fire hazard of a system is quantified by the probability with which the use of a system leads to fire loss. This fire loss probability is a function of the sub-probabilities with which the events occur that lead to a specified loss from fire. Three major events in the development of room fires in residential and commercial buildings have been singled out as the principal objectives of the research program; ignition, fire growth

to flashover, and extinguishment. The program will address the first two events, and develop the necessary techniques for the prediction of ignition probability after exposure, and of flashover probability after sustained ignition. The probabilities are functions primarily of the quotient of two characteristic times: the time an event is allowed to proceed (human contribution to hazard), divided by the time the event requires for its completion (system characteristic).

The program is aimed at the development of techniques for the prediction of fire hazards which will be applied by practitioners; that is, by the representatives of the fire services, building planners and designers, and by fire safety inspectors.

The Home Fire Project; *Howard Emmons*; Harvard University, Cambridge, Massachusetts; \$315,900 for 12 months beginning June 1, 1974

This award funds continuing research which is directed toward the development of an understanding of technical questions of ignition, growth, and extinguishment of a fire in a home. It is a cooperative program between Harvard University and Factory Mutual Research Corporation with the following tasks: 1) develop quantitative understanding of pyrolysis of wood and other cellulosic materials; 2) investigate the mechanism of fire growth in a room, involving the flow of combustion gases and flashover; 3) explain what water does in the process of fire extinguishment, through both cooling and smothering actions;

4) develop procedure for predicting the history of fire proceeding from an assumed ignition point using information in a drawing of a house; 5) provide useful quantitative basis for predicting radiative energy transfer from fires to neighboring fuel elements; 6) pursue pressure modeling of building fires using a specially designed 75ft³, 600 PSI tank facility; 7) establish useful regimes for approximate atmospheric pressure methods for modeling enclosure fires; 8) conduct a limited number of large-scale tests of room fires to verify and tie together the research results.

Physiological and Toxicological Aspects of Smoke Produced during the Combustion of Polymeric Materials; *Irving N. Einborn*; University of Utah, Salt Lake City, Utah; \$220,900 for 8 months beginning September 1, 1974

The objective of this research is to develop analytical procedures which will characterize the nature of the

combustion process of polymeric materials with respect to smoke generation and to determine the physiological

and toxicological consequences resulting from human exposure during smoke-producing combustion. The results should provide fundamental information necessary to develop improved materials and to devise better testing procedures for evaluating material hazards under realistic conditions. Polymeric materials representative of cellulose (including douglas fir), urethanes, and polyvinyl chlorides will be characterized and investigated for smoke production. Using a modified NBS smoke chamber and a special animal exposure chamber, experiments will be conducted to determine the effects of temperature and combustion products in the vital functions of test animals (male rats).

The gross effects of synergism due to the chemical effects of smoke components will also be evaluated. Experiments will be made to measure loss of sight during smoke exposure. Several large-scale tests will be run in NBS facilities to correlate laboratory experiments with conditions observed in real fires. In cooperation with the

Office of the Fire Marshal of Utah and the Salt Lake City Fire Department analyses will be made of human fire injuries by smoke in actual fires. The case studies will emphasize cause of death, temporary effects on body functions, and permanent effects on humans from fire exposure.

A cooperative protocol has been developed which permits continuous interaction with Federal, state and local units of the government. Numerous meetings have been held with government personnel, industry representatives, and members of the general public. Project personnel have participated as expert witnesses before the National Commission on Fire Prevention and Control and the Legislative Council of Utah. A major public educational program was initiated in May 1972. This unique, intensive public awareness effort appears to have contributed to an estimated decrease of 50% in personal injuries resulting from fires in the Salt Lake City area.

Fire Problems Research and Synthesis; R. M. Fristrom; Johns Hopkins University, Applied Physics Laboratory, 8621 Georgia Avenue, Silver Spring, Maryland 20910; \$20,100 for 2 months beginning April 15, 1975

This continuing project is directed towards the improvement of the quality and security of urban life through research that will provide new insight into the protection of citizens from unwanted fires and in advancing the operational effectiveness of the fire services.

1. *Combustion Research:* flame inhibition chemistry; polymer flammability using a new ignition technique; structure of counter flow diffusion flames of halogen-containing fuels (polyvinyl chloride); flame piloted bootstrap burner for conversion of flammable and/or toxic gases and smokes into oxidized nontoxic products.

2. *Fire Exposure Studies:* effects of exposures to smoke from a fire on nonfatal victims (firemen).

3. *Systems Analysis and Development:* complete evaluation of tactics console and mobile tactical unit.

4. *Education and Information:* support fire science instruction through seminars, workshops, survey articles, and bibliographic material; study effect of public education on fire incident frequency.

Additional funding was provided to complete funding for the current year and to update and distribute a Bibliography of RANN-Sponsored Fire Research Literature. The plan requires an update of material, including corrections, and distribution of the supplement to primary users.

Flame Spreading Across Liquid Fuels; Irvin Glassman; Princeton University, Princeton, N.J.; \$73,000 for 12 months beginning March 1, 1974

The continuing research will pursue a complete analytical solution in which both the gas and liquid phase phenomena are treated simultaneously in order to obtain the flame-spreading rate as an eigenvalue of the problem and to understand the relative importance of gas phase processes to the propagation mechanism. Theoretical work will continue efforts to develop the analytical approach, and will also study the steady (pool fire) combustion problem.

The development and evolution of the physical model

upon which the theory is based is guided by experimental efforts which measure: 1) exact propagation velocities over the liquid surface; 2) the subsurface induced flow field parameters (temperature and velocity distribution); and 3) the induced gas phase flow field. A new flow visualization technique has been developed and demonstrated for determining the liquid flow field velocity distribution, and a high resolution thermocouple rig was used for temperature measurements.

Contract for Partial Support of the Committee on Fire Research; Nelson T. Grisamore; National Academy of Sciences, Washington, D.C. 20418; \$22,000 for 21 months beginning July 1, 1974

This grant provides partial support for the Committee on Fire Research that was formed in 1955 to advise and consult on the development and conduct of a research program directed at an understanding of the spread and control of conflagrations of the fire storm and forest varieties. In recent years the interest has been increasingly directed toward prevention and suppression of urban fires, and those occurring at the interface of wild lands and metropolitan areas.

The Committee on Fire Research will publish the

usual three numbers of *Fire Research Abstracts and Reviews*, start preparation of the Eighth Edition of *Directory of Fire Research in the United States*, and will continue its basic mission of advice, recommendation, and persuasion leading to the identification and solution of real problems obstructing the development of adequate fire prevention and control. In addition, two symposia are planned for early 1975 — one on arson and incendiaryism, and the other on fire detectors.

Extinction of Flames by Powders of Metallic Salts; Daniel D. Konowalow; State University of New York at Binghamton; \$29,000 for 12 months beginning October 15, 1973

A fundamental study of the mechanism of flame inhibition and extinction by powdered salts, especially alkali carbonates, will be undertaken. Salts of this type are already known to be quite effective in this regard, and in fact are in use in practical extinguishers. It is thought that they may act in part through some chemical mechanism, but the nature of this mechanism, if any, is not known. If a mechanism could be demonstrated and quantified, it would make possible the optimization of the effectiveness of known inhibitors and would put the search for new inhibitors on a more scientific basis.

The postulated chemical inhibition depends on chemical species evaporated from inhibitors, but no

measurements have been reported on these. Therefore, the experimental program will consist of the development and use of methods for measuring alkali atoms, free radicals and temperature in inhibited flames. Appropriate methods are already available and in use in the laboratory and only need adaptation to heavily seeded flames. Correlations between evaporated species and inhibition, as evidenced by flame temperature, velocity and radical concentrations, will be sought, and mechanisms will be deduced. It is postulated that these data and its interpretation will allow a more logical approach to fire extinction.

NSF/RANN Conference on Fire Research; Stotbe P. Kezios; Georgia Institute of Technology, Atlanta, Georgia; \$10,000 for 6 months beginning May 1, 1974

The principal investigator will arrange and conduct a two-day conference where NSF/RANN research grantees will give progress reports on their research.

Fire protection personnel and others active in fire research will also be invited. Proceedings of the conference will be prepared and distributed.

Mechanism of Fire Propagation of Polymer Surfaces; Norman W. Ryan; University of Utah, Salt Lake City; \$44,000 for 12 months beginning July 15, 1973

Study will be made of a hypothesis concerning the mechanism of fire spread across the surface of a combustible polymer. The hot flame is lead by a small, fuel-lean flame, which is coupled by the convective action of a vortex to oxidative surface pyrolysis. This native pilot flame is the key to the stability, perhaps the existence, of the hot flame. It is proposed to characterize

the native pilot flame, then relate its behavior to the chemistry of flame spread as governed by the chemical nature of the polymer, with and without flammability-modifying additives. The objective is to put on a firmer scientific basis the selection and chemical treatment of polymers to reduce fire hazard.

Chemistry of Cellulosic Fibers; *Fred Shafizadeh*; University of Montana, Missoula, Montana; \$90,000 for 12 months beginning April 1, 1974

The continuing research project on the chemistry of cellulosic fires is a systematic study to determine the type of reactions and transformations involved. Considerable progress has been made by unraveling the sequence of complex reactions which result in the conversion of cellulosic materials to combustible volatile products and propagation of flaming combustion.

Study will continue on dehydration, decarboxylation, and charring reactions which compete with the sequence of transglycosylation and fission reactions to suppress or terminate the propagation of flaming combustion. In connection with the chemistry of flame retardants, research will first concentrate on halogens and boron, to be followed by Lewis acid, water, and complex systems.

Flame Spreading Over Solid Surfaces; *Merwin Sibulkin*; Brown University, Providence, R.I.; \$35,000 for 12 months beginning April 1, 1974

This is a continuation and extension of a previous award directed towards determining the mechanism of flame spread for wood and plastic cylinders having round and rectangular cross sections with several orientations. Analytical and experimental studies are included. It is proposed to extend this work in two directions. Burning on horizontal surfaces will be continued to study the significance of a preliminary finding that the flame propagation rate is independent of flame size. Surface temperature profiles ahead of the flame will be measured at several flame diameters to see if the extent of the preheat region is also independent of flame size. The horizontal burning configuration will then be used to study the air flow ahead of the flame front induced by free convection of the hot combustion gases. A two-channel

hot wire anemometer system will be used to measure flow velocity and temperature, and an energy balance method (similar to the technique used for cylinder burning) will be applied to obtain the surface heat flux. The second research direction is a study of flame spreading under near-extinguishment conditions using vertically downward-burning cylinders, which provide a steady, reproducible burning configuration. The experimental apparatus will be similar to that developed to measure the "limiting oxygen index." Measurements of flame propagation rates will be made as the O_2/N_2 ratio varies from atmospheric to extinguishment values. A study will then be made of changes in the temperatures and concentrations of stable species in the flame as extinguishment conditions are approached.

Flame Spread over Liquid Fuel; *Kenneth Torrance*; Cornell University, Sibley School of Mechanical and Aerospace Engineering, Ithaca, New York 14850; \$34,300 for 12 months beginning June 15, 1974

This award is for continued research to determine in a quantitative and detailed way the range of physical parameters which will permit a flame to spread over liquid fuels. A second objective is to determine whether or not experimentally observed flame steadiness can be predicted using such a model. An analysis will also be made on the effects of radiation on flame propagation using the model, and detailed comparison with experiment will be provided.

Results from prior research will be extended to the gas-liquid combustion problem which will require development of an appropriate model and numerical

procedure to handle evaporation, kinetic and fuel parameters will be included. This study will thus provide basic information on several questions which currently exist about fire spread over liquid fuels. Results of this research will be useful for predicting safe storage and handling ranges for liquid fuels, and may suggest new methods of fire extinguishment and control.

Results of the study will be presented at conferences and published in scientific papers, as well as distributed to other research workers in the field and to fire test laboratories.

Fire Propagation Along Solid Surfaces; *Forman A. Williams*; University of California, San Diego; 42,000 for 12 months beginning December 1, 1973

Current investigations of fire spread along flat surfaces of solids will be completed. The objectives are to

ascertain under what conditions conduction, convection or radiation is the dominant of heat transfer during fire

spread, and to characterize the chemical processes responsible for flame spread.

Measurements of temperature fields, heat fluxes, gas velocities, chemical compositions and rates of flame spread for samples of various thicknesses, with various orientations and with various backing materials, will be completed for polymethylmethacrylate. Some additional observations will be made for filter paper, cotton cloth,

and polyformaldehyde. Theoretical prediction of the flame-spread rate will be completed for polymethylmethacrylate, and the results will be compared with experiment. A more general theoretical study will be made, aimed at delineating regimes in which differing physical mechanisms control spread rates. This study will aid in assigning a suitable role to flame spread in flammability assessment.

Fire Safety in Urban Housing; R. Brady Williamson; University of California, Berkeley, California; \$239,400 for 8 months beginning November 1, 1974

The overall objective of this interdisciplinary research, jointly funded with the Earthquake Engineering program, is the development of a rational base for the fire-safe design of buildings. The research will lead to improved specifications, codes, and design procedures. Studies will focus on seven interrelated tasks: (1) modeling and fire development (flame spread modeling, formation of carbon particles, similitude laws, pre-flashover fire growth rates); (2) characterization of fire radiation; (3) polymer flammability (extend experimental techniques for measurement of polymer burning rates with an opposed flow diffusion burner, flame structure measurements); (4) decomposition of materials under actual fire conditions; (5) prediction of structural response of building components and systems in fire environments (extension of finite-element numerical methods, experimental studies of column, beam, and slab elements, parametric studies of typical structural configurations); (6) relationship between fire

severity and fire endurance; (7) fire-oriented behavior and organization in relation to fire-protection planning (completion of methodology for household fire safety assessment, examine large, highrise buildings, develop case study in fire protection planning). The selected research tasks are directed at the following goals: reduce risk of fire outbreak; provide for safety of occupants in case of fire; reduce probable property damage and potential paths to conflagurations in case of fire; and provide for safe and successful fire fighting.

The project has utilization as a integral part of the plan, with overall efforts as well as steps for each specific task. Both short time scale and long time scale efforts are included. Links have been established with other researchers, Federal, state and city housing and fire agencies (such as HUD, GSA, NBS, FTC, State Fire Marshal, City Code Officials), model code groups, testing organizations, and industrial groups.

Fire and Smoke Spread; Kwang-Tzu-Yang; University of Notre Dame, Department of Aerospace and Mechanical Engineering, Notre Dame, Indiana 46556; \$74,900 for 12 months beginning September 1, 1974

The primary purpose of this award is to provide the foundation for the development and use of theoretical predictions for describing fire and smoke spread in corridors. The theoretical predictions are based on a global approach as well as preliminary first principle calculations for a single corridor. The analyses will be highly coupled to small-scale experiments as well as full-scale experiments. The small-scale experiments, which will be carried out at Notre Dame, will provide valuable insight into, not only the development of the first principle analysis, but also will be used to judge its utility for future applications. Full-scale data from the National Bureau of Standards corridor facility will be employed.

This includes existing data in addition to future data gathered with supplementary instrumentation. The full-scale data will be compared to the global analysis, as well as used for input to the first principle formulation. Finally, the approaches will be evaluated in terms of their potential for providing meaningful information in the spread problem.

NBS is the primary Federal user group, although GSA and HUD may also make use of the findings. Reports will be distributed and papers submitted to technical journals and publications.

Properties of Combustion Products from Building Fires; Ben T. Zinn; Georgia Institute of Technology, School of Aerospace Engineering, Atlanta, Georgia 30332; \$74,900 for 12 months beginning October 1, 1974

The objective of this continuation research grant is the determination of the physical and chemical properties of the particulate and gaseous products generated by the burning of representative materials currently used in building construction and interior furnishings. A versatile small-scale smoke test chamber and facilities for the sampling and analysis of combustion products have been assembled. The combustion products generated in the chamber will be analyzed to determine the optical density of smoke, the particle size distribution, the particle chemical composition, the particle mass concentration, and the composition of the gaseous products. Initial testing will determine the dependence of the properties of the combustion products generated by the burning of polyurethanes, polyvinylchlorides and cellulose upon: (1) the size of the burning sample and the volume of the test chamber; (2) the geometrical configuration of the burning sample; (3) the temperature and composition of the chamber atmosphere; (4) the type of combustion (i.e., flaming or

nonflaming); and (5) the amount of ventilation. Data obtained will be compared with corresponding data obtained in commonly-used smoke test chambers. An attempt will also be made to determine whether any relationship exists between the various measured smoke properties and the customarily-measured light extinction coefficients.

The National Bureau of Standards will be kept informed of the progress as it is the major potential Federal user and also is tied into a University of Utah project conducting complementary research. This research work could find use in standards for materials and in connection with the deployment of smoke detectors in buildings. Efforts will also be made to communicate the findings with firesafety engineers, fire marshals, fire inspectors, and the general public through publications in non-technical journals and magazines, newspapers articles, and radio and television broadcasts.

Convective Flows Association with Room Fires; Edward E. Zukoski; California Institute of Technology, Pasadena, California; \$43,400 for 12 months beginning June 15, 1974

Turbulent and bouyant convection currents play an important part in fire development within a single compartment and in fire spread through a multi-compartmented structure. The aim of the research is to investigate the fluid dynamic aspects of these flows through the use of small-scale modeling experiments. Fluid dynamic aspects of an isolated room fire which will be investigated include the turbulent plume rising from fire, the ceiling layer formed by impingement of plume on the ceiling, the flow processes at the door or window,

and the flow of the hot gases outside the door or window. Particular emphasis will be placed on study of entrainment and mixing processes.

In the multi-room study, investigation will be made of the extent to which it is possible to construct a usefully accurate model of the flow processes occurring in a multi-room structure during a fire from an understanding of the characteristics of each element of the structure determined from tests of the isolated elements.

SOCIO-ECONOMIC RESPONSE TO NATURAL HAZARDS

The purpose of this research is to understand and evaluate the benefits and costs of different combinations of adjustments to natural hazards: prediction and warning, disaster preparedness, physical protection, land use management, insurance, and relief. Research is also aimed at finding the commonalities between adjustments for different hazards. The objective is to evolve an optimal natural hazards program and policy.

The Social Impact of Natural Hazards and Disasters Program now has established three basic objectives:

- Develop a reliable and valid understanding of the probable social and economic costs of the Nation's major natural hazards and other hazards for individuals, families, communities, regions, and the nation and its organizations and institutions.
- Survey and assess the several public and private disaster preparedness and response programs.
- Design, develop and test alternative approaches, plans, and procedures to enable society to prepare for, respond to, and recover from disastrous events.

Reducing Losses from Selected Natural Hazards: Role of the Public and Private Sector; *Howard C. Kunreuther;* University of Pennsylvania, Philadelphia, Pennsylvania 19174; \$148,850 for 12 months beginning March 5, 1975.

In recent years, the costs of disasters to the Federal government have skyrocketed. Apart from the growth in population and its concentration in urban areas, this is primarily due to increasingly liberal Federal disaster relief provisions to the private sector, with grants and low-interest loans. A principal reason for this development is the failure of individuals and businesses in hazard-prone regions to protect themselves adequately against potential damage from catastrophic events. This continuation award supports the completion of a research project which was initially funded in 1973. The study examines alternative policies for allocating the cost burdens of selected natural disasters.

Research is being undertaken on the following tasks: (1) Evaluation of the performance of alternative insurance and Federal disaster assistance programs through testing of competing models of individual behavior in response to low probability events. The evaluation of benefits and costs hinges on validating an appropriate model of the decision-making process of

individuals in the pre- and post-disaster periods. The models to be tested are the expected utility model versus the bounded rationality model. This project has been carried out through a stratified random survey sample of 2,055 individuals in 43 flood prone areas and 1006 individuals in 18 earthquake prone areas. (2) Estimation of the trade-off between insurance and direct means of mitigating disasters such as zoning and land use controls. This task will be undertaken by integrating the survey responses with an experimental simulation model of disaster effects upon particular communities.

During the grant continuation period, an attempt will be made to determine whether the costs of repairing disaster-caused damage to private residential property should be treated as a public or private responsibility. The primary research tasks to be accomplished during the concluding portion of this project are the analysis of the field survey data, the execution of the laboratory experiments, and the synthesis of the findings of these two major tasks.

Long-Range Economic Dislocations and Other Consequences of Natural Disasters: Phase I; H. Paul Friesma;
Northwestern University, Evanston, Illinois 60201; \$91,150 for 4 months beginning June 1, 1975

This interdisciplinary study is expected to focus on 20-25 communities for the purpose of examining the long range effects of two natural disaster agents (floods and tornadoes) which annually strike numerous communities across the nation. During its first phase only 4 communities will be studied, two will have experienced a flood and two will have experienced a tornado. The study is designed to focus upon economic dislocations, local governmental revenues and expenditure patterns, community organizational and governmental structure, land use and group and personal fortune. The project will use an interrupted time-series design, and will gather and analyze data from a relatively large sample of the communities which have suffered flooding and tornado disasters since the early 1950's through 1972. It will attempt to account for variation in the patterns of long term change on the basis of the type of natural disaster, the severity of immediate losses, the extent of preparedness, the extent of disaster warning, the social and economic base of the community, its political structure and the scope and rapidity of relief and rehabilitation efforts.

The first set of questions this research is intended to answer concerns the extent of the long-range changes and dislocations which follow natural disasters. It will assess which economic and social activities are sensitive to natural disasters in the long run, how sensitive those activities are, and what activities are insensitive to natural disasters following the immediate recovery.

The study will be both longitudinal and comparative. It will analyze aggregate indicators of community social, economic, and political activities using an interrupted time-series design, in which the disaster will be the interruption in the long-term trend. It is anticipated that data will be collected to cover a 10 year period, beginning 5 years before the disaster and extending 5 years after it has occurred. The essential measure of change, or dislocation, will be alterations in the trend(s) which occur, and are maintained, after the immediate recovery period has passed. The 20-25 communities will be selected from the universe of communities suffering tornado and water-related natural disasters during the period from the early 1950's until 1972.

WEATHER MODIFICATION

The purpose of the Weather Modification Program is to study those atmospheric mechanisms which can be or are being influenced by man to modify natural weather patterns and evaluate the impact of their modification upon society.

The objectives are to:

- More fully evaluate the impact of weather on man, especially in a technology-oriented, highly industrialized society such as that of the U.S., and to develop the full scientific base necessary for successful weather modification applications.
- Develop the operational predictive models and statistical methods and measurement systems which are essential to accurate, short-time evaluation of weather modification events, both advertent and inadvertent.
- Develop the tools and techniques for performing weather modification research through proof-of-concept experiments.

The research elements are:

- Inadvertent Weather Modification
- Societal Utilization
- Weather Hazard Mitigation
- Weather Modification Systems

INADVERTENT WEATHER MODIFICATION

The objectives of the Inadvertent Weather Modification element are to delineate the mechanisms whereby, and the extent to which, an agricultural region modifies its own climate; and an urban area modifies its surrounding weather, precipitation, and aerosol.

Modification of Convective Cloud Activity by an Urban Area; August H. Auer; University of Wyoming, Natural Resources Research Institute, Laramie, Wyoming 82070; \$134,300 for 10 months beginning April 1, 1975

The goal of this particular study within project METROMEX is to make comparative observations of urban and nonurban environments to determine processes responsible for differences in boundary layer signature, wind fields and resultant convective cloud behavior, traceable to urban-induced changes in heat, moisture, and aerosols.

The character and modification of life cycles of growing cumulus and cumulonimbus clouds due to heat, moisture and aerosol injections are observed while the meso-scale distribution of these substances, as well as particulate matter in the urban atmosphere, is analyzed as to its relation to regions of preferential convective cloud systems. The downwind plume is analyzed as to its character and extent while influenced by heat, moisture, wind and aerosols of the urban area. Differences in these factors, as well as particulate matter and the rural-urban

variations in solar and infrared radiation, are observed and correlated with the energy budget of the urban area.

There are users of METROMEX achievements in the scientific community who can be expected to utilize and apply these findings in a variety of endeavors. The University of Wyoming has operated equipment and exchanged data in formats applicable to the needs of several air pollution scientists involved in the EPA Regional Air Pollution Study in St. Louis. Furthermore, findings from METROMEX have been translated into possible implications for research into inadvertent weather modification from energy development, a research program contemplated for the Northern Great Plains region. Cloud physicists and weather modification scientists are regular users of METROMEX research. Radio, press, and TV interviews make possible efficient dissemination of all research and activities.

Inadvertent Weather Modification in the St. Louis Area; Roscoe R. Braham, Jr.; University of Chicago, Department of Geophysical Services, Chicago, Illinois 60637; \$261,000 for 10 months beginning April 1, 1975

The goal of this particular study within the METROMEX program is to establish the impact of urban nuclei upon precipitation processes and to map the extent of urban altered precipitation. Four interrelated objectives are addressed: (1) map, with radar, areas of urban altered cloud structures and urban influenced precipitation; (2) determine source strengths and loss functions for meteorologically important aerosols and cloud nuclei in urban atmospheres; (3) establish cause and effect relationships and levels of response of urban clouds to inadvertent modification; and (4) carry out a variety of studies of the urban boundary layer in cooperation with other METROMEX institutions.

Included among the tasks selected for emphasis by the Chicago group are: (1) provisions to take more

measurements concerning propagation of urban imprint at cloud base upward into the clouds; (2) continued probing of clouds above freezing level with a newly developed ice crystal counter; and (3) additional radar observations.

Most of the data generated in this program are disseminated through the University of Chicago Cloud Physics Laboratory Technical Note series. The Notes are catalogued by such groups as the Library of Congress, Defense Document Center and the National Technical Information Service. Chicago's group is regularly involved in radio, television, and press releases. Improved understanding of the physics of cloud modification has a direct impact on the field of cloud seeding and international weather modification.

Studies of Urban Effects on Rainfall and Severe Weather; *Stanley A. Changnon, Jr.*; University of Illinois, Illinois State Water Survey, Urbana, Illinois 61801; \$257,200 for 10 months beginning April 1, 1975

The goal of this particular study within METROMEX is to measure precipitation anomalies in the vicinity of St. Louis, identify the causes, and determine the impact on Illinois water resources and planned weather modification. The field effort will concentrate on the effects that urban areas have on cloud formation and motion, precipitation development and motion using radar and rain gauges, urban-produced turbulence, and measurements of severe weather and atmospheric parameters. The analysis focuses on intensive studies of selective storm periods to further sharpen hypotheses to explain the anomalies defined to date. Particular emphasis will be placed on the delineation of the causes of the anomalies and on final development of a predictive scheme for testing in other cities.

For the first time a newly completed weather radar will be available to make continuous three-dimensional

scans of the METROMEX study area to define the many critical aspects of precipitation development in the region. A new field effort for 1975 concerns the installation of four electrical field mill stations to measure atmospheric fields.

Two workshops were held in the St. Louis area in November 1974 for engineers. The purpose of these meetings was to bring groups such as the Corps of Engineers, city engineers, and private consulting engineers in the St. Louis area together to learn of the project's research results. Specific information relating to heavy rainfall frequencies and storm dimensions from METROMEX were supplied to three communities in the Illinois area located east of St. Louis, and the extensive results were furnished to the Illinois EPA to assist them in a design requirement for sewer systems in the suburban region.

Dual-Doppler Radar Investigation of Wind Flow Patterns in METROMEX; *Earl E. Gossard*; National Oceanic Atmospheric Administration (NOAA), Department of Commerce, Boulder, Colorado 80302; \$60,000 for 12 months beginning June 15, 1975

This award funds research using the NOAA dual-Doppler hardware and software system to measure the three dimensional wind flow patterns in the metropolitan area against which the recordings of other sensors in the experiment can be prepared, and which can be used to provide divergence and vorticity values over and downwind of the city. In addition, measurements of the transition in airflow patterns from metropolitan to rural areas will be undertaken, as well as an attempt to separate the heat island effect from roughness effects.

By monitoring the location and height of "first echoes" NOAA will attempt to identify local "hot spots"

of local weather cell formation relative to the city. NOAA will calculate the distribution of turbulent dissipation rate with height, and try to relate it to data acquired by other sensors in the experiment such as concentration of pollutants.

Utilization of the wind and circulation data and analysis obtained by NOAA will be accomplished largely by the other METROMEX participants: Illinois State Water Survey, University of Chicago, University of Wyoming, and Battelle Memorial Institute. Conferences, papers, journals, and news releases provide the bulk of dissemination activities under METROMEX.

Numerical Cloud Modeling: Application to Urban Effects on Precipitation; *Harry T. Ochs*; University of Illinois, Illinois State Water Survey, Urbana, Illinois 61801; \$63,400 for 10 months beginning April 1, 1975

In recognition of a significant need for information concerning the causes, extent and magnitude of inadvertent weather and climate modification, several federal agencies, including the National Science Foundation are presently supporting a major field program in St. Louis called METROMEX (Metropolitan Meteorological Experiment). The three general goals of METROMEX are: (1) to determine through extensive monitoring of meteorological variables the extent and location of the effects of St. Louis on precipitation and

related weather conditions; (2) to discover and quantify the causes of this effect; and (3) to develop methods, including numerical models, which will be capable of translating the results to other urban areas. After two summers of field effort sufficient data had been obtained to warrant the initiation and choice of a numerical modeling effort. This project will continue the numerical cloud modeling studies of urban altered precipitation initiated under previous research conducted by the University of Illinois.

This is a renewal of the numerical cloud modeling effort for METROMEX and is aimed at the fulfillment of original specific goals for modeling research to: (1) determine the primary urban factors and their relative contribution to the noted effect on precipitation; (2) establish a meaningful interaction with the field program; and (3) determine the critical field measurements necessary to ascertain the magnitude and location of the precipitation anomaly in other cities through numerical modeling. The primary goal of this continuation period is the application of available modeling tools to test hypotheses for the causes of the urban effect on precipitation that have been developed by METROMEX investigators.

The objectives of the modeling effort are being achieved through the application of numerical models which simulate the development of droplet spectra by the process of condensation and interactions between drops by collection and breakup. This simulation forms a portion of a model which depicts the complete life cycle of a cloud. In addition, an existing model which employs the same dynamical calculations but utilizes a parameterized description of microphysics is being obtained. The objectives of the modeling effort will be met through the application of these models to specific METROMEX situations.

Specific studies which will be undertaken or continued during this research year include: (1) determination of

the effect of cloud condensation nuclei variations across St. Louis on the development of precipitation by warm rain processes; (2) determination of the role of size range of nuclei for the initiation and production of rain; (3) the effects of cloud base heights on precipitation; (4) an evaluation of echo returns; (5) selection of a one-dimensional cloud model with a parameterized description of precipitation development; (6) the use of the one-dimensional cloud model in evaluating the relation between rainfall production and production of ice crystals; (7) a simulation of storms over St. Louis using the model; and (8) continued research into cloud initiation.

The current primary users of the numerical cloud modeling results are METROMEX scientists. The scientific community has been informed of ongoing METROMEX numerical modeling through the presentation of five papers at scientific meetings sponsored by the American Meteorological Society, American Geophysical Union, and the Institute of Electrical and Electronic Engineers. One paper has been submitted for publication in the *Journal of Applied Meteorology*. Scientists in disciplines such as advertent weather modification, global mesoscale modeling, pollution control and precipitation scavenging can use the generated research results as input to their studies or can apply the developed numerical tools to their investigations.

Climatic Alterations in the Great Plains Due to Widespread Irrigation; Paul T. Schickedanz; University of Illinois, Illinois State Water Survey, Urbana, Illinois 61801; \$55,500 for 24 months beginning June 1, 1974

It has been noted that the rainfall since 1955 in certain Great Plains climatic divisions (crop reporting districts) is now greater than in prior years. It has been suggested that this greater rainfall may be due to effects on the atmosphere from the regions of widespread irrigation which began in the mid 1940's. The purpose of this research is to determine if a rainfall anomaly due to irrigation exists, and if so, to determine the magnitude of the effect due to irrigation. Attention is also placed on possible alterations of other characteristics of the climate such as surface temperature, dew point temperature, cloudiness, and hailfall.

Phase One of the research effort involves the study of monthly rainfall data during the growing seasons in the

States of Nebraska, Kansas, Oklahoma, and Texas. In addition some data from Colorado and Nebraska will be used for upwind control purposes. Phase Two involves comparisons between the rainfall, the number of acres irrigated, and the number of acre-feet of water applied per acre for certain counties and months selected from the Phase One studies, in an attempt to provide insight into the true relationship between irrigation and precipitation. Phase Three tests the changes in several weather parameters for a limited number of stations which have long-term records (55 to 70 years). Phase Four is a special study to test the "chain reaction" theory for increased rainfall due to irrigation.

SOCIETAL UTILIZATION

The thrust of the Societal Utilization element is to evaluate societal reaction to weather modification, to determine societal expectations, and to identify the needs for the scientific base necessary to bring about successful application of weather modification.

Economic and Institutional Considerations of Suppressing Hail; *Larry M. Boone*; Economic Research Service, U.S. Department of Agriculture, Washington, D.C. 20525; \$54,500 for 12 months beginning October 1, 1973

This fund transfer provides support for the final portion of the third year of the study by the Economic Research Service of the U.S. Department of Agriculture to estimate the economic benefits which may be derived from the application of hail suppression technology to severe convective storms which threaten crops in areas subject to heavy hail damage. During the first year of the study, an estimate of crop losses was made by county for selected regions of the U.S., and county clusters that would be amenable to potential hail suppression activities were determined. During the second year of the study, prospective shifts in agricultural patterns which

may occur in the event of successful hail suppression were analyzed and included in the economic model. The third year of effort under this grant takes the form of a comparison of alternative forms of crop insurance, alternative levels of production, and costs of hail suppression for selected farm resource situations over a specified period. An analysis is being made in cooperation with the National Center for Atmospheric Research of alternative institutional arrangements for organizing, operating, and financing an operational hail suppression system.

Extended Area Effects from Local Weather Modification; *Lewis O. Grant*; Colorado State University, Department of Atmospheric Sciences, Fort Collins, Colorado 80521; \$280,000 for 12 months beginning December 1, 1974

This grant is the final phase of a three year project designed to investigate changes occurring downwind from weather modification efforts. The basic goal of the research is to provide information necessary to evaluate the social implications and the research requirements of weather modification. The specific goals are to provide: (1) knowledge for helping to develop procedures for augmenting precipitation over broad areas; (2) definitions of effects that could cause considerable "disbenefits" downwind from areas being intentionally seeded; (3) definitions of effects that could cause weather changes over areas so large that even broader scale processes might be affected; and (4) definition of effects that could cause adverse interaction among ongoing weather modification programs.

Complementary physical investigations and statistical analyses are being conducted. The physical studies involve both numerical modeling and field observations to determine: (1) flow trajectories from the release point of seeding agents to the clouds; (2) ice growth processes

within the clouds; (3) ice crystal movement through the clouds and downwind; (4) ice evaporative processes downwind; and (5) the interactions of seeding materials and ice particle residue with cloud water available in downwind clouds. The statistical efforts will determine extended area weather effects caused by large, well-documented weather modification programs that have already been completed.

The studies related to summertime clouds concentrate on analyses of extra-area effects relative to the National Hail Research Experiment. Emphasized in these studies are: (1) statistical analysis of precipitation and hail in an area up to 250 miles from the experimental area; (2) weather radar analyses for the area around and downwind of the experimental area; (3) satellite cloud analysis and surface temperature comparisons for seeded and non-seeded cases; (4) analyses of atmospheric and precipitation samples for the presence of silver, and; (5) atmospheric water balance analysis.

and allow development of meaningful toxicity threshold levels for use in management of weather modification programs. Background studies from specific impact area-

related projects have been presented in symposia and technical conferences.

Weather Modification Management Guidelines; James D. McQuigg; University of Missouri, Department of Atmospheric Sciences, Columbia, Missouri 65201, \$41,000 for 14 months beginning August 1, 1974

This grant extends for fourteen months a research project whose goal is the production of a compendium of quantified relationships between weather and certain basic human activities: energy demand and use, agricultural production, outdoor construction, and the extent and spread of diseases.

The preparation of guidelines over the period of research will involve the formation of an advisory panel and three meetings held at critical points to guide in the selection and use of material available.

In cooperation with the NOAA, results of this NSF-sponsored research have been used to produce a study of agricultural drought in the major wheat, corn, and soybean producing regions of the U.S. This study has

been forwarded through the Secretaries of Commerce and Agriculture to the White House.

The impact of climate variability on the world food situation has emerged as one of the most urgent problems we face at the present time. In cooperation with NOAA and with the assistance of representatives from the USDA, Dr. McQuigg was able to utilize the facilities and expertise developed under this and previous NSF grants in an analysis of the probabilities of unfavorable crop weather in the major grain producing regions of the world. The material contained in the resulting report is to be used by the State Department in preparation for a World Food Conference in Rome.

The Importance of Climate and Weather Alterations to Mankind; W. A. Mordy; Center for the Future, Santa Barbara, California 93109; \$99,900 for 15 months beginning July 1, 1974

The primary objective of this project is to assist in instituting a broad-based, long-range research and utilization planning process for the Societal Utilization component of the NSF/RANN Weather Modification Program. The purpose of the planning process is to maximize the social utility of the RANN Weather Modification program, and at the same time to implement needed research and development in both technical and socio-environmental aspects of deliberate and inadvertent weather modification.

The project establishes a Coordinator for the Societal Utilization component of the RANN Weather Modification Program. The coordinating and planning processes together will serve the further objectives of: introducing consideration of societal implications in the initial planning stages of weather modification research; encouraging earlier and closer interactions of social scientists and physical scientists in programs and projects; and facilitating mutual understanding and working relationships among physical and social scientists. An additional objective of the project is the dissemination of information and perspectives on weather modification growing out of the planning process in order to foster broad social understanding of the problems and opportunities of weather modification; these will be properly interpreted or simplified to

communicate with several different types of users.

The Coordinator, through the planning process, will help focus goals and plans, as they evolve, for developing the contribution of the Societal Utilization component of the Weather Modification Program. He will arrange meetings of the Societal Utilization group to foster interaction and mutual understanding among the various disciplines represented, and will help organize and coordinate group presentations of findings in appropriate circumstances. The Coordinator will also facilitate interaction of the group with the National Science Foundation, and coordinate reports on progress and utilization to the Foundation on behalf of the group.

As has been noted, a broad-based researcher-user process is needed to assist in setting goals and devising strategy, in order for plans to be realistic and to be implemented. Reports will be prepared for utilization in planning by the National Science Foundation Weather Modification Program administrators and principal investigators within this program, and publications will be disseminated to users of projects in the component, such as state officials with responsibilities for weather modification activities and agricultural and other associations.

Basic aspects of the research have progressed in accordance with the original work schedule. Only a limited portion of the field program, however, could be completed during the first winter season making it necessary to extend the field observation into the latter fall and winter of 1975. The wind tunnel modeling has emphasized improved simulation criteria and procedures, and the development of techniques for directly comparing data from the field observations with greatly expanded case studies from the wind tunnel simulations. An added objective of evaluating the Extended Area Effects Problem as related to NHRE has been smoothly incorporated into the work schedule.

From the utilization standpoint, the project plan involves interaction of the project scientists with user

groups to make them aware of the potential and characteristics of such extended area effects from weather modification. This includes contacts with a wide variety of societal representatives in order to acquaint them with the broader scale implications of their activities. These groups include: other physical scientists and weather operators; governmental representatives; social and environmental scientists; and the general public. Contacts have been made and continued with a wide range of users and impact evaluators to assist in the interpretation of the impacts and in the dissemination of results. A portion of these contacts are made through RANN's weather modification program, while somewhat more than half of the contacts are with other user representatives.

A Comparative Analysis of Public Reaction to Weather Modification Projects; J. Eugene Haas; Human Ecology Research Services, Inc., Loveland, Colorado 80537; \$76,000 for 12 months beginning October 1, 1974

This current award extends for one year previous research work aimed at developing a significant increase in our understanding of the issues and processes which lead to organized opposition to and support of weather modification technology. In addition, objectives include the effective dissemination of those findings to all interested parties.

The research consists of two principal efforts. The first involves monitoring the economic and social conditions of 37 different project areas around the country where weather modification technology is or was applied, or at least attempts are being made to start cloud seeding. The second effort is concentrated in South Dakota, where a panel of 326 citizens is being

interviewed periodically regarding their knowledge and views toward weather modification efforts. South Dakota is the site of considerable weather modification technology application efforts.

The most recent utilization activities of this group include conference reprint distributions following the Governor's Conference on Weather Modification in the United States, Sioux Falls, South Dakota, June 10-12 1974, as well as numerous other publications and meetings with the weather modification community. Thus far, research results have been used in the South Dakota Weather Modification Program as a basis for the organization of decision-making procedures.

Microbiological Impacts of Silver Iodide Used in Weather Modification; Donald A. Klein; Colorado State University, Fort Collins, Colorado 80521, \$46,600 for 12 months beginning October 1, 1974

Silver iodide is commonly used as a nucleating agent in weather modification programs. This agent accumulates predominantly in surface soils and aquatic mud environments with minimal subsequent movement once deposition has taken place. In the course of long-term weather modification operations, this agent may accumulate to various levels, and subsequently influence microbiological processes which are necessary to nutrient cycling and energy flow.

Short term laboratory studies are not likely to provide information on the possible long-term, sublethal effects of silver additions to soil microbial systems. To provide needed information on the threshold levels required to

cause discernable shifts in microbiological processes, the principal investigator is studying the effects of various levels of silver concentration in soils at various distances from silver iodide generator sites, and in soils containing naturally high silver concentrations. A comparison of these sites with remote areas where silver concentrations are low should make it possible to evaluate potential long-term, low level effects of residual silver on microbiological populations, carbon flow, and nutrient cycling. A continuation of a grant awarded in 1973, this program will provide valuable information on long-term silver iodide accumulation effects, which can't be obtained from monitoring current seeding operations

Design of a Hail Suppression Experiment in Illinois; *G. M. Morgan, Jr. and Stanley A. Changnon, Jr.*, University of Illinois, Illinois State Water Survey, Urbana, Illinois 61801; \$67,800 for 12 months beginning November 1, 1974

This project is aimed at determining the desirability, feasibility and environmental impact of a hail prevention experiment in Illinois. Such a project is considered important within a national framework since the Illinois hail climate is representative of that throughout the Midwest, and the crop-hail losses in the Midwest rank second nationally only to those of the Great Plains.

Recommendations on the advisability of conducting the experiment will be finalized through: (1) an evaluation of public attitude by a sampling method in the area of experiment; (2) storm forecasting studies based on historical data and data collected during the project's work; (3) radar detection of hail based on collected data; (4) studies of operational techniques based on historical and researched radar data; (5) studies to determine optimum seeding techniques based on the above and a literature study; and (6) measurements of silver content of rain and hail. A unique set of data collected during a series of severe midwestern storms will serve to bolster

the progress of the present program, but more importantly, it offers the opportunity to explore the community preparedness and warning problem.

An Illinois state law on the control of weather modification in Illinois has been enacted to insure proper conduct of future weather modification activities. Field and radar observations in 1974 have shown that cloud-based seeding techniques can be used successfully in Illinois.

Information derived from this research is used by other hail research projects, in the U.S. and abroad, the hail insurance industry, state legislators and other Illinois officials, and midwestern agricultural interests. Principal investigators from this program were invited to represent the U.S. and to take part in a planning meeting in Rome in November 1974. The meeting established a three-nation hail prevention experiment involving Italy, France, and Switzerland.

Second Inadvertent Weather Modification Workshop; *Vincent J. Schaefer*; State University of New York, Department of Atmospheric Sciences, Albany, New York 12222, \$33,000 for 12 months beginning April 1, 1974

This award provided for a Second Inadvertent Weather Modification Workshop conducted during October, 1974 at the Institute for Man and Science, Rensselaerville, New York. The purpose of the workshop was fourfold: (1) to bring together and summarize the most recent and authoritative information concerning inadvertent weather modification; (2) to enable the various groups which are intimately involved with inadvertent weather modification to discuss with each other interlocking aspects of the problem; (3) to provide opportunity for decision-makers in operating areas affected by weather modification to learn of the best current thinking about the problems and the possibilities for their solution within the framework of scientific, social and economic

constraints; and (4) to produce a planning document for the NSF Weather Modification Program Plan on Inadvertent Weather Modification.

Groups represented included the "producers" — those industrial and agricultural operations which give rise to weather modification processes; the "devisors" — the scientists and engineers who are concerned with understanding the mechanisms and operations useful for interfering with weather modification processes; and the "regulators" — the legislators and regulatory agency people who are concerned with the overall public interest in inadvertent weather modification.

Study Group on the Consequences of Weather Modification; *Howard J. Taubensfeld*; Southern Methodist University, School of Law, Dallas, Texas 75222; \$13,800 for 6 months beginning November 1, 1974

The weather modification program of the Federal government has developed along traditional agency lines with the specific purpose of meeting the sponsoring agency's mission objectives in each case. There was no central planning group which was charged with the responsibility of determining the overall needs of society in the field of weather modification and the relative or-

der of priority with which these needs should be met. As a result it is not clear how well the U.S. program in weather modification has grown to meet these needs when consideration is given to the political, economic, legal, ecological and social requirements of society for a weather modification capability. A Study Group on Societal Implications of Weather Modification was

formed by the Foundation at the request of the Interdepartmental Committee on Atmospheric Sciences (ICAS) in FY 1972 for the purpose of studying the needs of the country for weather modification operational capability and comparing these needs with the structure of the present Federal program as outlined in ICAS Reports 14, 15a, and 16.

This award is an additional six months beyond the third year of support which will enable the Interdepartmental Committee on Atmospheric Sciences to determine how well the Federal weather modification program, as now constituted, will meet the societal needs

of the nation, and where changes should be made.

Specific interactions with users include conferences, briefings, and papers concerning weather modification. Interactions included an address by the principal investigator to the entire federal weather modification community at the Fifteenth Interagency Conference on Weather Modification at Estes Park, Colorado, September, 1973. In addition to future addresses and chairmanships of weather modification conferences, the principal investigator will supervise a draft of the final report to be submitted to NSF and later dissemination to all interested federal agencies and appropriate users.

WEATHER HAZARD MITIGATION

The objectives of research on Weather Hazard Mitigation are to reduce the undesirable aspects of selected weather hazards. The major effort will be to continue the National Hail Research experiment (NHRE). The overall goal is to determine the potential for suppressing hail damage by cloud seeding, and the extent to which hail suppression can be accomplished effectively and efficiently on an operational basis.

National Hail Research Experiment; *David Atlas*; National Center for Atmospheric Research, Boulder, Colorado 80302; \$2,130,000 for 12 months beginning July 1, 1974

In the United States the annual agricultural loss due to hail storms is in excess of one-half billion dollars. While economic incentive to reduce damaging hail has long existed, it was not until the early 1970's that a definitive experiment on hail suppression was undertaken. The National Hail Research Experiment (NHRE) seeks to determine the potential for suppressing hail by cloud seeding and the extent to which hail suppression can be accomplished effectively on an operational basis. More specifically, the program objectives include:

1. The implementation of a statistical experiment aimed at proving or disproving the efficacy of hail suppression by the introduction of artificial seeding material such as silver iodide into storm systems.
2. Operation of a broad-based but highly focused and integrated research program aimed at understanding the mechanisms of both natural hail development and the effects of seeding on hail growth.
3. The execution of economic, social and legal studies aimed at assessing costs of a hypothetical hail suppression system, benefits and disbenefits, and social and legal factors relevant to the implementation of an operational system.

As the NHRE enters its fourth season, emphasis in the suppression experiment focuses upon critical review of

the experimental design as well as: (1) enhancement of suppression analysis staff by reassignments and new hires; (2) data base management reorganization stressing accuracy, accessibility, and comprehensiveness; and (3) establishing optimum statistical tests and methodology. Research in fiscal year 1975 emphasizes those factors critical to the suppression experiment. Studies on economic benefits and health hazard effects, in addition to the continuation of the cost-benefit studies of a hypothetical operational suppression project, are receiving strong emphasis.

NHRE maintains communications regarding on-going activities and general progress through such means as weekly news releases made during the field season and regular meetings of a citizen's council made up of local farmers and other individuals. Joint studies with the U.S. Department of Agriculture attempt to ascertain the feasibility of operational hail suppression programs in the Great Plains using on-going projects as examples. Exchange of data with the Crop Hail Insurance Actuarial Association should lead to improved estimates of local crop losses and the relation of physical hail parameters to crop damage. Economic studies based on data may lead to an operational strategy of combined hail insurance and suppression to minimize economic losses and risk.

Lightning Protection and Thunderstorms Electrification; *Charles B. Moore*; New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801; \$130,000 for 12 months beginning June 1, 1975

This grant will provide the last of four planned years of funding of a thunderstorm program carried out at the summit of the Magdalena Mountains near Socorro, New

Mexico, with the objective of determining the origin of thunderstorm electrification and its effects on lightning and precipitation growth.

Research objectives for this project period include: (1) investigation of lightning's anomalous behavior around elevated structures and development of improved means of lightning protection; (2) development of improved instrumentation to determine if lightning is responsible for enhanced growth of precipitation in thunderclouds; (3) determination of precipitation growth rates following lightning in thunderclouds; and (4) development of techniques to trigger lightning from thunderclouds.

Substantial progress has been accomplished by demonstrating: (1) a remarkable difference in the response of sharp and blunt lightning rods to approaching lightning leaders; and (2) the possibility of triggering lightning over land with rockets carrying wires. Efforts in this final phase of the project will be directed toward gaining a better understanding of why blunt and sharp lightning rods behave differently and

applying the knowledge to the design of more effective lightning protection systems.

The primary utilization plan for the result of this research involves the dissemination of information by direct contact, by talks and by publications. Help and advice is being provided to industrial and government users with lightning problems. Talks have been scheduled at Kennedy Space Center and at a meeting of The American Geophysical Union. A chapter is being prepared for a book on lightning to be published by Academic Press in September. A scientific paper entitled "Lightning Around Elevated Structures" is being prepared for the Journal of the Franklin Institute where many significant papers relative to lightning protection have been published. Written recommendations for the protection against lightning damage of sensitive electronic components and other artifacts will be prepared at the completion of this work.

WEATHER MODIFICATION SYSTEMS

This element is concerned with improvements in modification technology and evaluation techniques, particularly improved means to design, perform and evaluate weather modification experiments, predictive systems, and measurement methods.

Studies on the Dynamics, Energetics, Microphysics and Forecasting of Severe Local Storms; *Charles E. Anderson;* University of Wisconsin, Madison, Wisconsin 53706; \$96,000 for 12 months beginning January 1, 1975

The Cloud Physics Group of the Department of Meteorology, University of Wisconsin has been engaged in research studies on various aspects of the northeast Colorado severe local storms beginning in 1969, and is currently finishing a research program that commenced in 1971 on the "Features and Energy Budgets of Severe Local Storms in Northeast Colorado." The group is now in a position to exploit these findings to benefit directly the operational goals of the National Science Foundation in regards to the hail suppression experiment being executed by the National Hail Research Experiment (NHRE) Project (see page 000). This effort addresses the basic NHRE objectives which are: (1) to discover a seeding method or methods which will significantly decrease damaging hailfalls and, if possible, enhance rainfall; and (2) produce research which will give scientific insight into the mechanism of hail formation in order to make it possible to transfer hail suppression technology to geographical regions other than northeast Colorado.

An Accurate and Inexpensive Airborne Windfinding System; *John P. Chisholm;* Sierra Nevada Corporation, Reno, Nevada 89507, \$44,400 for 9 months beginning July 1, 1974

Airborne measurements of horizontal windfields are of vital importance to meteorological and weather modification research. Despite the need, there is a dearth of such data due to the high cost of the accurate navigation systems currently utilized for such measurements. Recent developments involving better utilization of the VORTAC system of air navigation have resulted in low cost navigational capability with sufficient accuracy to offer promise of providing a suitable base for the needed windfield measurements, and at the same time, of providing an economical, position-fixing system needed in meteorological research.

The major tasks of immediate concern under this project are:

1. Develop physical and numerical simulation of the circulation, hail embryo formation, and electrical charge distribution in local storms.

2. Devise an alternate approach to hail suppression by using chemical agents which act as ice suppressants and thereby prevent the appearance of the ice phase including hailstone embryos altogether. This approach, if successful, should increase rainfall by encouraging early droplet coalescence, thereby lessening the loss of water substance through anvil production.

3. Attempt to quantify results already obtained relating features of the mesoscale fields of equivalent potential temperature, surface wind patterns, and storm available potential energy to assist in the prediction of the location, time and intensity of these particular storms.

This grant provides funds to install, test, and compare the proposed system with the inertial navigation system on an NCAR aircraft. The specific steps taken were first to install the existing prototype navigation system in a meteorological research aircraft equipped with an inertial navigation windfinding system and the comparison of the two.

This windfinding system was configured for installation in a light aircraft in conjunction with NCAR personnel who provided guidance on the meteorological sensors to be utilized, and Atmospheric, Inc., who provided information for installing the system on their

aircraft. The resulting system was then installed and tested.

The results of this research will be made directly available to NCAR personnel, and NCAR in turn will report this information in their technical periodicals. Several commercial meteorological organizations are

aware of this project and will use the results if it proves successful. The position-fixing information is of interest to the navigational community who is kept thoroughly informed via concurrent cooperative efforts in the VORTAC improvement program.

Chemical Complexing of Silver Iodide-Alkali Iodide Aerosols Prepared for Cloud Seeding Purposes; *Briant L. Davis*; Institute of Atmospheric Sciences, South Dakota School of Mines and Technology, Rapid City, South Dakota 57701, \$103,900 for 24 months beginning September 1, 1972

Silver iodide (AgI) used in cloud modification in the field is usually vaporized from an acetone solution to facilitate handling. Since AgI is not directly soluble in acetone, "complexing materials" such as NaI or KI are usually added to the acetone to form a chemical complex with AgI to facilitate solution. Recently there has been considerable concern that the complexing material might have a significant effect upon nucleating efficiency of the nucleating particles produced from the generator. In a previous grant the principal investigator examined the effluent from a silver iodide-acetone generator using NaI as a complexing agent and discovered that three different hydrates are formed and that at least six different complexes can result. These complexes show a wide spread in nucleating efficiency, and can effect the overall performance of the nuclei depending upon which complexes dominate the effluent. This explains the wide

variation of results obtained from identical generators in the field.

Many field operators have now abandoned NaI and are using NH_4 as a complexing material with reportedly greatly improved nucleating efficiency.

This grant continues the analysis technique for both NH_4I and KI complexing materials to determine whether similar problems exist for these materials, and to assess the magnitude of their impact on nucleation efficiency. X-ray diffraction is the primary analytical tool used in the research. Research activities have been reported in professional journals, and results have been used by the South Dakota Weather Modification Commission, the Naval Weapons Center, private cloud seeding agencies, and educational institutions.

Cloud Seeding Generators for Biodegradable Organic Ice Nuclei; *Norihiko Fukuta*; University of Denver, Denver Department of Physics and Astronomy, Denver, Colorado 80201; \$100,400 for 12 months beginning July 15, 1974

One of the primary mechanisms available for purposeful weather modification is the changing of supercooled water into ice by the introduction of artificial ice nuclei. Such a triggering mechanism is currently being used for modification of summer rainfall, winter snowfall, supercooled fog, hail, and hurricanes. Currently, the most commonly used material for these artificial ice nuclei is silver iodide smoke, but there is growing concern that its continued use may result in undesirable effects on bacteria, plant, and some animal life. With increasing demands on silver for other technological uses, and its diminishing supply added to these concerns, it becomes prudent to undertake the development of alternative, environmentally acceptable forms of artificial ice nucleus generation before the situation becomes more acute.

The major objective of this research is to develop highly efficient cloud seeding generators which use

biodegradable, low cost, ecologically safe, and readily available organic compounds. Three different ice nucleus generators will be designed and constructed using both the supersonic and jet mixing methods of smoke particle production. The supersonic nozzle will be redesigned so as to maximize the desirable combination of particle size and nucleation efficiency.

The growing promise of using cloud seeding on the basis of this program attracted the interest of at least one company in Europe and one in the U.S. who have expressed interest in the manufacture of these generators when testing is completed. Additional investigations by Mr. Fukuta with pyrotechnic experts have indicated the strong possibility of adapting the products of this research to use in droppable pyrotechnic flares.

Cloud Simulation and Aerosol Laboratory; *Lewis O. Grant*; Colorado State University, Department of Atmospheric Sciences, Fort Collins, Colorado 80521; \$18,000 for 12 months beginning Nov. 1, 1974

This grant provides the NSF portion of an award funded by NSF, Department of Defense, Department of Interior, and the Department of Commerce to the Cloud Simulation and Aerosol Laboratory at Colorado State University. The purpose of this program is to provide a standard calibration facility for ice nuclei materials, generators, and instrumentation. Such a facility is basic to weather modification. This funding provides base support only, additional support coming from user fees.

This program by Colorado State University provides

experienced personnel, standard procedures and techniques, and state-of-the-art equipment and instrumentation for testing cloud seeding devices and agents. The facility supports the many research and operational weather modification programs now being conducted in this country and abroad, and is available to university, government, and private user groups. The basic objective is to provide standards for intercomparison and calibration in the development of improved seeding materials and equipment.

Dual-Doppler Radar Investigations of Wind Fields in Severe Storms; *Gordon C. Little*; National Oceanic and Atmospheric Administration, Wave Propagation Laboratory, Boulder, Colorado; \$60,000 for 12 months beginning July 1, 1974

This grant is to the National Oceanic and Atmospheric Administration (NOAA) to investigate wind fields in severe storms, especially hailstorms, through the use of a dual-doppler radar. The work will be carried out in the Colorado area in conjunction with the National Hail Research Experiment (NHRE) managed by the National Center for Atmospheric Research under NSF sponsorship. The NOAA Wave Propagation Laboratory has developed a technique of using the Doppler

information from two separate radars, scanning a common volume of atmosphere in which there is precipitation, to observe the total three-dimensional wind field in the volume. The particle velocity fields in a given plane can be simply calculated from the radial components sensed by each radar. The air motion in the plane can be found by estimating the terminal velocities of the particles and subtracting their contribution to the total particle velocity field.

Evaluation and Design of Weather Modification Experiments; *Joanne Simpson*; University of Virginia, Department of Environmental Sciences, Charlottesville, Virginia 22903, \$50,000 for 12 months beginning July 1, 1974

The purpose of this research is to improve the design and evaluation methods for modification of selected cumulus cloud systems, using a combination of numerical simulation and statistical analysis. The objective is to overcome the huge natural variations inherent in atmospheric processes, and the great expense and labor required to obtain adequate data. In this project the best available knowledge and measurement capability are used together with numerical simulation and several types of statistical tools, to select experimental situations where natural variability can be compensated for, modelled or predicted. Specific tasks include: (1) analysis of the 1973 Florida Area Cumulus Experiments (FACE) and suggestions for improved experimental design; (2) analysis of the seeding potential for West Coast winter storms as evidenced by Santa Barbara data on preliminary design for a proof-of-concept West Coast experiment; and (3) aid in the design of the High Plains Cumulus Experiment of the Bureau of Reclamation.

The following groups will use the output of the Project: National Oceanic and Atmospheric Administration in their continued analysis and operation of FACE, and in their design for an extratropical storm modification experiment; Bureau of Reclamation in their design and analysis of the High Plains Program; other governmental agencies, including NSF, who anticipate contributing to the future South West precipitation augmentation experiment; the scientific community and general public who benefit from the increased credibility that can result from weather modification experiments; the private sector in weather modification which benefits from the clarification steps to determine the probability of success of a given modification hypothesis when applied to specific conditions; State and local water management authorities; and the international community concerned with water resources.

APPENDIX

FY 1975 Awards and Active Projects in AENV

<i>Principal Investigator/ Institution</i>	<i>Title</i>	<i>Amount/ FY of Award</i>	<i>Effective Date/ Duration</i>	<i>Page</i>
ENVIRONMENTAL EFFECTS OF ENERGY				
Biggs, Robert B. Univ. of Delaware	Research on the Effects of Crude Oil Transfer and Upstream Refineries on Delaware Bay	\$300,800 FY 74	3/1/74 15	6
Biggs, Robert B. Univ. of Delaware	An Evaluation of Multi-Purpose Offshore Industrial Port Islands	\$216,830 FY 74	5/1/74 12	7
Whipple, William, Jr.	The Petroleum Industry in the Delaware Estuary	\$450,000 FY 75	3/1/75 12	7
ENVIRONMENTAL ASPECTS OF TRACE CONTAMINANTS				
Air Quality				
Pitts, James N. Univ. of California	Chemical Transformations in Photochemical Smog and Their Applications	\$495,700 FY 75	1/1/75 12	9
Richardson, David L. Arthur D. Little Inc.	A Study of Atmospheric Sulfate Pollution from Biological Sources	\$59,200 FY 75	6/15/75 6	9
Zoller, William H. Univ. of Maryland	Atmospheric Impact of Major Sources and Consumers of Energy	\$290,000 FY 75	10/1/74 11	10
Metals				
Birge, Wesley J. Univ. of Kentucky	Effects and Environmental Indicators of Metallic Pollutants on Vertebrate Embryos	\$61,700 FY 75	6/1/75 12	11
Carpenter, Roy Univ. of Washington	Geochemistries of Mercury, Arsenic and Other Metals in Puget Sound	\$59,500 FY 75	6/1/75 12	11
Chappell, Willard R. Univ. of Colorado	Transport and the Biological Effects of Molybdenum in the Environment	\$145,000 FY 75	6/1/75 12	12
Clarkson, Thomas W. Univ. of Rochester	Heavy Metals as Environmental Hazards to Man	\$241,000 FY 75	6/1/75 12	12
Edwards, Harry W. Colorado State Univ.	Environmental Contamination Caused by Lead	\$223,200 FY 76	7/1/75 12	12
Fulkerson, William Oak Ridge National Laboratory	Ecology and Analysis of Trace Contaminants	\$700,000 FY 75	6/1/75 7	13
Gordus, Adon A. Univ. of Michigan	Environmental Aspects of Trace Metals on Human Hair	\$131,000 FY 74	11/1/73 18	14
Hammond, Paul B. Univ. of Cincinnati	Sources of Lead in Children	\$77,800 FY 75	5/1/75 12	14

<i>Principal Investigator/ Institution</i>	<i>Title</i>	<i>Amount/ FY of Award</i>	<i>Effective Date/ Duration</i>	<i>Page</i>
Kneip, Theodore J. N.Y. University Medical Center	Cadmium in an Aquatic Ecosystem — Distribution and Effects	\$50,700 FY 74	5/1/74 12	15
Lower, William R. Univ. of Missouri	Drosophila as Indicators of Environmental Lead and Cadmium	\$30,000 FY 75	4/1/75 12	15
Parks, George A. Stanford Univ.	Mercury in the Biogeochemical Environment	\$85,000 FY 74	9/15/73 12	16
Rolfe, Gary L. Univ. of Illinois	An Interdisciplinary Study of Environmental Pollution by Lead and Other Metals	\$509,700 FY 75	10/1/74 12	17
Soldano, B. A. Furman Univ.	A Search for Non-Biogenic Photochemical Mercury Methylation Processes Involving Suspended Water Drops	\$30,600 FY 74	7/1/73 12	17
Wetherill, George W. Univ. of California	Human Lead Metabolism	\$66,000 FY 74	4/15/74 12	17
Wixon, Bobby Univ. of Missouri	An Interdisciplinary Investigation of Environmental Pollution by Lead and Other Heavy Metals from Industrial Development in the New Lead Belt of Southeastern Missouri	\$240,600 FY 75	9/1/74 12	18
Yost, Kenneth J. Purdue University	Environmental Flow of Cadmium and Other Trace Metals	\$372,000 FY 75	1/1/75 12	19
Nitrate				
Commoner, Barry Washington Univ.	A Study of Certain Ecological and Economic Consequences of the Use of Inorganic Nitrogen Fertilizer	\$300,000 FY 75	6/1/75 12	20
Pratt, Parker F. Univ. of California	Nitrate in Effluents from Irrigated Lands	\$490,100 FY 75	8/4/75 12	20
Organic Chemicals of Commerce				
Commoner, Barry Washington Univ.	Identification of Mutegenic Organic Compounds in Environmental Samples	\$180,200 FY 75	4/1/75 12	22
Hites, Ronald A. Massachusetts Inst. of Technology	Fates of Industrial Synthetic Organic Chemicals: A Case Study	\$107,900 FY 75	6/1/75 12	22
Supporting Methodology				
Almeida, Silverio P. Virginia Polytechnic Inst. and State Univ.	A Water Pollution Monitoring Laser Optical System	\$73,600 FY 75	7/1/75 12	24
Braman, Robert S. Univ. of South Florida	An Environmental Study of Selected Trace Elements	\$44,000 FY 75	6/1/75 12	24
Cahill, T. A. Univ. of California	Application of Alpha Scattering and X-ray Fluorescence to Real-Time Analysis of Trace Elements	\$15,000 FY 75	1/15/75 12	25
Chamberlain, Owen Lawrence Berkeley Laboratory	Investigation of the Use of the Resonance Raman Effect as an Environmental Monitor	\$78,500 FY 74	11/1/73 12	25

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Donnelly, Russell J. University of Oregon	Application of Cryogenic Techniques to Problems in Air Pollution	\$95,100 FY 74	2/1/74 13	25
Flinn, James E. Battelle Memorial Institute	Seminar on Early Warning Systems for Toxic Substances	\$4,900 FY 74	3/1/74 12	26
Goldstein, George M. U.S. Environmental Protection Agency	Plan for a National Environmental Monitoring Specimen Bank	\$100,000 FY 74	6/1/74 24	26
Hadeishi, Tetsuo Energy Research and Development Administration	Extention of IZAA Technique to Multiple Elements	\$99,200 FY 75	4/1/75 12	27
Hinkley, E. D. Massachusetts Institute of Technology	Diode Laser Multi-Pollutant Ambient Air Monitoring	\$116,800 FY 75	3/1/75 12	27
Metcalf, Robert L. Univ. of Illinois	Evaluation of a Laboratory Microcosm for Study of Toxic Substances in the Environment	\$61,600 FY 75	7/15/74 12	28
Mooradian, Aram Massachusetts Institute of Technology	Tunable Lasers for Application to Air Pollution Measurements	\$80,800 FY 75	5/1/75 12	28
Novakov, T. Univ. of California	Study of the Chemistry of Atmospheric Particulates by Electron Spectroscopy by Chemical Anaiysis (ESCA)	\$210,600 FY 75	7/1/74 12	28
Petric, William L. National Academy of Science	Continuing Support for the Subcommittee on the Geochemical Environ- ment in Relation to Health and Disease	\$10,000 FY 74	1/17/74 12	29
Proctor, Edward K., Jr. Stanford Research Institute	Remote Measurement of Air Pollutants	\$300,800 FY 73	5/1/73 24	30
West, Phillip W. Louisiana State Univ.	Research on Analytical Methods for the Determination of Trace Elements	\$28,200 FY 75	8/1/74 12	30
Williams, Colin B. IRT Corporation	Fluorescence Immunoassay Methods for the Detection of Organic Envi- ronment Contaminants	\$76,400 FY 75	3/1/75 12	31

Program Development and Utilization

Chan, Fred Y. Stanford Research Institute	Program on Ranking Manufactured Organic Chemicals for Research Priorities	\$145,400 FY 74	5/1/74 12	32
Dickson, Kenneth L. Virginia Polytechnic Inst. and State University	The Restoration and Recovery of Damaged Ecosystems	\$8,000 FY 75	1/1/74 12	32
Ellis, Robert H. Rensseleer Poly- technic Inst.	Planning and Management of Problem Oriented Interdisciplinary Research	\$600 FY 75	12/1/74 3	32

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Hemphill, Delbert D. Univ. of Missouri	Ninth Annual Conference on Trace Substances in Environmental Health	\$15,000 FY 75	6/1/75 12	33
Nelson, Norton New York Univ.	Workshop to Select Organic Chemicals for Environmental Research	\$15,000 FY 74	5/1/75 12	33
Neuhold, John Inst. of Ecology	Ecosystem Processes and Organic Contamination	\$59,900 FY 75	1/15/75 12	33
Totter, John R. Oak Ridge National Laboratory	NSF/RANN Trace Contaminants Program Information Service	\$10,200 FY 74	4/1/73 18	34

REGIONAL ENVIRONMENTAL MANAGEMENT

Land Use Allocation

Anderson, Orson Univ. of California	Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region	\$147,900 FY 75	6/1/75 12	36
Bosselman, Fred R. Ross, O'Keefe, Hardies Babcock and Parsons	Coordination of Environmental and Land Use Controls	\$324,800 FY 74	6/1/74 18	37
Brewer, John W. Univ. of California	Land Use, Energy Flow and Decision Making in Human Society	\$147,000 FY 75	1/1/75 6	38
Castle, Emery N. Oregon State Univ.	Equity Considerations and Compensation Techniques as Related to Increased Public Control of Land Use	\$98,700 FY 75	7/1/74 18	38
Chatland, Harold Assoc. of Monterey Bay Area Governments	Regional Interaction of Resource Utilization, Environmental Quality and Economic Development	\$14,800 FY 74	5/1/74 8	38
Craven, Clyde W. Jr. Oak Ridge National Laboratory	Regional Environmental Systems Analysis	\$745,000 FY 74	6/1/73 18	39
Delflache, Andre P. Lamar University	Control of Land Subsidence in the Texas Gulf Coast Area	\$68,700 FY 74	6/1/73 24	39
Drake, Charles L. Dartmouth College	Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region	\$78,700 FY 75	6/1/75 12	36
Fruh, E. Gus Univ. of Texas	Methodology to Evaluate Alternative Coastal Zone Management	\$328,200 FY 75	6/1/75 12	40
Gannon, John E. Univ. of Michigan	Ecological and Sociological Determinants of Land Use Decisions	\$375,000 FY 75	3/1/75 18	40
Godschalk, David R. Univ. of North Carolina	Defining the Constitutional Issues of Growth Management	\$64,800 FY 75	5/1/75 12	41
Goldman, Charles R. Univ. of California	Environmental Management Research in the Lake Tahoe Basin	\$425,000 FY 75	11/1/74 12	42

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Haimes, Yacov Y. Case Western Reserve University	Multiobjective Analysis in the Maumee River Basin	\$55,000 FY 75	4/1/75 16	42
Heady, Earl O. Iowa State Univ.	National Environmental Models of Agricultural Policy, Land Use, and Water Quality	\$486,700 FY 74	6/1/74 24	43
Ingram, Helen M. Univ. of Arizona	Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region	\$16,400 FY 75	6/1/75 12	36
Jameson, Donald A. Colorado State Univ.	Regional Analysis and Management of Environmental Systems	\$320,900 FY 75	9/1/75 12	43
Kidd, David E. Univ. of New Mexico	Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region	\$175,800 FY 75	6/1/75 12	36
Kramer, Paul J. Duke Univ.	Cooperative Evaluation and Analysis of Cost Effectiveness of Appli- cations of Controlled Environmental Facilities	\$89,400 FY 75	7/1/75 12	44
Kunitz, Stephen J. Univ. of Rochester	Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region	\$9,600 FY 75	6/1/75 12	36
Levy, Jerrold E. Univ. of Arizona	Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region	\$102,500 FY 75	6/1/75 12	36
Little, Ronald L. Arizona State Univ.	Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region	\$40,800 FY 75	6/1/75 12	36
Mann, Dean E. Univ. of California	Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region	\$20,000 FY 75	6/1/75 12	36
Mar, Brian W. University of Washington	Assessment of Selected Environmental Modeling Projects	\$6,200 FY 75	5/1/75 6	45
Meadows, Dennis L. Dartmouth College	Natural Resources Availability and Policy Implications in the United States	\$133,300 FY 74	9/15/73 12	45
McCarthy, Michael M. Atomic Energy Comm.	Regional Environmental Systems Analysis	\$193,400 FY 75	1/1/75 10	46
Niemann, Bernard J. Univ. of Wisconsin	National Symposium on Data Requirements and Special Information Systems for Identifying, Planning and Regulating Geographical Areas of Critical Environmental Concern	\$4,000 FY 75	5/1/75 4	46
Northrop, Gaylor M. Center for the Envi- ronment and Man	The Impact of Economic Development and Land Utilization Policies on the Quality of the Environment	\$35,500 FY 75	5/1/75 6	47
Price, Monroe Univ. of California	Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region	\$26,300 FY 75	6/1/75 12	36
Raper, C. David North Carolina State University	Cooperative Evaluation and Analysis of Cost Effectiveness of Appli- cations of Controlled Environmental Facilities	\$101,500 FY 75	7/1/75 12	44

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Reuss, John W. Montana State Univ.	Impact of Large Recreational Development Upon a Semi-Primitive Environment	\$261,000 FY 74	7/1/73 18	47
Rosenbaum, Nelson Urban Institute	Assessment of Programs for Public Participation in State Land Use Decision-Making	\$72,900 FY 75	6/1/75 9	48
Schreuder, Gerald F. Univ. of Washington	Forest Land-Use Allocation and Environmental Systems Evaluation	\$249,900 FY 74	6/1/74 18	48
Stone, John Mitre Corporation	Seminars on Cellulose Conversion and Leaf Protein Production	\$6,600 FY 75	3/1/75 3	49
Stuart, David G. Montana State Univ.	Impact of a Large Recreational Development Upon a Semi-Primitive Environment	\$43,000 FY 75	1/1/75 12	49
Thomas, Harold A, Jr. Harvard University	Analysis of a New Approach for Environmental Policy Evaluation	\$212,900 FY 74	7/1/74 12	49
Thompson, Russel G. Univ. of Houston	National Economic Models of Industrial Water Use and Waste Treatment	\$404,200 FY 74	5/1/74 16	50
Walther, Eric G. N. Arizona Society of Science and Art	Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region	\$27,800 FY 75	6/1/75 12	36
Williams, Michael D. John Muir Inst.	Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region	\$106,200 FY 75	6/1/75 12	36
Residuals Management				
Boersma, L. Oregon State Univ.	Utilization of Waste Heat in a System for Management of Animal Residuals to Recover and Recycle Nutrients	\$71,500 FY 75	7/1/75 12	51
Chamberlain, Theodore Chesapeake Research Consortium, Inc.	Research on the Chesapeake Bay to Provide the Knowledge Base for Waste Outfall Management	\$160,000 FY 75	10/1/74 2	52
Dick, Richard I. University of Delaware	Process Selection for Optimum Management of Regional Wastewater Treatment Residuals	\$59,100 FY 75	7/1/75 14	52
Elkan, Gerald H. N.C. State Univ.	The Role of Microorganisms in the Decomposition of Deep Well Injected Liquid Industrial Wastes	\$73,300 FY 74	7/1/73 24	53
Guerra, Carlos R. Public Service Electric and Gas Company	Integration of Thermal and Food-Processing Residuals into a System for Commercial Culture of Fresh-Water Shrimp	\$127,900 FY 76	7/1/75 16	53
Kadlec, Robert H. University of Mich.	Feasibility of Utilization of Wetland Ecosystem for Nutrient Removal from Secondary Municipal Wastewater Treatment Plant Effluent	\$140,000 FY 76	7/1/75 12	54
Mellroy, William Grumman Ecosystems Corporation	Separation of Cellulose Fiber from Mixed Municipal, Industrial, and Agricultural Residuals for Utilization as a Constituent of Animal Feed	\$50,900 FY 75	3/1/75 6	55
Koegel, Richard Univ. of Wisconsin	Improvement and Evaluation of Techniques for the Mechanical Removal and Utilization of Excess Aquatic Vegetation	\$160,000 FY 74	7/1/73 36	55

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Lauria, Donald T. Univ. of North Carolina	Regional Sewerage Planning by Mixed Integer Programming	\$17,000 FY 74	4/1/73 18	56
Metcalf, Theodore G. Univ. of New Hampshire	Control of Virus Pathogens in Municipal Wastewater and Treatment Residuals by Irradiation with High-Energy Electrons	\$43,000 FY 76	7/1/75 12	56
Odum, Howard T. University of Florida	Feasibility of Utilizing Cypress Wetlands for Conservation of Water and Nutrients in Effluent from Municipal Wastewater Treatment Plants	\$223,600 FY 75	5/1/75 12	57
Probst, Ronald F. Water Purification Assoc.	Western Water Needs for Energy Conversion and Processing with Environmental Quality Constraints	\$36,900 FY 74	6/1/74 4	57
Queen, W. H. Chesapeake Research Consortium, Inc.	Management of Physical Alterations to the Edges of Chesapeake Bay and Their Effects on Environmental Quality	\$280,800 FY 75	12/1/74 7	58
Rathje, William J. University of Arizona	Socioeconomic Correlates of Household Food Residuals	\$15,200 FY 75	4/1/75 5	58
Ryther, John H. Woods Hole Oceano- graphic Inst.	Research on Management of Effluent from Secondary Wastewater Treatment Utilizing a Marine-Aquaculture System for Removal of Inorganic Nutrients	\$250,000 FY 74	5/15/74 12	59
Ryther, John H. Woods Hole Oceano- graphic Institution	Human Enteric Viruses in a Waste-Recycling Aquaculture System	\$104,000 FY 74	7/1/73 24	60
Sagik, Bernard P. University of Texas	Virus Survival in Soils Injected with Municipal Wastewater Treatment Residuals	\$58,900 FY 75	2/1/75 12	60
Schad, Theodore M. National Academy of Sciences	Management of Mining Residuals by Placement into Underground Voids	\$12,300 FY 75	2/1/75 2	60
Schmidt-Collerus, Josef J. Denver Research Inst.	Characterization of Contaminants in Oil Shale Residuals and the Potential for Their Management to Meet Environmental Quality Standards	\$40,000 FY 75	3/15/75 12	61
Slotta, Larry S. Oregon State Univ.	Assessment of Impact on Estuarine Ecosystems Resulting from Residuals Management by Dredging	\$276,000 FY 76	7/1/75 12	61
Smith, James L. Colorado State Univ.	Land Management of Subsurface — Injected Wastewater Liquid Residuals	\$68,900 FY 75	5/1/75 12	62
Subramanian, R. V. Washington State Univ.	Immobilization of Hazardous Residuals by Encapsulation	\$37,400 FY 75	3/1/75 18	63
Sullivan, J. Kevin Chesapeake Research Consortium, Inc.	Relative Impact of Selected Pollutants from Diffuse and Discrete Sources on Quality of Water in the Chesapeake Bay	\$192,600 FY 75	12/1/74 7	63
Trump, John G. Massachusetts Inst. of Technology	High Energy Electron Irradiation of Wastewater Liquid Residuals	\$198,000 FY 75	5/1/75 12	64

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Urban-Rural Environments				
Clark, Edwin Council of Environmental Quality	Study of the Economic, Environmental, Natural Resource and Social Effects Associated with Alternative Metropolitan Development Patterns	\$25,000 FY 75	7/1/75 18	65
Conant, Ralph W. Southwest Center for Urban Research	Environmental, Political and Economic Basis for Decision Making in Land Use Management	\$225,900 FY 75	12/1/74 12	65
Cox, Doak C. Univ. of Hawaii	Hawaiian Environmental Simulation Model	\$225,200 FY 75	10/1/74 12	66
Croke, Kevin G. Argonne National Laboratory	Environmental Control and Land Use Interactions in the Chicago Region	\$390,000 FY 74	9/1/73 24	73
Johnson, Ralph W. University of Washington	Applicability of Selected European Laws, Institutions and Policies to Environmental Problems in the United States	\$85,900 FY 74	6/1/73 18	67
Koenig, Herman E. Michigan State Univ.	Design and Management of Rural Ecosystems	\$178,500 FY 75	7/1/75 12	67
Linville, Jack American Inst. of Planners	Urban Ecosystems Applied-Access Study Workshop	\$39,100 FY 75	7/11/74 18	68
Mack, Dick A. Atomic Energy Commission	Survey of Instrumentation for Environmental Monitoring	\$113,900 FY 75	6/1/75 12	68
Maninger, R. C. Univ. of California	Development of a San Francisco Bay Area Air Pollution Model	\$30,000 FY 75	2/15/75 6	69
Miner, J. Ronald Idaho Research Foundation, Inc.	Evaluation of Alternative Approaches to Control Odors from Animal Feed Lots	\$13,650 FY 75	1/1/75 6	69
Okun, Daniel A. Univ. of North Carolina	Applicability of Reorganization of Water Management in England to Wastewater Management in the United States	\$19,100 FY 74	7/1/73 18	70
Priest, Donald E. Urban Land Inst.	Techniques for Increasing Project Scale and Improving Land Use Balance in the Urbanization Process	\$58,000 FY 75	5/15/75 8	70
Russel, Philip B. Stanford Research Institute	Development of an Acoustic Sounder Network for Air Pollution and Land-Use Applications	\$44,900 FY 75	4/1/75 12	71
Scrimshaw, Nevin S. MIT	A Comprehensive Analysis of Protein Resources: Present Status, Future Requirements, and Research Needs	\$181,900 FY 75	1/15/75 6	71
Socolow, Arthur A. Commonwealth of Pennsylvania	Environmental Geology Applied to Rural/Urban Needs	\$55,800 FY 75	6/1/75 6	72

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Stearns, Forest Univ. of Wisconsin	Urban Ecosystem Studies	\$10,000 FY 74	5/15/74 8	72
Steinitz, Carl Harvard Univ.	The Interaction Between Urbanization and Land	\$375,100 FY 75	2/1/75 12	72
Steinitz, Carl Harvard Univ.	Collaborative Workshop for Testing a Regional Model of the Boston Southeast Sector	\$23,000 FY 75	9/1/74 9	73
Tolley, George S. Univ. of Chicago	Environmental Control and Land Use Interactions in the Chicago Region	\$597,000 FY 74	9/1/73 24	73
Urthe, Edward E. Stanford Research Institute	Development of an Acoustic Sounder Network in the San Francisco Bay Area	\$46,100 FY 74	6/1/74 9	75
Vukovich, Fred M. Research Triangle Institute	An Optimum Meteorological and Air Pollution Sampling Network Selection in Urban Areas	\$75,000 FY 75	12/1/75 12	75
Wilson, David G. Massachusetts Insti- tute of Technology	An Investigation of the Potential for Resource Recovery from Demolition Residuals	\$39,000 FY 75	1/15/75 8	75
Wittwer, Sylvan National Academy of Sciences	Study of Changing Climatic and Weather Patterns and Their Effects on Agricultural and Renewable Resource Productivity	\$150,000 FY 75	5/1/75 12	74

EARTHQUAKE ENGINEERING

Berg, Joseph W. National Academy of Sciences	Partial Support of the Committee on Seismology	\$15,800 FY 74	7/1/73 24	78
Biggs, John M. Massachusetts Inst. of Technology	Evaluation of Seismic Safety of Buildings	\$236,500 FY 75	9/1/74 24	78
Bogdanoff, John L. Purdue University	Seismic Resistance of Fossil-Fuel Power Plants	\$372,100 FY 75	1/1/74 24	79
Bolt, Bruce A. Univ. of California	Design Earthquake Parameters	\$65,500 FY 75	7/1/75 24	79
Brune, James Univ. of California	Laboratory and Numerical Simulation of Nearfield Earthquake Ground Motion	\$93,200 FY 75	6/1/75 24	80
Chopra, A. K. Univ. of California	Earthquake Response of Dams Including Hydrodynamic and Foundation Interaction	\$89,400 FY 75	8/30/74 24	80
Clough, Ray W. Univ. of California	Energy Absorption Characteristics of Structural Systems Subject to Earthquake Excitation	\$940,400 FY 74	11/1/73 12	80
Clough, Ray W. Univ. of California	National Information Service in Earthquake Engineering	\$994,500 FY 75		81
Clough, Ray W. Univ. of California	A High Speed Data Acquisition System for Earthquake Engineering Research in Davis Hall	\$152,500 FY 74	3/1/74 12	81

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Cornell, C. Allin Massachusetts Inst. of Technology	Structural Loads Analysis and Specification	\$303,000 FY 74	9/1/73 24	81
Cox, Doak C. Univ. of Hawaii	Pacific Tsunami Catalog	\$17,200 FY 74	7/1/73 12	82
Crist, Robert A. National Bureau of Standards	Workshop on Earthquake Resistant Masonry Construction	\$20,800 FY 75	6/1/75 4	82
Drenick, R. F. Polytechnic Institute of Brooklyn	A Minimax Procedure for Specifying Earthquake Motions	\$32,500 FY 75	4/1/75 24	82
Duke, C. Martin Univ. of California	Effects of Site and Source on Earthquake Ground Motions	\$366,200 FY 74	7/1/73 36	82
Eberhard, John P. American Institute of Architects Re- search Corporation	Architect's Role in Reducing Earthquake Damage to Buildings	\$20,000 FY 75	4/1/75 7	83
Fintel, Mark Portland Cement Association	Shear Walls in Earthquake Resistant Structures	\$744,800 FY 74	1/1/74 18	83
Galambos, T. V. Washington University	Feasibility Study of Dynamic Tests on Full Scale Eleven Story Building In Pruitt-Igoe Housing Project	\$20,000 FY 75	4/1/75 3	83
Goel, Subhash C. Univ. of Michigan	Inelastic Hysteresis Behavior of Structural Members Subjected to Com- bined Cyclic Bending and Axial Forces for Use in Studying the Behavior of Braced Frame Structures During Earthquakes	\$125,800 FY 75	1/15/75 24	84
Hart, Gary C. Univ. of California	Century City: Full Scale Seismic Laboratory	\$295,100 FY 74	7/1/73 36	84
Hass, J. E. Univ. of Colorado	Socioeconomic and Political Consequences of Earthquake Prediction	\$114,100 FY 75	2/1/75 7	84
Hawkins, Neil M. Univ. of Washington	Earthquake Induced Bond of Reinforced Concrete	\$84,600 FY 74	9/1/74 12	85
Hawkins, Neil M. Univ. of Washington	Seismic Resistance of Concrete Slab to Column and Wall Connections	\$115,300 FY 75	2/1/74 12	85
Hegemier, G. A. Univ. of California	Earthquake Response and Damage Prediction of Reinforced Concrete	\$718,000 FY 74	3/1/74 18	85
Housner, George W. California Inst. of Technology	Effects of Damage From Strong Earthquakes	\$436,800 FY 75	9/13/74 24	86
Hudson, Donald E. California Inst. of Technology	Earthquake Engineering Instrumentation	\$245,300 FY 74	6/1/74 12	86
Hudson, Donald E. California Inst. of Technology	National Information Service for Earthquake Engineering	\$104,000 FY 75	5/1/75 12	86

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Hwang, Li Sen Tetra Tech, Inc.	Tsunami Research and Engineering Applications	\$95,700 FY 75	6/1/74 12	87
Jones, Martin V. New England Bureau, Inc.	Mini Technology Assessment of Earthquake Prediction Techniques and Their Applications	\$21,000 FY 74	6/1/74 6	87
Jones, Barclay G. Cornell Univ.	Regional Analysis for Development Planning in Disaster Areas	\$91,200 FY 73	11/17/72 24	87
Knopoff, Leon Univ. of California	Stochastic Seismology	\$112,500 FY 74	10/15/73 24	87
Kozin, Frank Polytechnic Inst. of Brooklyn	Optimal Filtering Techniques Applied to Analysis and Modeling of Earthquake Data	\$174,700 FY 74	6/1/73 24	88
Kramer, Samuel National Bureau of Standards	Development of Comprehensive Seismic Design Provisions	\$415,000 FY 75	9/9/74 20	88
Kunrcuther, Howard C. University of Pennsylvania	Reducing Loses from Selected Natural Hazards	\$429,600 FY 74	7/1/73 18	88
Lee, Kenneth L. Univ. of California	Instrumentation for Seismic Earth Pressure Measurement	\$8,500 FY 74	4/1/74 12	89
Matthiesen, R. B. U.S. Geological Survey	Strong Motion Instrumentation Program	\$700,000 FY 75	10/1/74 12	89
McCue, Gerald M. McCue, Boone, Tomsick	Building Enclosure and Finish Systems	\$70,300 FY 75	11/7/74 9	89
Newmark, N. M. Univ. of Illinois	Design for Protection Against Natural Hazards	\$476,500 FY 75	5/1/75 24	90
Raichlen, Fredric California Inst. of Technology	A Study of Tsunamis	\$108,600 FY 75	5/15/75 18	90
Sangrey, D. A. Cornell Univ.	Behavior of Fine Grained Soil Under Earthquake and Other Repeated Loading	\$97,400 FY 75	6/1/74 24	91
Scholl, Roger E. John A. Blume and Associates	Project Rio Blanco Low-Rise Motion Damage Study	\$19,400 FY 74	7/1/74 9	91
Scott, Ronald F. California Inst. of Technology	Dynamic Soil Testing by Centrifuge	\$82,200 FY 75	10/15/74 12	92
Seed, H. Bolton Univ. of California	Analysis of Soil Structure Interaction Effects for Massive Embedded Structures During Earthquakes	\$109,600 FY 74	7/1/74 24	92
Shah, Haresh C. Stanford University	Measurements and Evaluation of Dynamic Characteristics of Structures	\$39,100 FY 74	6/1/74 12	92

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Sozen, Mete A. University of Illinois	Effects of Earthquake Motions on Reinforced Concrete Buildings	\$316,100 FY 75	9/16/74 24	93
Simonson, T. R. G. M. Simonson & T. R. Simonson Engineers	Seismic Resistant Design of Mechanical and Electrical Systems	\$70,200 FY 75	3/1/75 9	93
Streeter, Victor L. Univ. of Michigan	Nonlinear Saturated Soil Motions Resulting from Earthquakes	\$144,900 FY 75	6/15/74 24	93
Weisbacker, L. W. Stanford Research Institute	A Technology Assessment of Earthquake Prediction	\$283,500 FY 74	6/1/74 12	94
White, Richard N. Cornell Univ.	Shear Transfer in Thickwalled Reinforced Concrete Structures Under Seismic Loading	\$71,300 FY 75	6/1/75 12	94
Whitman, R. V. Massachusetts Inst. of Technology	Seismic Design Analysis for Eastern Metropolitan Areas	\$648,500 FY 74	6/5/74 30	94
Wiggins, John H. J. H. Wiggins Company	Cost-Benefit Risk Analysis of Research Budgeting for Selected Natural Hazards	\$41,500 FY 75	6/30/75 9	94
Wobbeking, Bernard American Society for Engineering Education	Summer Institute on Protective Design	\$18,300 FY 75	3/15/75 12	95
Wu, Theodore Y. California Inst. of Technology	Theoretical Studies of Tsunamis	\$92,500 FY 75	5/15/75 18	95
FIRE RESEARCH				
Bender, Richard Univ. of California	Architectural Approaches to Fire Safety	\$33,500 FY 75	11/1/74 12	96
Corlett, Richard C. University of Washington	Mechanics of Wildfire Suppression	\$5,000 FY 75	6/1/75 3	96
Durbetaki, P. Georgia Inst. of Technology	Prediction of Fire Hazard in Buildings	\$64,400 FY 74	4/1/74 12	97
Edmunds, Howard Harvard University	The Home Fire Project	\$315,900 FY 74	6/1/74 12	97
Einhorn, Irving N. University of Utah	Physiological and Toxicological Aspects of Smoke Produced During the Combustion of Polymeric Materials	\$220,900 FY 75	9/1/74 8	97
Fristrom, R. M. Johns Hopkins Univ.	Fire Problems Research and Synthesis	\$20,100 FY 75	4/15/75 2	98
Glassman, Irvin Princeton Univ.	Flame Spreading Across Liquid Fuels	\$73,000 FY 74	3/1/74 12	98
Grisamore, Nelson T. National Academy of Sciences	Contract for Partial Support of the Committee on Fire Research	\$22,000 FY 75	7/1/74 21	99

<i>Principal Investigator/ Institution</i>	<i>Title</i>	<i>Amount/ FY of Award</i>	<i>Effective Date/ Duration</i>	<i>Page</i>
Konowalow, Daniel D. University of New York	Extinction of Flames by Powders of Metallic Salts	\$29,000 FY 74	10/15/73 12	99
Kezios, Slothe P. Georgia Institute of Technology	NSF/RANN Conference on Fire Research	\$10,000 FY 74	5/1/74 6	99
Ryan, Norman W. University of Utah	Mechanism of Fire Propagation on Polymer Surfaces	\$44,000 FY 74	7/15/73 12	99
Shafizadeh, Fred University of Montana	Chemistry of Cellulosic Fibers	\$90,000 FY 74	4/1/74 12	100
Sibulkin, Merwin Brown University	Flame Spreading Over Solid Surfaces	\$35,000 FY 74	4/1/74 12	100
Torrance, Kenneth Cornell Univ.	Flame Spread Over Liquid Fuel	\$34,000 FY 75	6/15/74 12	100
Williams, Forman A. Univ. of California	Fire Propagation Along Solid Surfaces	\$42,000 FY 74	12/1/73 12	100
Williamson, R. Brady Univ. of California	Fire Safety in Urban Housing	\$239,400 FY 75	11/1/74 8	101
Yang, Kwang-Tzu Univ. of Notre Dame	Fire and Smoke Spread	\$74,900 FY 75	9/1/74 12	101
Zinn, Ben T. Georgia Inst. of Technology	Properties of Combustion Products from Building Fires	\$74,900 FY 75	10/1/74 12	102
Zukoski, Edward E. California Inst. of Technology	Convective Flows Association with Room Fires	\$43,400 FY 74	6/15/74 12	102

SOCIO-ECONOMIC RESPONSE TO NATURAL HAZARDS

Kunreuther, Howard C. Univ. of Pennsylvania	Reducing Loses from Selected Natural Hazards	\$148,850 FY 75	3/15/75 12	103
Friesma, H. Paul Northwestern University	Long-Range Economic Dislocations and Other Consequences of Natural Disasters	\$91,150 FY 75	6/1/75 4	104

WEATHER MODIFICATION Inadvertent Weather Modification

Auer, August H. University of Wyoming	Modification of Convective Cloud Activity by an Urban Area	\$134,300 FY 75	4/1/75 10	106
Braham, Roscoe R., Jr. University of Chicago	Inadvertent Weather Modification in the St. Louis Area	\$261,000 FY 75	4/1/75 12	106

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Chagnon, Stanley A. University of Illinois	Studies of Urban Effects on Rainfall and Severe Weather	\$257,200 FY 75	4/1/75 12	107
Gossard, Earl E. National Oceanic and Atmospheric Administration	Dual-Doppler Radar Investigation of Wind Flow Patterns in Metromex	\$60,000 FY 75	6/15/75 12	107
Ochs, Harry T. University of Illinois	Numerical Cloud Modeling	\$63,400 FY 75	4/1/75 10	107
Schickedanz, Paul T. University of Illinois	Climatic Alterations in the Great Plains Due to Widespread Irrigation	\$55,500 FY 74	6/1/74 24	108
Societal Utilization				
Boone, Larry M. United States Depart- ment of Agriculture	Economic and Institutional Considerations of Suppressing Hail	\$54,500 FY 74	10/1/73 15	109
Grant, Lewis O. Colorado State Univ.	Extended Area Effects from Local Weather Modification	\$280,000 FY 75	12/1/74 12	109
Haas, J. Eugene Juman Ecology Research Service	A Comparative Analysis of Public Reaction to Weather Modification Projects	\$76,000 FY 75	10/1/74 12	111
Klein, Donald A. Colorado State Univ.	Microbiological Impacts of Silver Iodide Used in Weather Modification	\$46,600 FY 75	7/1/75 12	111
McQuigg, James D. Univ. of Missouri	Weather Modification Management Guidelines	\$41,000 FY 75	8/1/74 14	110
Mordy, W. A. Center for the Future	The Importance of Climate and Weather Alterations to Mankind	\$87,000 FY 75	7/1/74 15	110
Morgan, G. M. Univ. of Illinois	Design of a Hail Suppression Experiment in Illinois	\$67,800 FY 75	11/1/74 12	112
Shaefer, Vincent J. State Univ. of N.Y.	Second Inadvertent Weather Modification Workshop	\$33,000 FY 74	4/1/74 12	112
Taubenfeld, Howard J. Southern Methodist University	Study Group on the Consequences of Weather Modification	\$13,800 FY 75	11/74 6	112
Weather Hazard Mitigation				
Atlas, David National Center for Atmospheric Research	National Hail Research Experiment	\$2,130,000 FY 76	7/1/75 12	114
Moore, Charles B. New Mexico Inst. of Mining and Technology	Lightening Protection and Thunderstorms Electrification	\$130,000 FY 75	6/1/75 12	114
Weather Modification Systems				
Anderson, Charles E. Univ. of Wisconsin	Studies on the Dynamics, Microphysics, and Forecasting of Severe Local Storms	\$96,000 FY 75	1/1/75 12	116

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Chisholm, John P. Sierra Nevada Corp.	An Accurate and Inexpensive Airborne Windfinding System	\$44,400 FY 75	7/1/74 9	116
Davis, Briant L. Institute of Atmospheric Sciences	Chemical Complexing of Silver Iodide-Alkali Iodide Aerosols Prepared for Cloud Seeding Purposes	\$103,900 FY 73	9/1/72 24	117
Fukuta, Norihiko University of Denver	Cloud Seeding Generators for Biodegradable Organic Ice Nuclei	\$100,400 FY 75	7/15/74 12	117
Grant, Lewis O. Colorado State Univ.	Cloud Simulation and Aerosol Laboratory	\$18,000 FY 75	11/1/74 12	118
Little, Gordon C. National Oceanic and Atmospheric	Dual-Doppler Radar Investigations of Wind Fields in Severe Storms	\$60,000 FY 75	7/1/74 12	118
Simpson, Joanne University of Virginia	Evaluation and Design of Weather Modification Experiments	\$50,000 FY 75	7/1/74 12	118

