

SUMMARY OF AWARDS 1976

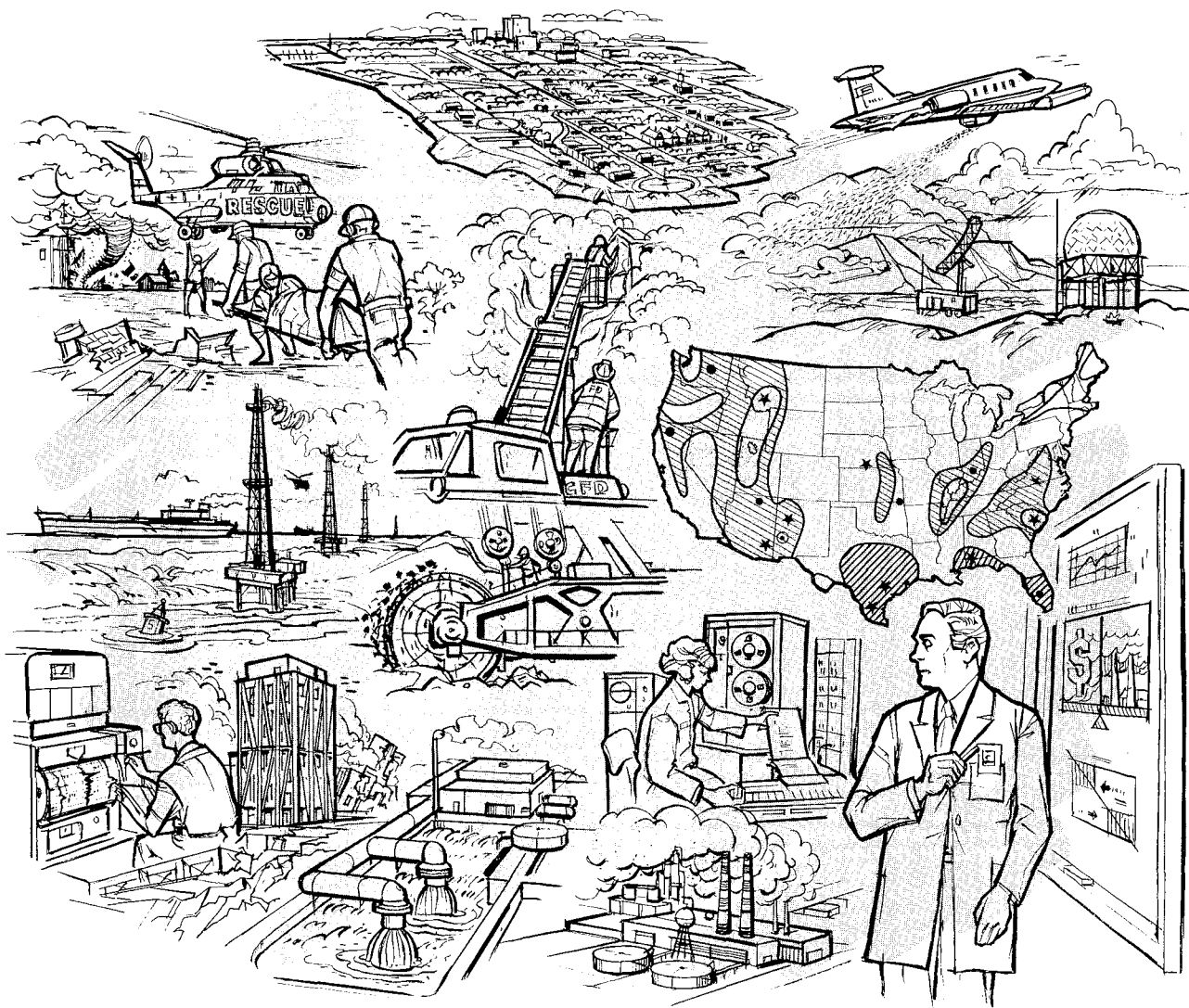
DIVISION OF ADVANCED
ENVIRONMENTAL RESEARCH AND TECHNOLOGY



NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

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INTRODUCTION

In 1971, the Research Applied to National Needs (RANN) Program was created in an effort to focus U.S. scientific and technical resources on selected problems of National importance for the purpose of contributing to their timely, practical solution. The RANN Program serves as a link between NSF's basic research programs and the development, demonstration, and operational programs of Federal mission agencies, State and local governments, and industry.

RANN Program objectives and research are based upon the specific needs of the Nation, and related challenges. Considerable emphasis is placed on the evaluation, dissemination, and utilization of the results of the research supported. Generally, the RANN Program seeks to: increase the effective use of science and technology in dealing with National problems involving public interest; shorten the lead time between basic scientific discoveries and relevant practical applications; and provide early warning of potential National problems, and initiate assessments and research useful in avoiding or solving such problems.

To better achieve its objectives, RANN focuses its efforts in five major problem areas: Resources, Environment, Productivity, Intergovernmental Science and Research and Development Incentives, and Exploratory Research and Technology Assessment.

The RANN Environment subactivity was established to enhance the Nation's capability to mitigate environmental hazards, whether natural or man-caused. The goal of the subactivity is predicated upon both the need to assure that the Nation's environmental objectives are being achieved

at least cost, and a desire to more effectively reduce both human suffering and Federal and State expenditures required to cope with needs before, during, and after natural disasters.

This report presents brief summaries of projects funded by the Division of Advanced Environmental Research and Technology (AENV) during fiscal year 1976. The report describes the nature of the Divisions's seven subelements: Chemical Threats to Man and Environment; Environmental Effects of Energy; Regional Environmental Management; Earthquake Engineering; Fire Research; Societal 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 the individual Division-funded research projects or information pertaining to research in areas of science currently investigated by the Division, are encouraged to contact the Principal Investigator directly, or the Division of Advanced Environmental Research and Technology.

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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 enhance the Nation's capability to mitigate environmental hazards, whether natural or man-caused. In pursuance of this goal, the Division objectives are predicated on two major needs:

- To assure that the Nation's environmental objectives are being achieved at least cost.
- To carry out research that is focused on human needs before, during, and after natural disasters.

The Advanced Environmental Research and Technology Division is organized into two program elements: (1) Managing the Natural Environment, and (2) 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 earthquakes, weather, and fire. The objectives are to:

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

In order to better deal with the research areas, the Division has divided the two major program elements into seven subelements:

MANAGING THE NATURAL ENVIRONMENT

- Chemical Threats to Man and Environment
- Environmental Effects of Energy
- Regional Environmental Management

DISASTERS AND NATURAL HAZARDS

- Earthquake Engineering
- Fire Research
- Societal Response to Natural Hazards
- Weather Modification

During fiscal year 1976, a total of \$25,546,000 in awards was distributed by the Division: Chemical Threats to Man and Environment (\$5,323,000); Environmental Effects of Energy (\$1,224,000); Regional Environmental Management (\$5,898,000); Earthquake Engineering (\$6,527,000); Fire Research (\$1,174,000); Societal Response to Natural Hazards (\$1,169,000); and Weather Modification (\$4,231,000).

The Summary presents brief descriptions of projects funded during fiscal year 1976. The Summary is organized by program subelement and by objectives within each subelement. For each research project described, the problem area addressed by the research is detailed, and an attempt is made to indicate how the research may help solve that problem. An alphabetical listing of each award by Principal Investigator is included in Appendix A.

DEFINITIONS

The following report presents brief descriptions of awards for scientific research given by the Division of Advanced Environmental Research and Technology during the period July 1, 1975 through June 30, 1976. All references made in this document to actual award amounts are subject to adjustment by financial statements prepared by NSF at the close of the fiscal year 1976.

The following definitions are essential to an understanding of Division activities:

- 'Award' refers to financial support given in the form of a grant, contract, or other arrangement, depending upon the nature of the research work to be completed and the terms of performance.
- 'Effective Date' refers to the calendar date on which NSF funding of a research project becomes active.
- 'New' refers to an award which has received no prior support from NSF, regardless of whether the principal investigator has received support on previous occasions.
- 'Renewal' refers to follow-on support of a project which is currently supported.
- 'Supplement' refers to the addition of funds to an existing NSF supported project without increasing the duration of NSF support.
- 'Principal Investigator' refers to the chief scientist or administrator who is responsible for coordinating the research plan and fiscal expenditures as an NSF-sponsored awardee.
- 'Institution' refers to any college, university, public or private laboratory, industry, or other organization, whether operating for profit or on a nonprofit basis, as well as State and local governments and Federal organizations.

Division-initiated funding actions excluded from this report are:

- Purchase Orders
- Funds for Personnel (Intergovernmental Personnel Act)
- International Travel Awards

Where awards have received support from other organizations within or outside of NSF, only Division support has been indicated. In addition, when individual awards or supplements have been made using funds only from other agencies or divisions, these awards are not included in this report.

DIVISION OF ADVANCED ENVIRONMENTAL RESEARCH AND TECHNOLOGY*

Acting Division Director Charles C. Thiel, Jr.
Special Assistant Marvin E. Stephenson
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Managing the Natural Environment

Chemical Threats to Man and Environment

Program Managers:
Marvin E. Stephenson
Richard A. Carrigan
Jarvis L. Moyers
Carter K. Schuth

Environmental Effects of Energy

Regional Environmental Management

Program Managers:
Edward H. Bryan
Gordon H. Jacobs
Terry R. Sopher
J. Eleonora Sabadell

Disasters and Natural Hazards

Earthquake Engineering

Program Managers:
John B. Scalzi
Henry J. Lagorio
S. C. Liu

Fire Research

Societal Response to Natural Hazards

Program Managers:
George W. Baker
William A. Anderson

Weather Modification

Program Managers:
Currie S. Downie
Richard A. Dirks

*As of October, 1, 1976.

MANAGING THE NATURAL ENVIRONMENT

The Program element Managing the Natural Environment aims to provide 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: 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; assess the environmental consequences of advanced and innovative technologies for processing energy and for storing and transporting energy and fuels; and continue research on land use, urban hydrology, and waste water disinfection.

The Program subelements in this area are:

- Chemical Threats to Man and Environment
- Environmental Effects of Energy
- Regional Environmental Management

CHEMICAL THREATS TO MAN AND ENVIRONMENT

The Chemical Threats to Man and Environment subelement is focused on identifying, quantifying, and assessing the impact of the spread of hazardous chemical compounds on the environment and human populations. Many of the compounds are released deliberately or inadvertently in large quantities into the environment at one or more points in their production use cycles. The majority of these materials can be considered to have a potentially hazardous human and environmental impact. The benefits of manufactured chemicals, with a net sales of over \$80 billion in 1974, and the potential benefits of new compounds, are so great that there exists strong justification for corresponding efforts to find better ways of assessing and reducing their hazardous side effects.

The objectives of this subelement are to:

- Identify and quantify contaminants resulting from manufacture, use, and disposal of organic and inorganic chemicals.
- Assess the potential for damage to ecosystem communities, populations, and ecological species along contaminant flow paths.
- Improve existing techniques in analytical chemistry specifically applicable to achieving the above objectives.

Research areas of specific interest within the Chemical Threats to Man and Environment program subelement are:

- Airborne Contaminants
- Environmental Assay Methodology
- Metals and Organometallic Compounds
- Nitrates
- Organic Chemicals of Commerce
- Program Development and Utilization

AIRBORNE CONTAMINANTS

The purpose of the Airborne Contaminants subelement is to identify, characterize, and quantify contaminants produced from atmospheric precursors of man-made and natural origin.

Chemical Transformations in Photochemical Smog and Their Application to Air Pollution Control Strategies; *Pitts, James N., Jr.*; Statewide Air Pollution Control Center, University of California, Riverside, California 92502; \$319,700 for 12 months beginning January 1, 1976.

This project is jointly funded by the Advanced Environmental Research and Technology and the Advanced Energy Research and Technology divisions of NSF, and allows for the continuation of research begun in 1975 on the development of a model of the chemistry of photochemical smog. The specific objectives of this project are to : 1) prepare an experimental validated model for chemical transformations into photo-chemical smog; and 2) elucidate the formation and role of particulates in photochemical air pollution. Principal goals for this third year of the study are the extension, refinement, and validation of the chemical process model. The basis for model validation is the experimental program on chemical reactions in synthetic gas mixtures and ambient air to generate concentration-time profiles for the reactants, the transient intermediate species, and the products, so as to describe how the raw pollutants from sources transform chemically to the final smog mixture. Experiments will be done in the SAPRC 200-cubic foot smog reaction chamber, believed to be the most advanced facility in the nation.

The primary goal of the first 18 months has been accomplished. This goal was the formulation of a

sophisticated computer model of photooxidation systems involving two representative hydrocarbons; propene and n-butane. Progress has begun on the formulation of a practical mechanism for an aromatic (toluene) photooxidation system, for which few kinetic and mechanistic data are available. This has been achieved in a closely coupled program between modeling and smog chamber groups.

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. In addition, The State Air Pollution Research Center (SAPRC) maintains a vigorous program of information dissemination through several channels. The SAPRC publishes a periodical, California Air Environment, which is distributed to over 3000 individuals and organizations. Articles touch on criteria for air quality standards, research findings, health effects, and related matters.

Chemical and Physical Characterization of Submicron Aerosols; *John H. Seinfeld*; California Institute of Technology, Pasadena, California 91125; \$301,300 for 24 months beginning June 1, 1976

Although the total mass of particulate pollutants in an urban atmosphere is generally small compared with that of gaseous pollutants, aerosols nevertheless contribute significantly to visibility degradation and health effects. Despite many years of in-

vestigation, the origins and evolution of urban air pollution aerosols remain poorly understood in comparison to our understanding of gaseous pollutants.

Current knowledge about the formation, growth, coagulation, transport and deposition of atmospheric particles lags far behind that of gasphase interactions, as it is more difficult to do both experimental work and theoretical interpretations of the results when liquid or solid aerosols are involved, as well as gases. Despite the difficulties involved in study of heterogenous systems (those containing two or more of the phases: gas, solid, liquid), it is essential that we gain a better understanding of them, especially as they pertain to air pollution problems.

Research to date has shown that a substantial fraction of particulate matter is secondary, that is, formed from chemicals initially released as gases such as SO₂, NO, and hydrocarbons. These secondary particles are probably more serious air pollutants than primary particles (those released from sources as particles) because they are small enough to cause intense light scattering (haze) and to be deposited efficiently in human lungs. They also carry major portions of the irritants on particles, and various organic compounds, some of which are known to be carcinogenic. Thus, for control of air pollution it is essential that we learn the

mechanisms by which very fine primary particles are formed in combustion sources, how particles subsequently grow (by reactions with gases) and coagulate, how they are transported, and how they are ultimately deposited at ground level by settling or precipitation.

The Caltech project is designed to answer many of the questions about aerosols that were posed above. The research program consists of theoretical and experimental studies aimed at elucidating the processes affecting the distribution of chemical species with respect to particle size for submicron aerosols. Major objectives of the program are: (1) to determine the processes which govern the emissions of submicron particles from combustion sources; (2) to develop a comprehensive mathematical model capable of simulating the dynamics of the size and composition distribution of air pollution aerosols; and (3) to develop a low-pressure impactor capable of fractionating particles below 0.5 micrometer diameter and use this impactor in conjunction with the combustion studies and in measurements of trace-metal concentrations in ambient air and in the vicinity of power plant plumes.

Sources, Transformations, and Speciation of Atmospheric Pollutants; *William H. Zoller;* University of Maryland, College Park, Maryland 20742; \$340,000 for 12 months beginning September 1, 1975

This award continues research on the trace elements and polycyclic aromatic hydrocarbons in size-graded particulates emitted by power plants (coal and oil fired), municipal refuse and sewage-sludge incinerators, automotive traffic, airports, and the rural background. The objective is to identify sources of toxic elements and to trace the origins of ambient particulates. A second objective is to elucidate certain aspects of homogeneous gas reactions in polluted air and to determine the conditions that control ozone formation in power-plant and industrial plumes.

This grant extends the study to the combustion of refuse-derived fuel and to industrial sources represented by steel making, petroleum refining, cement manufacture, and non-ferrous smelting.

Trace elements are analyzed by neutron activation and atomic absorption. Polycyclic aromatic hydrocarbons are measured in the particulate and gas phases. Studies in the meteorological forecasting of stagnation periods will assist in evaluating the significance of the source emissions.

Aircraft sampling will continue to elucidate the factors controlling the appearance of ozone bulges in power plant and industrial plumes by coordinated measurements of ozone, hydrocarbons, nitrogen oxides, carbon monoxide, humidity, condensation nuclei, and temperature. In addition, studies of rainfall pH will attempt to correlate the acidity of rain with the chemistry of power plant emissions.

ENVIRONMENTAL ASSAY METHODOLOGY

The objective of the Environmental Assay Methodology subelement is to develop advanced instrumentation and analytical methodology for the collection, identification, and quantification of organic compounds present in a variety of environmental media.

A Water Pollution Monitoring Laser Optical System; *Silverio P. Almeida;* Virginia Polytechnic Institute & State University, Department of Physics, Blacksburg, Virginia 24061; \$113,400 for 12 months beginning July 1, 1976

Knowledge of the concentration and types of diatoms in water has been shown to be a reliable and accurate measure of the biological condition of a given body of water.

This project is a continuation of an award designed to develop a laser optical system for monitoring water pollution. Presently, this is performed by identifying and counting manually the various diatoms in water samples observed with a microscope, but this technique is subjective, expensive, and too slow for detection of rapidly changing conditions. The proposed laser optical system is designed automatically to scan and count the types and numbers of various diatoms in a given sample.

Coherent spatial filtering techniques are employed in the system. Potential diatoms in water samples are compared under laser light in a microscope with previously obtained patterns of diatoms of various types and the match between the sample and pattern is checked via computer under various orientations. The computer then stores the counts of various diatom species.

The basic hardware and computer programs have already been developed. The present year will be a critical one for extensive testing and refinement of the system.

An Environmental Study of Selected Trace Elements; *Robert S. Braman;* University of South Florida, Tampa, Florida 33620; \$41,700 for 15 months beginning June, 1, 1976

Several years ago, the environmental research community awoke to the realization that mercury residues that had been thought to become insoluble in the aquatic environment, and therefore biologically inactive, were transforming to soluble methyl mercury species that were even more toxic than common soluble inorganic mercury forms. Since these methylated species are soluble in water, they can be easily transported in the aquatic environment, resulting in exposures of living forms at locations far from the original source. This process is called "biomethylation" because of the biochemical processes involved in the conversion of these species to methylated substances.

It is known that mercury is not the only element that is biomethylated in nature. The objective of this research project therefore is to determine what trace elements are susceptible to biomethylation in the environment. Since the formation and transport of toxic methyl mercury in the aquatic environment is itself a recent discovery, it follows that investigations should be conducted of other metals and metalloids that behave analogously to mercury on the assumption that these other metals might also yield toxic products that can be easily transported in environmental pathways.

The objectives of this study are to: 1) develop new methodologies for detecting and measuring

trace levels of individual methylated and non-methylated metals in environmental samples; and 2) apply these methodologies in the search for other biomethylated species in the environment.

Specifically, the research is directed at completing a systematic review of the possibilities of additional unsuspected biomethylations of potentially toxic chemical elements.

Low-Level Hydrogen Sulfide Measurements in Ambient Air; *Robert S. Braman;* University of South Florida, Tampa, Florida 33620; \$24,700 for 12 months beginning June 1, 1976

It is possible that biogenic sources in the natural environment contribute hydrogen sulfide (H₂S) gas in amounts that contribute significantly to the observed levels of particulate sulfate in the air of certain regions. According to this hypothesis, dissolved sulfate is reduced to hydrogen sulfide in estuaries, rivers, marshes, or in other situations where anaerobic muds exist. Recent research has shown that the resulting hydrogen sulfide, if present in low concentrations, can survive passage through overlying aerated water and be evolved into the atmosphere where it eventually would be oxidized to some form of particulate sulfate. These airborne sulfate particles are believed to be a prime factor for adverse health effects. If these biogenic sources are important contributors to the ambient levels of particulate sulfate in the air of certain regions, the relative significance of anthropogenic sources, like power plants, would have to be reevaluated.

No accurate method for measuring the low ambient levels of hydrogen sulfide in air exists, and so the question of whether or not biogenic sources do contribute hydrogen sulfide gas remains unanswered. There exist techniques for monitoring hydrogen sulfide at higher concentrations, and

these techniques are being used for other RANN-supported research, where plants are exposed to air containing hydrogen sulfide at levels of 30 to 3000 parts per billion in a test of the effects on vegetation of H₂S released in geothermal power production. However, normal ambient air is believed to contain hydrogen sulfide at levels ranging from 0.01 to 0.40 parts per billion. For accurate measurement at this level, a method sensitive to about 0.001 parts per billion is needed.

Therefore, this research is focusing on developing a method of sufficient sensitivity that can be used in the field, and that can measure values at ambient levels well above the limit of detection. Reliable quantitative estimates of biogenic contributions of H₂S and of sulfate particulates derived from it are needed for comparison with anthropogenic sources.

The method depends upon absorption of hydrogen sulfide in metal-coated beads and its subsequent expulsion and measurement in a direct-current arc discharge or a flame emission detector. Sensitivities well below 0.01 part per billion are believed possible, perhaps as low as 0.0002 parts per billion if 100-liter samples are taken.

The Isotope-Shift Zeeman-Effect Spectrometer for Measuring Multiple Chemical Elements and Compounds; *Tetsuo Hadeishi;* Energy Research and Development Administration, San Francisco Operations Office, University of California, Berkeley, California 94720; \$100,200 for 12 months beginning April 1, 1975

The chemical analysis of traces of metals and other chemical elements in diverse materials is often done by the atomic absorption method, but the procedure requires, in general, some prior chemical preparation of samples in order to put the elements sought into a solution suitable for introduction into the flame atomizer of the atomic absorption apparatus. The Isotope-Shift Zeeman-Effect Atomic Absorption Spectrometer (IZAA) avoids the prior chemical preparation by volatilizing the sample material directly into the optical path of the

spectrometer, correction for background absorption being made by using Zeeman-shifted spectral lines as probes of the backgrounds.

Earlier work has concentrated on measurements of mercury, lead, and cadmium in biological materials. The current program undertakes to apply the technique to representative chemical elements throughout the periodic table and to certain molecular forms, e.g., diatomic gases of interest in air pollution studies.

Chemiluminescent Analysis of Hydrogen Peroxide in the Ambient Atmosphere; *Gregory L. Kok;* Harvey Mudd College, Claremont, California 91711; \$35,900 for 24 months beginning June 1, 1976

After several decades of research and control measures, photochemical smog remains a severe economic, health, and aesthetic problem in the Los Angeles basin and, during warm weather in particular, throughout the rest of the U.S. Recent control measures are proving slowly effective in reducing air pollution, but involve costly restrictions and/or modifications to both industrial and private operations and equipment. The validity of smog production models must be verified most carefully, since even small modifications of the mechanisms on which we base our calculations may have enormous financial and technological impact through regulations imposed to curtail smog formation.

Analyses for NO, NO₂, O₃, SO₂ and some hydrocarbons are now made routinely in the ambient atmosphere. Reactions of these species in the atmosphere are moderately well known and give a good starting point for most models of photochemical smog. To further extend photochemical smog models, analyses are needed for species such as hydrogen peroxide (H₂O₂), nitrous acid (HONO), and nitric acid (HNO₃).

Analytical measurements on the concentration of hydrogen peroxide in the ambient atmosphere

are of particular interest because of the participation of hydrogen peroxide in the formation of photochemical smog. Currently available methods for this analysis are unsatisfactory because they are slow and involve several steps. The principal investigator of this project proposes to develop an automated, liquid-phase chemiluminescent analyzer for the determination of H₂O₂ in the ambient atmosphere. Three objectives are to be realized from this study: 1) the design and construction of the chemiluminescent analyzer; 2) design and construction of a calibration system for the generation of sub-pmm (parts/million) amounts of hydrogen peroxide in the gas phase; and 3) analytical studies on the concentration of hydrogen peroxide in the ambient atmosphere.

Information obtained from this study is to be published in scientific journals and made available directly to workers in the field of air pollution monitoring. In addition, the instrumentation will be constructed as much as possible from readily available components to make it easy for other research groups desiring analysis on H₂O₂ to build this type of analytical instrumentation.

Diode Laser Multi-Pollutant Ambient Air Monitoring; *Robert T. Ku;* Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, Massachusetts 02173; \$117,000 for 12 months beginning March 1, 1976

The overall objective of this project is to devise and test a laser remote measurement system for monitoring gaseous pollutants at their concentration levels in ambient air. This is to be achieved by absorption spectroscopic measurements integrated over a path length of the order of one kilometer. Diode lasers tuned to specific wavelengths of pollutant molecules are used as light sources in an instrumented van equipped to receive a return signal from a remotely sited retro reflector.

Pollutants gases to be studied are carbon monoxide, nitric oxide, ozone, and ammonia. To the extent possible, other pollutant gases will be investigated to evaluate the possibilities of extending the technique to many pollutants by using widely tunable lasers.

The prime user of this research is the U.S. EPA, which is jointly funding the project. Potential users include other branches of the Federal government and utility and industrial firms.

Tunable Lasers for Application to Air Pollution Measurements; *Aram Mooradian;* Lincoln Laboratory, Massachusetts Institute of Technology, 244 Wood Street, Lexington, Massachusetts 02173; \$80,200 for 12 months beginning April 1, 1976

This project seeks to lay new groundwork for the application of absorption spectroscopy for measur-

ing the concentrations of gaseous pollutants in research on smog formation and the monitoring of

gaseous species in polluted air. This is possible because of a new development in ultrahigh resolution spectroscopy at Lincoln Laboratory of MIT. A tunable near-infrared source operates by generating the different frequency between two lasers, and it affords a wholly new order of spectral resolution. 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 represents a great step forward in spectroscopic capability needed for research on the chemistry of atmospheric pollutants at ground level, and for the planning of comparable studies of the effects of contaminant gases on the stratospheric ozone layer.

The grant supports a survey of the spectra of molecules absorbing in the 2.2 to 4.2 micrometer region, e.g., low molecular weight hydrocarbons, and other species having hydrogen stretching vibrations in this region. Although spectral lines are broadened in studies at atmospheric pressure, such as in research on smog chemistry or ambient pollution modeling, the Doppler-limited

wavelength data will be useful in deconvolving overlapping spectral features. The Doppler-limited resolution should also be useful in studies in the stratosphere.

The specific objective of the project 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. The purpose of this is to make available a large body of new spectral data needed by scientists who are working on remote sensing technology and who are doing research on devices for measuring critical chemical species in the troposphere and the stratosphere.

Molecules to receive attention because of their part in air pollution research are: hydrogen peroxide, formaldehyde, formic acid, nitrous acid, and nitric acid. Low molecular weight hydrocarbons will be examined because the data will be applicable in design studies for long-path atmospheric monitoring technology. Also included will be surveys of the spectra of ammonia, water vapor, sulfur dioxide, and carbon dioxide.

Study of the Chemistry of Atmospheric Particulates; *Tihomir Novakov*; Energy Research and Development Administration, San Francisco Operations Office, University of California, Berkeley, California 94720; \$187,400 for 12 months beginning October 1, 1975

Most research on the particulates of polluted air deals with their bulk chemical composition. The surface layers of particles, however, often have special chemical properties determined by the absorption of accessory substances. This research seeks to define the chemical characteristics of the surfaces of particles from ambient air and from pollutant sources to better understand their genesis, their physiological and catalytic properties, and their agglomeration behavior. A second major objective is to specify the molecular, rather than the elemental, composition of particulates. Photoelectron spectroscopy, also known as ESCA

(electron spectroscopy for chemical analysis), will be employed.

An inventory of inorganic molecular species in various types of ambient and source-enriched particulates will be completed. Factors affecting the occurrence of molecular forms of sulfur, nitrogen, and other elements in particulates from combustion sources will be determined. The effects of catalytic surfaces of carbon and other particulates on the reactions of gaseous species will be defined, and the quantitative significance of non-photochemical formation of sulfates and nitrates on carbon particles will be assessed.

Remote Measurement of Air Pollutants; *Edward K. Proctor*; Stanford Research Institute, Menlo Park, California 94025; \$165,000 for 12 months beginning May 1, 1976

Both in the study of air pollution problems and in the routine measurement of air pollutants for con-

trol and enforcement purposes, there is a great need for instruments that could be placed at one

point and measure concentrations of gaseous air pollutants for many kilometers in each direction and at various altitudes up to 2 km. Taking measurements of that type with present day technology would require a complicated and expensive network of monitors around the area in question.

Clearly a need exists for reliable remote sensing methods and this project is designed to accommodate this need. The overall objective of the project is to develop laser methods for remote measurement of concentrations of atmospheric trace gases such as SO₂, O₃, NO₂, etc.

Most of the work employs the differential absorption laser-radar (DIAL) technique whereby the transmitted beam is back-scattered from atmospheric particles. The beam is tuned to light of wavelengths that are strongly absorbed by the molecule of interest. From the time delay between the sending and receipt of pulses by a telescope at the sending site one can determine gas concentrations at various distances along the path.

Research on Analytical Methods for Measurement of Trace Contaminants; *Philip W. West*; Louisiana State University, Baton Rouge, Louisiana 70803; \$80,400 for 12 months beginning August 1, 1975

This is a continuation of an award which seeks to perfect the measurement of trace amounts of impurities in diverse materials, and to achieve these measurements with such accuracy that they may be reproducible from one laboratory to another.

The three basic objectives of the project are to: 1) complete work on the production of standard toxic dusts having known particle size and pre-determined and accurately adjustable chemical composition for standardizing routine analytical

Under the present grant, which is a continuation of a previous NSF award, the investigators will improve the techniques described above and develop additional infrared techniques for measurements of various gases.

With the remote systems envisaged, authorities could quickly detect the onset of a pollution episode and immediately start shutting down major pollution sources. Moreover, violations of emission regulations could be quickly detected and authorities could respond quickly to these violations. Remote sensors would also aid pollution sources themselves. Where power plants are required to monitor pollutants in the vicinity of their stacks, remote sensors could do the job more quickly and more economically than networks of point monitors, and plant managers could then take appropriate steps to reduce emissions.

work and for inhalation toxicology studies; 2) achieve superior methods of trace contaminant analysis by combining the heated graphite atomizer technique with preconcentration of metallic elements by solvent extraction, and with the reductive generation of gaseous hydrides of metalloidal elements; and 3) test the feasibility of the permeation technique for preconcentrating organic contaminants in water, with subsequent transfer to the concentrated substances for analysis by gas chromatography.

METALS AND ORGANOMETALLIC COMPOUNDS

The purpose of this subelement is to research the effects of organometallic compounds on human health and ecosystem structure and function.

Geochemistries of Mercury, Arsenic, and Other Metals in Puget Sound; *Roy Carpenter*; University of Washington, Department of Oceanography, Seattle, Washington 98185; \$49,500 for 12 months beginning June 1, 1976

Because a portion of the Puget Sound coastal and estuarine environment has been contaminated by chlor-alkali and smelting plants, it is possible to compare the biogeochemical behavior of arsenic and mercury from natural and anthropogenic sources in both fresh and salt water. More information on the forms in which these metals are present is needed because the uptake and release of metals by organisms and the biological effects of the metals on organisms all depend on the chemical form of the metals.

The researchers in this study are completing studies of the sources, sinks, routes, and rates of transfer of mercury and arsenic between different aquatic reservoirs and between different chemical forms. They have established, through previous NSF funding, the general background values for uncontaminated waters in the Puget Sound and are now concentrating on the contaminated areas.

Cadium in an Aquatic Ecosystem: Distribution and Effects; *Theodore J. Kneip*; New York University, School of Medicine, 550 First Avenue, New York, N.Y. 10016; \$75,800 for 12 months beginning August 1, 1975

The objective of this research project is to study the effects of cadmium and nickel in an aquatic ecosystem. The study, now in its third and final year, is focusing on a nickel-cadmium battery plant located near Cold Spring on the Hudson River. Substantial amounts of both elements have contaminated a nearby marsh, thereby affording a unique opportunity to study the aquatic behavior and effects of cadmium and nickel.

Specifically, the goals of the project are: 1) to develop data relating to the physical distribution of

The main objective for this year's research is to complete the identification of 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 non-toxic forms. Temporal, spatial, and chemical species distribution data are being collected to estimate rates and mechanisms of mercury and arsenic movements.

A materials balance for arsenic in Puget Sound is being developed to allow for the prediction of future movements of arsenic through the system. In addition, research is continuing on the metabolism of metals in major classes of finfish and shellfish that are important economically in Puget Sound.

these elements in the ecosystem in terms of rates, routes, and reservoirs which exist, including the major parameters that determine these factors; 2) to determine the food web distribution and the interaction between the physical and food web systems; and 3) to define toxicities for a number of organisms and the relation to effects on biota as noted in the field.

Work proposed for the third year of the project is designed to complete those facets of the study needed to achieve the initial overall goals.

Emphasis in the ongoing work is being placed on the determination on the rates and routes of physical transport, on food web distributions, and on

laboratory uptake studies. The latter includes combined uptake and toxicity studies on benthic organisms.

An Interdisciplinary Study of Environmental Pollution by Lead and Other Metals; *Gary L. Rolfe*; University of Illinois, Urbana, Illinois 61801; \$571,400 for 18 months beginning January 1, 1976

The general objectives of this project are to determine and evaluate the effects of lead on productivity of both agricultural crops and urban vegetation resulting from the continued use of leaded gasoline, and to determine the distribution of particulates in urban systems to which humans are subjected with possible associated health hazards.

The original goal of the project, which is now in its final year of funding, was to establish inputs, distribution, pools, and sinks of lead in a typical midwestern agricultural ecosystem with a small urban component as a basis for evaluating the problem resulting from automobile lead emissions. These studies are now complete and form the basis for the two final research objectives. These are to: 1) determine the current or potential effects on productivity of both agricultural crops and urban vegetation impacted by the use of lead in gasoline; and 2) determine the urban distribution of lead and characterize lead-containing particulates in urban systems to which humans are subjected. Successful completion of this objective will help answer the major unanswered question concerning lead today: what are the sources and their relative contributions to lead poisoning of urban children?

An Interdisciplinary Investigation of Environmental Pollution by Lead and Other Heavy Metals from Industrial Development in the New Lead Belt Of Southeastern Missouri; *Bobby G. Wixson*; University of Missouri, Rolla, Missouri 65401; \$191,300 for 12 months beginning September 1, 1975

This is the final year of support for a research project that is examining 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.

The final 12 months of the study will be divided into two six-month stages. The first six months will be devoted to completing program research objectives and data collection; the last six months will be

Risk/benefit methodology is being applied to both of the above-mentioned problem areas in order to weigh the risks to plant growth and yield and to human health in urban systems versus the energy and economic benefits of the continued use of lead in gasoline.

Information resulting from the project is being disseminated by project research reports, publications in the scientific literature, presentations at scientific meetings, and personal interaction with project investigators and scientists and/or decision makers at other universities or research groups. Increased emphasis is to be placed on data utilization. Communication has been developed with State and Federal environmental and housing authorities that will allow for direct utilization of much of the data generated by the project. Contacts in the agricultural area are being encouraged to promote utilization of the lead effects on crop yield data. In addition, the results from this study and two other RANN-supported lead studies at other institutions, (University of Missouri at Rolla and Colorado State University), will be published in book form.

used for analysis and evaluation of the data, for dissemination of data and methods to industry, Federal and State agencies.

Specifically, some of the tasks for the final year include: (1) continuous monitoring of dustfall and wetfall at five sites in Crooked Creek Watershed to provide data for validating the Oak Ridge Unified Transport Model, a model which describes the transport of pollutants through environmental compartments; (2) the study of the absorption stability of metal humates from forest litter leachate; (3) the study of the potential of humic acids as

a treatment technique for removing heavy metals from industrial waste; (4) the study of effects of heavy metals on stream life; and (5) the continua-

tion of study on the association of heavy metals in aquatic vegetation.

Environmental Flow of Cadmium and Other Trace Metals; *Kenneth J. Yost*; Purdue University, Institute of Environmental Health, Pharmacy Building, West Lafayette, Indiana 47907; \$401,600 for 12 months beginning January 1, 1976

This project is concerned with the environmental problems that are 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. Solutions to environmental problems caused by trace contaminants invariably require regulation of the primary sources of these materials, that is, the establishment of emission/effluent standards. In devising such standards, the attempt is made to weigh environmental and public health effects against the technical feasibility and economic implications of imposing such restrictions on the process or operation responsible for the release. A comprehensive and effective analysis of the problem must then consider both elements: 1) the source of the contaminant, and 2) the environmental pathway and sites of accumulation of the dispersed material. The overall objective of this project, then, is to provide data which will contribute to the national formulation of emission/effluent standards that will adequately protect the environment while minimizing the economic impact of these standards on the metals industries.

During this fourth year of the project, emphasis is being placed on source factors and environmental behavior and effects. The source factors study includes emission sampling operations for the steelmaking industry and research on waste treatment recovery systems in the electroplating industry. Studies in the area of environmental behavior and effects are attempting to establish acceptable levels of toxicity in order to ensure continuity of the principal biotic components of the ecosystem.

The user community for the results of this research are principally regulatory agencies who must set source and environmental standards, groups representing sources on which standards will be imposed, and community of individuals interested by reason of profession and/or concern. Data dissemination has been carried out through presentations at professional meetings, publications in professional journals, close collaboration with the user community on an informal basis, and yearly topical meetings which deal with specific areas of project research.

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.

N-Nitroso Derivates of Pesticide; *David H. Fine;* Thermo Electron Corporation, 85 First Avenue, Waltham, Massachusetts 02154; \$103,000 for 18 months beginning January 1, 1976

According to the EPA, "as a family of carcinogens, the nitrosamines have no equals." Nearly every nitrosamine subjected to animal studies is found to be carcinogenic. Many secondary and tertiary amine compounds are known to react with nitrites to form nitrosamines. Because of the possible formation of nitrosamines in meat or in the body, the FDA recently placed new restrictions on the use of nitrite compounds as a preservative in bacon.

Many agricultural herbicide, insecticide and fungicide formulations in use today contain compounds that are secondary or tertiary amines or compounds which can be readily hydrolyzed to form secondary amines. Since it is known that many secondary and tertiary amines are easily nitrosated in the presence of nitrite ions to form the highly carcinogenic N-nitroso derivatives, it is presumed that these reactions occur between pesticides and nitrites in soil. The magnitude of this problem is illustrated by the fact that over 2,000

compounds that are possible precursors of N-nitroso compounds are in use as pesticides in the U.S. today. However, until recently there has been no analytical technique with the required sensitivity to detect these compounds at the expected low levels in the environment.

In the proposed study, the researchers will look for N-nitrosamine derivates in soil, water, and agricultural crops from areas treated with known amounts and types of pesticides. Samples will be subjected to gas-phase chromatography (gpc) and high-pressure liquid chromatography (hpc). Materials separated by gpc and hpc will then be passed into the Thermal Energy Analyzer (TEA), developed by Thermo Electron Corporation, which is a very specific analyzer for N-nitroso compounds. In addition, measurements of the yields of N-nitroso compounds from several important classes of pesticides will be made under simulated soil and ground-water conditions.

Nitrate in Effluents From Irrigated Lands; *Parker F. Pratt;* University of California, Davis, California 95616; \$618,200 for 24 months beginning June 1, 1975

Because crops do not utilize all the nitrate supplied by fertilizers, some nitrate leaches into tile lines, or it drains to underground water bodies. The resulting contamination can cause the eutrophication of surface waters or it can lead to the accumulation of nitrate in surface or underground drinking water supplies to levels posing a public health hazard. In the irrigated farmlands of the western states, nitrate levels in waters draining below the root zone

often substantially exceed the U.S. Public Health Service standard for drinking water. The needs of society for agricultural productivity and for environmental protection come into conflict because of the tendency for a productive agriculture to leak nitrate into water supplies.

This project is designed to help reconcile these conflicting needs by determining how soil conditions and farm management practices control the

leaching of nitrate, and by relating these findings to knowledge of nitrogen requirements for optimum crop production. By consolidating in a single funding source the support of both the environmental and the agricultural aspects of the research, the project fulfills one of the key purposes of the RANN program—to ensure the coordinated support of research that might otherwise be fragmented by piecemeal support from agencies having diverse, and potentially conflicting, mission.

On cropped field plots fertilized with isotopically labeled nitrogen, the fate of nitrate of fertilizer origin is determined under different irrigation regimes and rates of nitrogen application by mass spectrometric measurements.

Observations of nitrate leakage from farmlands are correlated with soil type and management practice to identify those situations most significant for nitrate contamination of waters. Nitrate measurements are made on tile drain waters and on waters draining to aquifers.

Experiments are designed to assess the importance of gaseous losses of nitrogen for eliminating

excess nitrate from soils, and to identify conditions that would favor this means of minimizing leakage of nitrate to drainage pathways.

In this fourth year of study, laboratory and field determinations of the rates of transformation of different nitrogen substances in soils under drainage conditions have been completed. Mathematical models are not being developed to describe the downward movement of water and nitrate under irrigation and cropping cycles. During the next two years—the final years of the study—the researchers will focus on integrating the results of the entire program into a user-oriented output in the form of interpretations of standard soil mapping associations for characterizing cropping systems as to their tendencies to release nitrate to drainage pathways. This will result in the ability to determine what soil/crop management systems are most likely to contaminate water supplies, and how alternative practices can be adjusted to minimize nitrate pollution.

ORGANIC CHEMICALS OF COMMERCE

The objective of the Organic Chemicals of Commerce subelement is to develop methodologies for hazard prediction of organic chemicals. In addition, the subelement seeks to: (1) determine the transport, effects, and fates of critical organic compounds which pose threats to human populations and environments in high exposure areas; (2) investigate the health effects on humans of persistent low-level exposure to critical organic compounds in areas of high release; and (3) assess the economic, legal, and socio-political implications of hazardous levels of specific organic compounds in the environment.

Effect of Chemical and Physical Properties of Organic Compounds on Their Biodegradation; *Martin Alexander*; Cornell University, Department of Agronomy, Ithaca, New York 14853; \$120,929 for 12 months beginning September 1, 1975

In general, the objectives of this research program are to develop data that would facilitate the prediction of the behaviors, fates, and effects of organics in the environment. This would allow the chemical industry and the regulatory agencies to predict more chemicals from among the tens of thousands of commercial chemicals that should receive priority attention.

The specific goals of this research project are to establish principles of compatibility or non-compatibility as regards biodegradation. It focuses on the biodegradation of individual organic compounds and mixture of chemicals of environmental importance. Individual organic compounds will be studied in order to determine why readily degradable molecules become resistant when particular substituents are added to the molecules, to establish why some biodegradable substances are not metabolized readily in certain environments, and to assess the significance of cometabolism (the failure of microbes to degrade molecules, the products of which do not support growth) to the biodegradation of chemical pollutants.

Less than 100 characteristic groups of atoms (the functional groups of organic chemistry: -C-H, -O-H, -NH₂, etc.), when joined in various combinations, act as the building blocks out of which all organic chemical molecules are constructed. Each of these atomic groupings confers its own characteristic properties on every substance in which it

occurs, making it possible to systematize knowledge about all organic substances by formulating general principles based on the behavior of individual functional groups.

In this project, experiments will be performed in which classes of substances representing common functional groups (like a representative set of phenols of varying physical properties) are exposed to chemical, physical, and microbiological conditions representing typical environmental exposures. The experimental observations are to consist of measurements on the degradation of the substances to innocuous products, or their conversion to other chemical forms that might be more, or less, hazardous.

Results of this project will be of value to several users. First, organic chemical manufacturers are increasingly under pressure to develop new compounds that are less toxic and less persistent, and the expected results of this study will be instrumental in the design of new environmentally compatible organic chemicals. Secondly, both the Office of Toxic Substances and the Office of Pesticides Programs in EPA have responsibilities for regulating organic chemicals. Both have expressed the need for hazard prediction capability based on the structure and properties of the chemicals. Since this project is directly related to this concern, both of the above offices will receive results of this project in a timely manner.

Identification of Mutagenic Organic Compounds in Environmental Samples; *Barry Commoner;*
Washington University, Center for the Biology of Natural Systems, St. Louis, Missouri 63130; \$174,900
for 12 months beginning July 1, 1976

In recent years man has become environmentally exposed to a wide and increasing variety of chemicals, some of which are mutagens. Man's genes constitute his most precious heritage, and deterioration in gene quality can result in a corresponding decrease in the quality of life. Clinically recognizable genetic diseases currently affect about 6% of the population during their lifetime, and this figure is believed to be a substantial underestimate due to difficulties in recognizing many genetic diseases. The concern for mutagens is compounded by the fact that many of them are also known to be carcinogenic.

These concerns have led scientists to develop and apply fast, inexpensive test systems capable of detecting environmental mutagens. Once the tests are developed, they can be used to analyze suspect environmental samples to determine the identity of mutagens in the environment. Organic chemicals representing a wide variety of functional groups and structures must also be tested so that structure/biological activity relationships can be determined. These relationships must be known if the behavior and effects of organics are to be predicted.

Fates of Industrial Synthetic Organic Chemicals: A Case Study; *Ronald A. Hites;* Massachusetts Institute
of Technology, Cambridge, Massachusetts 02139; \$157,500 for 12 months beginning July 1, 1976

The environmental hazard caused by various synthetic industrial organic compounds is now well known. Pesticides, polychlorinated biphenyls, chloro-fluoromethanes, tetrachloro-dibenzodioxane, and phthalate esters are only a few examples of industrial organic compounds which have been found to have deleterious environmental effects. One of the most 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 quantities of the organic compounds in the wastewater from such industrial sites and to know what happens to these chemicals once they have entered the environment.

The purpose of this project, which is in its second year, is to identify and quantify the organic

This project has several objectives related to the problems discussed above. First, investigators are working on improvements of the Ames bacteriological test, which is a much more rapid screening test for mutagenic chemicals than the traditional slow and expensive animal tests. Second, they are applying the Ames test to a large number of chemicals already known to be carcinogenic or non-carcinogenic to determine the reliability of the Ames test. Third, they are examining environmental samples for the presence of chemicals that give positive Ames tests, indicating the presence of mutagens. Once positive mutagenic tests are obtained, the specific mutagenic chemical can be identified by the electron-spin resonance spectrum of radicals formed from the chemicals.

Due to prior NSF funding, all of the above are in progress. This award provides an extension during which time the investigators will work to determine the pathways of organic carcinogens from their origins in water and air to man, and also to determine the total human exposure to carcinogens.

compounds in the effluent waters from several organic chemical manufacturing sites. During the first year, effluents from seven sites were studied, primarily by gas-chromatography/mass-spectrometry methods. During the present grant, more detailed studies of the effluents from two of those plants will be made, including measurements of organic chemicals in water sediments, and organisms, at various distances downstream, in order to determine fates of the chemicals after release. A survey will also be made of organic chemicals in the Delaware River, as some of the largest chemical plants in the country deposit wastes in the River. People in areas adjacent to the River have unusually high rates of cancer which may be related to their exposure to organic carcinogens.

Immediate user groups of this study are the EPA and the companies cooperating in the research. Dissemination of the results to a wider user community will take place with the assistance of MIT's Industrial Liaison Program (ILP), a program designed to bring MIT technical advances to the attention of industry. ILP will sponsor a day-long

seminar to which concerned user groups will be invited and at which results and conclusions will be presented. Another interested concern is the Delaware Basin Commission in Trenton, New Jersey, which is responsible for the long-term clean-up of the Delaware River system.

Mammalian Screening Tests for Mutagenic Chemicals and Chromosome Inabilities; *T. C. Hsu*; University of Texas System Cancer Center, M.D. Anderson Hospital & Tumor Institute, 6723 Bertner Avenue, Houston, Texas 77025; \$68,100 for 12 months beginning January 1, 1976

Cancer authorities estimate that about 80% or more of cancer incidence is caused by local environmental factors. Some of these are probably natural causes such as excesses or deficiencies of certain chemicals in local soil and water. Others stem from personal habits such as smoking. But an unknown, and possibly very large factor is exposure to manufactured organic compounds or their degradation products in the environment—pesticides, plastics, food additives, etc. For example, the high incidence of a rare form of liver cancer among workers in the vinyl chloride industry suggests strongly that vinyl chloride or an associated compound is a powerful carcinogen. There is now great concern about the possibility of effects caused by the very widespread use of the polymeric form, polyvinyl chloride (PVC) in sandwich bags, plastic wraps, bottles, etc.

The Trace Contaminants sub-program on Organic Chemicals of Commerce is designed to take a careful look at potentially dangerous organic chemicals in the environment. One of the major difficulties in this field is identifying the chemicals that are carcinogenic or mutagenic. Historically, this has been done by exposure of the chemicals to animals and search for induced cancers. This approach has many drawbacks, however, and a need exists for the development of simpler, faster and less expensive tests that would screen potentially harmful chemicals for further testing.

NSF is presently supporting work at Washington University in St. Louis on variations of the "Ames Test." This test employing various

strains of Salmonella bacteria, is quite promising in terms of distinguishing between carcinogenic and non-carcinogenic compounds, but it is unlikely that any single test will prove to be 100% reliable. Therefore, it is essential that other lines of testing be pursued and that is the purpose of this project.

In this project, tests based on mammalian cells will be developed and tested. Changes of chromosome processes and structure will be used: mitotic anomalies, aberrations and sister chromatid exchanges (SCE). *A priori* it is expected that such effects of chemicals on mammalian cells will provide a more direct indication of possible effects on humans, especially their germ-lines, than tests involving bacteria. About 50 known mutagens and non-mutagens will be subjected to the tests to determine their reliability and reproducibility. Several anesthetic compounds will be tested to seek possible correlations with observed excessive rates of birth abnormalities involving offspring of operating-room personnel. The frequency of SCE chromosome modifications in cells from human blood will be measured to observe any correlation with susceptibility of persons to cancer. Blood from patients undergoing chemotherapy will be investigated for possibly elevated rates of SCE modification of cells. Germ-line chromosomes from two species of laboratory animals will be mapped for possible future development of additional tests of chemicals.

The major user groups will be scientists within EPA and NIH as well as investigators supported by those groups and NSF/RANN.

Chemical Oxidation Processes in Aquatic Environments; *Theodore Mill;* Stanford Research Institute, 333 Ravenswood Avenue, Menlo Park, California 94025; \$152,110 for 24 months beginning June 1, 1976

About 20,000 organic chemicals are manufactured in this country every year in quantities of over a million pounds each. Nearly 500 new organic compounds enter commercial channels each year. A significant fraction of these chemicals is lost to the environment during their manufacture, transportation, and use, or in the disposing of products made from them. Organic chemicals in wide variety are thus distributed in soil, water, and air in concentrations that may increase to dangerous levels if the compounds are not readily degraded by chemical or biological processes.

Environmental protection agencies must frequently make decisions regarding these large numbers of chemicals based on incomplete information, for it is unreasonable to expect that detailed research on the environmental behavior of so

many substances will be undertaken. Moreover, regulatory agencies tend to concentrate their research efforts on specific substances already perceived as potential environmental threats. There is needed, therefore, a broad base of scientific knowledge that would allow extrapolation from the data on a few representative chemicals to the entire universe of organic compounds. This project then, as a part of the RANN Chemical Threats subelement, is concentrating on the generalities of chemical processes governing the degradation of organic chemicals, and on the properties of natural aquatic systems that influence oxidative degradation. The research is confined to non-biological oxidation processes. The roles of photochemical, catalytic, and free radical processes will be investigated.

The Extent of Exposure of Migrant Workers to Pesticides and Pesticide Residues: *Clarence B. Owens;* Florida A&M University, Tallahassee, Florida 32307; \$200,000 for 18 months beginning August 11, 1975.

Migrant workers are among those agricultural workers who are most exposed to adverse socio-environmental conditions. These workers and their families are largely from nonwhite and minority populations. They suffer a greater risk from exposure to pesticides and their residues than more stable farm workers because of their sustained and repeated exposure to a greater variety of pesticides and pesticide residues.

Lack of information in general, and the difficulties associated with tracking and monitoring itinerant workers to obtain field data have hampered any efforts to design policies that would improve the occupational and health conditions of the migrant worker. Likewise, efforts to design standards for pesticide and pesticide residue exposure have been complicated by the lack of data which combines clinical, epidemiological, and environmental data.

This project is jointly supported by NSF, the National Environmental Research Center at Triangle Park, N.C., and the Office of Research and Development and the Office of Pesticide Program of the Environmental Protection Agency in Washington, D.C. It is a field investigation of migrant worker exposure in which the project team will travel with migrant crews for a twelve-month period and collect data on such factors as health, education, housing conditions, incidence of ill-health and pesticide-related illness, and amounts and types of pesticide usage.

The goal of the project is to provide information to be used in improving the design of programs and policies affecting agricultural health and safety in the area of pesticide exposure.

Chemical Structure, Reactivity, and Carcinogenicity of Halohydrocarbons; Benjamin L. Van Duuren; New York University School of Medicine, Institute of Environmental Medicine, 550 First Avenue, New York, N.Y. 10016; \$380,000 for 24 months beginning April 1, 1976

Halogenated hydrocarbons, both saturated and unsaturated, are industrially produced in large quantities and often become widely distributed in the environment. Many of these compounds are close structural analogs of the carcinogens: vinyl chloride and trichloroethylene. Historically, chemicals that are cancer-causing in humans have been identified as carcinogens only after their discovery during epidemiologic studies based on occupational exposure. However, with the advances made during the past 30 years in chemical carcinogenesis research, it is now possible to expect that the carcinogenicity of certain chemicals may be predicted generally, if not specifically.

This project concerns the integrated study of a major class of commercially important organic chemicals for the purpose of determining the

linkage between the chemical properties of these compounds and their adverse biological behavior. The halohydrocarbons selected for the study are: vinylidene chloride, perchloroethylene, allyl chloride, 1,3-dichloropropene, chloroprene, hexachlorobutadiene, ethylene dichloride, ethylene dibromide and tetrabromoethane. The principal aim of the work is to determine the relationships between chemical structure, reactivity with a variety of reagents, stereochemistry, *in vivo* and *in vitro* metabolism, and carcinogenic activity. Through these studies, the nature of the activated carcinogenic intermediates of those carcinogenic halohydrocarbons which need to be metabolically activated can be determined. The studies will also yield new information on those compounds which are direct-acting carcinogens.

PROGRAM DEVELOPMENT AND UTILIZATION

The objectives of the Program Development and Utilization subelement are to assist the Chemical Threats to Man and Environment subelement 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.

Information Support Services for Trace Contaminants Program; *Emily D. Copenhaver*; Oak Ridge National Laboratory, Information Center Complex, P.O. Box X, Oak Ridge, Tennessee 37830; \$135,000 for 12 months beginning April 1, 1976

Since 1973, the Toxic Materials Information Center, Information Center Complex, of Oak Ridge National Laboratory, has provided a variety of information support services to the Chemical Threats to Man and Environment Program of NSF-RANN. These activities have been funded as a part of the Ecology and Analysis of Trace Contaminants grants, which terminated on December 31, 1975.

This grant renewal provides for information services for the Chemical Threats to Man and Environment Program directly through the Information Center Complex, which includes the Toxic Materials Information Center (TMIC) and the Environmental Response Center of the ORNL. The information provided by the Information Center Complex is intended for the broad community of users of this information as well as NSF/RANN.

Workshop on the Chemistry of Atmospheric Sulfur; *James P. Friend*; Drexel University, Philadelphia, Pennsylvania 19104; \$27,600 for 3 months beginning May 1, 1976

For the past two decades, the air pollution effects of sulfur compounds have caused great concern. Despite intense study during this period, many key questions remain unanswered, e.g., 1) which atmospheric sulfur species cause significant health effects?; 2) whether sulfur species that affect biological species arise from anthropogenic SO₂ or from biogenic sources?; 3) whether control of sulfur emissions is the most efficient way to mitigate problems caused by atmospheric sulfur or if

The services include: 1) the preparation of documents summarizing current literature on halogenated organic compounds, particularly those of environmental and human health concepts; 2) the publication and distribution of a bimonthly abstract journal and newsletter covering all research results published by Trace Contaminants program grantees; 3) the annual publication of the Trace Contaminants Directory of program participants; 4) the management of a technical information system file; and 5) the operation of an environmental response and referral center for the user community and those concerned with the environmental and human health aspects of trace contaminants.

there are other key factors that could be more easily controlled?

Answers to these questions are badly needed by EPA and local pollution agencies for regulatory purposes and by industries, especially power companies, whose operations would be affected.

Recently, many new and sophisticated techniques for studying these unanswered questions have

been developed, but the studies will be very costly to perform. It is therefore essential for investigators to have a clear picture of the questions that need to be answered, the techniques available, and the work already in progress, so that they can design their own research to attack key questions and avoid duplication of work already done.

Under this project, a workshop will be held in order to bring together key researchers on various aspects of the sulfur problem so that they can learn about the questions, techniques, and research to

date. Areas to be covered in the workshop are health effects of sulfur species; natural and anthropogenic sources of atmospheric sulfur compounds; chemical and physical interactions of these species after release; transport phenomena; and experimental methods for study of these aspects of the total problem.

Participants are to include people from ERDA, EPA, EPRI and NSF/RANN, as well as many prominent researchers who are involved in work on atmospheric sulfur questions.

Tenth Annual Conference on Trace Substances in Environmental Health; *Hemphill, Delbert D.*; University of Missouri, Columbia, Missouri 65201; \$15,000 for 12 months beginning June 1, 1976

The Tenth Annual Conference on Trace Substances in Environmental Health is a continuation of a series of scientific meetings held under the auspices of the University-wide Environmental Health Program of the University of Missouri.

The purpose of these Conferences is to explore the effects of trace amounts of organic and inorganic chemical substances on man and ecosystems. The Conferences examine the occurrences of these substances in environmental media, biota, and foods, and the processes by which they are transported through environmental pathways or produce their effects on living forms and ecosystems.

Specific objectives of the Conference are to: 1) bring together the various disciplines concerned with the effects of trace substances in the environment; 2) exchange the latest scientific information in the interdisciplinary areas that relate the information on trace substances to the health of man and his ecosystem; 3) define the indirect effects of trace substances upon man through changes in his

ecosystem; 4) explore methodology for the evaluation and control of the effects of these trace substances; and 5) publish the Conference proceedings so that researchers unable to attend the meetings may avail themselves of the material presented.

No other comparable conference on the effects of trace substances in the environment is presently held in this country or abroad on a continuing basis. The Conferences have brought together specialists from such fields as toxicology, chemistry, nutrition, geology, geochemistry, pathology, plant sciences, and epidemiology. The Conferences are important to the RANN Program on Chemical Threats to Man and Environment in developing its research support relating to contaminants and natural trace chemicals in the geochemical environment. In addition, they provide a forum for Program grantees to present their research findings and for Program staff to alert workers in the field to new developments and priorities. In this way, the Conferences provide a vital link between the Program and its prospective clientele.

An Identification of the Potential Users of RANN's Trace Contaminant Program; *Edward M. Martin*; Environmental Quality Systems, Inc., 1160 Rockville Pike, Rockville, Maryland 20852; \$14,800 for 12 months beginning June 1, 1976

In the last few years, the Federal government has been trying to develop a system whereby the results of federally sponsored R&D activity could be transferred to the private sector as well as to state and local governments. NSF's RANN program has been very interested in this effort

because of the Program's philosophy, that of supporting research directly related to national needs.

The Chemical Threats to Man and Environment subelement, as part of RANN/AENV, is therefore involved in this effort. As the focus of the program

changes, there is a need to systematically identify the entire range of potential users of new program output and to incorporate into the program those information transfer mechanisms which will most effectively develop a continuing liaison between program and user. This project is intended to help improve communication between program and current user groups and to identify a new array of user groups for the proposed program of activity in Chemical Threats to Man and Environment.

The research plan includes: 1) a review of the present technical outputs of the Chemical Threats to Man and Environment subelement; 2) a

systematic categorization of all the users of the CT program and the various information transfer mechanisms used to reach this audience; 3) the development of detailed lists of the users in each category detailed down to the cognizant organization unit; and 4) the preparation of a working document which incorporates the product of all tasks into a format which will guide the research utilization activities of individual projects in a coordinated delivery of information to the hierarchy of users identified as beneficiaries of the program.

ENVIRONMENTAL EFFECTS OF ENERGY

The objective of the Environmental Effects of Energy subelement is to develop the scientific knowledge needed to reduce conflicts between increased energy production and environmental quality. The Energy Research and Development Administration now assumes the lead responsibility for identifying major environmental problems associated with advanced energy technologies. NSF/RANN, therefore, will fund no new initiatives under an AENV Environmental Effects of Energy subelement.

Computer Model for Oil Spill Movement in Delaware Bay; *Robert B. Biggs*; College of Marine Studies, University of Delaware, Newark, Delaware 19711; \$186,600 for 12 months beginning April 1, 1976.

This is a continuance of an 18-month project originally funded by NSF in FY 1974. The Lower Delaware Bay is the site of an extensive transfer of crude oil from large tankers to small vessels. Frequently, small spills occur, and the potential for a massive spill is always present. The objective of this study is to develop a computer model which predicts the 2-dimensional movement of an oil spill in Delaware Bay in terms of locations and time. The computer model will predict oil movement in relation to current and wind conditions, bottom topography, size of spill, and viscosity of oil. This capability allows for the efficient placing of equipment during a clean-up operation. In addition, the

model will show where a spill is likely to migrate during a given season of the year, thus indicating where, along the shoreline, clean-up equipment should be stored for the most advantageous use.

The goals for the remaining year of the study are to: (1) incorporate into the model severe wind conditions and the behavior of frontals; (2) complete water-oil emulsification studies; and (3) complete remote sensing studies for the purpose of tracking the spills and validating the study. In addition, different ways of handling incoming oil shipments in the Lower Delaware Bay will also be evaluated.

Chemistry, Fate and Removal of Trace Contaminants From Low- and Medium-Salinity Geothermal Waste Waters; *Kenneth Y. Chen*; Environmental Engineering Program, University of Southern California, Los Angeles, California 90007; \$118,500 for 15 months beginning April 1, 1976

The goal of this project is to study, in detail, the chemistry of inorganic constituents which occur in low- to medium-salinity geothermal waters, with special emphasis on arsenic, boron, and fluorine. Although it has been shown that geothermal waters carry a large number of trace metals, only arsenic (As), boron (B), and fluorine (F), for many low- to medium-salinity waters, occur in amounts considered harmful to man. In fact, the work during the first year of this study has demonstrated

that most low-salinity waters can be used for drinking or agricultural purposes if only one, two, or at the most, three elements were removed—those being As, B, or F.

The results of this year's study will provide the capability to predict the chemical form of a trace constituent in water of given salinity and anionic composition, and will also provide the information necessary to devise a practical means of removing

arsenic, boron and fluorine from geothermal waters. Emphasis is to be placed on sorption studies as a means of removing As, B and F from the waters, and on thermodynamic/equilibrium

studies designed to indicate the speciation of a heavy metal in the waters as a function of salinity and anionic composition.

Microbiological Effects of Petroleum Accumulation on Beaches; *Rita R. Colwell*; University of Maryland, College Park, Maryland 20742; \$92,000 for 12 months beginning March 15, 1976.

This project is part of a broader AENV-sponsored study designed to evaluate the effects of oil which has spilled on different beach types.

The purpose of this study is to evaluate the environmental effects of spilled oil on microorganisms of beaches. This is important and timely research because microorganisms play a vital role in the life cycle of higher animals and plants; and because their destruction can result in plant loss which, in turn, reduces the stability of beaches. In addition, microorganisms contribute significantly in degrading spilled oil, thus providing a natural means of clean-up after a spill.

The research plan involves the collection of sediment and water samples and (1) measuring the effect of oil on microorganism populations; (2) evaluating effects of oil on oil-degrading bacteria by monitoring bacteria during degradation of a control oil; and (3) assessing the potential for bacteria to degrade oil by inoculating oil samples with organisms and analyzing organic extracts as a function of time. These factors will be evaluated for their relevance to different types of beaches in the spill area, resulting in the information necessary to rate or rank beaches on the basis of beach type in terms of potential for damage to microorganisms and potential for degradation of the spilled oil.

Beach Morphology in Relation to the Distribution of Oil From a Spill in the Straits of Magellan: A Comparison with Potential Spill Sites in New England and Alaska; *Miles O. Hayes*; University of South Carolina 29208; \$98,600 for 12 months beginning December 15, 1975.

In August, 1974, the supertanker *Metula* ran aground in the Straits of Magellan. Nearly 18 million gallons of crude oil spilled into the water and about 80% of that was washed ashore. Brief studies made over a 12-month period from August 1974 to August 1975 indicate that much of the oil washed ashore is still on the beaches—along nearly 100 km of shoreline. Chemical studies indicate that, at least during the first 5 months following the accident, the oil on the beaches underwent little degradation.

The objective of this research is to develop a land-form classification of beaches in the Straits of Magellan and to measure the amounts of oil that has accumulated on the different classes of beaches as a result of oil spills. This information would be useful in predicting the extent of oil spill damage on a particular class of beach. In addition, a study of the beach processes would also indicate changes occurring through wave action.

To date, the beaches have been classified, amounts of oil noted, wave action studied, and over 65 detailed beach profiles measured along 100 km of shoreline. Permanent survey stakes have been set so that changes in beach form can be measured in the future. It has been found in beaches subject to erosion that an important means of oil removal is by wave and current action which actually destroy a part of the beach by removing sediment and oil. The oil is lost to the water and the resulting clean sediment is then washed up onto another

beach. On other beaches, the in-place oil is being covered by fresh sediment being washed in from previously eroded beaches. Although this process is understood, the rate at which it occurs is not. Rate information can be obtained by using the survey stakes which were placed along the beaches by the Principal Investigator during the original trip to the beaches in February 1976. In August 1976 the researchers will return to the beaches to measure new beach profiles in order to calculate the rate of beach destruction and build-up in the six months between trips. At this time, beach processes in winter will also be studied. Previous NSF studies have shown that parts of the Straits of Magellan are strikingly similar to coastal areas of New England and Southern Alaska. The rate information obtained by studying the Chilean beaches will provide valuable data pertaining to the New England & Alaskan beaches; such as, the type of damage to expect, the nature of wave processes, and the rate at which wave action will either clean a beach or cover existing oil with fresh sediment.

Because of the expected increase of oil activity (production, refining, transportation, and storage) in N.E. & Southern Alaska, the probability of oil spills in these areas will increase. Information from this research project will provide researchers with data for classifying New England Alaskan beaches on the basis of potential spill damage and will also be useful in the planning of sites for petroleum facilities.

Time-Variable Emissions of Air Pollutants; *Glenn R. Hilst*; The Research Corporation, 125 Silas Deane Highway, Wethersfield, Connecticut 06109; \$90,000 for 12 months beginning April 1, 1976.

The objective of this research is to design a program of fuel burning for power plants which takes advantage of the natural tendency of the atmosphere to disperse pollutants. The underlying principal for such a program is that during periods of high atmospheric dispersion, an operation can be changed (by switching from low- to high-sulfur coal, for example) so that existing EPA ambient standards are not exceeded even though the total output of a pollutant may be increased.

This project was originally funded in FY 1975 for 12 months, and during that time a computer program was developed to evaluate SO₂ output in terms of atmospheric conditions and power plant operation (e.g., use of scrubbers or fuel switching).

During the present year, the program will incorporate weather predictions into a scheme of power plant operation. In this way, based on weather forecasts, a program can be established to consider

various operational modes in terms of maximum emissions and minimum cost, the goal being to stay within established ambient standards. Any combination of the following modes can be considered by the predictive program: fuel switching, tall

stacks, pre-treatment of fuel, load switching, and scrubber operation. Since this program is general, it can be applied to any power plant where meteorological data are available.

The Environmental Effects of Noise from Geothermal Resource Development; *Philip Leitner*; St. Mary's College of California, Moraga, California 94575; \$29,000 for 7 months beginning September 1, 1976.

The purpose of this research is to assess the effects of noise from a geothermal operation on wildlife. Noise levels at such operations are very high, and although they are not continuous, do occur with a high degree of frequency. Most of the noise originates from the venting of wells and from drilling.

What effect this noise may have on animals and their auditory organs is not known. This research project is based on this concern and is designed to answer the following questions: 1) What are the second characteristics (intensity, frequency, duration) to which animals are exposed in an operating geothermal area?; 2) Can noise of the type occurring in a geothermal area do physical damage to the auditory system of an animal?; 3) Does comparable auditory damage actually occur in animals exposed to the same noise under natural field conditions?; 4)

Does wildlife tend to avoid areas of geothermal noise?; 5) Does the noise make or interfere with communication signals important to the survival or reproduction of wildlife populations?; 6) Is there evidence of significant differences in species diversity, population densities, or reproductive success in study sites within an operating geothermal field as compared to similar undisturbed sites?

Specific research tasks are designed to answer these questions. The study will provide both physiological and ecological data; two factors which, in addition to esthetic considerations, are needed in order to assess the effect of noise from a geothermal operation. First-year findings suggest that animal behavior is not affected at sound levels below 65-70 db, and that level is usually reached at the outer margin of the facility construction area.

Geohydrological Environmental Effects of Geothermal Power Production; *John W. Pritchett*; Systems, Science and Software, P.O. Box 1620, La Jolla, California 92038; \$113,000 for 12 months beginning June 1, 1976.

Jointly funded by the Divisions of Advanced Environmental Research and Technology and Advanced Energy Resources Research and Technology*, this award supports research to develop a computer model for studying the behavior of a geothermal reservoir system under conditions of fluid withdrawal and injection. Specifically, programs will be developed for evaluating three specific environmental hazards: subsidence, induced seismicity, and ground water pollution resulting from injection of spent brines. The program will be time dependent, three dimensional, and treat multiphase liquids in a heterogeneous and non-rigid rock matrix.

These studies are being accomplished by incorporating within the computer programs those data

which are being generated from an operating geothermal production and injection facility which is operated by San Diego Gas & Electric Co. in the Imperial Valley. In addition, the subsidence model will be field validated against production and subsidence data from the Wairakei area of New Zealand. The end result of this entire project is to produce a mathematical model and computer program which allows some degree of prediction of physical changes in the reservoir system during withdrawal and injection of geothermal fluids.

*Note: the award amount presented here only includes funds from the Division of Advanced Environmental Research and Technology.

Physico-Chemical Reactions of Metals in Petroleum With Beach Sediment; *Joseph H. Rule;* Department of Geological Sciences, University of Tennessee, Knoxville, Tennessee 37916; \$56,300 for 15 months beginning June 1, 1976.

This research project is closely related to two other NSF-funded studies which were prompted by the large oil spill that occurred in August 1974 in the Straits of Magellan. In that spill, nearly 18 million gallons of crude oil was lost, and about 80% of that oil as washed up on to the beaches. Subsequent studies show that much of the oil is still there.

The emphasis of this project is on studying the physical-chemical interaction between oil and beach sediment, particularly on the partitioning of heavy metals between oil and sediment. The distribution of oil in terms of sediment type will also be studied.

This research is desirable for two reasons: 1) the presence of metals plays a vital role in the productivity of oil-degrading bacteria; and 2) heavy metals may have a profound effect on nutrients in soil

which would affect plant growth and subsequent beach stability. An end product of the research is to define biological and physico-chemical effects of oil in terms of beach type so that results can be applied to similar beach types in other areas. For this reason, study of the Chilean beaches is especially valuable because of the similarity of the Chilean beaches to New England and southern Alaskan beaches—areas of the United States likely to experience a considerable increase in petroleum activity in the not-too-distant future.

The goals of this research will be accomplished by studying samples in one small area of the Straits which serves as a microcosm of the entire region. This area, the Punta Anegada, comprises a number of different types of beach sediment, all of which have been heavily inundated by oil.

Evaluation of Broadband Seismic Spectra as a Means of Distinguishing Natural from Induced Earthquakes; *Alan Ryall;* University of Nevada, Reno, Nevada 89507; \$29,900 for 12 months beginning June 1, 1976.

The development of geothermal resources in the Imperial Valley, California, raises concern over induced seismicity because of the large quantities of water that will be withdrawn and injected into the subsurface. For example, a 1,000 MW plant may require subsurface disposal of as much as 150 million gallons/day of waste brines. Next to subsidence, induced seismicity is probably the major concern in the Imperial Valley.

Minor earthquakes occur frequently in the Imperial Valley, and it would be highly advantageous to be able to differentiate between natural and induced earthquakes. Broadband seismic spectra may contain features which can serve to make this distinction.

This research project is aimed at making a thorough search of the literature and a careful study of selected broadband data to evaluate the likelihood of developing a seismic discriminant. This study is not aimed at developing a discriminant; rather the goal is to collect enough information so that researchers can determine whether or not a discriminant can be developed. If this is so, the research will also indicate what sort of studies could lead to the actual development of the discriminant. Existing data is to be utilized for this research project and only a small amount of new data will be generated.

An Assessment of The Effects of Energy Development In The Fort Union Basin, Montana and Neighboring States; *Arnold J. Silverman;* Department of Geology, University of Montana, Missoula, Montana 59801; \$3,000 for 3 months beginning April 1, 1976.

This is a renewal of a grant originally funded in FY 1975 to make an economic projection study of the

coal demand for the Northern Great Plains. The objectives of the project are to acquire environmental

and economic data for assessing the environmental effects resulting from increased coal mining and energy development in the Fort Union Basin. These data will be used for the purpose of designing means of minimizing environmental damage.

A major segment of the original research project is entitled "Montana Coal Demand Study" which projects the probable levels of coal development in Montana and adjacent states for the next 5, 10, and 25 years.

Behavior of H₂S In The Atmosphere And Its Effects On Vegetation; *C. Ray Thompson*; Statewide Air Pollution Research Center, University of California, Riverside, CA. 92502; \$89,000 for 12 months beginning April 1, 1976.

Although it has been known that H₂S is a common effluent at geothermal operations, data are lacking on the atmospheric decomposition of the gas and its effects on plants. H₂S damage to vegetation is well known, but the levels at which such damage occurs is not. Thus, the objective of this research is to define the atmospheric concentrations of H₂S which cause damage to plants and to study the persistence of H₂S in the atmosphere.

During the first year of this study, research demonstrated that both rapid- and slow-growing plants sustain damage through exposure to atmospheric concentrations of H₂S in the range of 30-300 ppb. Emphasis during this first year of the study was on wild flora.

The Petroleum Industry In The Delaware Estuary; *William Whipple, Jr.*; Rutgers University, Water Resources Research Institute, Cook Campus, New Brunswick, NJ 08903; \$350,000 for 12 months beginning May 1, 1976.

The objective of this research is to evaluate the effect of petroleum pollutants on the Delaware estuary. This is a continuation of a study originally funded in FY 1974 for the purpose of evaluating the idea that increased refinery production would also increase the hydrocarbon input into the river.

Year I was devoted to developing research methods and to the gathering of preliminary data. Findings from Year II of this study suggest that refineries are only one of the sources of hydrocarbons for the estuary. Other industries and urban runoff contribute considerably more petroleum

In view of the valuable findings of this demand study, this renewal award is being provided for the purpose of making copies of the complete report available to government agencies and to persons doing research in the subject area. In addition, approximately 1,000 copies of an abbreviated report are being distributed according to the mailing list of the Northern Great Plains Resources Program.

Current emphasis is on defining more precise limits at which H₂S damage occurs. This will be done by the continuous fumigation of plants in greenhouses with a mixture of H₂S and carbon-filtered air. The experiments will be conducted using agricultural crops such as lettuce and sugar beets as well as on wild species. The mechanisms responsible for physiological damage will be studied by sulfur analysis of plant fractions.

At the conclusion of this 12-month study, data will be available to indicate if ambient levels of H₂S at geothermal facilities are capable of producing damage to common plants such as alfalfa, grapes, lettuce, pinto beans, and sugar beets.

waste to the river than do the refineries. In addition, it has been found that petroleum wastes from a variety of sources are harmful to biota.

Although the goal of this research is still to identify the sources and nature of hydrocarbons and to evaluate their effects on biota, the questions to be answered now are the extent to which refineries can increase their activities; and what controls are needed on municipal activity to minimize input of hydrocarbons. Emphasis during Year III is on better definition of sources of hydrocarbon pollution;

identification of specific toxicants in oils; evaluation of chronic effects on aquatic animals using an in-situ floating laboratory; and the effect of petroleum wastes on marshland ecosystems. Source work is being accomplished by extending measurements

from storm sewers and tributaries to the entire metropolitan area through examination of land-use patterns. The bioassay work is now moving from the laboratory into the field so that effects to biota can be measured in the natural environment.

REGIONAL ENVIRONMENTAL MANAGEMENT

Research in Regional Environmental Management is designed to enhance man's ability to deal effectively with regional environmental problems. Focus is on environmental problems of selected regions and their component interrelated factors, including economics, growth, resource availability, social, institutional, and organizational, as well as physical factors. This user-oriented research is designed to produce information of value to the planning and management of regions or natural resources with maximum benefit and minimal environmental disruption. A continuing effort at coordination and information exchange between investigators and Federal agencies, State and local governments, and industry is maintained.

The objectives of the subelement are to:

- Evaluate attitudes of various societal groups toward the physical environment and demand for resource use; define factors influencing changes in attitudes and values concerning the environment; and assess the cost and benefits to various societal groups for alternative levels of environmental quality.
- Analyze economic and legal mechanisms as management options available to decisionmakers, the specific environmental effects of such options, and the potentially favorable or detrimental effects of other forms of public policy.
- Synthesize and evaluate management strategies utilizing appropriate environmental, economic, and social information.
- Identify the resource and ecosystem relations affected by development so as to be able to predict consequences of alternative strategies to correct environmental problems.

In pursuance of these objectives, the Regional Environmental Management subelement is divided into six research areas:

- Environmental Risk Management
- Institutional Aspects of Regional Environmental Management
- Land Use
- Regional Environmental Systems Evaluation and Synthesis
- Residuals Management
- Urban Hydrology

ENVIRONMENTAL RISK MANAGEMENT

The Environmental Risk subelement constitutes a response to a National need to know and understand those natural events and human activities capable of harmful environmental consequences. To enhance our ability for management of environmental risks, the following needs are recognized:

- Clarify and develop appropriate environmental risk objectives, and identify the array of environmental hazards, and structure an understanding of their causes.
- Develop measures for estimating and comparing the consequences of activities or events while predicting risks and evaluating them according to social, economic, environmental, and other standards and objectives.
- Devise techniques and means for managing environmental risk and implementing risk control measures.
- Evaluate risk management strategies for effectiveness and equity.

Workshops For Collaborative Research On Risk Assessment And Environmental Hazards of Human

Origin: *Robert W. Kates*; Clark University, Department of Geography, Worcester, Mass 01610; \$49,900 for 12 months beginning June 1, 1976

Some technological and natural risks are under-assessed, their hazards continue to imperil humankind. Some risks are overassessed, and resources are squandered in their abatement or opportunities foregone in their avoidance. And many hazards remain unidentified. Is society hostage to the chance of discovery?

Research is needed in the area of technological risk assessment. This was the subject of a recent research effort by two major international organizations, the Scientific Committee on Problems of the Environment (SCOPE), International Council of Scientific Unions, and the UNESCO-coordinated Man and the Biosphere Program (MAB). As a result of this research effort, 3 critical areas of research were identified: the identification of hazards; the estimation and evaluation of risks; and the communication of risk assessments and related societal decisionmaking and policy.

The purpose of this award is to define the next stage of research activity in each of these three

areas. Specifically, the aim is to enable specially organized working groups to move beyond the assessment of current research needs to the planning of collaborative work directly applicable to the three areas of technological risk assessment listed above.

One working group in each of the three research areas—hazard taxonomy, risk estimation and social evaluation, and communication—is preparing two working papers which serve as draft work plans in each area. Each group is made up of 7-9 persons and includes both potential collaborators in the research area and reviewers from the US MAB directorate and from the international SCOPE network. Preparation of the papers includes working with the group and a follow-up meeting for potential collaborators.

The final report is to be in several forms—workshop reports with working papers, work plans for MAB and SCOPE, progress reports and research agendas to NSF/RANN, and collaborative proposals for further work.

INSTITUTIONAL ASPECTS OF REGIONAL ENVIRONMENTAL MANAGEMENT

This element conducts research to determine the effects and effectiveness of a variety of growth management policies, laws, and programs, vis-a-vis solution of environmental problems or protection of environmental values. In addition, factors affecting the implementation of relevant policies and laws as well as the measurement of performance are analyzed.

Study of State Environmental Laws: The Illinois Environmental Protection Act; The Vermont Land Gains Tax; The Adirondack Park Agency Act; *Fred R. Anderson*; Environmental Law Institute, Suite 620, 1346 Connecticut Avenue, NW, Washington, DC 20036; \$204,600 for 15 months beginning May 15, 1976

In the late 1960's and early 1970's several innovative state laws were enacted with the intent of dealing more effectively with environmental problems. The laws generated much interest, not only within the enacting state but in other states as well. To date, few attempts have been made to monitor and evaluate implementation of these laws in order to produce objective and meaningful answers to questions about the effects and effectiveness of such laws.

The purpose of this research is to evaluate strengths and weaknesses of 3 different state environmental laws and to assess their applicability to other settings. Each law is different in purpose, has stimulated considerable interest nationally as models, and has been in existence long enough that

its progress can be analyzed. The 3 laws to be studied are: 1) the Illinois Environmental Protection Act, which consolidated state agencies and established new processes for enforcing air, water, noise and land pollution standards; 2) the Vermont Land Gains Tax, which attempts to reduce land speculation by imposing a heavy tax burden on gain realized from the rapid resale of land for subdivision; and 3) the New York Adirondack Park Agency Act which established a regional control system based on a comprehensive land use plan.

An in-depth case study approach is to be used to analyze each law with regard to effectiveness in achieving legislative goals, ease of implementation, effect on government responsiveness and accountability, political acceptability, and fairness.

The Design of Development Management Systems; *Robert C. Einsweiler*; University of Minnesota, School of Public Affairs, Minneapolis, Minnesota 55455; \$199,300 for 19 months beginning June 1, 1976

In recent years, considerable nationwide interest has been generated in seeking ways to more effectively manage growth or development in order to achieve a variety of public purposes. A major source of innovative efforts to manage growth has been local governments on the fringe of metropolitan areas where intense growth pressure has developed over the past decade. Attempts to use governmental powers to manage the rate, type,

amount, location, timing or sequencing of physical development in a jurisdiction are described as development management systems. Many such systems have been developed by local governments and have been considered for use as models for adoption or adaptation elsewhere. However, experience to date indicates that a number of important design considerations have been inadequately

considered. Some of these are: 1) the effect of existing governmental policies and controls on development; 2) side effects of system implementation; 3) extraterritorial and extrajurisdictional consideration; 4) legal, administrative and planning implications; 5) compatibility between elements of a system, between systems and the governmental setting, and between systems and their goals; and 6) need for monitoring in order to measure performance.

To assist in solving these problems, this project has 2 major objectives. The first is to develop a con-

ceptual framework for guiding the design of development management systems; and the second is to explore important considerations related to measuring system performance. Accomplishment of these objectives will facilitate improved design of development management systems in terms of compatibility with goals, administrative and planning capacity, and with intergovernmental requirements. In addition, better guidance will be obtained on what aspects of a system need to be monitored and on how systems can be revised to reduce unintended side effects and improve achievement of objectives.

Defining the Constitutional Issues of Growth Management; *David R. Godschalk*; Center for Urban and Regional Studies, University of North Carolina, Chapel Hill, North Carolina 27514; \$8,900 for 10 months beginning December 15, 1975

In recent years, numerous urban and rural communities faced with rapid growth rates began to formulate and adopt growth policies to control the rate, volume, character, and location of growth. These growth management programs consist of complex mixes of regulatory, planning, and incentive techniques. The authority of localities to adopt such growth controls, has been challenged by numerous law suits especially in terms of alleged infringement of Constitutional rights.

A grant was awarded in Fiscal Year 1975 to support research with the following objectives: to thoroughly analyze growth management Constitutional issues and to formulate planning guidelines which conform with Constitutional principles. Ma-

major research tasks included: 1) identification of major growth management approaches; 2) analysis of unique factors in different approaches; 3) analysis of Constitutional challenges and principles; 4) analysis of major planning approaches used; 5) analysis of strengths and weaknesses of approaches in terms of Constitutional principles; and 6) identification of future trends.

Research was completed in April, 1976, and this supplemental award was provided to fund the preparation and dissemination of project results in a format of high utility to planners, lawyers, public officials, developers, and citizens at the local government level.

LAND USE

The objective of the Land Use element is to provide an improved scientific information base for maintaining environmental quality and managing regional environmental problems through land use decisionmaking. General research initiatives include efforts to: (1) determine land use impacts of selected governmental policies and programs and private activities; (2) determine physical, socio-economic, and environmental effects of various land uses; (3) determine problems, effects, and effectiveness of particular land use policies, decisionmaking processes, and management programs and techniques in achieving environmental and socio-economic goals; and (4) 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 (\$577,606 for 12 months beginning June 1, 1976); *Orson L. Anderson*; University of California at Los Angeles, Institute of Geophysics and Planetary Physics, Los Angeles, California 90024; "Study of Kaiparowits Resources, and Coordination of Natural Science Components"; (\$133,800). *Wallace S. Broecker*; Columbia University, Lamont-Doherty Geological Observatory, Palisades, N.Y. 10964; "Physical Hydrology"; (\$33,600). *Helen M. Ingram*; University of Arizona, Department of Political Science, Tucson, Arizona 85721; "Environmental Impact Statements in Energy Decision-Making"; (\$18,000). *Stephen J. Kunitz*; University of Rochester, Department of Preventive Medicine and Community Health, Rochester, New York 14642; "Epidemiological Research Among Sub-Populations Affected by Lake Powell Developments"; (\$9,900). *Ronald L. Little*; Utah State University, Department of Sociology, Logan, Vermont 84321; "Socio-economic Impacts of Lake Powell Developments on Non-Reservation Populations"; (\$75,000). *Jerrold E. Levy*; University of Arizona, Department of Anthropology, Tucson, Arizona 85721; "Study of Socio-economic Impacts of Lake Powell and Industrial Developments on the Navajo Indians, and Coordination of Social Science Components"; (\$83,700). *Dean E. Mann*; University of California at Santa Barbara, Department of Political Science, Santa Barbara, California 93106; "Decisionmaking in the Colorado River Basin"; (\$19,700). *Monroe Price*; University of California at Los Angeles, School of Law, Los Angeles, California 90024; "Law Components of Integrated Lake Powell Studies"; (\$31,900). *Robert C. Reynolds, Jr.*; Dartmouth College, Department of Earth Sciences, Hanover, New Hampshire, 03755; "Studies on Physical Limnology, Geochemistry, and Sedimentation"; (\$66,800). *Eric G. Walther*; The John Muir Institute for Environmental Studies, Inc., Berkeley, California 93106; "Air Quality, Plume Analysis, and Impacts of Economic Development"; (\$105,100)

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) legal and hydrologic factors in consumptive water use in the region, (7) predict future significant changes in the Lake Powell ecosystem; (8) recreation demand and environmental quality in the Glen Canyon National Recreation Area; (9) assess the impact of energy development around Lake Powell; and (10) environmental, and socioeconomic consequences of fluctuating elevations of Lake Powell waters.

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 Tribal Council. Communications have also been maintained with in-

Coordination of Environmental and Land Use Controls; *Fred P. Bosselman*; Ross, Hardies, O'Keefe, Babcock, and Parsons, One IBM Plaza, Chicago, Illinois 60611; \$12,000 for 5 months beginning June 1, 1976

This award provides a supplement to a grant originally designed to investigate and evaluate methods by which the various systems of land use and environmental control can be coordinated. A wide variety of independent control systems has evolved at the Federal, State, and local levels. Attempts to coordinate these independent systems to achieve optimum land use decisions, in light of the objectives of all systems, have proven less than completely successful.

A Study of the Economic, Environmental, Natural Resource, and Social Effects Associated with Alternative Metropolitan Development Patterns; *Edwin H. Clark*; Council on Environmental Quality, 722 Jackson Place, N.W., Washington, D.C. 20006; \$25,000 for 7 months beginning May 1, 1976

This award has been made to supplement a grant from the previous fiscal year. The original grant is entitled, "A Study of the Economic, Environmental, Natural Resource and Social Effects Associated with Alternative Metropolitan Development Patterns," and is a study jointly sponsored by CEQ, HUD, DOT, EPA, FEA and RANN with management leadership by CEQ. The objective of the study is to compile and analyze existing knowledge on the effects of metropolitan development patterns

and how those patterns are affected by government policies, programs and regulations. The original contract provided for a thorough review of the literature prior to proposing a study design for estimating effects of alternate development patterns. This review led to the conclusion that air quality was the most important effect to study, but that the method of analysis originally planned was not likely to provide insights on the

The existing control systems in five test regions were examined, along with applicable Federal, State, and local legislation and regulations. Control system officials, developers, and other knowledgeable persons were interviewed to determine how the control systems are actually implemented.

Study results will be published and distributed by the Conservation Foundation and the Urban Land Institute.

importance of development patterns to air quality. It was decided that air quality modeling was the only suitable method of analysis.

Consequently, AENV has provided the additional funds necessary to carry out this portion of

the research. This addition to the original contract will significantly add to the analyses of environmental effects associated with alternative development patterns. The original project schedule has not been modified.

Preservation of Farmland and Environmentally Valuable Landscapes; *Robert E. Coughlin*; Regional Science Research Institute, 3831 Walnut Street, Philadelphia, Pennsylvania 19104; \$126,160 for 15 months beginning June 1, 1976

In recent years, numerous State and sub-State governments have become increasingly concerned with the loss of farmland and other environmentally and aesthetically valuable land caused by urbanization. This concern has led to the search for methods of preserving such land. Several approaches, such as differential assessment programs and exclusive rural use zoning and agricultural districting, have been attempted as part of this preservation effort. However, little is actually known about the effectiveness of these new programs and a limited understanding of the nature of the conflict between urbanization and farming still exists.

Therefore, the primary objective of this research is to estimate the probable effectiveness and costs of selected State plans for preserving agricultural land in urban areas. The research is to be done in 2 phases, and the objectives of the first phase are: 1)

to document the nature and magnitude of the agricultural lands problem in urban areas; 2) to analyze factors which affect the viability of farming on the urban-rural fringe; 3) to assess selected land use controls as to effectiveness, cost, political feasibility, ease of administration; and 4) to estimate the costs of development rights easements and the effect of removing undeveloped land from the market, and to assess the market for controlled land.

Phase 2 is to involve the application of Phase 1 findings and methodology to the assessment of 3 advanced and innovative state plans already in effect. These plans will be analyzed for cost effectiveness, political feasibility and ease of administration. Based on this analysis, recommendations will be made to improve already existing plans or to administer new ones.

Environmental Management and Research in the Lake Tahoe Basin; *Charles R. Goldman*; University of California, Institute of Governmental Affairs, Davis, California; \$200,000 for 12 months beginning November 1, 1975

As one of the deepest lakes in the world, situated in an area of great natural beauty, Lake Tahoe is a natural resource asset of the United States. However, the very elements which have attracted vast numbers of people to the area are now being threatened by residential and commercial development. Disruption of the terrestrial and aquatic environments has resulted from the increased human population. Although the altitude of the Lake Tahoe Basin produces an especially fragile environment, many of the problems encountered here are representative of the rapid urbanization which is taking place in recreational communities across the United States.

This project is aimed at providing an improved scientific base for environmental management of the area and involves biological-physical and socio-political approaches. The aquatic/terrestrial section is continuing to concentrate its effort on the Ward Valley watershed. The program provides a continuous record of qualitative and quantitative data on water arriving as snow or rain and flowing through the watershed into the lake. Tributaries of Ward Creek representative of different kinds of disturbances (parking lots, ski slopes, condominiums, etc.) are being examined so that the effect of man's activities on the water quality of the lake can be assessed. A mathematical lake model is to be

developed to predict the effect of watershed development on lake water quality. The researchers have been working closely with major private and State, regional and federal groups in the basin and

will make results immediately available to these groups to assist in the solution of problems of resource management in the area.

Local Land Use Development Management Through Capital Improvements Programming; *James Hoben;* Department of Housing and Urban Development, Division of Community Development and Management Research, Office of Asst. Secretary for Policy Development and Research, Washington, D.C., 20410; \$100,000 for 14 months beginning May 15, 1976

In recent years, numerous communities have become interested in formulating more explicit and comprehensive policies concerning the nature and quality of community life. As they have done so, they have sought improved or new methods for managing or controlling the amount, type, location, timing and quality of development and land use in the community. This has been accompanied by a growing recognition that provision of public services and facilities also has a direct effect on land use and development. Historically, decisions on capital improvements have usually been made on a fragmented, single-purpose basis, with little consideration for the implications these improvements may have for community land use and growth. Some local governments have now begun to con-

sider the linkage of capital improvements programming (CIP) with their overall land use and development policies.

The purpose of this project is to assess the theory and local government practice related to linkage of capital improvements programming with land use and development policies. Specific research tasks include: 1) review of the literature; 2) reconnaissance to identify relevant local government experience, and 3) comparative analysis of selected practices. The goal of the project is to produce reports useful to city and county governments. This action is an interagency transfer for joint support of a contract to be awarded by HUD to the American Society of Planning Officials.

Water Resources Planning Methodologies; *Mac McKee;* Utah State University, Logan, Utah 84322; \$54,600 for 8 months beginning July 1, 1976

Present regional resource planning efforts often present the extremes of detailed comparisons of alternative plans using technical criteria to abstract considerations for the achievement of broad social objectives. A sound, comprehensive planning effort should link specific technical efforts to the achievement of broader objectives. Such an integration would make water resource planning more rational and more socially responsible. Actions and their consequences would be more firmly linked.

This award seeks to assess the feasibility, costs, and utility of integrating a broad social evaluation method for regional resource planning, TECHCOM, developed by the Technical Committee of the Water Resources Research Centers of the Thirteen Western States with the plan-specific Surrogate Worth Trade-Off Technique (SWT). At the outset this integration of approaches is expected to enhance the social responsibility of water resource

planning efforts and to provide needed data handling systemization.

TECHCOM uses a hierarchical arrangement of social goals and sub-goals to aid in reducing general goals to more explicit quantifiable objectives. SWT uses measurable parameters related to technical objectives to identify a functionally acceptable range of water development alternatives and to provide marginal performance characteristics of alternative plans for more rational trade-offs and choices.

The research team will use highly informed consultants to develop, refine, and review a design for integrating the two methodological approaches. The site focus of the project is the Maumee River Basin, which includes parts of northwest Ohio, northeast Indiana, and southeast Michigan. On-site efforts, prior to design, will center on the gathering of information and data in order to

specify the region's water resource planning and broader goals, functional and institutional constraints, and the costs of technical and data inputs. On-site post design efforts with the assistance of personnel from the Great Lakes River Basin Commission, will include an examination of the usefulness of the expected results of the combined methodologies and remaining information gaps.

Environmental Analysis for Development Planning; *Peter G. Rowe*; Southwest Center for Urban Research, 1200 Southmore Street, Houston, Texas 77002; \$125,600 for 15 months beginning February 1, 1975

Unplanned industrial development in urbanizing areas surrounding urban cores has resulted in many immediate environmental problems and secondary impacts associated with 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 development entity is difficult. This project, which is in its final year of funding has focused on the impact of impending large-scale industrialization and accompanying urbanization in a rural agricultural area in Chambers County, Texas. There is a unique opportunity to analyze the effect of industrial development in this rural area, still sparsely populated and sufficiently isolated to provide a laboratory situation for the examination of growth processes and their environmental effects.

The research is designed to meet the need for techniques to assist decisionmakers in the direction of land use at the urban fringe. The techniques will provide the means to classify land according to performance standards, to relate environmental characteristics to supportable uses, and to identify control mechanisms and management strategies to apply such standards. The approach includes the

All data generated by the project is to be made available to the Great Lakes Basin Commission (GLBC) and other interested planning agencies in the Basin. The results will be disseminated in the form of a technical report to the sponsor, the Review Committee and federal and state agencies. In addition, one or more technical journal articles is expected to result from the project.

compilation of a comprehensive inventory of natural environmental data describing the study area which is incorporated into a computer-oriented data base. Next, a computer assisted methodology estimates the natural environmental capability to support various types of land development. This process involves identification of geographic areas having similar environmental characteristics called "natural environmental capability units," and the potential impact of selected land areas on each capability unit can then be estimated. The goals of the study have been to: 1) provide a scientific analysis of land and environment in the urbanizing area of Chambers County, Texas; 2) analyze Federal, State, and regional land use policies to identify the regulatory constraints upon public and private land use activities; and 3) investigate the present and potential governmental institutions to adopt and carry out a sound land management program. The major products of the study will be the technical documentation of results and a handbook. These are to be distributed among local, state, and federal officials engaged in environmental management activity, and to selected private land developers and industrial groups.

The Interaction Between Urbanization and Land: Quality in Environmental Planning and Design; *Carl F. Steinitz*; Harvard University, Department of Landscape Architecture, Gund Hall, Cambridge, Massachusetts; \$188,600 for 12 months beginning January 15, 1975

Many problems have arisen as a result of land-use planning decisions made on the basis of discrete problems rather than on the basis of the interrelated economic, social, and environmental impacts of such decisions. These land use problems are especially critical at the fringe of many large urban areas where rural communities are being impacted

by growth from rapidly urbanizing areas. Decisionmakers in the rural areas find themselves totally unprepared to deal with land use problems associated with such growth, and they are also without techniques to predict or shape growth.

The objective of this research is to develop methodologies which would assist State, regional

and local decisionmakers and citizens groups to predict the environmental, economic, and social impacts of urbanization and to analyze the various legal constraints on such growth. The study area for this project is the Boston Region Southeast Sector, an area poised for rapid urbanization and representative of such areas at the urban fringe of many of our large urban areas. Various model components are being developed which will share a technical infrastructure consisting of a data base,

a computer data-processing system which includes a variety of spatial and other analysis programs, and a series of graphic and other output devices. These models can be linked in a variety of modes (simulation, optimization, gaming) to provide specific information or answers to policy questions, especially in areas of rapid suburbanization. Almost all of the models are operational and are being tested on issues identified by State, local and regional decisionmakers.

Impact of a Large Recreational Development Upon a Semi-Primitive Environment: A Case Study; *David G. Stuart*; Montana State University, Institute of Applied Research, Bozeman, Montana 59715; \$13,500 for 6 months beginning April 1, 1976

This is a supplement to a grant which funded an in-depth case study of the socio-economic and environmental impacts of a large scale recreational development in a semi-primitive environment, "Big Sky", in the Gallatin Canyon. After establishment of a pre-development data base for selected environmental and socio-economic variables,

monitoring was initiated in order to analyze impacts resulting from construction and use of the development. All research has been completed.

This supplemental award is to provide for preparation of final reports in a format appropriate for use by decisionmakers.

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 August 1, 1975

This is a renewal of a project whose objectives include: completing the work necessary to make Paretian analysis useful to local and regional environmental control agencies; transferring the method and results of the analyses to several agencies with which there has been continual dialogue; and making additional conceptual developments to Paretian analysis and its predictive ability.

This method is constructed on the thesis that an environmental control agency tends to be responsive to the wishes of a number of different interest groups, each of which has a fairly well-defined framework for evaluating the impact of possible agency decisions from its own point of view. The central concept here is that decisions will be "Pareto admissible."

The Pareto Environmental Analysis (PEA) method which is being developed formalizes the decisionmaking process. It involves a method for identifying interest groups and quantifying their evaluation of alternatives. The tool is intended to

improve decisions and make decision technicians far more useful.

In this final phase of the project, environmental policy issues related to five problem areas are to be analyzed, and this analysis will aid in the development of general methods and techniques for using Pareto Analysis as a means of evaluating the political feasibility of various decisions. The problem areas that have been identified 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.

In addition, efforts will be concentrated on producing a monograph that provides an introduction to PEA; practical applications; the development of PEA theory; and conclusions in which PEA is evaluated and advantages and disadvantages are discussed.

National Economic Models of Industrial Water Use and Waste Treatment; *Russel G. Thompson*; University of Houston, Department of Quantitative Management Science, Houston, Texas 77004; \$123,600 for 8 months beginning July 1, 1975

This is a supplemental award for a study that has established sets of mathematical linear programming models for representative plants of major water-using industries. The purpose of the models is to provide an economic basis for effluent control and effluent control-related decisions.

The objectives of the project are to: 1) refine, extend and verify linear programming models of representative plants for heavy water-using industries; and 2) transfer models to industry and government units. Results of this project will aid in decisionmaking in both industry and government. Particular emphasis has been given to the quantities of water withdrawn and consumed, the costs of intake water treatment, the quantities of waterborne residuals generated, and the costs of treating

the residuals or disposing of them in alternative ways. Transfers have taken place in the Houston-Galveston Area Council; the Office of Information Services, Office of Texas Governor; Texas water agencies; and the Effluent Guidelines Division and Data and Monitoring Division of the EPA.

This supplement will: 1) make the results of this three-year effort widely available in published form by providing funds to facilitate publication of the first monograph of a three-monograph series; and 2) provide operational funds to permit adequate response to OMB's desire to use the models to cross-check data emanating from other agencies. The latter constitutes a significant utilization exercise.

On Optimum Meteorological and Air Pollution Sampling Network Selection in Urban Areas; *Fred M. Vukovich*; Research Triangle Institute, P.O. Box 12194, Research Triangle Park, North Carolina 27709; \$80,500 for 12 months beginning December 1, 1975

The establishment of air quality standards has brought about the need to develop an air quality and meteorological sampling network in urban areas. This proposal is designed to test models for a technique to optimize sampling network selection for wind, field, and air pollution distribution in urban areas developed under an earlier grant. Among the factors which govern the decisions as to the nature of a sampling network are: the sampling network must accurately depict the air pollution distribution in the urban area in order to monitor the air quality in space and time, and as a result of the data obtained from the network, prediction of pollutant concentrations must be possible for management strategies.

The results of the investigation will provide environmental managers with a model for an optimum sampling network which will assist in determining pollutant concentration. An optimum network will be determined for St. Louis, Missouri. Verification of the sampling network will be performed coincidentally with the Regional Air Pollution Study (RAPS) supported by the Environmental Protection Agency. The network has two prim-

ary purposes. The first is to provide data for an analysis of air pollution at any time over the urban region in order to determine if and where a particular pollutant concentration has exceeded the standard. The second purpose is to provide a data base for both short- and long-term predictions of the concentrations of a particular pollutant over the urban region. An additional task is to determine the feasibility of using historical wind data (i.e., distribution of wind speeds and directions) from a synoptic weather station, together with simulated wind fields in the vicinity of that station to predict wind distributions. A review of the state-of-the-art made at an EPA symposium revealed that no existing air quality networks could satisfy EPA goals. Therefore, there exists an urgent need for this research so that an objective technique that meets EPA's requirements may be met. RTI has made contracts with the National League of Cities/Conferences of Mayors and expects to inform city mayors and city managers of the existence and purpose of the project. This is to be done by disseminating manuals and giving lectures on the system.

REGIONAL ENVIRONMENTAL SYSTEMS EVALUATION AND SYNTHESIS

The objective of the Regional Environmental Evaluation and Synthesis element is to conduct research into the overall utility of major environmental/economic modeling efforts, in general, and prior RANN-sponsored efforts, in particular.

Technical Review and Assessment of Application of the LIRAQ Model; *Bruce A. Egan*; Environmental Research and Technology, Inc., 696 Virginia Road, Concord, Massachusetts 01742; \$19,600 for 2 months beginning June 1, 1976

The NSF has supported the development by the Lawrence Livermore Laboratory of a numerical model for conventional and photochemical air pollution in the San Francisco Bay area. 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 to assess the effect of various postulated emission control strategies on local air quality.

The purpose of this current project is to support an analysis by Environmental Research and Technology, Inc., of the technical elements of the model as well as its potential application to areas outside

of the study area for which it was originally prepared. Examination of the technical bases of the model will cover completeness of the modeled chemistry, the physical verisimilitude of the fluid dynamical descriptions, and the accuracy of the numerical algorithms used to solve the chemical and advective-diffusive model equations. Existing and potential market areas for the model are to be identified, as well as the benefits to be gained by its use, and the necessary model modifications and/or adaptations required for utilization in such market areas.

Assessment of Selected RANN Regional Environmental Systems Modeling Projects: Transfer and Comparability Testing; *Brian W. Mar*; University of Washington, Department of Civil Engineering, Seattle, Washington 98195; \$140,200 for 24 months beginning February 1, 1976

The Division of Environmental Systems and Resources Program in Regional Environmental Systems (RES) of NSF has provided much support in recent years for projects in applied research to enhance the management of environmental quality in coastal areas, semi-primitive areas and at the rural-urban interface. In many of these projects, modeling has been a central but controversial theme.

Because of the complexity of regional environmental problems, reductionist approaches that attempt to isolate a cause and effect relationship are failing. Modeling approaches have the potential

for success in helping to solve these problems, but are being rejected without adequate assessment. This non-selective rejection creates a void in the attack on environmental management.

An earlier study by the PI on this project was conducted for the purpose of evaluating the projects previously funded by RES in this field. The results indicate that the projects had failed to conceptualize and define models, to organize the modeling team in the construction and validation of these models, and to document and communicate their findings.

It is the purpose of this study to undertake these activities in order to maximize the potential contribution of the projects and to determine if the data obtained from these projects can benefit others facing similar regional environmental management issues.

Specifically, the objectives of the study are: 1) to document the status of model development, application and transfer for the major RANN/RES projects; 2) to assess past project transfer efforts,

respond to needs for transfer assistance, and develop guidelines for future model transfer efforts; 3) to identify, study and test related model components for comparability and validity; 4) to identify critical gaps and achievements in the environmental modeling activities already underway; and 5) to disseminate the results of analyses and tests and to make recommendations to RANN program managers, model builders, and users.

Assessment of the Generalizability of Socio-Economic Environmental Systems Models; *David E. Monarchi*; Colorado Office of State Planning and Budgeting, Management Science Division, Denver, Colorado 80203; \$157,100 for 12 months beginning July 1, 1976

The State of Colorado is committed to building a systematic analytical capacity to address its concern for long-range planning issues and site-specific analyses of technical and policy related planning problems. Such capacities and problems are the concerns of many states. Colorado seeks to develop an efficiently produced socio-economic-environmental systems modeling hierarchy to enable state officials and others to examine systems interactions and explore the temporal paths resulting from alternative planning choices. To build this system efficiently, the State proposes to transfer promising model elements developed elsewhere and use state-developed criteria to evaluate their usefulness.

With this award, the research/utilization team will assemble and build the data base for a test region and use it as the basic core for a test and evaluation center. Such a facility serves the State's needs by: 1) establishing a "proving ground" for

the examination of socio-economic environmental models developed in other parts of the country and having potential utility for Colorado; 2) facilitating the development of an interactive process with State officials for delineating State modeling needs and specifications; and 3) developing technical model-transfer abilities among students, State officials and others.

A series of seminars and conferences with state officials are to be held to aid in the identification of the State's needed modeling specifications. Ongoing test center evaluations will be used in the seminars to maintain model specification realism.

While serving State needs, the National need to test the substance, utility, and costs associated with the use of various models is also served by the Colorado test facility. Many models require essentially similar data. Once generated, the test area data base can be used for numerous model investigations.

Onshore Impacts of Offshore Oil and Gas: Methodology Development and Test; *Thomas Myers; Roy F. Weston, Incorporated, Weston Way, West Chester, Pennsylvania 19380; \$229,181 for 12 months beginning July 1, 1976**

Impending oil and gas developments on the U.S. Outer Continental Shelf (OCS) raise prospects that vital energy supplies will be expanded. Such activities are likely to produce a variety of benefits and costs to the U.S., while onshore communities and regions are particularly affected and already evidencing certain needs. In order to enhance benefits and limit social, environmental, as well as monetary costs, cognizant Federal and State agen-

cies must be able to accurately anticipate direct and indirect effects of OCS development.

Specific objectives of the project are to: (1) assemble, assess, and link appropriate economic and environmental assessment methodologies; (2) test this methodological package on the Baltimore Canyon Region; and (3) prepare documentation on the impact methodologies for use by Federal and State planning officials. The project is jointly

funded with the Department of Interior, Bureau of Land Management, and the Department of Commerce, Office of Coastal Zone Management.

*Note: the reference made here to award funding only reflects that portion contributed by the Division of Advanced Environmental Research and Technology.

RESIDUALS MANAGEMENT

The objective of the Residuals Management element is to synthesize residuals management strategies for minimizing environmental risk. Coupled with the need for solutions to problems of residuals management is recovery of potential resource values of waste constituents.

Impact of Pollutants From Diffuse Sources on Quality of Water in the Chesapeake Bay; *David L. Correll;* Chesapeake Research Consortium, Inc., 100 Merryman Hall, Johns Hopkins University, Baltimore, Maryland 21218; \$399,200 for 11 months beginning June 1, 1976

This award provides for the continuation of a project whose objective is to determine the impact of selected pollutants from diffuse (non-point) sources of the Chesapeake Bay in order to provide the basis for recommendations of management practices to minimize the effects of these pollutants on the Bay and the region of which it is a part. Specific objectives of the study are to: 1) determine the rate of release and total amounts of nutrients, particulates and bacterial indicators of pollution from land-use characteristics of the Chesapeake Bay region; and 2) develop and test procedures for extending the data obtained from research sites to other sub-regions of the Bay and ultimately utilize these procedures in the determination of the role non-point sources play in the pollution of the Bay.

This research was initiated as a component part of the Rhode River portion of research undertaken by the Chesapeake Research Consortium from June 1973 to September 1974. During that period, five monitoring stations were constructed and runoff samples were analyzed for concentrations of organic and mineral particulates, phosphorus, nitrogen, organic matter, *Coliforms*, *Streptococci*, and *Salmonella*. In November 1974 these studies were intensified as two additional monitoring stations were completed, two tidal-flux stations were completed and instrumented, and the planning stages began for two additional tidal-flux stations. The data obtained from the original five monitoring stations were analyzed with respect to land use and reported at two conferences sponsored by the U. S. Environmental Protection Agency. These data

generated much interest by Maryland and Virginia State officials, and a need was expressed for testing the applicability of the data gathered at Rhode River to the entire Chesapeake Bay region. Late in 1975, work began on the York River to test the similarities of diffuse source area yield loading rates to those measured on the Rhode River.

Much of the State planning agency and EPA-interest generated by this project stems from the need to take into consideration the impact of pollutants from non-point sources in regional planning for water pollution control.

In accordance with Congressional interest to initiate an intensive study of Chesapeake Bay* and assignment of this mission to the U.S. Environmental Protection Agency, a more recent award transfers the management responsibility for research relating to diffuse sources of pollution in the Chesapeake Bay to the U.S. Environmental Protection Agency, Region III. Mr. Daniel Snyder, Director of the Chesapeake Bay Studies Program, Environmental Protection Agency is the Bay Studies Program Director. The shift in management responsibility took place on July 1, 1976. A closely coordinated study sponsored by the EPA-Athens, Georgia Water Quality Laboratory is examining samples collected in the NSF-sponsored research for pesticide-residue content.

A series of published documents is scheduled from this project, some of which will be data analyses, evaluation and explanations of methods

of diffuse source analysis developed, and recommendations for transfer of procedures to other coastal zone regions. These documents will be useful to management agencies in evaluating the relative importance of diffuse and point sources of pollution to Chesapeake Bay and the prediction of

land use effects on source, amounts and kinds of pollutants.

*Department of Housing and Urban Development—Independent Agencies Appropriation Bill, 1976 Senate Report No. 94-326, July 21, 1975

Environmental Quality Aspects of Recycling Lubricating Oil; *Peter M. Cukor*; Teknekron, Inc.; Berkeley, California 94704; \$169,600 for 14 months beginning March 1, 1976

Of the one billion gallons of lubricating oil used annually in the United States, less than 10% is re-refined for re-use as a lubricant. The remainder is used as a fuel for dust control on dirt roads or discarded. These practices result in the release of contaminants including oxides of lead, other heavy metals and polynuclear aromatic compounds to adversely affect the environmental quality.

The objective of this research is to determine the feasibility of reducing barriers to re-use of lubricating oils as lubricants which would reduce threats to regional environmental quality resulting from current patterns of disposal. A major barrier to significant use of refined lubricating oil has been identified as a lack of "documentation" of its quality, a consequence of which has been relative failure by re-refiners to penetrate the "high quality (profit)" commercial and industrial markets. The net effect has been to delay potential environmental quality benefits that will result from extensive commitment to management of crankcase oil pollutants by concentrating them in re-refinery sludges.

Strategies for the reduction of institutional barriers to adoption of re-use alternatives and for increased investment in re-refining include the use of re-refined oils by state and local government agencies in order to establish product acceptability and the retailing of re-refined oils by one or more major oil companies.

Sludges produced by re-refining processes likewise contain substances which if not properly managed will adversely affect environmental quality of a region.

To assess environmental risk associated with management of these sludges, laboratory analyses of soils and sludges are being utilized in a geohydrological model to predict effects on groundwater quality from placement on land of residual sludges. Results are expected to be applicable in the management of other hazardous residuals from municipal and industrial sources.

Process Selection for Optimal Management of Regional Wastewater Treatment Residuals; *Richard I. Dick*; University of Delaware, Newark, Delaware 19711; \$65,000 for 12 months beginning July 1, 1976

Approximately 40-50% of the total costs of wastewater treatment are attributable to management of treatment residuals (sludges). Analyses of current residual sludge management practices indicate that major shortcomings exist, including: failure to integrate sludge treatment and subsequent management with the wastewater treatment processes; failure to control inputs at the source; and indifference to the effect that return flows from sludge treatment processes have on wastewater treatment. This problem is likely to become worse as requirements for higher degrees of treatment result in the production of larger quantities of sludges with qualities that complicate the manage-

ment problem. These increased quantities of sludges must be effectively dealt with in order to meet environmental quality constraints and to conserve energy and resources.

This project is a continuation of an award that has as its objective the synthesis of a procedure for analysis of cost and performance of processes used to treat sludge to permit selection of the appropriate sequence for minimizing cost, energy, resources and environmental impact and to achieve public acceptance.

Mathematical descriptions of the performance and cost of individual processes are being

developed and optimal combinations and operating conditions are being identified by integrating them into systems for residuals management. Fundamental sludge properties and operational and economic variables are being used to formulate the cost models. The combined effect of significant in-

dividual variables on overall process performance can thus be evaluated and the models applied to a wide variety of sludge types and local situations. Results of the project will be evaluated by potential users at a seminar and workshop and will be summarized in a technical manual.

Utilization of Soil Invertebrates in Stabilization, Decontamination and Detoxification of Residual Sludges from Treatment of Wastewater; *Roy Hartenstein*; State University of New York; Syracuse, New York 13210; \$88,500 for 12 months beginning June 1, 1976

Soil invertebrates feed on rotted wood and leaves rich in fungi, bacteria and protozoa to produce humus and thus improve the physical properties and structure of soil in which they are active. As municipalities adopt land-application as a management procedure for their wastewater and treatment plant sludges, it is assumed that these "natural processes" in the soil will accommodate application of sludge to permissible limits established by scientific evidence and good judgment. Clearly, a better understanding of these natural processes will lead to a better understanding of limitations to use of soil for wastewater management and sludge stabilization and thus result in more efficient use of land dedicated to this purpose.

The research is planned to be conducted over a period of two-years, the first of which will be

utilized in conducting laboratory investigations with various types of sludges, soils and soil invertebrates with the objective of designing field-evaluations planned for the second year. The research is directed toward determination of the maximum rate at which invertebrates can function to stabilize organic substances in sludge. In addition, the roles of soil invertebrates in nitrogen fixation and in the inactivation of pathogenic microorganisms are being investigated as are the changes in the structure of the biological community in soils during chemical and biological stabilization of the sludges. Results are expected to be used to provide the basis for better management of land-application systems for both sludges and wastewater.

Application of Sequencing Batch Reactors for Treatment of Municipal and Industrial Wastewaters; *Robert L. Irvine*; University of Notre Dame; Notre Dame, Indiana 46556; \$66,100 for 12 months beginning June 1, 1976

The National goal of the Water Pollution Control Act Amendment of 1972 (PL 92-500) is that the discharge of all pollutants into the nation's waters be eliminated by 1985. It is clearly important to encourage research directed toward meeting this goal. Disadvantages of continuous flow systems presently used have not been sufficient to reverse the trend toward their use and away from batch-treatment methods. However, PL 92-500 encourages a reexamination of treatment concepts that promise to meet its standards of performance at a lower cost and with higher standards of reliability. The use of sequencing, batch reactors offers such a potential.

The objective of this research, then, is to investigate application of controlled, unsteady-state

operations and processes to treatment of wastewater for attainment of better consistency and reliability than is practically possible using conventional, continuous, steady-state methods.

The principal investigator of this project is focusing his attention on the potential offered by adaptation of "fill and draw" to utilize its advantages, which include stepwise equalization, quiescent sedimentation, modular construction and the ability to restrain release of wastewater until it is certain that discharge standards have been attained. Reintroduction of a fill and draw mode of operation may provide a significant means of meeting the challenge of new standards of performance and reliability of treatment plants.

Feasibility of Utilization of Wetland Ecosystems for Nutrient Removal from Secondary Municipal Wastewater Treatment Plant Effluent; *Robert H. Kadlec*; University of Michigan; Ann Arbor, Michigan 48109; \$129,900 for 16 months beginning July 1, 1976

Treatment of wastewater has as its primary and secondary objectives the removal of suspended solids and carbonaceous material that would otherwise exert a demand upon oxygen resources of the receiving waters. In addition, nutrients remaining in the effluent from secondary treatment can stimulate the growth of algae and other aquatic vegetation which upon death and decay also exert a demand for oxygen. Alternatives for solving this problem include removal of the nutrients by chemical precipitation. However, another alternative is the use of highly productive wetlands into which secondary effluent can be directed and within which nutrient removal can be achieved simultaneously with an increase in the productivity of the wetland. Use of a wetland for this purpose can be considered a problem of designing a system of constraints on the supply rate and distribution of the effluent that permits the marsh to maintain itself and function in a manner such that water output meets environmental quality standards while simultaneously maintaining the viability of the wetland ecosystem.

The objective of this project is the determination of the feasibility of using a peat marsh to achieve goals of advanced treatment for municipal wastewater. In this phase, a ten-acre site in the Houghton Lake Wildlife Research Area is being

flood-irrigated with effluent from the Roscommon Township Wastewater Treatment Plant. Monitoring of effects, results of which are being utilized to validate and adjust the ecosystem models includes hydrologic, nutrient, microbial and vegetation components of the ecosystem.

Ground and marsh water quality are being monitored for nitrate, ammonia, ortho- and total phosphorus, chloride, calcium, magnesium, potassium and sodium. In addition, wastewater and water from surface and well-sampling locations are being subjected to analysis for biochemical oxygen demand, suspended solids and coliforms. The absorptive capacity of soil and litter are being determined and potential economic benefits from timber and peat harvesting are being estimated. The design of a full-scale treatment facility for the research site and development of a management plan are terminal objectives of this phase. An evaluation procedure for application of this concept to other locations is to be completed and distributed to potential users. The consulting engineering firm of Williams and Works, Inc. of Grand Rapids, Michigan is conducting an evaluation of the applicability of this concept to similar wetlands in Michigan under a separately-funded but coordinated award (see AEN 76-20812).

Regionalization of Wastewater Collection and Treatment—Location, Scale and Construction Sequence of System Components; *Donald T. Lauria*; University of North Carolina, Department of Environmental Sciences and Engineering, Chapel Hill, North Carolina 27514; \$34,600 for 12 months beginning March 1, 1976

Regionalization offers the potential of realizing economies of scale in construction and operation of treatment plants. However, a substantial part of the investment made in wastewater management facilities is in the collection system. To achieve a lowest-cost solution for wastewater management to improve regional environmental quality, the economy of scale for treatment plant facilities must be balanced against the cost of aggregating the wastewaters. Consulting engineers are limited in the amount of work that can be done in examining alternative systems by limited financial resources of the client and the complexity of the problem.

This research is directed toward increasing the efficiency with which alternative locations, scale and construction-sequence of wastewater management system components can be analyzed. A model developed with prior NSF/RANN support will be used to identify low-cost options for regional management of wastewater for preliminary design. The research plans for this project includes cooperation of several consulting engineering firms to obtain problems being analyzed by conventional planning procedures, operation of the model for identification of alternative low-cost solutions, comparison of results obtained using

conventional procedures with results obtained using the model and the improvement and simplification of the computational procedure.

A workshop will be held devoted to the study of specific cases. This workshop will provide for the

Control of Virus Pathogens in Municipal Wastewater and Treatment Residuals by Irradiation With High-Energy Electrons; *Theodore G. Metcalf*; University of New Hampshire; Durham, New Hampshire 03824; \$40,700 for 12 months beginning July 1, 1976

This award provides for the continuation of research directed toward acquisition of suitable procedural methods and background data for evaluation of the potential role of high energy electrons in disinfection of wastewater treatment plant residuals. Radiation dose and virus inactivation relationships are being determined in the presence and absence of oxygen and under variations in pH, temperature and pressure utilization the electron radiation research unit at the Deer Island Wastewater Treatment Plant in Boston. In addition to determining the viral-inactivation efficiency of high energy electrons; desorption, separation and concentration methods for enumeration of infec-

critical review of the procedure developed in this research as well as an assessment of its transferability to practitioners and recommendations for improvement.

tious virus particles in sludges are being investigated with the objective of improving virus assay techniques with respect to their accuracy and reliability.

This work is being conducted in collaboration with Dr. J. G. Trump, High Voltage Laboratory, Massachusetts Institute of Technology. The awards share a common utilization plan, an important component of which is location of the research unit at a potential user site, and coordination with the Commonwealth's Department of Natural Resources and the United States Environmental Protection Agency.

Feasibility of Utilizing Cypress Wetlands for Conservation of Water and Nutrients in Effluent from Municipal Wastewater Treatment Plants; *Howard T. Odum*; University of Florida, Gainesville, Florida 32611; \$223,600 for 12 months beginning May 1, 1976

This is a continuation of an award whose objective is to determine how cypress wetlands can be utilized to manage a region's water resources and to recycle and conserve nutrients and water from regional wastewaters while simultaneously providing regional greenbelts for esthetic enhancement and wildlife protection. Cypress wetlands are scattered throughout the southeastern United States and would be available for management of wastewater if questions about the consequences of such use could be answered. Currently, wetlands are being rapidly drained and displaced by developments and ditching. Serious problems relating to the appropriate management of municipal wastewater have developed as the Nation's population increased in size and concentration. The use of wetlands could result in large economic savings by providing advanced treatment from municipal wastewater that has received secondary treatment.

Although there are attractive features in the use of wetlands for the recycling of wastewater because they conserve water, use nutrients and provide conservation areas, there are sound reasons for careful investigation of wetland ecosystem response. This research is directed toward a study of cypress domes to determine their potential utilization for management of effluent from secondary treatment of municipal wastewater. Results to date indicate that cypress wetlands can over a long period of time absorb application of one inch of treated effluent per week. A preliminary economic analysis indicated that the use of the cypress domes compares favorably with alternative procedures for achieving advanced wastewater treatment objectives. A handbook of cypress wetland management is in preparation for use by land planners to incorporate utilization of wetlands into a plan for management of regional water resources.

Management of Physical Alterations to the Edges of the Chesapeake Bay and Their Effects on Environmental Quality; *William H. Queen*; Chesapeake Research Consortium, Inc., 100 Merryman Hall, Johns Hopkins University, Baltimore, Maryland 21218; \$310,900 for 12 months beginning July 1, 1975

This award is for the final year of a research project which has been directed toward assessment of the environmental significance of physical alterations to the shoreline of Chesapeake Bay with concentration on developing methods for predicting environmental effects from trends and rates of shoreline alteration. Recommendations, guidelines and criteria for management of coastal development will be completed based upon selective analysis of permit applications for alterations, case studies of a representative set of permit applications and shoreline studies of selected Bay counties. Issues addressed have included the cumulative impacts resulting from incremental alterations, the capability of the regulatory agency permit process to address the problem of cumulative impacts and the informational needs of regulatory agency personnel related to their responsibilities for granting permits for physical alterations to the shoreline.

Results of previous work under this grant are being utilized to guide consideration of permit applications for alterations to the shoreline of Chesapeake Bay by the regulatory agencies including the Baltimore and Norfolk Districts of the U.S. Army Corps of Engineers.

Although the research objectives have been expressed in terms of the physical alteration problems of the Chesapeake Bay, these same shore zone alteration problems are similar along much of the coastal shoreline of the United States. Therefore, any new procedures, techniques and methodologies for addressing these problems within the Bay region are likely to be useful to other regions of the United States with comparable pressures for development of shoreline property for commercial residential and recreational purposes.

Virus Survival in Soils Injected With Municipal Wastewater Treatment Residuals; *Bernard P. Sagik*; The University of Texas at San Antonio, San Antonio, Texas 78285; \$72,400 for 12 months beginning May 1, 1976

Intensive application to land has recently emerged as an alternative to the problem of what to do with residual sludges from treatment of municipal wastewater despite the lack of knowledge regarding potentially adverse effects on the soil and technical limitations of the process. Direct injection appears to provide advantages of economy, technical superiority and more acceptable esthetic and environmental impact than is possible to achieve with other methods of placement on land. As with other application methods, pathogenic organisms including viruses are removed from wastewater and concentrated in residual sludges and this is of potential significance in the ultimate acceptability of soil-application as a regional management procedure for these residuals.

The objective of this project is evaluation of the potential contamination significance by viruses on soils into which residuals have been injected. This project is coordinated with a project sited at Colorado State University which includes field-injection experiments at Boulder, Colorado and Williamsburg, Virginia. Surface runoff samples from the injection fields at these locations are being analyzed to determine whether viruses are being absorbed or inactivated. In addition, soil samples are being extracted to achieve enteric virus recovery immediately and at several times after injection. Parallel studies are being conducted in Bastrop County, Texas to determine the degree of viral leaching as a function of simulated rainfall and/or irrigation, and the degree of virion movement through soils.

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, Denver, Colorado 80210; \$33,200 for 12 months beginning March 1, 1976*

Advancements in oil shale processing technology, increasing demands for energy, progressively higher costs for oil and the existence of vast, domestic deposits of oil shale have combined to make large-scale production of crude oil from shale potentially feasible. However, both low temperature surface and in-situ retorting, alone or combined, will result in production of a ton of carbonaceous shale residual ash for each barrel of oil produced. Wastes from these processes are of significance because they may contain large quantities of residual organic material which may have potentially harmful effects on environmental quality. The presence of organic material may adversely influence compaction of the residual ash.

This award provides for the continuation of a project whose objective is to determine the amount and kind of organic components in carbonaceous spent shale and the effects of these components on regional environmental quality. The information obtained from this study will lead to the establishment of the scientific and technical basis for policy decisions relative to development of this resource, regulation of processing, and management of its

residuals to meet environmental quality constraints.

The research plan includes an investigation of the potential effects on regional environmental quality of solubilization and leaching by ground and runoff water, volatilization of potential air pollutants, contaminants present in a airborne carbonaceous particulate matter from oil shale processing operations and compounds formed by auto-oxidation of organic compounds volatilized from the waste and its subsequent transfer into air.

This project is being jointly supported by coordinate funding from the National Science Foundation, the U.S. Environmental Protection Agency (EPA), the Federal Energy Administration (FEA), and the Energy Research and Development Administration (ERDA). A workshop and conference was held in May of 1976, Proceedings of which will be widely distributed to potential users of its content.

*Note: reference made in this summary to an actual award amount includes only those funds supplied by the Division of Advanced Environmental Research and Technology.

Assessment of the Impact on Estuarine Ecosystems Resulting from Residuals Management by Dredging; *W. Lee Schroeder*; Oregon State University; Corvallis, Oregon 97331; \$123,000 for 6 months beginning July 1, 1976

Many desirable environmental impacts result from dredging. Channels are created and maintained and increased shellfish production results from the removal of choked inlets. An increased food supply and the increased circulation in dredged areas reduces the impact of municipal and industrial residual sludges that would otherwise result from their deposition.

Negative environmental impacts attributable to dredging are less well-defined. Acute effects may be highly visible and easily measured but poorly understood as to their actual impact. On the other hand, long-term impacts of less visible and more difficult-to-measure effects may result from dredging and related activities.

Annually, dredging results in shifting the location of approximately 400 million cubic yards of material at a cost exceeding \$150 million. Approximately one-half of the material dredged is classified as mixed sand and silt, gravel, and shells. The major part of the remainder dredged is a mixture of soil constituents including clay, silt and topsoil. A small fraction consists of organic muck, sludge, peat and residual sludges from industrial and municipal sources.

Much of the research relating to operational aspects of dredging is being conducted or funded by the U.S. Army Corps of Engineers. This research is being coordinated by the Principal Investigator

with the Corps program to provide insights, perspective and context for application of results and methodology to assess and minimize environmental effects on estuarine ecosystems. Field research is sited at Coos Bay, Oregon, and includes studies of the sulfate-reduction process 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 popula-

tions. An estuarine sediment model is being utilized to analyze transformation of iron, sulfur, and carbon by bacterial degradation.

Results of this research will allow for the prediction of changes which follow perturbations of sediment and prediction of their effects on estuarine benthic ecosystems. The project is to conclude with publication of a series of manuals to assist in the preparation of environmental impact statements for dredging projects. A workshop/conference is planned to be held in the Spring of 1976 (Washington, D.C.) to discuss results with potential users.

Land Management of Subsurface-Injected Wastewater Liquid Residuals; *James L. Smith*; Colorado State University; Fort Collins, Colorado 80521; \$86,100 for 16 months beginning May 1, 1976

This is a continuation of research directed toward evaluation of the technical and economic feasibility of managing municipal wastewater treatment plant residual sludges by direct injection into soil. Shallow soil-injection, utilizing equipment developed by Colorado State University is being evaluated for determination of relative economy energy requirements, esthetic and sanitary acceptability. Concurrently, an analytical model of subsurface injection is being calibrated with field data from injection sites.

The objective of this continuation period is to develop a systematic approach for evaluation of potential injection sites that will lead to their accepta-

ble operation. Environmental criteria, site-specific information, personnel qualifications and recommended monitoring procedures will be included with criteria for design of the system and for operational and maintenance costs. Close coupling of research with representative users, an integral part of this project, is providing a realistic assessment of its acceptability. Results will also provide a base for more comprehensive environmental impact analysis of using injection as an alternative to other procedures for managing liquid residuals and will provide local governments and their consultants with information to assist them in designing subsurface injection sites.

Relative Impact of Selected Pollutants From Diffuse and Discrete Sources on Quality of Water in the Chesapeake Bay; *J. Kevin Sullivan*; Chesapeake Research Consortium, 100 Merryman Hall, Johns Hopkins University, Baltimore, Maryland 21218; \$186,500 for 6 months beginning July 1, 1975

This is a continuation of a project which has as its objective the determination of the relative impact of selected pollutants from diffuse and discrete sources on the quality of water in the Chesapeake Bay. This study is to provide the basis for recommendation of management practices that will minimize the effect of pollutants on water quality in the Chesapeake Bay.

Specific project objectives are to: 1) develop recommendations for coastal zone land use and development policies and sewerage strategies for dealing with non-point source pollutants; 2) determine the need for standards and procedures for

wastewater treatment to minimize the acutely toxic effects of residual chlorine on estuarine organisms; and 3) complete assessment of the effects of nutrients from point sources on the biota of certain areas of the Bay. Emphasis is also to be placed on incorporating CRC research results of wastewater management issues into research management and planning activities for the Chesapeake Bay.

Procedures include: gaging and monitoring of 12 watersheds representing the principal land use types in the Chesapeake Bay Coastal zone; determination of the effect of land use on concentrations

of pollutants; concentration of pollutants in receiving water; determination of acute and chronic toxicity of free chlorine and chloramines to selected estuarine organisms; development of a model to

predict chlorine concentrations arising from single and multiple sources; and an assessment of completed work on the effect of nutrients on the biota of the bay.

Use of Wetlands for Management of Pond-Stabilized Domestic Wastewater; *Jeffrey C. Sutherland;* Williams & Works, Inc., Grand Rapids, Michigan 49506; \$31,200 for 7 months beginning June 1, 1976

The objective of this study is to assess the feasibility of utilizing fresh-water wetlands in combination and pond-stabilization to achieve regional wastewater management objectives. This engineering feasibility study is being coordinated with RANN-supported research underway at the University of Michigan. The objective of which is to complete field verification of wetland ecosystem models constructed during a prior study of peat wetlands in the Houghton Lake Wildlife Research Area, Roscommon Township, Michigan. Results of the studies to date indicate that application of

wastewater to wetlands results in removal of nutrients to satisfactory levels with no negative environmental consequences.

Expected results of this research includes the identification of specific locations in Michigan where wetland application of effluents is technically possible. Cost comparisons at these locations are being made with alternative management concepts as well as preliminary estimates of applicability of this concept adjoining states with comparable wetlands.

High Energy Electron Irradiation of Municipal Wastewater Liquid Residuals; *John G. Trump;* Massachusetts Institute of Technology, Cambridge, Massachusetts 02139; \$200,000 for 12 months beginning May 1, 1976

Management of residual sludges from wastewater treatment processes is a major problem of municipalities and regional wastewater management districts, accounting for approximately one-half of the capital and operating costs of wastewater treatment. Nationally, a population of 300 million persons can be expected to produce 11 million tons of sludge annually. Current management practices include discharge directly to inland waters, conveyance and discharge into the ocean, incineration followed by disposal of ash residues by land-fill, temporary storage in earth cavities, application to land as a fertilizer or soil conditioner and intensive application to land with no intent to cultivate a crop.

Residual sludges contain the originally suspended organic and inorganic solids of the wastewater including pathogenic bacteria, viruses and higher-life forms of significant potential pathogenicity. Their disinfection and possibly sterilization is technically possible by incineration or treatment with chemical disinfectants such as chlorine. Incineration tends to transfer pollutants to air, is expensive and nonconservative for

beneficial recycle of organic matter and nutrients to soil. To meet the chemical demand of the sludges with disinfecting chemicals and then develop a sufficiently high concentration for disinfection or sterilization is technically possible but economically and energetically not feasible. Chemical addition-compounds formed in such a process could themselves be as hazardous as the organisms inactivated.

Ionizing energy has the potential for providing a technically feasible approach to disinfection with reduced energy requirements and at lower cost than alternatives. The process utilizes electrons accelerated in vacuum to high energy by a high voltage. They emerge as a focussed beam which is repeatedly swept across a thin wide band of moving sludge or rapidly flowing wastewater.

The technical and economic feasibility of disinfecting liquid municipal wastewater residuals with high energy electrons is being evaluated at the Deer Island Wastewater Treatment Plant of the Metropolitan District Commission in Boston. The radiation source is a high voltage 50 kilowatt

electron accelerator arranged in a shielded enclosure to deliver doses controllable from 100,000 to one million rads. Bacterial and viral disinfection, parasitic deinfestation, improvement in sludge dewatering characteristics and effects of radiation on trace substances including heavy metals and organic compounds are being studied. Data being obtained will provide the basis for determining the disinfection dosage and the associated energy use and costs. Modes of utilization in existing and new wastewater treatment plants and engineering data essential for design, operation

and maintenance of such a facility will be determined.

This research is coordinated with an award to the University of New Hampshire and includes participation by the Departments of Chemical Engineering and Food Science and Nutrition, Massachusetts Institute of Technology. The Commonwealth of Massachusetts and the Metropolitan District Commission of Boston are providing financial and in-kind support for this project.

URBAN HYDROLOGY

The Urban Hydrology element is aimed at developing a framework to increase the information base of the processes of interaction between the land and water systems, in order that this material may be utilized to improve water resources planning and management. Objectives include: (1) assessment of the influence of a variety of land uses on quality and quantity in the aquatic system; (2) evaluate the integrated impacts of land, air, and water pollution; (3) measure and predict erosion and sedimentation in natural environments and areas disturbed by urbanization processes; (4) predict and measure costs and benefits of alternative policies and management schemes for water resources planning in urban areas; and (5) measure and predict societal attitudes and perception of alternative water resources management schemes.

Hydrometeorological Studies Addressing Urban Water Resource Needs; *Stanley A. Changnon;* University of Illinois, Illinois State Water Survey, Box 232, Urbana, Illinois 61801; \$254,200 for 12 months beginning February 1, 1976

The mammoth growth of our cities has been made possible by a series of engineering solutions to the ever-developing regional water resource problems created by the largely unplanned, horizontal growth. The enormous sprawl of some American cities has frequently encompassed two or more natural hydrologic entities (drainage basins), often resulting in the development of complicated engineering works that alter drastically the natural drainage paths and water balance to serve the needs of the city. The design and operations of these sophisticated and complicated urban water resource systems have become major engineering, management, and environmental problems. Despite the complexity of water-management schemes, however, the problem of "rain design criteria" for hydrologic systems which require knowledge of the frequency, intensity, time-space dimensions and movement of heavy rainstorm still exists.

The objectives of this project are to: provide better methods for collecting and analyzing precipita-

tion data for hydrologic design problems, so as to improve design characteristics of sewer systems and other hydraulic structures; develop an operational rain prediction-monitoring system for the study area utilizing a combination of radar and raingage data output; and establish methods and techniques for transferring the research findings to a number of other cities with similar storm runoff problems. The study is to be undertaken in Chicago, a city which has urban hydrological problems representative of a number of large American cities. Despite the construction of a massive complicated hydrological system, problems of storm runoff still exist. At peak loads, flooding occurs and pollutants are carried into Lake Michigan, the source of the water supply for the city. New techniques for prediction of the impact of water from atmospheric sources into urban hydrologic systems would assist in more efficient use of the existing system and its improvement by the design of additions.

Control of Land Subsidence; *Andre P. Delflache;* Lamar University, Department of Civil Engineering, Beaumont, Texas 77710; \$19,600 for 7 months beginning December 1, 1975

Land subsidence due to ground water withdrawal is a world-wide phenomenon. In the United States, it has been observed in areas subjected to both ground water withdrawal and oil and gas extraction.

Damages attributable to subsidence are direct, indirect, or a combination of both. Direct damage to buildings, pavement, utility lines and drainage is caused by differential compaction and the reactivation of old faults or the generation of new ones. Indirectly, subsidence of low lands causes the loss of property due to permanent inundation. Even more important, it increases the risk of flooding during severe storms. This phenomenon is particularly evident in the Houston-Galveston area and has been well documented. Between 1943 and 1971, the entire city of Houston subsided from 1 foot at the west end to 5 feet at the east end. Much of the area adjacent to the Galveston-Trinity Bay is susceptible to flooding. This large body of water is connected to the Gulf of Mexico and therefore is subject to extremely high tides during major hurricanes. If more subsidence occurs, additional areas comprising heavily industrialized and densely populated centers such as the Houston ship channel, Pasadena, northern Baytown, Clear Lake and the Lyndon B. Johnson Space Center (NASA) will be at the mercy of the hurricanes.

Collaborative Research on Environmental Pollutants and the Urban Economy; \$430,300 for 12 months beginning November 15, 1975; *George S. Tolley;* University of Chicago Department of Economics, Chicago, Illinois 60637; (\$223,300). *Alan S. Cohen;* Argonne National Laboratory, Argonne, Illinois 60439; (\$207,000).

It is generally recognized that air and water quality are closely associated with certain categories of land use. The converse, that air and water quality control policies may have a profound affect on land use and may indeed thwart the efforts to achieve original air and water quality objectives is only just being recognized. However, environmental control policies could be utilized in achieving land use objectives if reliable techniques existed for determining the interactions of environmental quality control and land use.

This project, which is a collaborative effort between the University of Chicago and the Argonne

The objective of this proposal, which is in its third year of funding, is to develop a technique which, when incorporated in ground-water 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, in the selection of aquifer intervals to be exploited, and in the tolerable rates of depletion. The application of the technique will minimize and possibly halt subsidence where it is objectionable, thereby reducing damages being incurred by urban systems. The proposed technique will permit the calculation of the anticipated amount and rate of subsidence associated with a given rate of fluid pressure decline over a given area when the physical stratigraphy of the underlying aquifer systems and the in-situ consolidation characteristics of the aquitards are known. Laboratory equipment will simulate field conditions, and the calculation of the anticipated amount and rate of subsidence will be based on the analyses of clay samples which are representative of the major aquitards underlying the Houston-Galveston area. A manual is to be prepared which will allow this technique to be applied to areas where subsidence occurs.

National Laboratory, has as its objective the development of a framework in which the benefits and costs of alternative environmental control policies can be evaluated. It is particularly concerned with gaps in knowledge regarding water pollution control policies. In order to relate the benefits and costs of water control policies, the following general modeling areas will form the structure for specific research efforts: administrative response modeling to predict organizational and resource decisions made by local and state agencies in response to air and water pollution policies; emission and effluent source response

modeling to estimate emission effluent rates, control techniques, and control costs to reduce pollution discharges; dispersion and damage modeling to predict air and water quality effects of the emission of pollutants; and spatial modeling to analyze locational tendencies of major pollutants and their locational responses to environmental policies.

These modeling areas are applied to specific policies relating to Federal air and water pollution control policies that are likely to have a significant impact on the urban economy such as the Clean Air Act, National Environmental Protection Act, Federal Water Pollution Control Act, and those policies and legislation.

DISASTERS AND NATURAL HAZARDS

Destruction of property caused by natural hazards such as earthquakes costs billions of dollars and thousands of lives each year. In addition, extensive damage is attributed to certain weather hazards such as hail, drought, lightning, and highway fog. The Disasters and Natural Hazards Program element seeks to develop methods and techniques that can provide more cost-effective protection for man and his works from the life loss, injury, property damage, social dislocation, and economic and ecological disruption caused by natural hazards and disasters.

The four Program subelements are:

- Earthquake Engineering
- Fire Research
- Societal Response to Natural Hazards
- Weather Modification

EARTHQUAKE ENGINEERING

Earthquakes are potentially the most devastating of natural disasters. The NSF Earthquake Engineering subelement supports a broad, basic, and applied research activity in all aspects of engineering, geotechnical geology, social, and behavioral sciences which are aimed at developing methods and procedures for the mitigation of earthquake disasters. The subelement'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 the 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 subelement is directed toward the following objectives:

- Develop economically feasible design and construction methods for building earthquake resistant structures of all types.
- Develop procedures for integrating information on seismic risk with on-going land use planning processes.
- Develop an improved understanding of social and economic consequences of individual and community decisions on earthquake related decisions.
- Present program results in forms usable by the affected interest communities to control the vulnerability to earthquakes.

Underground Lifelines in a Seismic Environment; *M. L. Baron*; Weidlinger Associates, 110 East 59th Street, New York, New York 10022; \$407,430 for 24 months beginning June 1, 1976

Lifelines supply and distribute essential services and functions to communities. A substantial percentage of these are placed underground, fulfilling a vital role in conducting and distributing energy, communication, transportation, and water. The continued maintenance of these systems in seismic areas is not only vital to the health and safety of the communities they serve, but they also represent nearly one half of the total investment in structures. The safeguarding of these services is, therefore, clearly in the national interest.

At the present time, only rudimentary provisions in a few building codes exist to regulate the planning, design and construction of underground lifelines. The major reason for this meager amount is the almost complete absence of scientific and

technical knowledge regarding the detailed behavior of these structures in seismic environments. The purpose of this project is to improve such knowledge and to apply it through cost-benefit and optimization studies to planning, design and construction of lifeline structures.

Research will concentrate on underground water distribution lifelines. The specific tasks include: 1) a survey of underground water lifelines; 2) the development of appropriate seismic input; 3) methodology development for modeling and analysis; 4) methodology application to real systems; and 5) risk and cost-benefit studies of lifeline systems. The results of the research will be presented in the form of design aids, guides, and specifications.

Structural Design Implications of Recent Seismic Research Results; *V. V. Bertero*; University of California, Berkely, California 94720; \$152,900 for 18 months beginning January 1, 1976

As a consequence of the considerable significant experimental and analytical research that has been carried out during the last ten years, new and important information has been acquired in the field of earthquake engineering, particularly in the area of mechanical behavior of structural systems under earthquake excitations. However, present building codes and special provisions for seismic design fail to adequately reflect newly acquired knowledge. This has resulted in a gap between the research findings and the incorporation of these findings into practice. This project will fill that gap by integrating the available research findings into prac-

tical information that will be useful to engineers and professionals who are involved in a seismic design. The goal of the project is to consolidate all relevant information into a report which can be used by practicing engineers to improve earthquake-resistant construction.

The specific areas of research include: (1) selection of design earthquakes; (2) selection of structural material and structural systems; and (3) predictions of mechanical behavior of structures. These objectives are accomplished by collecting and analyzing relevant data and then disseminating it to the user community.

Seismic Resistance of Precast Concrete Panel Buildings; *John H. Biggs*, MIT, Cambridge, Massachusetts 02139; \$64,200 for 12 months beginning September 1, 1975

The precast concrete industry has developed panel buildings to a point where they represent an economically viable product with a rapidly growing market. This project is intended to determine the feasibility of reinforced concrete panel construction for high rise buildings in seismic regions of the country. The study will determine whether or not increasing the capability of the panel buildings for resistance to earthquake ground motion through modification will impair their relative economy. In addition, the researchers will use data obtained to determine if present building code provisions are appropriate for buildings in seismic

regions, and if not, to develop recommendations for necessary code changes.

To achieve the objectives of this project, analytical and physical tests are performed on precast components to determine internal forces and stresses and to identify weak points. Then, modified structural details are evaluated to see that weak points have been strengthened and overall building resistance to ground motion has been enhanced. Dynamic analyses are then utilized to evaluate modified structural details under different levels of ground motion input and as a function of the proportion and height of buildings.

A Strong Motion Seismograph Array in Northern Baja California—Northwestern Sonora, Mexico; *James N. Brune*; University of California, San Diego, P.O. Box 109, La Jolla, California 92307; \$112,600 for 24 months beginning February 15, 1976

Although sparsely populated, Northern Baja California and Northwestern Sonora are of special interest seismically because they lie within the continuous belt of earthquakes that extend the length of California, and are associated with the San Andreas fault system.

At present, The Seismic Engineering Branch, United States Geological Survey, is maintaining clusters of accelerographs near the Mexican border in both the San Diego and Imperial Valley areas. As

more networks of strong motion instruments are designed, it is reasonable to expect them to cross international boundaries, such as that between California & Mexico. It is important that an extensive array of strong motion instruments be deployed just south of the international border in order not to miss recording any moderate or large earthquakes.

This project is a cooperative one between the National University of Mexico (UNAM) and the

University of California, San Diego (UCSD), which will establish an array of strong motion instruments. The accelerographs will be installed in the Northern Baja-Northwestern Sonora region of Mexico. The specific objectives of this project are to: (1) record future moderate or large earthquakes on the strong motion array; 2) study the source

mechanisms, stresses, and maximum accelerations and velocities from strong motion data being recorded; and 3) delineate the truly reliable earthquake environment of the region in engineering terms for practical applications in structural design and planning.

Investigation of the Effect of 3-Dimensional Parametric Earthquake Motions on Stability of Inelastic Building Systems; *Franklin Y. Cheng*; University of Missouri, Rolla, Missouri 65401; \$35,900 for 18 months beginning June 15, 1976

It has been shown by analytical studies of plane structural systems that the interaction of horizontal and vertical earthquake components can cause a structure to be dynamically unstable under certain conditions. Recent experimental work on reinforced concrete members also indicates that a biaxial ground motion can significantly reduce the energy dissipation capacity, and that an increase of ductility requirements is expected. Because an earthquake motion and a building system are three-dimensional in character, it is important to study the instability and ultimate capacity of building systems subjected to three-dimensional motions.

These instability studies will include the overturning effect of vertical, static, and inertial forces, which act through sidesway displacements, and the structural systems will be investigated through the elastic range to the condition of collapse. The

ultimate capacity of a system will be determined by observing the dynamic response history from the viewpoint of damping, geometrical nonlinearity, elastic and inelastic materials.

An analytical procedure and a general computer program will be developed to study the following specific objectives: 1) the identification of structural parameters that cause a system to be sensitive to 3-dimensional ground motion; 2) the observation of the response history of different structures to various motions; 3) the study of the ductility demands at critical sections of the constituent structural members; 4) the observation of energy absorption characteristics; and 5) the comparison of the observed ductility requirements with current building code requirements for the purpose of making an engineering evaluation and recommendation.

Seismic Behavior of Structural Systems-Behavior of Complete Structures; *Ray W. Clough*; University of California at Berkeley; \$303,700 for 12 months beginning February 1, 1976

Since 1966, NSF has sponsored a series of research projects aimed at obtaining detailed information on the actual performance of the seismic behavior mechanisms of structural elements and components. This type of information is necessary before a major goal of the project, predicting the inelastic response of structures subjected to seismic behavior, can be realized.

As a result of continuing research efforts and an expanding number of faculty participants in this project, a gradual shift in the emphasis of the research has taken place. In early years, the development of experimental facilities, such as an earthquake simulator, was given the highest

priority. Later, the emphasis was on utilizing these facilities and, most recently, the formulation of mathematical models and their correlation with experimental results have received top priority. Four major areas of seismic behavior of structural systems are being investigated: the behavior of complete structures, the behavior of structural components, the analysis and design of structures and the behavior of masonry construction.

Specific objectives of this project are to develop techniques for performing shaking table tests of large-sized structural systems; to measure the simulated earthquake response to such systems; and to correlate the measured seismic activity with

the results of digital computer analyses. Improvements will also be made in the mathematical

models and analysis procedures which will provide for better correlations.

Seismic Behavior of Structural Systems: Behavior of Masonry Construction; *Ray W. Clough*; University of California, Berkeley, California 94720; \$88,100 for 12 months beginning April 1, 1976

Masonry construction is used extensively for housing and office buildings, but these structures, when compared to steel or reinforced concrete structures, are particularly susceptible to earthquake damage because of their relatively low shear strength and moment resistance. The researchers in this study plan to conduct experimental and analytical investigations of the seismic behavior of masonry construction in order to gain a better understanding of the earthquake behavior of these structures; develop improved design methods for such structures; and minimize the potential life loss and property damage associated with masonry structures due to earthquakes.

The specific objectives of this project are to: 1) conduct wall panel tests to determine the dynamic characteristics of masonry structures; 2) perform

correlation studies with force vibration tests to determine the damping and soil-structure interaction effects; and 3) determine the elastic constants of masonry structures by wave propagation analysis.

Experimental investigations include a series of single pier tests for parametric study and the development of a spandrel beam test program. Analytical investigations include forced vibration correlation studies and determination of equivalent elastic constants by wave propagation method.

The results of this study will be made available to building officials, designers, and code bodies for the development of more sophisticated techniques of seismic design and code specifications for masonry structures.

Workshop on Earthquake Resistant Masonry Construction; *Robert A. Crist*; National Bureau of Standards, Gaithersburg, Maryland 20234; \$75,900 for 14 months beginning May 1, 1976

An improperly designed masonry structure is particularly susceptible to earthquake damage because of its inherent low shear strength and moment resistance. Nevertheless, masonry construction has been used extensively for housing and office buildings, and many of these structures are located in earthquake-prone regions.

Many researchers are aware of this problem, and therefore, many research projects on earthquake-resistant masonry construction are in progress both nationally and internationally. Because of these world-wide studies and the desire for improved masonry design criteria, a need exists 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; 3) assess the accomplishments of the research as it applies to the development of improved or new masonry design criteria; and 4) review needs and priorities for future research.

In order to achieve these goals, the investigators plan to conduct a one-week workshop in the United States. Participants are to be invited on a worldwide basis and are to be researchers who have demonstrated interest in, and who have made significant contributions to, masonry research. Other participants will include representatives from the National Science Foundation, the masonry industry, and professionals who have demonstrated expertise in design of masonry buildings.

The proceedings of the workshop will be published and distributed to the professional community. The results of the proceedings may be used to generate research projects which will benefit practicing engineers, architects, building officials, model code groups, regulatory agencies, product manufacturers, and researchers.

Implementation of a Procedure to Maximize the Learning from Destructive Earthquakes; *C. Martin Duke;* Earthquake Engineering Research Institute, Oakland, California 94609; \$191,500 for 36 months beginning February 1, 1976

Progress in earthquake engineering is more strongly influenced through direct experiences in destructive earthquakes than in any other way. Such earthquakes provide the only test of the ability of engineered works to withstand seismic forces. Learning from the investigation of earthquakes can be maximized through the development of a selective and systematic gathering of data rather than the collection of general information.

The objective of this project therefore, is to implement a procedure for gathering and disseminating critical information obtained from destructive earthquakes to practicing professionals, government organizations, and trade associations as a means of maximizing procedures dealing with earthquake disaster mitigation. Implementation of the procedures will result in the consistent collection of information most useful to design and public policy initiatives in hazard mitigation.

Training teams will conduct seminars in the mitigation of earthquake hazards in areas where

the greatest need and interest are found. Methodology related to the organization and maintenance of data banks of important local information and resources will be developed and provided to interested jurisdictions. In addition, problem areas in response and coordination plans involving an actual earthquake will be identified by EERI. Experienced investigators will assist at the scene of an earthquake by making a quick reconnaissance and by training local investigators in appropriate assignments. These teams will also assist the affected communities in post-earthquake recovery. In the event of destructive earthquake, EERI will act as administrator and coordinator in organizing professional reconnaissance teams, establishing field headquarters, and arranging for special services from engineering and scientific support groups. The project staff will cooperate with local and regional officials in the affected area.

Study of Behavior of Structural Walls in Earthquake Resistant Structures; *Mark Fintel;* Portland Cement Association, Old Orchard Road, Skokie, Illinois 60076; \$551,000 for 18 months beginning February 15, 1976

The behavior of multistory 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 structural walls. To date, there has been some hesitancy by structural designers to use structural walls for earthquake resistance. This reluctance appears to be based on a belief that such walls may not possess the necessary deformation capacity to survive strong earthquakes.

The observed behavior of multistory residential and office buildings subjected to actual earthquakes as well as analytical dynamic response studies have indicated that such buildings are called upon to sustain significant inelastic deformations. Survival of such buildings depends heavily on adequate ductility, a capacity to develop the necessary inelastic deformations at critical regions without significant loss of strength.

Performance of properly designed frame-structural wall systems in recent earthquakes has been good. The satisfactory performance of these structures when subjected to actual earthquakes indicates that the structural walls possess deformation capacity in excess of the demand imposed by the earthquake response. The verification of this observation, both analytically and experimentally, can lead to an important contribution to earthquake-resistant design philosophy.

This project, which is in its second year of funding, has as its objectives the determination of deformation and stiffness requirements of structural walls subjected to strong ground motions. These requirements will be established through analysis and experiment.

The various analytical and experimental objectives are: to develop a computer program to be used by professionals in designing new buildings, to

develop recommendations for design procedures, to determine load-deformation characteristics for structural wall systems subjected to reversing loads, to determine the ductility and flexural strengths of structural systems subjected to reversing loads, and to develop design procedures for

structural walls to provide sufficient strength and ductility.

The findings and recommendations resulting from this study will be made available to code groups and professionals.

Optimal Earthquake Design of Energy Production, Storage, and Distribution Systems; *Alfred M. Freudenthal*; The George Washington University, Washington, D.C. 20006; \$140,400 for 24 months beginning February 1, 1976

Structures built in seismic regions are required to function properly in a forcing environment characterized by random earthquake occurrences and intensities. Considering the earthquake susceptibility of structures, a concern that arises is what level of protective measure is necessary to achieve a certain degree of reliability against possible damage and loss. In order to address this concern, engineering risk and optimal design of structures in seismic areas must be studied.

This project focuses on the elements of risk, cost, and loss associated with earthquakes as important

design parameters in developing structural design methods. Specifically, the objectives of this project are to: 1) establish a new structural design concept on the basis of maintaining a proper balance between the cost of providing a protective measure and the expected cost of earthquake damage; 2) develop procedures of optimal design for ultimate seismic load carrying capacity and functional reliability of structures; 3) apply these procedures in the design of important industrial facilities; and 4) make the results of the study available to user groups, and prepare guidelines for making the optimal design and planning decision.

Development of Plans to Study the Socioeconomic Effects of Earthquake Predictions; *Charles E. Fritz*; National Academy of Sciences, Washington, DC 20418; \$149,700 for 18 months beginning September 1, 1975

A report has been prepared by the National Academy of Sciences entitled, "Earthquake Prediction and Public Policy," which the Federal Disaster Assistance Administration, HUD, is using as a basis for the formulation of public policy relating to an expected earthquake prediction capability. The report concentrated on the following factors: warning of public officials and the general public, governmental actions to mitigate the loss of life and property. In addition, the report included many recommendations that require further research action. Briefly, some of these recommendations are: that prediction should be part of a complete program for earthquake hazard reduction; that an anticipatory research capability for future earthquake predictions should be developed to examine social, economic, legal and political effects; that socioeconomic monitoring should be concurrent with geophysical monitoring; that investigations should be made of experiences in other countries regarding the effects of introducing prediction; and that clarifying legislation is needed in order to

minimize legal ambiguities that may hamper officials in responding to earthquake predictions. The purpose of this research is to examine the areas of action noted in the above recommendations.

The specific objectives of this study are: (1) to identify basic problems and hypotheses to be addressed by future research on (a) the social, economic, political, behavioral, and legal effects of earthquake predictions and warnings; and (b) the actions that might be taken to optimize the use of predictions and warnings in saving lives, protecting property, and minimizing social disruption; (2) to develop a program plan to study these problems and hypotheses in selected earthquake prediction events; (3) to outline the requirements for future studies of the socioeconomic effects of earthquake predictions and warnings on communities and regions both before and after an earthquake; (4) to develop methodological and technical guidelines and prototype data-collection forms to be used in pre-and post-disaster socioeconomic research relating to earthquake prediction and warnings; (5) to

develop criteria for establishing priorities for future research; and (6) to prepare a report summarizing the work accomplished in this study.

The NAS plans to conduct this study with the assistance of the Panel on Socioeconomic Studies of

Earthquake Prediction. Meetings will be held throughout the year and workshops are to be conducted to help formalize each area of the study.

Full Scale Tests on Eleven Story Building in the Pruitt-Igoe Housing Project of St. Louis; *Theodore V. Galambos*; Washington University, St. Louis, Missouri 63130; \$219,000 for 12 months beginning June 1, 1976

The purpose of this project is to study and test existing, full-scale reinforced concrete, multi-story frame structures under realistic loading conditions. This is being done in order to provide researchers and design engineers with data for improving the design and construction of earthquake-resistant buildings. Knowledge of the performance of such buildings is usually gained from theoretical and analytical studies, from laboratory tests of the materials, components and scaled models, and from field reconnaissance study of damaged structures after a major earthquake event.

The principal objective of this study is to perform full-scale tests on complete structurally sound contemporary structures with the intent of exploring the actual limit states of performance. The scheduled demolition of thirty or more eleven-story reinforced concrete frame apartment buildings

of relatively contemporary construction provides a unique opportunity to subject buildings to dynamic excitation simulating earthquake loading. From these tests, data can be obtained for deriving realistic design criteria for earthquake resistive structures. The research plan includes three operations: 1) a determination of in-situ dimensional and material properties; 2) the performance of small amplitude shaking tests to obtain elastic dynamic properties; and 3) the performance of large-amplitude dynamic tests to determine how dynamic properties change with amplitude in the non-linear range, with and without walls in place.

The field tests will be conducted on one or more buildings in the Pruitt-Igoe Housing Project at St. Louis, Missouri. The buildings are scheduled for total demolition in the near future.

Scale Modeling and Testing of Structures for Reproducing Response to Earthquake Excitation; *James M. Gere*; Stanford University, Stanford, California 94305; \$70,100 for 12 months beginning May 15, 1976

Structural tests to date on dynamic earthquake simulators generally have been of two types. In one type of test, the aim was to verify integrity for a small component or mechanical subsystem which could be excited at its full scale. In the other tests, the data were intended to validate theoretical methods to improve the accuracy of analyses of various types of civil engineering structures. A general capability does not exist for constructing replicas of actual buildings, bridges, dams, and other structures, to reproduce adequately the non-linear range behavior in which they respond, absorb and dissipate energy, and ultimately fail under prescribed earthquake excitations.

Conventional methods for structural tests are generally expensive in material and labor costs.

Discussions with groups in the user community have revealed that the identification of a common type of material for scale models to reproduce elastic and inelastic behavior of structures would lead to great savings, and replica model tests would provide a valuable and inexpensive complement to theoretical analyses. The objective of this study is to achieve a routine capability for simulating and reproducing, on existing small-scale test facilities, the earthquake response history of large structures. The research plan includes a comprehensive literature search; synthesis and extension of modeling theory; assembly of data on metallic and non-metallic material properties; development and application of small-scale construction techniques; development of instrumentation methods; and construction and testing of prototype structures.

The successful completion of the proposed project on scale modeling tests could lead to the avoidance of accidental deaths and injuries; savings in

costs of repair or replacement; economical earthquake insurance; and improved reliability of service delivery systems.

Support of Committee on Natural Hazards, Commission on Socio-Technical Systems; *Nelson T. Grisamore;* National Academy of Sciences, Washington, D.C.: \$60,000 for 12 months beginning May 1, 1976

This is a continuation of an award granted to the Committee on Natural Hazards, Commission on Socio-Technical Systems of the National Academy of Sciences. The principal objective of the project is to determine how the techniques of engineering can be applied to improve public safety and welfare in the event of natural disasters, including earthquakes; and to encourage engineering research to be more effective in dealing with all natural hazards. In addition, the investigators plan to establish a publication program for the dissemination of disaster mitigation information to professional bodies and institutions, government representatives, disaster assistance organizations, and research groups.

The specific tasks to achieve these objectives are to: 1) publish three final reports describing three separate aspects of earthquake engineering in an updated edition of the Earthquake Engineering Research Report; 2) investigate at least three case studies of current natural disasters occurring during the 12 months' period of the contract; 3) make recommendations governing the placement of strong-motion instruments in the United States; 4) write a natural disaster report on wind engineering; and 5) publish final reports on the following natural disasters: a) Darwin, Australia, cyclone of December 25, 1974; b) the Atlanta tornado of March 24, 1975; c) the Mantaro River, Peru, landslide of April 25, 1974.

Earthquake Response of Reinforced Concrete Masonry Buildings; *Gilbert A. Hegemier;* University of California, San Diego, CA; \$789,739 for 24 months beginning February 1, 1976

Little is known about the linear and nonlinear behavior (rheology) of reinforced concrete masonry structures when subjected to seismic events. Presently apartment buildings are being constructed with block masonry units, their reinforcement based on minimum requirements established by reference to specific tests or previous field observations. Information on the ability of loadbearing concrete masonry units to sustain earthquake shocks is not as complete as the information available for other structural materials. This lack of knowledge with regard to concrete masonry raises serious questions concerning its structural integrity, public safety and economy when used in seismically active regions of the country.

The objective of this research project, therefore, is to determine the basic knowledge required for safe masonry construction. This is to be accomplished by 1) developing a basis for rational earthquake response and damage analysis of loadbearing reinforced concrete masonry structural elements through laboratory experiments designed to determine the rheology of reinforced and unrein-

forced concrete masonry assemblages and typical connections; 2) recommending preliminary analysis procedures and seismic design principles for reinforced concrete masonry structural elements and connections typical of multistory construction, through the use of case studies, which will include computer simulations of specimen cases as well as computer simulations of complete buildings and the comparison of old and new design concepts; and 3) disseminating the results of this research to the user community in a timely manner, and by indicating the significance and practical impact of the findings.

The results of this research will be the development of computational procedures to be used by practicing engineers in predicting, with sufficient accuracy and economy for practical purposes, the rheological response of actual structures under strong earthquakes, the amount of damage likely to occur, and the possibility of complete collapse. The results will also provide information necessary for making design provisions.

Seismological Investigation of Strong Ground Motion—The San Fernando Earthquake; *Donald V. Helmberger*; California Institute of Technology, Pasadena, California 91104; \$114,800 for 24 months beginning February 1, 1976

Recent advances in the understanding of actual faulting processes, progress in the calculations of ground motion in realistic earth models, and current investigations of the ground motion generated by recent earthquakes, provide mutually reinforcing evidence that existing seismological methodology can be of considerable value in the deterministic appraisal and estimation of strong ground motion in the frequency band of engineering interest.

The development of reliable, low-cost, strong motion accelerographs have been accountable for important advances in the earthquake engineering field and have permitted the gradual accumulation of a number of significant strong motion records of important earthquakes at local distances. Much data were accumulated during the San Fernando, CA, earthquake and these data, coupled with detailed seismologic/tectonic observations of this earthquake and the seismological advances noted above, made it possible to understand in some detail the observed strong ground motion arising

from a damaging and locally destructive southern CA earthquake.

The specific objective of this proposal is to perform theoretical and observational investigations of the strong ground motion generated by past earthquakes; develop a numerical model for it, and to examine the capabilities and limitations of the methodology by applying the model to the San Fernando earthquake data. The ultimate goal is to examine in great detail the observed ground motion data arising from a locally destructive earthquake and to predict the local earthquake motion based on the known physical properties of the source, propagation path, and site-source geometry.

This project is intended to broaden the knowledge in strong motion seismology through theoretical and observational investigations, and to integrate this knowledge with engineering understanding of the strong motion phenomena for the development of a rational ground motion model for engineering and design applications.

Translation of Russian Book, "The Tashkent Earthquake of 26 April 1966"; *G. W. Housner*; California Institute of Technology, Pasadena, California 91125; \$18,100 for 18 months beginning April 1, 1976

The knowledge of earthquake source mechanisms, wave propagation and transmission, ground motion, and soil and structural response, is essential to the development of reliable methods for earthquake-resistant design. Although much analytical and experimental data pertaining to these factors exist, one of the most valuable resources for learning about seismic response is the data from actual earthquakes.

On April 26, 1966, a destructive strong-motion earthquake took place in Tashkent, USSR. An ex-

haustive study on all aspects of the earthquake was made by local scientists and the results were documented in a Russian Book. This book represents a comprehensive study and valuable research tool on one of the most significant strong motion earthquakes in Central Asia.

The principal investigator of this project is to have this book translated into English. The book will then be made available to researchers and practitioners in the fields of seismology and earthquake engineering in the United States.

Behavior of Reinforced Concrete Frame Elements Under Biaxial Lateral Loadings; *James O. Jirsa*; University of Texas, Austin, Texas 78712; \$392,300 for 14 months beginning October 1, 1975

Recent studies indicate that seismic response of structures may be severely influenced by biaxial lateral motions. However, experimental studies of

the past decade have concentrated mainly on the behavior of structures under unidirectional lateral loading and compressive axial loads. Experimental

studies are needed in order to assess the significance of biaxial lateral forces on structural response.

The objectives of this research project are to evaluate the importance of load history (bidirectional lateral loads and varying axial load levels) on the response of columns and beam-column joints of reinforced concrete structures; to develop design recommendations for the shear strength of columns and beam-column joints under skewed lateral loads and various levels of axial loads; and

to develop models for predicting the behavior of columns and beam-column joints when subjected to large shear forces.

The results of this study will be used in predicting the behavior of columns and beam-columns, to develop procedures for design of new buildings, and to evaluate the strength of existing buildings. These design procedures will be used by engineers and building code officials in evaluating building resistance to seismic loadings.

Statistical Investigation of Engineering Seismology; *Leon Knopoff*; University of California, Los Angeles, California 90024; \$136,300 for 24 months beginning February 1, 1976

There are two methods to project future earthquake occurrences and seismic signals in a given region: (1) the physical approach, which is based on the understanding of the physics of signal source; and (2) the statistical approach, which is based on the knowledge of the prior history of the signal. Most of the previous seismic risk studies have followed the statistical approach and were performed on the basis of local or regional seismicity. Very few studies have taken the fault rupture mechanism into consideration. In order to improve the accuracy or reliability of short term (near future) earthquake risk assessment, an event projection (simulation) model based on both the physics of the source and the historical data is needed.

The objective of this project, is to improve the linear fault model previously developed by the author, to quantify the risk in meaningful engineering terms, and to develop a risk-map for engineering applications. The physical conditions which directly influence on control the epicentral

migration and spacetime rarefractations of seismic activity are to be identified. Characterization of high-risk areas by various tectonic parameters such as the intrinsic breaking strength of the fault, the dynamic friction, and their variations due to ground water seepage and geometrical barriers are to be analyzed.

The existing operational seismicity simulation software package at The University of California at Los Angeles will be used and together with the analytical and computer experiment efforts will be directed toward production and analysis of synthetic earthquake catalogs (i.e., artificially generated sequences of earthquake events). The basic development of computational algorithms and underlying theory will also be continued and extended. Results will then be integrated with existing statistical and physical data to determine the source parameters and seismicity constants of the region, and to assess the earthquake risk of the region for engineering applications.

Earthquake Stability of Reinforced Earth Structures; *Kenneth L. Lee*; University of California, Los Angeles, California 90024; \$165,900 for 24 months beginning February 1, 1976

Reinforced earth structures offer many technical and economical advantages over the conventional types of construction. Because of the potential safety hazards associated with the failure of many earth structures, it is necessary to have a complete understanding of the behavior of such structures under both static and dynamic loads. A critical unknown in seismic areas is the response of rein-

forced earth structures to earthquake loading conditions.

The objective of this proposal is to continue the research on the development of analysis and design methods for reinforced earth structures under earthquake conditions. Specifically, studies in the research plan include: 1) model tests on a small

(UCLA) shaking table; 2) model tests on a (Berkeley) 20 x 20 ft shaking table; 3) field ambient and forced vibration tests; 4) soil-tie friction experimental studies, and (5) studies using finite elements and other analytical techniques.

Results from these studies will enable engineers to proceed with seismic designs for particular projects involving reinforced earth structures.

Earthquake Disaster Mitigation as Principle of Land Use Planning; *Jack Linville, Jr.*; American Institute of Planners, Washington, D.C. 20005; \$204,000 for 14 months beginning January 15, 1976.

The planning profession is faced with the problem of how to plan for and manage the nation's growth in the coming years. Except for flood plain ordinances and limited attempts at earthquake fault hazard zoning, the field of natural disasters has basically been ignored in land use areas.

Proposed land use planning programs require input from the planning professions to solve problems associated with land use field activities. The project will incorporate planning solutions for seismic safety into land use considerations and model land development standards. In addition, methods of incorporating environmental risk management and land planning within the planning profession will be developed and institutionalized.

Specifically, the objectives of this project are to: (1) adopt seismic safety elements in comprehensive land use plans; (2) coordinate disaster mitigation research relating to earthquake damage and planning issues; (3) identify future research needs and priorities for the planning profession in order that the practice of planning for seismic safety may become a regular component of land use planning.

Research will be conducted through the use of case studies, national and regional workshops, and a publications program that will distribute earthquake hazards mitigation information to the planning profession.

Operation of the National Program in Strong Motion Instrumentation; *R. B. Matthiesen*; United States Geological Survey, Seismic Engineering Branch, Washington, D.C.; \$735,000 for 12 months beginning October 1, 1975

This is a continuation of an award which provides for the support of the National Strong-Motion Instrumentation Network. This Network is operated by the USGS with the financial support of the NSF in cooperation with other public and private organizations, some of which contribute instrumentation and/or reimburse USGS for maintenance operations.

The objective of this activity is to collect information on potentially damaging earthquake-generated ground motions and the related effects on man-made structures. The determination of the nature of potentially damaging ground motion and the response of structures to this motion is essential for engineering and seismological studies dealing with the reduction of damage and loss of life due to earthquakes. This information is required by the engineering seismology research community, by structural design engineers, by regulatory agencies, and by planners at all levels.

The NSF/RANN Earthquake Engineering subelement has developed three specific objectives to be achieved in the area of Ground Motion/Data Services: 1) to support a research program to measure pertinent strong motion for the purpose of validating, calibrating, and/or formulating theories of earthquake response; 2) to support the designer's need for earthquake motion information at varying geological and seismological sites; and 3) to obtain a comprehensive data base to perform micro-regionalization of earthquake risk areas based on events in the area.

This project is directed at all aspects of each of these objectives and consists of four major activities: program management, network design, network operations, and data management.

The results of the investigations of this data will be utilized in engineering and seismology research, by design engineers and by regulatory agencies at the Federal, State, and local levels.

Building Enclosure and Finish Systems; Design Procedures Considering Interaction of Building Components During Earthquakes; *Gerald M. McCue*; McCue Boone Tomsick, San Francisco, California 94111; \$92,000 for 8 months beginning April 1, 1976

Recent earthquake history, including the Guatemala earthquake of 1976, demonstrates the need for the reconsideration of the architectural design process related to the non-structural components and systems of buildings subject to seismic activity. Building damage patterns resulting from seismic events indicate that architectural components interact with each other and with the primary structure of a building in causing damage to one another. Most current design procedures consider architectural building components as individual elements of a building rather than as a part of a system acting collectively in a dynamic mode.

Specific objectives of the project are to: 1) develop design procedures, examples and case studies to illustrate and test the dynamic interaction of building components in order to determine design criteria and solutions for architectural elements; 2) present these design procedures to the professional community for utilization; and 3) provide an understanding of the interaction among building components during a seismic event so that effective collaboration among relevant professional disciplines can result in improved earthquake-resistant design of buildings and facilities.

Assessment of Seismic Design of High-Rise Elevator Systems; *Kelvin L. Merz*; Ayres & Hayakawa Energy Management, Los Angeles, California; \$37,800 for 6 months beginning June 1, 1976

The vulnerability of high-rise elevator systems to earthquake damage has been well documented in earthquake damage studies and reconnaissance reports. Statistics for elevator damage due to the 1971 San Fernando earthquake provided an indication of the critical elevator damage patterns in high-rise buildings which result when an earthquake of moderate magnitude occurs near a major metropolitan area. The occurrence of a major earthquake near or in an urban area would damage and impair an even greater number of building elevator systems due to the larger area experiencing significant ground motion.

will serve as an educational publication for the building design profession, developers, and regulatory bodies. In addition, the results will indicate areas for future research and testing necessary to assure functional elevator systems within high-rise buildings and critical facilities following a major earthquake.

The objective of this research project is to provide a review, assessment, and evaluation of the seismic design methods utilized in high-rise elevator systems in earthquake-prone areas. The result of the study is to be a single source document that

In order to arrive at an accurate assessment of the current design considerations given to high-rise elevator systems, the research plan includes the review and evaluation of: current code requirements; professional design practice; design considerations of the basic elevator components; design considerations of the emergency usage of elevators; and an examination of the specifications and design details included in construction documents.

Vulnerability of Transportation and Water Systems to Seismic Hazards; *Irving Oppenheim*; Carnegie-Mellon University, Schenley Park, Pittsburgh, Pennsylvania 15213; \$187,000 for 24 months beginning May 1, 1976

Results of earthquakes usually include damage to utility systems, communications, general transportation systems, water systems, fire and emergency systems. Following an earthquake, communities

have been without some of these services for weeks and months before they were repaired.

Lifeline engineering is the evaluation of the dependency of urban regions on their service

systems. The essential features of lifelines are their geographical extent and their redundancies, or lack thereof. The lifeline's geographic spread covers the area within which seismic damage may cause failure of an urban system.

This project focuses on the general transportation system and associated water systems in order to determine a lifeline model which can be used to measure the performance and the principal causes of failure or decreased performance in these systems. The model will recognize the effects of redundancies in the system, the geographical

features of the total system, and will contain the principal seismic failure criteria.

The lifeline models and earthquake risk calculations are to be generated and performed for selected major east-central cities. The techniques will be presented in a manner facilitating their use by other analysts. The results of the analyses of the selected cities will serve to illustrate the increased seismic risk encountered in a lifeline analysis (as opposed to an in-situ structural analysis) and the further increased relative risk for east-central areas.

Seismic Behavior of Structural Systems; Analysis and Design of Structures; *Joseph Penzien*; University of California, Berkeley, California 94720; \$122,600 for 12 months beginning April 1, 1976

One of the major goals of earthquake engineering is to predict the inelastic response of structures subjected to severe earthquake excitation. Considerable effort has been devoted to the development of computer programs for performing such analyses. However, early in the development of these programs, it became apparent that the ability to perform nonlinear structural analyses greatly exceeded the understanding of the seismic behavior mechanism of structural elements and components. Before reliable computer predictions can be made, more detailed information on the actual damage performance of such components is needed.

The goal of this research is to provide a better understanding of seismic performance and modes of failure of structures through advanced experi-

mental and analytical investigations. The results of these investigations are to be directed toward the development of improved seismic analysis and design methods, subsequently, these methods will be applied to practical situations. The design methods to be developed will insure a balance between cost and safety.

In this project, efforts are to be focused on a number of needed analytical areas in order to increase the reliability of controlling seismic damage according to acceptable criteria. The research findings from other related projects at Berkeley will be used and synthesized in this project to develop the improved analysis and design capabilities for earthquake-resistant steel and reinforced concrete structures.

Seismic Behavior of Structural Systems—Behavior of Structural Components; *Egor P. Popov*, University of California, Berkeley, California 94720; \$182,500 for 12 months beginning April 1, 1976

One of the major goals of earthquake engineering is to predict the inelastic response of structures subjected to severe earthquake excitation. A general approach to structural response analysis is to model each of the members or components comprising the complete structure and then to mathematically assemble these component models in order to simulate the behavior of the complete structure. Toward this end experimental and analytical studies of the behavior of structural components are needed. The objectives of this proposal are to: 1) continue experimental work on relatively large-scale components of structural systems, 2) in-

corporate the experimental results into the mathematical modeling development efforts, and 3) correlate the experimental results with calculated results and to develop broadened capabilities for analyzing the inelastic behavior of structural components under seismic conditions.

Five study tasks are included in this project. They are: 1) an evaluation of the ductility and load resistance of simple K-braced frames; 2) the development of practical methods for earthquake design of combined ductile frame and in-filled frames/wall systems; 3) the assessment of the

behavior of reinforced concrete beams, and beam/column components; and 5) the development and application of computer programs for analyzing the inelastic behavior of isolated structural components.

The results of the experimental work will be used as the basis for the construction and verification of mathematical modeling of structural com-

Non Linear and Coupled Seismic Effects; *Jose M. Roesset*; Massachusetts Institute of Technology, Cambridge, Massachusetts 02139; \$145,000 for 24 months beginning September 1, 1975

At present, a considerable amount of work is being done in the area of soil-structure interaction. Although the knowledge and understanding of the problems have greatly improved in recent years, there is still some confusion concerning the validity and range of applicability of different analytical methods, the importance of different effects and the degree of complexity required to obtain a reasonable accuracy.

To date, the following objectives have been achieved and reported: a) the validity of the iterative linear approach to reproduce nonlinear soil behavior in soil amplification studies has been investigated; b) a computer program for the study of the dynamic interaction between two masses resting on the surface of a soil stratum or an elastic half space has been developed; and 3) a 3-dimen-

ponents. The analytical work and experimental efforts are complementary so that the capabilities for analyzing the inelastic behavior of structural components can be broadened. The research findings of the project will lead to a better understanding of structural behavior and improved methods of analysis and design of earthquake-resistant steel and reinforced concrete structures.

sional finite element computer program has been implemented and the solutions from this program have been compared with 2-dimensional results.

The specific objectives of this project are to build upon the results already developed and to investigate the following areas specifically: a) the comparison of 2- and 3-dimensional solutions for similar conditions and adequate equivalent models of the structure; b) an evaluation of the effect of embedded vs. surface foundations in relation to the input motion at the base of the structure; c) an investigation of the effect of flexibility rather than rigidity on the foundation slab; d) the effect of adjacent structures and the importance of this effect in relation to embedment, frequency dependency and slab flexibility; and e) the development of simplified procedures for design office use.

Earthquake Engineering Project, Republic of Tadzhikistan, U.S.S.R.; *Christopher Rojahn*; United States Geological Survey, San Francisco, California 94105; \$77,500 for 12 months beginning June 1, 1976

This project has evolved from discussions among U.S. and U.S.S.R. scientists and engineers who have been participating in the earthquake research programs established under the U.S./U.S.S.R. May 1972 Joint Agreement on Environmental Protection. It is based on the premise that exchange of knowledge between Russian and U.S. engineers and seismologists dealing with seismic effects will be beneficial to U.S. scientists. The project includes the exchange of information and the comparison of strong motion recording techniques between the two countries. Specifically, this calls for: the installation of an array of strong-motion recording accelerographs in the Dushanbe-Garm region, Republic of Tadzhikistan, U.S.S.R., on a long-term basis; the research and documentation of Soviet

test data compiled at the full-scale structure test site near Dushanbe where explosives are used to generate strong ground motions; the testing of a building instrumented with a U.S. accelerograph system at the test site; and the visit of 7 leading U.S. earthquake engineering experts to a U.S.S.R. test site and Nurek Dam, the largest earth-filled dam in the world.

Building response is to be studied by the use of explosives and local earthquakes and data collected by instruments of both countries is to be reviewed and compared. A new technique for placing strategic locations in the building will be examined for accuracy of predictions of building response.

Analysis of the Seismic Stability of Earth Dams; *H. B. Seed*; University of California, Berkeley, California 94720; \$173,500 for 24 months beginning February 15, 1976

The near failure of the San Fernando Dams in the earthquake of February 9, 1971 has led to increased concern over the seismic stability of embankment dams and the usefulness of older methods to evaluate seismic stability. However, many older earth dams, built before any seismic design techniques were in use, are known to have survived extremely strong earthquake shaking without any detrimental effects.

Presently, the standard method of evaluating the seismic stability of earth dams against sliding during earthquakes has been the pseudo-static method analysis. This method has proved to be inadequate, and a thorough reassessment of seismic stability problems for critical structures, e.g., earth embankment dams, and the usefulness of conventional methods of evaluating seismic stability, is urgently needed.

As part of this project, a study will be made of the significant differences between earth dams known to have performed well and dams known to have performed poorly during strong earthquake shaking to determine the factors responsible for the differences in behavior. Specific objectives of the project are to: 1) establish a data base concerning the field behavior of earth dams during earthquakes so that adequate and inadequate types of construction can be identified; 2) investigate the adequacy of dynamic analysis methods in predicting satisfactory and unsatisfactory performance of earth dams during earthquakes; and 3) develop simplified but rational procedures for evaluating the earthquake shaking. The results of this project will contribute significantly to both improved safety and economy in the design of these critical earth dam structures.

Measurement and Analysis of Vibrations of Oil Refinery Structures; *Haresh C. Shah*; Stanford University, San Francisco, California 94305; \$190,600 for 24 months beginning April 1, 1976

Recent earthquakes have demonstrated that industrial facilities can be severely damaged due to ground shaking. In particular, the risk of damage to oil refinery facilities, which are vital for supplying energy needs to communities, is very great. Furthermore, the risk of major fires due to oil spills from damaged tanks and other structures is also very high. Estimation of dynamic response due to past seismic events and the prediction of response to future earthquakes are severely hampered by a lack of knowledge of the actual vibrational characteristics of these structures.

The objectives of this proposal are to: 1) determine the dynamic properties of tall refinery columns; 2) develop proper mathematical modeling techniques for refinery structures; and 3) evaluate the appropriateness of the current design provisions for refinery structures to determine what modifications may be warranted.

The results of this research will provide an important data source on the vibration properties of tall refinery columns and will lead to recommendations for improvements in seismic design procedures for these structures.

Investigations into the Dynamic Soil Properties by Torsional Simple Shear Device; *Mehmet A. Sherif*; University of Washington, Seattle, Washington 98105; \$170,500 for 24 months beginning November 15, 1975

The objective of this research project is to investigate the behavior of foundation material of clays and sands to determine their reaction to seismic forces. In this way, designers of building foundations can determine the best type of foundation for a building in a specific soil type location.

A torsional simple shear device is to be employed to investigate the dynamic properties and behavior of clays and sands. In this procedure, simulated earthquake motions are to be applied to a shake table in order to observe the strength characteristics of various types of sands and clays when subjected to earthquakes of varying intensities.

The investigation of clays will determine: a) the loss of strength; b) the dynamic shear moduli; and c) the damping characteristics. Investigation of sands will determine: a) equivalent dynamic shear moduli of wet sands, and the effect of moisture content and degree of saturation; b) damping of wet and dry sands as a function of shear force

levels, soil density, degree of saturation, and confining pressures.

Soil engineers will use the results of this project to design building foundations that will lessen damages due to seismic forces.

Operation of the Universities Council for Earthquake Engineering Research; *Wilfred D. Iwan*; California Institute of Technology, Pasadena, CA 91104; \$50,000 for 24 months beginning September 1, 1976

This project is for continuation of the activity of the Universities Council for Earthquake Engineering Research, which was set up originally because it was apparent that university research has certain unique features that distinguish it from similar work in non-university connected laboratories. The purpose of the Council is to provide a vehicle for the free exchange of information on university research plans, priorities, and programs; and to assist in the coordination of university research efforts.

The council organizes periodic national meetings of research investigators in Earthquake Engineering. These meetings consist of reports on current university research and working subgroup discussions on directions for future research. The proceedings of these national meetings are made available to all interested parties. All univer-

sity research investigators with an active interest in Earthquake Engineering are welcome to participate in UCEER activities. The affairs of the Council are handled by a four-man Steering Committee and an Executive Secretary, who is the Principal Investigator of the research project.

The UCEER will use this renewal award to continue in much the same manner as it has in the past three years. The EX SEC will perform the functions necessary to meet the objectives of the Council. A substantial portion of the work in the coming months is to be devoted to the planning of the Fourth National Meeting of UCEER and the publication of the proceedings of that meeting. Another area of interest for the Council is the possibility of sponsoring joint symposiums for industry/university interaction at Earthquake Engineering related technical meetings.

General Assembly on Earthquake Preparedness and Response; *Lizette Weiss*; Association of Bay Area Governments, Berkeley, California \$14,500 for 4 months beginning February 1, 1976

The fragile geology of the San Francisco Bay Area is well known, primarily through the events of 1906, in which several hundred persons lost their lives and the city of San Francisco was severely damaged. The current population of the 9 counties surrounding the San Francisco Bay is now approximately five million persons, and most of the people comprising this number live on or near the Hayward and San Andreas fault systems. Many experts in the field of earthquake science are indicating that another major quake in the region is inevitable, probably before the turn of the century.

Along with this awareness is an indication that there are many policy actions in earthquake disaster mitigation which state and local governments could perform but which are not currently being addressed or implemented. Additionally, much of the information available on the mitigation of

earthquake hazards is not being provided to local governments in a systematic way.

The objective of this project, then, is to educate and inform local government officials and their staffs of current developments in earthquake preparedness and response issues in order to develop action on public policy options, capital investment, planning and implementation of disaster mitigation procedures. In addition, a general assembly on Earthquake Preparedness and Response is planned for the staffs of local and regional agencies and locally elected officials. Experts in the fields of public policy, engineering, geology, seismology, planning, and government will make presentations at the assembly, and these presentations will lead to recommendations for action and implementation by local government.

Summer Institute on Protective Design; *B. Wobbeking*; American Society for Engineering Education, Washington, D.C. 20036; \$65,600 for 9 months beginning March 15, 1976

A summer institute is to be conducted to orient and qualify selected architectural and engineering faculty participants to teach university students and practicing engineers and architects the technical aspects of analysis and design methods in the mitigation of losses from natural hazards.

The Summer Institute program will be conducted in conjunction with Defense Civil Preparedness Agency (DCPA) and will be a two-week concentrated course. The Defense Civil Preparedness Agency will provide living quarters at the staff

college at Battle Creek, Michigan, administrative services, reproduction of lecture notes, technical literature such as manuals, slides, reprints of papers and notes.

Participants are to be selected from universities across the country based on the submission of an application and necessary qualifications. Following completion of the course, participants will be qualified to conduct similar courses for practicing professionals in their region of the country.

Formulation and Expression of Seismic Design Provisions; *Richard N. Wright*; National Bureau of Standards, Gaithersburg, Maryland 20834; \$34,000 for 15 months beginning May 1, 1976. *Steven J. Fenves*; Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213; \$23,000 for 15 months beginning May 15, 1976

"Building Practices for Disaster Mitigation: Development of Comprehensive Seismic Design Provisions" is an NSF/RANN-Funded project of the National Bureau of Standards and the Applied Technology Council (ATC).

A preliminary draft of the design provisions was released earlier this year for the purpose of soliciting comments from a wide range of professional, business and industry groups. This draft represents the work of a multidisciplinary team to resolve the major technical issues involved and to express the technical content of the provisions on a consistent basis.

The objectives of this study are to: 1) assist the ATC in the preparation of the final document; 2)

publish the provisions embodied in the ATC project's final report; and 3) make the design provisions suitable for specific categories of users, including Federal, State and local regulatory agencies and model code organizations.

The ATC project will be studied to insure that the basic premises of the entire development, suitability for adoption, ease of updating, and consistency of provisions are truly reflected in the final document. In addition to making the design provisions available to users, this documentation will also provide a reference for those who adopt and update the design provisions.

Workshop on Earthquake Disaster Mitigation by the Architectural Profession; *Duncan M. Wilson*, AIA Research Corporation, Washington, D.C. 20006; \$116,100 for 8 months beginning November, 1, 1975

The principal objective of this project is to identify research activities which address the problems within the scope of architectural design as they influence the earthquake resistivity of structures, and to establish priorities for these areas of essential research. In the recent past, most of the research on earthquake problems relating to buildings has concentrated mainly on structural aspects. However, there is a growing awareness that, although structures may not collapse during an earthquake, the

functions of the buildings may well be interrupted or terminated due to the failure of architectural design features and details. In order to deal with this problem, several research projects are underway which bear upon the influence of architectural aspects of buildings in seismic zones.

The purpose of this project is to organize and conduct a workshop in Earthquake Disaster Mitigation by the Architectural Profession. The workshop

is to be approximately one week long. For part of the time, researchers will present findings and report on the current status of their projects. During the remainder of the week, the workshop participants will assemble into separate groups to discuss the current research activities and provide recommendations for research to be conducted in specific areas of architectural design. These recom-

mendations are to be incorporated into an overall research program for architectural design to improve earthquake resistance of buildings. Because tornadoes and hurricanes are also subject to dynamic forces which are similar to earthquake forces, they too, will be considered in the discussions.

FIRE RESEARCH

Technical oversight responsibilities for the following Fire Research grants were recently turned over to the Fire Research Center of the National Bureau of Standards, United States Department of Commerce, as the Center now assumes the lead responsibility for fire research. NSF assumes only the fiscal management responsibilities associated with these grants through the duration of funding that each had assumed prior to this arrangement. Funding of these and related projects will be assumed by the Fire Research Center, NBS, subject to the program directives, plans, and availability of funds, etc., of the agency.

Prediction of Fire Hazard From Fabrics and Building Materials; *P. Durbetaki*; Georgia Institute of Technology, School of Mechanical Engineering, Atlanta, Georgia 30332; \$61,500 for 12 months beginning September 15, 1975

This program is designed to develop the techniques required to relate, in a rational manner, fire hazards to test methods. An outgrowth of a project on fire ignition that was monitored by the Government Industry Committee on Fabric Flammability (GIRCF), the program is directed at obtaining experimental data and extending the modeling analysis required for the prediction of fire hazard from fabrics, furniture, interior decorations, and building materials. Specific objectives of this research are to:

- Establish procedures in obtaining experimental data on ignition under broad exposure conditions, varied geometry, and various materials.
- Establish procedures in the evaluation of the ignition probability.
- Modify and extend the modeling analysis for the prediction of ignition time.

The project will have four tasks of combined experimental research and analysis.

- (1). Measurement of ignition statistics on thermally thick media, subject to convective (gas flame) heating.
- (2). Assessment of sample size and ignition source size on the ignition time; measurement of ignition on thermally thin assemblies, subject to convective and radiative heating.
- (3). Measurement of ignition statistics on thermally thin media at various orientations, subject to convective heating.
- (4). Effect of heating rate during pyrolysis on the ignition temperature of pyrolysate-air mixtures.

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.

Physiological and Toxicological Aspects of Smoke Produced During the Combustion of Polymeric Materials; *Irving N. Einhorn*; University of Utah, Department of Materials Science and Engineering, Salt Lake City, Utah 84112; \$355,000 for 21 months beginning October 1, 1975

The objectives of this award are to: develop analytical procedures which will characterize better the

nature of the combustion processes of polymeric materials with respect to smoke generation and;

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, 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 Sprague-Dawley rats). The gross effects of synergism due to the chemical effects of smoke components will be evaluated. Experiments will also 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.

Ignition and Flame Spread; *Howard W. Emmons;* Harvard University, Department of Engineering and Applied Physics, Cambridge, Massachusetts 02138; \$80,000 for 12 months beginning December 1, 1975

This award funds continued 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 the Factory Mutual Research Corporation. In general, the Factory Mutual effort will center on analysis and interpretation of the experimental data, while a research fellow at Harvard will proceed analytically. The program is overseen and coordinated by W. Emmons to insure complete integration of the results.

During the past three years, three full scale, fully furnished and instrumented bedrooms have been burned and a large amount of experimental data has been acquired. Careful comparative analysis will occur during this funding period on the data from the three fires. Phenomena such as the relation between moisture absorbed in combustibles and flashover will be evaluated using the results of the three control fires. At Harvard, the direct computation of the course of a bedroom fire will be at-

tempted starting from a drawing of the room and a description of its furnishings. All data and methods from the three previous fires, and all pertinent data from the literature will be applied to a general enclosure fire. From this analysis, it is hoped, the course of a complex room fire can be predicted.

The Factory Mutual Research Corporation will conduct the following tasks during this time period: performance comparison of various inexpensive heatflux gauges; use of imbedded thermocouples; interpretation of data from ray radiometers; analysis of radiant heat flux feedback; overall energy balance of the room vs. time; smoke radiance vs. time; evolution of the ceiling gas layer room cooling and extinguishment by sprinkler; and formulation of models from fire growth to flashover.

The above research will be an important step in learning how a large scale fire actually behaves, so as to be able to devise discerning small scale flammability tests for fire safety codes.

Flammability Studies of Cellular Plastics; *Richard S. Magee;* Stephens Institute of Technology, Hoboken, New Jersey 07030, \$64,400 for 12 months beginning April 15, 1976

Modern technology has seen the introduction of larger and more sophisticated living and transportation units that have elaborate interiors and furnishings made from new materials. Sufficient knowledge about the fire safety aspects of these

materials is lacking and, as a result, the potential danger to life and capital investment is high. For several years, there has been a growing appreciation that an important criterion by which to evaluate the fire hazard from a particular material is the

rate at which heat is released during burning, which is strongly dependent on the mass burning rate of the combustible solid. The rate of heat release will determine the escape time for a given situation. Previous research has shown that some solids are 2 to 3 times more resistant to burning than other solids, consequently encouraging a slower fire growth rate in a given situation.

The overall objective of the research investigation will be to correlate the results of fundamental polymer characterization studies and fundamental fire dynamic studies on a variety of cellular plastic materials with the ratings or values assigned to these materials by various laboratory test standards and procedures, and their performance in geometrically full-scale tests.

Specific objectives of the program are to:

- Determine the physiochemical characteristics of the cellular plastics under study.
- Perform a fundamental fire dynamic investigation of the burning intensity of these cellular plastics.
- Collect the performance of these materials in standard tests from continuing or completed studies.

Flame Spreading Over Solid Surfaces; *Merwin Sibulkin*; Brown University, Providence, Rhode Island 02912, \$35,400 for 12 months beginning August 1, 1975

The primary objective of this research program is to obtain experimental and analytical results which enable fire protection engineers and fire fighters to make quantitative predictions of fire growth rates. A potential for improvement of the fire safety aspects of building codes is foreseen through a quantitative knowledge of fire growth rates. In addition, an understanding of the theoretical basis of flame spreading should lead to more rational ways of testing the relative flammability of different materials. The ability to predict fire spread rates is important in determining the magnitude of the blaze the firefighter would confront, and the time available for safe evacuation of building occupants.

In addition, the research project seeks to extend investigations of flame spreading to near extinguishment conditions. The goal of this portion of the work is to determine why materials will not sustain a flame under certain conditions. The desired application of this work is to improve the

- Obtain the contribution of these materials to early fire development and early fire growth under a variety of building enclosure geometries.

- Analyze and compare the data from the fundamental chemical and fire dynamic studies with results from standard tests and large scale tests to determine those material physiochemical properties which are most critical in determining the level of fire hazard.

- Obtain a series of curves for the mass burning rates of these materials over a sufficient range of realistic fire conditions so that: (1) designers, architects, and fire protection engineers will have a sound technical basis on which to evaluate the potential fire hazard of a given material in a specific application; and (2) fire dynamic specialists concerned with predicting temperature-time and concentration-time curves in a burning enclosure will have the necessary boundary condition data.

engineer's ability to design nonflammable structures and, if possible, suggest improved methods of extinguishing fires.

The apparatus used is similar to that used to measure the "limiting oxygen index". Previous work has shown downward flame propagation on cylindrical fuel rods to be a stable, reproducible burning configuration. Experiments will be on polymethyl methacrylate (PMMA) rods in gas mixtures having O_2/N_2 ratios which vary from atmospheric to extinguishment values, and in gas mixtures with extinguishing agents added. Flame propagation rate, surface regression rate, surface temperature, flame temperature, and concentrations of stable species will be measured. The effects of changes in these quantities on the heat fluxes to and from the fuel surface will be determined. The results will be used to investigate the relationship between heat losses and flame extinguishment.

Flame Spread Over Liquid Fuel; *Kenneth Torrance*; Department of Mechanical and Aerospace Engineering, Cornell University, Ithaca, New York 14850; \$40,400 for 18 months beginning February 1, 1976.

This award completes a project that has been funded by RANN since 1972. The objective is to determine in a quantitative way the range of physical parameters which will permit a flame to spread over liquid fuels at sub-flash temperatures. Numerical models will be formulated and evaluated. A second objective is to determine whether or not experimentally observed flame unsteadiness can be predicted by such a model.

Information provided by the research will be useful for improving methods of fire extinguishment and control, for the engineering design of certain industrial combustion processes and fuel storage facilities, and for predicting safe storage and handling ranges for liquid fuels. Information generated will contribute to the ability to predict in advance, and ultimately control, the fire hazard of

flammability characteristics of present and future liquid fuels.

During this, the final continuation period, the following tasks will be pursued: influence of layer depth and initial temperature; determination of flame spread for one case, all other parameters prescribed; comparison with flame spread data for alcohol and hydrocarbon fuels; effect of Prandtl number and surface tension force; effects of gas phase buoyancy and other density variations; effect of relative motion of indraft air; effect of superimposed flame radiation; possible means of flame extinguishment by varying or controlling parameters of the unburned fuel. In addition, a detailed comparison of prediction with experiment will be undertaken.

Diffusion—Flame Extinction in Relationship to Fire Suppression; *Furman A. Williams*; Department of Applied Mechanics and Engineering Sciences, University of California, La Jolla, California 92037; \$59,900 for 24 months beginning September 1, 1975

This award continues research aimed at obtaining a fundamental understanding of mechanisms of fire suppression by pursuing theoretical and experimental research on extinction of diffusion flames, and on the structures of diffusion flames subjected to suppressants. Suppressants included in this study are: nitrogen, halons (particularly 1301), water sprays, and possibly dry powders. Fuels tested will include a variety of liquid and solid fuels of different reactivities. The experimental configuration to be studied is the counterflow diffusion flame produced by directing the oxidizing gas stream (containing the suppressant) downward onto the burning surface of the condensed fuel. Concentration and temperature profiles will be taken along with extinction conditions.

Since diffusion flames usually characterize most fires, it is important that emphasis be placed on studying such phenomenon. Much of the earlier research, on chemical suppression in particular, has been focused on premixed fires.

In addition to focusing on flame structure, attention will be devoted specifically to conditions for extinction. It has been found that by coupling these carefully controlled laboratory experiments on extinction with detailed theoretical analysis of the flow, it is possible to extract overall kinetic parameters applicable specifically to diffusion-flame combustion. The present program will include extinctions produced by chemical suppressants such as CF_3Br , and also to extinctions produced by water sprays.

Data from this research will be interpreted on the basis of a theory resting on the concept of the existence of a critical Damkohler number for extinction. Certain refinements to the theory will be made, but principally, the theory will be applied for extracting kinetic information under new conditions (especially in the presence of chemical and heterogeneous suppressants), and for predicting suppression under nonideal conditions.

Fire Safety in Urban Housing; *R. Brady Williamson;* University of California, Berkeley, California 94720; \$261,000 for 12 months beginning November 15, 1975

The overall objective of this continuing interdisciplinary research, jointly funded with the Earthquake Engineering program, is the development of a rational base for the fire-safe design of buildings. Some of the applied goals of the project are to improve materials and structures from a fire safety viewpoint and to provide scientific and engineering input to the process of formulating codes, standards, and other fire related legislation. The selected research tasks are directed at the following goals: (1) reduce risk of fire outbreak; (2) provide for safety of occupants in case of fire; (3) reduce probable property damage and potential paths to conflagrations in case of fire; and (4) provide for safe and successful fire fighting.

The project currently consists of six major inter-related tasks, each having goals, research plans, and schedule: (1) modeling and fire development; (flame spread modeling, formation of carbon parti-

cles, similitude laws, preflashover 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) relationship between fire severity and fire endurance; (6) 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).

An integral part of the plan is the link that has been established with other researchers, Federal, state, and city housing agencies (i.e., 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;* Department of Aerospace and Mechanical Engineering, University of Notre Dame, Notre Dame, Indiana 46556; \$80,100 for 12 months beginning September 1, 1975

The objective of this research is to develop a better understanding of the behavior of fire and smoke in corridors and rooms through the development of a numerical model capable of predicting fire and smoke spread in an enclosure as a function of fuel loading, geometry, and properties of lining materials. The project has a strong link between model development and experiments, and includes a cooperative effort with the National Bureau of Standards.

During this continuation period, a floating zone turbulence model will be developed; the combustion model will be refined using an Arrhenius type rate equation and species generation and movement; and the radiation model will be expanded to include the effect of gaseous radiation. Data from small and full scale experiments will be used to verify the accuracy of the numerical code. The numerical code will be applied to a variety of full scale and small scale fire spread situations in rooms

and corridors such as enclosures with doors and/or windows, corridors with connecting rooms and doors or windows, fire plumes with ceiling, wall, and floor interactions, and room ventilation studies. In addition, the code will be applied to hazard rating tests such as the E-84 tunnel test, in order to provide further insight into the meaning of these tests as related to the behavior of the materials in full scale fire situations. The integrated, experimental-analytical research project provides an important input to the understanding of the behavior of real fire and smoke spread, and movement in a variety of room corridor combinations and fire-load conditions as would be found in typical homes and high rise buildings.

NBS is the primary Federal user group, although GSA and HUD may also use the findings. Reports will be distributed and papers submitted to technical journals and publications.

Properties of Combustion Products From Building Fires; *Ben T. Zinn;* School of Aerospace Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332; \$93,000 for 12 months beginning October 1, 1975

This continuing research work seeks to reduce the hazards of particulate and gaseous combustion products from materials used in construction and interior furnishings. The research will: (1) develop the facilities and experimental techniques that are needed to determine the particle size distribution and total mass of smoke particles, the chemical properties of both smoke and gaseous products, and the optical properties of smoke; (2) determine the dependence of the smoke and gaseous products generated by the combustion of various materials on the temperature and composition of the chamber atmosphere, the type of burning, (i.e., flaming or nonflaming combustion), the radiant heat flux to the sample in non-flaming combustion, and

amount of ventilation; and (3) develop a reliable small-scale testing method that could be used to predict the characteristics of the smoke and gaseous products generated in full-scale fires.

The research project is divided into two principal tasks, each of which is concerned with a different part of this project. Task I is concerned with the design, fabrication, installation, and calibration of the experimental facilities needed for performing the research. Task II is concerned with the detailed determination of the characteristics of the products generated during combustion of various materials in a small-scale combustion chamber under carefully controlled condition.

Convective Flows Associated With Room Fires; *Edward E. Zukoski;* California Institute of Technology, Pasadena, California 91104; \$43,800 for 12 months beginning June 1, 1976

This research is aimed at developing a sufficient understanding of gas motions produced by natural and forced convection so that predictions can be made of the motion of combustion products and fresh air in building fire situations. The information is to be incorporated in a simple mathematical model which can be used in the development of building construction codes, and in the development of tactics to be used in controlling building

fires. Fluid dynamic aspects of an isolated room fire which will be investigated include the turbulent plume rising from the fire; the ceiling layer formed by impingement of the plume on the ceiling; the flow processes at the door or window; and the flow of hot gases outside the door or window. Particular emphasis will be placed on study of entrainment and mixing processes.

SOCIETAL RESPONSE TO NATURAL HAZARDS

The broad objective of the subelement Societal Response to Natural Hazards is to evaluate recent and ongoing disaster-related programs of mission agencies at Federal, state, and local levels, and in private sectors. The research is designed 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 three basic objectives of the subelement are to:

- Develop an understanding of the probable economic and social costs of the Nation's natural hazards.
- Survey and assess the several public and private disaster preparedness and response programs.
- Design, develop, and test alternative approaches to enable society to prepare for, respond to, and recover from disastrous events.

Long-Range Economic Dislocation and Other Consequences of Natural Disasters; *Paul Friesema*; Center for Urban Affairs, Northwestern University, 20400 Sheridan Road, Evanston, Illinois 60201; \$45,200 for 4 months beginning April 1, 1976.

This research was originally funded in 1975 in order that a prototype study could be conducted in four communities which had been hit by natural disasters. The goals of the project were to identify and measure the economic and other disruptions which occur, after short-range relief and rehabilitation activities have been completed; and to examine and explain the variance in long-run effects which occur from community to community. It was originally planned that this prototype study would be followed by a large-scale comparative study of 20-25 disaster-struck communities. After their summer field experience (1975), the staff concluded that time-series data were available and that natural disasters were not apt to result in major long-range economic dislocations. However, the project staff was not satisfied with the quality of the readily available data for measuring the socio-economic magnitude of disastrous events and the quality of the data for measuring governmental and extra-community financial assistance and relief which are provided disaster-stricken communities. In addition, the staff concluded that in-

direct and second-order economic consequences of natural disasters should be investigated. Therefore, based on these conclusions, the staff decided that an in-depth study of these two basic measurement problems in the four prototype communities was more important than the previously planned large-scale study of 20-25 additional communities.

This grant, then is awarded to provide support for additional research on the basic measurement problems, and the amount of damage and relief, in the four communities involved in the study from the outset. The objective is to develop procedures for solving the measurement problems and to collect substantive information on the amount of damage sustained and external relief received in each community. A second objective is to explore and establish second-order consequences of the disasters, such as changes in the economic base of a given community.

Findings from the original study and the renewal award will be integrated in one final report.

Socioeconomic and Political Consequences of Earthquake Prediction; *J.E. Haas;* University of Colorado, Boulder, Colorado 80302; \$427,100 for 15 months beginning May 1, 1976

Accurate earthquake prediction could reduce potential loss and disruption resulting from earthquakes. Extended lead times would make it possible to inspect and strengthen buildings; upgrade building codes so that new structures would be less susceptible to damage; improve zoning regulations to restrict construction in especially hazardous areas; and make plans for possible evacuation.

Negative consequences, however, could result from earthquake predictions, in that investment companies might reduce their commitments to construction and development in the designated area. This could lead to a general slowdown in the economy of the area and a rise in unemployment. Public services would be reduced as a result of a shrinking tax base.

The objective of this research is to obtain empirical data on how citizens and various types of organizations in earthquake hazard areas are likely to respond to credible earthquake predictions. This will be accomplished by obtaining and interpreting a comprehensive set of empirical findings regarding probable response of organizations and citizens to early credible earthquake predictions; formulating and applying an effective means of informing organizations and the public of the findings and their implications; testing the impact of the findings on organizations that participated in the research process; and evaluating alternative legislative and administrative actions that may be useful to implementing the recommendations arrived at through work on the project.

Research Program on Natural Disaster Recovery Processes: Relief, Rehabilitation and Preparedness; *Peter H. Rossi;* University of Massachusetts, Amherst, Massachusetts 01002; \$496,575 for 14 months beginning May 1, 1976

A basic philosophy and policy of this Nation has always been that the victims of natural disasters should be aided by society in recovering from such catastrophic occurrences. Numerous Federal legislative acts have been passed to rationalize and coordinate the various disaster programs which have proliferated in both the public and the private sectors. However, an adequate scientifically derived knowledge base does not exist for evaluating the Nation's recent and on-going preparedness and mitigations programs. Although we know that tremendous sums have been and are being spent from the Federal treasury for disaster programs we do not have complete information on the total cost and effectiveness of past or present programs.

The objective of this project is to describe accurately and analyze recent and on-going U.S. disaster preparedness relief and rehabilitation programs, and to develop policy and program

alternatives. Of necessity, this requires a carefully integrated, large-scale national research program on the Nation's major hazards. This project will concentrate on two major areas: 1) a post audit of census tract data for all SMSA's for 1960 and 1970. All tracts impacted during the decennial period will be identified by year of impact and type of disaster. Non-impacted tracts and non-impacted SMSA's for analytical purposes, will constitute control areas. Archival data will supplement the census data; 2) state- and community-level studies of the variation in response to mitigation and preparedness programs, a descriptive account of the actual decision making process in the formulation and implementation of disaster policies, and the identification of barriers to policy changes. Results of this study will be published for user agencies as well as the scientific community. And user agency seminars will be conducted by the project staff.

Natural Hazards Research and Applications Information Center; *Gilbert F. White* University of Colorado, The Institute of Behavioral Science, Boulder, Colorado; \$200,500 for 24 months beginning March 1, 1976

The objective of this research is to provide an organizational mechanism (an information service) for accelerating the dissemination and use of information in dealing with geophysical hazards. It is the work of the center staff to detect emerging trends and special needs and to organize timely conferences or meetings concerning these trends and needs for interested scientists and representatives of user agencies. It is also a responsibility of the staff to respond on a quick turnaround basis to requests for appropriate information; to distribute a quarterly newsletter, and to plan an annual workshop. To date, there are no comparable ac-

tivities for natural hazards in the U.S. such as this one planned by Dr. Gilbert White, the staff director.

Dr. White will maintain and extend his numerous contacts with officials in Federal, state, local, and private sectors of the natural hazards community in addition to identifying and utilizing existing information networks among public interest and consumer groups. The activity of the information center will be evaluated at the end of eighteen months, at which time recommendations will be developed for the future of the center after its presently-planned 3-year period.

WEATHER MODIFICATION

The purpose of the Weather Modification subelement is to establish the concept of weather modification as a tool to help fulfill societal needs. The research seeks 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 on society.

The objectives of the subelement are to:

- Develop and test weather modification technologies which mitigate the undesirable effects of weather, such as damage caused by hail or drought.
- Identify problems and opportunities arising from the inadvertent modification of weather by human activities.

The Weather Modification subelement is divided into five research areas:

- Improved Weather Modification Technology
- Inadvertent Weather Modification
- Social, Legal, and Economic Impact of Weather Modification
- Weather Hazard Mitigation
- Weather Modification in Support of Agriculture

IMPROVED WEATHER MODIFICATION TECHNOLOGY

The objective of the Improved Weather Modification Technology subelement is to utilize predictive models, advanced measurement systems, and statistical analyses to improve experimental design and evaluation.

Development of Cloud Seeding Generators for Biodegradable Organic Ice Nuclei: *Norihiko Fukuta*; University of Denver, Department of Physics and Astronomy, Denver, Colorado 80201; \$133,100 for 12 months beginning August 1, 1975

This is a renewal proposal for a program of organic ice nuclei generator development for cloud seeding, including a cooperative cloud seeding project as a result of a generator development success.

The objective of this project is to engineer effective, economical and ecologically acceptable ice nuclei smoke generators in order to meet national needs in various weather modification areas.

Organic ice nuclei under development are 1,5 dihydroxynaphthalene, metaldehyde, and phloroglucinol. They are effective, economical, ecologically acceptable, free of downwind effect and safe in aircraft operation. Two different generator designs, one for ground seeding and another for airborne seeding, utilize a supersonic

nozzle expansion method of smoke particle formation, a breakthrough in ice nuclei generator technology. A third generator for airborne seeding employs a jet mixing method of smoke formation and has been successfully developed.

The central smoke generator development program is supported by three research programs—the study of supersonic nozzle design, the study of ice nucleation behavior of generated smoke particles, and the measurements of vapor

pressure and water solubility of the organic compounds. To transfer the successfully developed technology of the jet mixing type airborne smoke generator using 1,5-dihydroxynaphthalene, a seeding program is proposed, cost-shared and in cooperation with the South Dakota Division of Weather Modification and NOAA. The aim of this seeding program is to establish effectiveness of the nucleant for glaciation of supercooled cumuli using a clearly defined statistical evaluation method.

Collection and Processing of Multiple Doppler Radar Data in NHRE; *Earl E. Gossard*; National Oceanic and Atmospheric Administration, Environmental Research Laboratory, Boulder, Colorado 80301; \$135,006 for 14.5 months beginning May 15, 1976

The objectives of the National Oceanic and Atmospheric Administration—Wave Propagation Laboratory (WPL) effort is to provide radar support to the National Hail Research Experiment (NHRE) (see page 104) during the 1976 Summer field experiment in northeastern Colorado, and the reduction, processing, and analysis of the radar data resulting therefrom. WPL will: (1) provide Doppler radars and operators while operating the equipment during the field experiment; (2) produce new software and modify existing software at WPL necessary to process multiple radar data; (3) assist NHRE in the reduction and processing of data from the radars (WPL and NHRE); and (4)

analyze, interpret, and synthesize the results obtained from the multiple radar operations.

WPL will provide five operators plus two pulse-Doppler radars, operating the radars in conjunction with NHRE radars during the period of May 15 to May 31 1976, in accordance with the schedule of other experiments as directed by NHRE. WPL and NHRE will share responsibility for the software needed to reformat field tapes from all radars to be compatible with the existing analysis software. One product of the software development will be a coherent, documented, smoothly running data processing system available for multi-radar users.

Testing and Calibration Program for Cloud Seeding Materials, Seeding Generators, and Nucleus Observing Instruments; *Lewis O. Grant*; Colorado State University, Department of Atmospheric Sciences, Fort Collins, Colorado 80521; \$10,800 for 12 months beginning July 1, 1975

This renewal grant is for the NSF contribution to the continued support of a standard calibration facility. This facility provides a standard of comparison for ice nucleation materials, cloud seeding generators, and ice nucleus measuring instrumentation. Since 1973 the support of this facility has been shared by the four primary users—NSF, NOAA, DOI, DOD—on a use basis.

Such a facility has been and is basic to a standardization of weather modification systems. Support is provided only for professional direction of the facility and for testing and calibration programs.

Evaluation and Design of Weather Modification Experiments; *Joanne Simpson*; University of Virginia, Department of Environmental Sciences, Charlottesville, Virginia 22903; \$73,000 for 9 months beginning July 1, 1975

The purpose of this research is to improve design and evaluation of modification experiments on

cumulus clouds and systems, using the combined tools of numerical simulations, measurements and

statistics (both classical and Bayesian). This proposal seeks to overcome the major obstacle to successful weather modification, namely the natural variations inherent in atmospheric processes and the great expense and labor required to obtain adequate data.

This project is using a combined cloud model-statistical approach which will be developed and tested on the following past, on-going, and planned weather modification experiments: 1) the Santa Barbara winter, convective orographic seeding experiment; 2) the 1970-76 NOAA Florida Area

Cumulus Experiment; 3) the planned High Plains Cumulus Experiment of the Bureau of Reclamation.

Recent hearings conducted by the Subcommittee on Climate Change of the Environmental Resources Committee of the Domestic Council clearly emphasized the need for improved statistical evaluation techniques in judging the results of weather modification experiments. This lack is holding up progress in weather modification, and this proposed work is an effort to remedy this need.

Silver Iodide Tracing in South Florida; *Joanne Simpson*; University of Virginia, Department of Environmental Sciences, Charlottesville, Virginia 22903; \$15,000 for 12 months beginning July 1, 1975

The 1973 Florida Area Cumulus Experiment (FACE) was conducted during a three month period in South Florida with the major objective being to measure the effects of cloud seeding on aerial rainfall. An additional objective was to trace the silver iodide material that was released. Rainwater and aerosol samples were collected and analyzed for silver and ice nuclei concentrations. The FACE experiment will be continued during the summer of 1975-76 in South Florida. The tracing of silver iodide is an essential part of the experiment for the following reasons: 1) on a "typical" seed day, up to 20 kgm of silver iodide are released with-

in the 1300 sq. km operational network. The ecological ramifications and persistence of silver iodide should be studied, since a complete tracing study has never been performed under this type of massive seeding operation. If the silver iodide persists and if it retains its ice nucleation characteristics, then it may "contaminate" other cloud systems in different locations at later times.

State and local authorities, various other government agencies, the cloud physics sector, and the entire South Florida community will benefit from the results of this study.

Silver Iodide Seeding Rates and Snowpack Augmentation; *Joseph A. Warbuton*; Desert Research Institute, University of Nevada, Sage Building, Stead Campus, Reno, Nevada 89507; \$49,900 for 6 months beginning July 1, 1975

This award provides for continuation of a project whose goal is to develop a physico-chemical seeding assessment system. If successful, such a system would provide more rapid weather modification assessment. The silver iodide seeding is being conducted in the Lake Tahoe-Truckee River-Reno Catchment area of the eastern Sierra Nevada. The seeding program itself is supported by funds from the Bureau of Reclamation and the State of Nevada at no cost to NSF/RANN.

Specific objectives of the project are: 1) to provide an independent tool for assessing the effectiveness of silver-iodide seeding in increasing the winter snow pack in the eastern region of the Sierra Nevada; 2) to provide a method of determining

whether seeding projects on the Nevada side of the Sierra will be beneficial to the people located in that area; and 3) to determine the downwind effects of weather modification projects on the western slopes of the Sierra Nevada in California. This will involve maintaining the mountain laboratories and equipment installed under this RANN program.

The work plan is to include the chemical analysis of 300 precipitation samples for silver and indium content; the analyses of 4,000 feet of ice crystal replication film for typing, sizes and accretional growth; the construction of two indium aerosol generators and telemetry control systems for remote operations; the determination of chemical composition and particle size distributions of

indium aerosol; and chemical transfer efficiency studies for indium trace analysis.

The results of this research effort are expected to produce a technique for improved and more rapid evaluation of cloud seeding weather modification projects. This technology can then be used by the Bureau of Reclamation of the Department of In-

terior in providing additional precipitation for the High Plains area and elsewhere throughout the western water-limited area of the U.S. The information will also be useful to NOAA, Department of Commerce in the evaluation of their seeding efforts, and to commercial seeders who must evaluate the results of their efforts.

INADVERTENT WEATHER MODIFICATION

The objective of the Inadvertent Weather Modification subelement is 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.

The majority of the research on inadvertent weather modification is concentrated in the Metropolitan Meteorological Experiment (METROMEX) in St. Louis. The research seeks to provide better definition of the causes of, and reasons for, the precipitation anomalies observed downwind of the city.

Lidar Acoustic Sounder and Radiometer Investigations; *August H. Auer*; University of Wyoming, Natural Resources Research Institute, Laramie, Wyoming 82070; \$52,800 for 12 months beginning July 15, 1975

This study is part of project METROMEX (Metropolitan Meteorological Experiment) which is a cooperative research effort of several participants including: the University of Illinois, University of Chicago and the University of Wyoming. The study is taking place in the St. Louis area for the purpose of defining urban-produced anomalies in precipitation, clouds, and severe weather.

The goal of this particular part of the METROMEX program is to use indirect sounding techniques quantitatively to evaluate urban effects on aerosol, cloud, and precipitation distributions, including such characteristics as depth of the mixed layer and its vertical rate of growth; cloud quantity; cloud-base heights; and geometrical relationships among aerosol, cloud, and precipitation structures. Derived atmospheric structures will be related to the surface level and interpreted in terms of dynamic processes (thermal stability and/or convective activity).

The study is to concentrate on mobile data collection using the Mark IX lidar facility. The lidar is unique in providing, while at rest or in motion,

continuous information on mixing depth, upper haze layers, convective or layered structure, vertically integrated aerosol concentrations, cloud developments, and cloud-base height.

The lidar van will be augmented with additional sensors to derive space and time contours of near-surface aerosol density, solar radiation, temperature, and humidity. The lidar program will be coordinated with the University of Wyoming aircraft flights. An acoustic sounder will be continuously operated at a fixed urban site to provide further information on mixing depth and convective activity. An array of solar flux radiometers will be positioned to derive urban/rural variations in surface heating because of aerosol and cloud distributions, and to study mid-day surface heating effects on afternoon aerosol distributions, cloud formations, and precipitation amounts.

The data will be cooperatively analyzed by the University of Wyoming and SRI so that the results may be effectively used in the METROMEX studies related to boundary layer structure, cloud physics, and atmosphere radiation.

Metropolitan Meteorological Experiment (\$856,300 for 14 months beginning February 1, 1976; *Auer, August H.*; Modification of Convective Cloud Activity by an Urban Area; University of Wyoming, Natural Resources Research Institute, Laramie, Wyoming 82070; \$178,700 for 14 months beginning February 1, 1976. *Braham, Roscoe R., Jr.*; Inadvertent Weather Modification in the St. Louis Area; University of Chicago, Department of Geophysical Services, Chicago, Illinois 60637; \$301,800 for 14 months beginning February 1, 1976. *Changnon, Stanley A., Jr.*; Studies of Urban Effects on Rainfall and Severe Weather; University of Illinois, Illinois State Water Survey, Urbana, Illinois 61801; \$311,500 for 14 months beginning February 1, 1976. *Ochs, Harry T.*; Numerical Cloud Modeling: Application to Urban Effects on Precipitation; University of Illinois, Illinois State Water Survey, Urbana, Illinois 61801; \$64,300 for 14 months beginning February 1, 1976

Project METROMEX (Metropolitan Meteorological Experiment) is a cooperative research effort of several participants including the University of Illinois, University of Chicago and the University of Wyoming. This research work represents the last year of a six-year program in the St. Louis area to define urban-produced anomalies in precipitation, clouds and severe weather, measuring their impacts, and developing methods for predicting similar anomalies and their impacts in the vicinity of other urban-industrial sites. The program is defining impacts in many areas of applications including urban and regional planning, hydrology, agriculture downwind of cities, weather forecasting, planned weather modification, air pollution control and regulatory strategies, airport siting, and airport operations.

The *University of Illinois* has concentrated on a numerical cloud modeling effort designed to contribute to delineating and quantifying the causes of the severe storm and precipitation anomalies. Another important part of this research has been to develop a method for transferring the results of this investigation in the St. Louis area to other urban-industrial areas. One- and two-dimensional numerical cloud models are utilized to investigate various hypotheses for the causes of the urban area effects on clouds and rainfall patterns, and to explain both dynamical and microphysical effects induced by the urban-industrial complex. Field data collected by other METROMEX investigators serves as both input to, and verification of, the models. Controlled departures from observed conditions in the model aid in understanding the relative importance of various parameters in determining the results.

The *University of Illinois* is also focusing its research efforts on an operation of a ground-based network of raingages for measuring rainfall and

radar for measuring cloud and storm behavior patterns. This continuation effort is to focus on analysis of previous observations without an additional field effort. The work plan consists of four major activities: analyses, interpretations and synthesis, final summarization and reporting, and user interactions. The final effort is to concentrate on intensive studies of selective storm periods to further sharpen hypotheses to explain the anomalies defined to date (30% increases in rainfall, 25% increases in thunderstorms, 50% increases in heavy rainstorms, and 200% increases in hail). Considerable effort is to be devoted to dissemination of the final results and user interactions.

Research efforts at the *University of Wyoming* include limited additional aircraft measurements during the 1976 summer season, and completion of the data analysis, interpretation, integration and synthesis of the results, and summarization and publication of the final report with wide dissemination to potential users. Analytical efforts are to concentrate on urban effects on cloud formation and motion, urban heat islands, the boundary layer, aerosols and particulates, atmospheric moisture and heating, and precipitation development. Solar and infrared radiation in the urban and rural areas will be examined to determine the contribution of aerosols and water vapor to urban and rural energy balance. The distribution of heat, moisture, winds and particulates will be mapped for both the rural and urban-influenced atmosphere for non-convective as well as pre-convective activities.

The *University of Chicago* is using an instrumented cloud physics Lockheed Lodestar airplane and a ground-based height finder radar to measure and study differences between the urban and surrounding areas in aerosol particle population, cloud and ice nuclei spectra, cloud behavior, severe

storms and precipitation characteristics. This effort will be largely in the nature of gap-filling measurements to supplement the previous observations and provide critical data where needed.

Results and findings from all participants in this project will be integrated into a METROMEX Final

Report. In addition, a user workshop is being planned for the Spring of 1977 after the METROMEX data will have been analyzed. Participants in this workshop will include representatives from various user agencies.

Inadvertent Weather Modification by Effluents from Coal-Fired Electric Power Plants: *Peter Hobbs;* University of Washington, Department of Atmospheric Sciences, Seattle, Washington 98105; \$181,400 for 24 months beginning June 15, 1976

One of the crucial problems facing the Nation is to develop adequate energy resources without serious deterioration in the quality of our environment. Since coal is the most plentiful fossil fuel available in the United States, particular attention must be paid to the atmospheric effects of coal-burning power plants. While several projects are under way to investigate the effluents from coal-power plants, a program has yet to be undertaken to study the effects of the effluents from power plants on clouds, precipitation and the weather. Such effects may be considerable since coal-power plants emit much heat, moisture, particulate and gaseous material into the atmosphere.

The objective of this study is to determine the effects on visibility, clouds and precipitation of the effluents from modern coal-power plants. Measurements will be made from a research aircraft which is equipped with state-of-the-art in-

strumentation for measuring particles, gases and the structure and microphysics of clouds. Particular attention will be paid to the effluents from the plants and their effects on drop size distributions, ice particles and the production of precipitation in clouds located downwind from the power plants. The data obtained will be analyzed to determine the difference in cloud processes and precipitation of ambient conditions vs. those prevailing as a result of the plume contaminants. Results from this project should aid in the evaluation of the environmental effects of coal-fired generators and assist in the siting of new power plants. Prime users of the results will be regional, state and Federal agencies concerned with energy development, research, ecology and land utilization, and engineering firms engaged in air pollution impact studies and control systems.

Airborne Mapping of the Urban Plume of St. Louis with a Cloud Condensation Nuclei (CCN) Spectrometer; *V.K. Saxena;* University of Denver, Denver Research Institute, Denver, Colorado 80210; \$21,700 for 12 months beginning May 15, 1976

This research in inadvertent weather modification will produce maps of the spectrum of cloud condensation nuclei (CCN) in the St. Louis area in order to determine the upwind spatial variability of CCN on a single day, to map the plume downwind, to investigate the growth of urban CCN, and to determine when and under what conditions a downwind secondary maxima in CCN occurs. This data will be a valuable addition to the information already obtained by METROMEX investigators. CCN are important to the METROMEX program for the following reasons: 1) they play a vital role in the formation of precipitation in clouds; 2) CCN

have been found to be the best tracer of air originating from urban-industrial areas, and 3) CCN appear in some cases to be derived from a gas-to-particle conversion process, and are involved in acid rain.

The Denver Research Institute CCN spectrometer will be installed in the University of Chicago cloud physics aircraft and flown in the St. Louis area coincident with other Project METROMEX investigations during the summer of 1976. The field data will be compiled in a form that can be used in cloud models for understanding the

microstructure of clouds in the urban environment and predicting urban-rural differences in cloud characteristics.

The proposed in-situ airborne measurements of the CCN spectrum resulting in real-time display of

CCN within an interval of 15 seconds will provide heretofore unavailable information on CCN and will greatly improve the transferability of METROMEX results to other urban areas.

SOCIAL, LEGAL, AND ECONOMIC IMPACT OF WEATHER MODIFICATION

The thrust of the Social, Legal, and Economic Impact of Weather Modification subelement 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. Research in the subelement extends across the disciplines of political, social, legal, economic, ecological, and physical sciences in an effort to investigate the impact of weather modification technology on man.

A Comparative Analysis of Public Response to Weather Modification; *Barbara Farhar*; Human Ecology Research Services, Inc., 855 Broadway, Boulder, Colorado 80302; \$82,000 for 15 months beginning December 1, 1975

This research builds on the results of six years of sociological study of public response to, and decision processes involved, in weather modification. Societal acceptance of weather modification activities presents a major hurdle to the implementation and completion of any field program. Research has shown that a small percentage of individuals opposed to tampering with weather processes can be very effective in the termination of such a research project. Thus, good management guidelines are essential for the application of weather modification technology in a manner which minimizes the disruption of society. The following objectives have been formulated for developing these guidelines: 1) develop a sound understanding of the issues and actions which lead to public acceptance or rejection of weather modification technology; 2) develop a causal model of the acceptance/rejection process; 3) develop management recommendations concerning the tractable (manipulable) variables in the causal model; and 4) disseminate findings and policy recommendations to potential users, decision-makers, and the general public.

Data is to be collected by both individual survey and community level information monitoring in South Dakota, where the fourth year of operational precipitation enhancement and hail suppression is currently being conducted. Analyses will yield both descriptive information on social response to weather modification in South Dakota, and testing of preliminary hypotheses concerning acceptance and rejection processes. Successful validation of the preliminary hypotheses together with response patterns will provide the framework for the development of a causal model of the acceptance/rejection process. Because some factors relevant to acceptance of weather modification are not amenable to change through policy decisions (i.e., occurrence of negative weather events) these factors constitute variables affecting public response which will not be affected by policy. Therefore, management recommendations will be derived from an evaluation of those factors which are matters of policy choice.

A Field Experiment to Test a Hypothesis of the Reality, Characteristic, and Magnitude of Extended Area Effects From Weather Modification; *Lewis O. Grant*; Colorado State University, Department of Atmospheric Sciences, Fort Collins, Colorado 80521; \$215,700 for 11 months beginning December 1, 1975

This proposal is for completion of a post hoc study begun in January 1973 entitled: "Extended Area Effects from Local Weather Modification", and also for testing hypotheses related to extended area effects of weather modification.

There is now increasing evidence that the effects of intentional weather modification programs may extend over a considerably broader geographic area than that for which the operations are planned. The completed portions of the post hoc analyses are consistently showing strong indications of statistically significant increases in precipitation, several hundred miles beyond the intended target areas. This research, therefore, is an investigation of changes occurring downstream from planned weather modification efforts. The goals are to provide: 1) knowledge to aid in developing procedures for augmenting precipitation over broad areas; 2) definition of effects that could cause considerable "disbenefits" downstream from areas being intentionally seeded; 3) definition of effects that could cause weather changes over areas so large that broader scale atmospheric processes might be affected; 4) definition of effects that would cause adverse interaction among on-going weather modification programs.

While the results derived from post hoc analyses appear strong, they cannot be tested in an unbiased manner from existing data or from limited physical experiments. The importance of extended area effects to all weather modification underlies the necessity for continued research. Part of this research is to complete the analyses of extended area data related to past weather modification experiments in the Rocky Mountains and Great Plains of the US, and in Israel, as a continuation of a previous NSF grant. These analyses combine physical investigations and statistical analyses to determine the extended area effects of weather modification programs and to develop hypotheses which describe the processes producing downstream effects. The second part of this research will be to develop a field experiment design based on results of the post hoc analyses together with results from continuing physical experiments and numerical modeling studies.

Successful completion of this research will form the basis for specifically evaluating extended-area effects on societal activities, and will directly assist in the formulation of policies on public issues related to weather modification.

Management of Nucleating Agents Used in Weather Modification: Development of Microbial Threshold Toxicity Criteria; *Donald A. Klein*; Colorado State University, Fort Collins, Colorado 80521; \$46,200 for 15 months beginning October 1, 1975

The purpose of this project is to provide information on the potential long-term effects on microbiological ecosystems of nucleating agents used in weather modification, particularly by silver iodide nucleants. The study concentrates on soil and aquatic microbial ecosystems, as these have been found to be the most critical areas for accumulation of such agents; and on the location of ecologically important mineralization processes which may be sensitive to the presence of these materials.

Specific research objectives are to: 1) provide user-compatible information on the potential long-term effects of weather modification seeding agents

on the impacted ecosystems, and to better understand the specific ways in which soil and aquatic microbial ecosystems will respond when silver iodide or other nucleating agents might be imposed on these systems; 2) determine the level of accumulated seeding agents which can occur in a given ecosystem to establish threshold toxicity levels with maximum resolution; and to make this information available to potential users; and 3) develop an ecological assessment capability for weather modification agents.

The research plan is to include continued analysis of field treatment plots in grass, spruce, and aspen communities to improve the resolution

of previous results; further analysis of generator site silver gradients; and laboratory studies of aerobic and anaerobic aquatic systems.

Results of this study are being used to prepare the Environmental Impact Statement for silver

iodide seeding in the National Hail Research Experiment (NHRE), the Bureau of Reclamation HIPLEX Experiment, and other experimental and operational cloud seeding programs.

WEATHER HAZARD MITIGATION

The objective of the Weather Hazard Mitigation subelement is to reduce the undesirable aspects of selected weather hazards. The major effort is in the study of hail research. The NSF sponsored National Hail Research Experiment (NHRE) is attempting to determine the potential for suppressing hail damage by cloud seeding, and the extent to which hail suppression might be accomplished economically on an operational basis.

National Hail Research Experiment; *Donald Veal*; Center for Atmospheric Research, Boulder, Colorado 80302; \$2,361,000 for 12 months beginning August 1, 1975

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) is designed to determine whether hail suppression by cloud seeding on the high plains of the United States can be feasible, desirable, and cost effective.

The following research objectives have been selected as constituting an effective approach to the hail suppression problem: 1) implementation of a statistical experiment aimed at proving or disproving the efficacy of suppression of hail by the introduction of artificial seeding material such as silver iodide into the storm systems; 2) a broad-based, 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, environmental, and legal studies to assess costs of a hypothetical hail suppression system, including benefits and drawbacks and social and legal factors relevant to the ultimate implementation of an operational hail suppression program.

Since potential users of NHRE's research results span a wide spectrum, various methods will be used to disseminate the conclusions. These methods include preparations of articles for journals and house organs, symposia, presentations keyed to the interests of specific governmental agencies, and news releases during periods of field operations.

WEATHER MODIFICATION IN SUPPORT OF AGRICULTURE

The objective of the Weather Modification in Support of Agriculture subelement is to develop a better understanding of weather variability and its significance to food production, and to develop specific applications of weather modification technology as it relates to agricultural needs.

An Assessment of the Present and Potential Role of Weather Modification in Agricultural Production;

Lewis O. Grant; Colorado State University, Department of Atmospheric Sciences, Fort Collins, Colorado 80521; \$11,800 for 9 months beginning July 1, 1975

The potential impacts of weather modification on agriculture are of increasing importance since the capabilities for weather modification are increasing, and agriculture is coming under increasing stress in meeting critical world food needs. Agriculture itself is experiencing additional pressure as demands for agricultural products increase and our technology becomes increasingly dependent upon non-renewable resources. In addition, a trend seems to be developing toward a less favorable climate.

The general objective of this research is to make an authoritative assessment of the present and potential role that weather modification can play in increasing national and world agricultural production. It is likely that weather modification can have a major impact in the areas climatically marginal for agriculture and in the main agricultural areas

where crop production is under stress. The potential of weather modification to national agricultural productivity and careful identification of agricultural areas which might benefit from weather modification are not well documented. The specific goals of this study are: 1) to identify potential capabilities of weather modification in terms of agricultural productivity, and 2) to focus the priorities for weather modification research in terms of maximum benefits to agriculture.

The research plan includes a workshop of weather modification and agricultural experts from which will be derived an authoritative document of weather modification's role in increasing world agricultural production. Findings will be distributed among technical and institutional groups, research administrators, the agricultural community, and the general public.

Assessment of Weather Modification in Alleviating Agricultural Water Shortages During Droughts;

Floyd A. Huff; Illinois State Water Survey, University of Illinois, P. O. Box 232, Urbana, Illinois 61801; \$71,900 for 18 months beginning November 1, 1975

Significant progress has been made in recent years in the acquisition of scientific knowledge and in the development of engineering technology relevant to the application of weather modification. The two major beneficiaries of successful weather modification would be agriculture and hydrology through 1) relief of moisture stress in plants during the

growing season, and 2) alleviation of municipal and industrial water supply shortages. Obviously, the major need for successful weather modification is during periods of drought in those regions where surface waters are the major source of supply and irrigation facilities are not available.

The objective of this research is to provide quantitative data and information needed in decision-making processes pertaining to weather modification for alleviation of agricultural droughts of various intensity in the Midwest and other areas of similar precipitation climate. This knowledge is essential in evaluating the consequences of weather modification, but this factor has been largely ignored in previous scientific studies which have concerned themselves primarily with how cloud processes are affected by seeding. Therefore, this research should contribute substantially to man's knowledge of the limitations of weather modifica-

tion in agricultural applications, specifically precipitation augmentation.

This research will assist in determining the scope and direction of future research in weather modification, and will point the way for studies in similar climatic regions of the world where different crops are the major source of food supply. This is especially timely research in that world food supply problems are mounting and the midwestern United States will continue to play an active role in helping to overcome this problem.

APPENDIX

The Division of Advanced Environmental Research and Technology—FY 1976 Awards*

<i>Principal Investigator/ Institution</i>	<i>Title</i>	<i>Amount/ FY of Award</i>	<i>Effective Date/ Duration</i>	<i>Page</i>
CHEMICAL THREATS TO MAN AND ENVIRONMENT				
Airborne Contaminants				
Pitts, James N. University of California-Riverside	Chemical Transformations in Photochemical Smog and their Applications to Air Pollution Control Strategies	\$319,700 FY76	1/1/76 12	9
Seinfeld, John California Institute of Technology	Chemical and Physical Characterization of Submicron Aerosols	\$301,300 FY76	6/1/76 24	9
Zoller, William A. University of Maryland	Atmospheric Input of Major Sources and Consumers of Energy	\$340,000 FY76	9/1/75 12	10
Environmental Assay Methodology				
Almeida, S. P. Virginia Polytechnic Institute	A Water Pollution Monitoring Laser Optical System	\$113,400 FY76	7/1/76 12	11
Braman, Robert S. University of South Florida	An Environmental Study of Selected Trace Elements	\$41,700 FY76	6/1/76 15	11
Braman, Robert S. University of South Florida	Low-level Hydrogen Sulfide Measurements in Ambient Air	\$24,700 FY76	6/1/76 12	12
Hadeishi, Tetsuo Lawrence Berkeley Laboratory	The Isotope-shift Zeeman-Effect Spectrometer for Measuring Multiple Chemical Elements and Compounds	\$100,200 FY76	4/1/76 12	12
Kok, Gregory L. Harvey Mudd College	Chemiluminescent Analysis of Hydrogen Peroxide in the Ambient Atmosphere	\$35,900 FY76	6/1/76 24	13
Ku, Robert T. Massachusetts Institute of Technology	Diode Laser System to Measure Trace gases by Long-path Infrared Absorption	\$117,000 FY76	3/1/76 12	13
Moordian, Aram Massachusetts Institute of Technology	Tunable Lasers for Applications to Air Pollution Measurements	\$80,200 FY76	4/1/76 12	13
Novakov, Tihomir Lawrence Berkeley Laboratory	Study of Chemistry of Atmospheric Particulates	\$187,400 FY76	10/1/75 12	14

*Note: all references made to actual award amounts are reflections of AENV-funded research only. No reference is made to any additional funds from sources outside the Division unless indicated. (See Definitions)

<i>Principal Investigator/ Institution</i>	<i>Title</i>	<i>Amount/ FY of Award</i>	<i>Effective Date/ Duration</i>	<i>Page</i>
Proctor, Edward K. Stanford Research Institute	Remote Measurements of Air Pollutants	\$165,000 FY76	5/1/76 12	14
West, Philip W. Louisiana State University	Research on Analytical Methods for the Measurements of Trace Contaminants	\$80,400 FY76	8/1/75 12	15
Metals and Organometallic Compounds				
Carpenter, Roy University of Washington	Geochemistries of Mercury, Arsenic and Other Metals in Puget Sound	\$49,500 FY76	6/1/76 12	16
Kneip, Theodore J. New York University	Cadmium in an Aquatic Ecosystem: Distribution and Effects	\$75,800 FY76	8/1/76 12	16
Rolfe, Gary L. University of Illinois	An Interdisciplinary Study of Environmental Pollution by Lead and Other Metals	\$571,400 FY76	1/1/76 18	17
Wixson, Bobby G. University of Missouri-Rolla	An Interdisciplinary Investigation of Environmental Pollution by Lead and Other Heavy Metals from Industrial Development in the New Lead Belt of Southeastern Missouri	\$191,300 FY76	9/1/75 12	17
Yost, Kenneth J. Purdue University	Environmental Flow of Cadmium and Other Trace Metals	\$401,600 FY76	1/1/76 12	18
Nitrate				
Fine, David H. Thermo Electron Corporation	N-Nitroso Derivatives of Pesticide	\$103,000 FY76	1/1/76 18	19
Pratt, Parker F. University of California-Riverside	Nitrate in Effluents from Irrigated Lands	\$618,200 FY76	6/1/75 24	19
Organic Chemicals of Commerce				
Alexander, Martin Cornell University	Effects of Chemical and Physical Properties of Organic Compounds on their Biodegradation	\$120,929 FY76	9/1/75 12	21
Commoner, Barry O. Washington University	Identification of Mutagenic Organic Compounds in Environmental Samples	\$174,900 FY76	7/1/76 12	22
Hites, Ronald A. Massachusetts Institute of Technology	Fates of Industrial Synthetic Organic Chemicals: A Case Study	\$157,500 FY76	7/1/76 12	22
Hsu, T. C. University of Texas	Mammalian Screening Tests for Mutagenic Chemicals and Chromosome Instabilities	\$68,100 FY76	1/1/76 12	23
Mill, Theodore Stanford Research Institute	Chemical Oxidation Processes in Aquatic Environment	\$152,110 FY76	6/1/76 24	24

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Owens, Clarence B. Florida A&M University	The Extent of Exposure of Migrant Workers to Pesticides and Pesticide Residues	\$200,000 FY76	8/1/75 18	24
Van Duuren, B. L. New York University	Chemical Structure, Reactivity and Carcinogenicity of Halohydrocarbons	\$380,000 FY76	4/1/76 24	25
Program Development and Utilization				
Copenhaver, Emily Oak Ridge National Laboratory	Information Support Services for Trace Contaminants Program	\$135,000 FY76	4/1/76 12	26
Friend, James P. Drexel University	Workshop on the Chemistry of Atmospheric Sulfur	\$27,600 FY76	5/1/76 3	26
Hemphill, Delbert D. University of Missouri Columbia	Tenth Annual Conference on Trace Substances in Environmental Health	\$15,000 FY76	6/1/76 12	27
Martin, Edward M. Environmental Quality Systems, Inc.	An Identification of the Potential Users of RANN's Trace Contaminant Program	\$14,800 FY76	6/1/76 12	27
ENVIRONMENTAL EFFECTS OF ENERGY				
Biggs, Robert B. Univ. of Delaware	Computer Model for Oil Spill Movement in the Delaware Bay	\$186,000 FY76	4/1/76 12	29
Chen, Kenneth Y. Univ. of Southern California	Chemistry, Fate, and Removal of Trace Contaminants From Low-and Medium-Salinity Geothermal Waste Waters	\$118,500 FY76	4/1/76 15	29
Colwell, Rita R. Univ. of Maryland	Microbiological Effects of Petroleum Accumulation on Beaches	\$92,000 FY76	3/15/76 12	30
Hayes, Miles O. Univ. of South Carolina	Beach Morphology in Relation to the Distribution of Oil From a Spill in the Straits of Magellan: A Comparison with Potential Spill Sites in New England and Alaska	\$98,600 FY76	12/15/75 12	31
Hilst, Glen R. The Research Corporation	Time-Variable Emissions of Air Pollutants	\$90,000 FY76	4/1/76 12	31
Leitner, Philip St. Mary's College	The Environmental Effects of Noise From Geothermal Resource Development	\$29,000 FY76	9/1/76 7	32
Pritchett, John W. Systems, Science and Software	Geohydrological Environmental Effects of Geothermal Power Production	\$113,000 FY76	6/1/76 12	32

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Rule, Joseph H. Univ. of Tennessee	Physio-Chemical Reactions of Metals in Petroleum with Beach Sediment	\$56,300 FY76	6/1/76 15	33
Ryall, Alan Univ. of Nevada	Evaluation of Broadband Seismic Spectra as a Means of Distinguishing Natural From Induced Earthquakes	\$29,900 FY76	6/1/76 12	33
Silverman, Arnold J. Univ. of Montana	An Assessment of the Effects of Energy Development in the Fort Union Basin, Montana, and Neighboring States	\$3,000 FY76	4/1/76 3	33
Thompson, C. Ray Univ. of California	Behavior of H ₂ S in the Atmosphere, and Its Effects on Vegetation	\$89,000 FY76	4/1/76 12	34
Whipple, William, Jr. Water Resources Research Inst.	The Petroleum Industry in the Delaware Estuary	\$350,000 FY76	5/1/76 12	34

REGIONAL ENVIRONMENTAL MANAGEMENT

Environmental Risk Management

Kates, Robert W. Clark University	Workshops for Collaborative Research on Risk Assessment and Environmental Hazards of Human Origin	\$49,900 FY76	6/1/76 12	39
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Institutional Aspects of Regional Environmental Management

Anderson, Fred R. Environmental Law Institute	Study of State Environmental Laws: The Illinois Environmental Protection Act; The Vermont Land Gains Tax; The Adirondack Park Agency Act	\$204,600 FY76	5/15/76 15	40
Einsweiler, Robert C. Univ. of Minnesota	The Design of Development Management Systems	\$199,300 FY76	6/1/76 19	40
Godschalk, David R. Univ. of North Carolina	Defining the Constitutional Issues of Growth Management	\$8,900 FY76	12/15/75 10	41

Land Use

Anderson, Orson L. Univ. of California	Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region	\$133,800 FY76	6/1/76 12	42
Bosselman, Fred P. Ross, Hardies, O'Keefe, Babcock, and Parsons	Coordination of Environmental and Land Use Controls	\$12,000 FY76	6/1/76 5	43
Broecker, Wallace S. Columbia Univ.	Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region	\$33,600 FY76	6/1/76 12	42
Clark, Edwin H. Council on Environmental Quality	A Study of the Economic, Environmental, Natural Resource, and Social Effects Associated with Alternative Metropolitan Development Patterns	\$25,000 FY76	5/1/76 7	43

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Coughlin, Robert E. Regional Science Research Institute	Preservation of Farmland and Environmentally Valuable Landscapes	\$126,160 FY76	6/1/76 15	44
Goldman, Charles R. Univ. of California	Environmental Management and Research in the Lake Tahoe Basin	\$200,000 FY76	11/1/75 12	44
Hoben, James HUD	Local Land Use Development Management Through Capital Improvements Programming	\$100,000 FY76	5/15/76 14	45
Ingram, Helen M. Univ. of Arizona	Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region	\$18,000 FY76	6/1/76 12	42
Kunitz, Stephen J. Univ. of Rochester	Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region	\$9,900 FY76	6/1/76 12	42
Little, Ronald L. Utah State Univ.	Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region	\$75,000 FY76	6/1/76 12	42
Levy, Jerrold E. Univ. of Arizona	Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region	\$83,700 FY76	6/1/76 12	42
Mann, Dean E. Univ. of California	Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region	\$19,700 FY76	6/1/76 12	42
McKee, Mac Utah State Univ.	Water Resources Planning Methodologies	\$54,600 FY76	7/1/76 8	45
Price, Monroe Univ. of California	Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region	\$31,900 FY76	6/1/76 12	42
Reynolds, Robert C., Jr. Dartmouth College	Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region	\$66,800 FY76	6/1/76 12	42
Rowe, Peter G. Southwest Center for Urban Research	Environmental Analysis for Development Planning	\$125,600 FY76	2/1/75 15	46
Steinitz, Carl F. Harvard University	The Interaction Between Urbanization and Land	\$188,600 FY76	1/15/75 12	46
Stuart, David G. Montana State Univ.	Impact of A Large Recreational Development Upon a Semi-Primitive Environment: A Case Study	\$13,500 FY76	4/1/76 6	47
Thomas, Harold A. Harvard University	Analysis of A New Approach for Environmental Policy Evaluation	\$212,900 FY76	8/1/75 12	47
Thompson, Russel G. Univ. of Houston	National Economic Models of Industrial Water Use and Waste Treatment	\$123,600 FY76	7/1/76 8	48
Walther, Eric G. John Muir Inst.	Collaborative Research on the Assessment of Man's Activities in the Lake Powell Region	\$105,100 FY76	6/1/76 12	42
Vukovich, Fred M. Research Triangle Institute	On Optimum Meteorological and Air Pollution Sampling Network Selection in Urban Areas	\$80,500 FY76	12/1/75 12	48

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Regional Environmental Systems Evaluation and Synthesis—				
Egan, Bruce A. Environmental Research and Technology, Inc.	Technical Review and Assessment of the LIRAQ Model	\$19,600 FY76	6/1/76 2	49
Mar, Brian W. Univ. of Washington	Assessment of Selected RANN Regional Environmental Systems Modeling Projects	\$140,200 FY76	2/1/76 24	49
Monarchi, David E. Colorado State Planning and Budgeting	Assessment of the Generalizability of Socio-Economic Environmental Systems Models	\$157,100 FY76	7/1/76 12	50
Myers, Thomas Roy F. Weston, Incorporated	Onshore Impacts of Offshore Oil and Gas: Methodology Development and Test	\$229,181 FY76	7/1/76 12	50
Residuals Management				
Correll, David L. Chesapeake Research Consortium	Impact of Pollutants From Diffuse Sources on Quality of Water in the Chesapeake Bay	\$399,200 FY76	6/1/76 11	52
Cukor, Peter M. Teknekron, Inc.	Environmental Quality Aspects of Recycling Lubricating Oil	\$169,600 FY76	3/1/76 14	53
Dick, Richard I. Univ. of Delaware	Process Selection for Optimal Management of Regional Wastewater Treatment Residuals	\$65,000 FY76	7/1/76 12	53
Hartenstein, Roy State Univ. of New York	Utilization of Soil Invertebrates in Stabilization, Decontamination and Detoxification of Residual Sludges from Treatment of Wastewater	\$88,500 FY76	6/1/76 12	54
Irvine, Robert L. Univ. of Notre Dame	Application of Sequencing Batch Reactors for Treatment of Municipal and Industrial Wastewaters	\$66,100 FY76	6/1/76 12	54
Kadlec, Robert C. Univ. of Michigan	Feasibility of Utilization of Wetland Ecosystems for Nutrient Removal from Secondary Municipal Wastewater Treatment Plant Effluent	\$129,900 FY76	7/1/76 16	55
Lauria, Donald T. Univ. of North	Regionalization of Wastewater Collection and Treatment-Location, Scale and Construction Sequence of System Components	\$34,600 FY76	3/1/76 12	55
Metcalf, Theodore G. Univ. of New Hampshire	Control of Virus Pathogens in Municipal Wastewater and Treatment Residuals by Irradiation With High-Energy Electrons	\$40,700 FY76	7/1/76 12	56
Odum, Howard T. Univ. of Florida	Feasibility of Utilizing Cypress Wetlands for Conservation of Water and Nutrients in Effluent From Municipal Wastewater	\$223,600 FY76	5/1/76 12	56
Queen, William H. Chesapeake Research Consortium, Inc.	Management of Physical Alterations to the Edges of the Chesapeake Bay and Their Effects on Environmental Quality	\$310,900 FY76	7/1/75 12	57
Sagik, Bernard P. Univ. of Texas	Virus Survival in Soils Injected With Municipal Wastewater Treatment Residuals	\$72,400 FY76	5/1/76 12	57

<i>Principal Investigator/ Institution</i>	<i>Title</i>	<i>Amount/ FY of Award</i>	<i>Effective Date/ Duration</i>	<i>Page</i>
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	\$33,200 FY76	3/1/76 12	58
Schroeder, W. Lee Oregon State Univ.	Assessment of Impact on Estuarine Ecosystems Resulting from Residuals Management by Dredging	\$123,000 FY 76	7/1/76 6	58
Smith, James L. Colorado State	Land Management of Subsurface-Injected Wastewater Liquid Residuals	\$86,100 FY76	5/1/76 16	59
Sullivan, J. Kevin Chesapeake Research Consortium	Relative Impact of Selected Pollutants From Diffuse and Discrete Sources on Quality of Water in the Chesapeake Bay	\$186,500 FY76	7/1/76 6	59
Sutherland, Jeffrey C. Williams & Works, Inc.	Use of Wetlands for Management of Pond-Stabilized Domestic Wastewater	\$31,200 FY76	6/1/76 7	60
Trump, John G. Massachusetts Inst. of Technology	High Energy Electron Irradiation of Municipal Wastewater Liquid Residuals	\$200,000 FY76	5/1/76 12	60
Urban Hydrology				
Changnon, Stanley A. Univ. of Illinois	Hydrometeorological Studies Addressing Urban Water Resource Needs	\$254,200 FY76	2/1/76 12	62
Cohen, Alan S. Argonne National Laboratory	Collaborative Research on Environmental Pollutants and the Urban Economy	\$207,000 FY76	11/15/75 12	63
Delflache, Andre P. Lamar University	Control of Land Subsidence	\$19,600 FY76	12/1/75 7	63
Tolley, George S. Univ. of Chicago	Collaborative Research on Environmental Pollutants and the Urban Economy	\$223,300 FY76	11/15/75 12	63
EARTHQUAKE ENGINEERING				
Baron, M.L. Weidlinger Associates	Underground Lifelines in a Seismic Environment	\$407,430 FY76	6/1/76 24	66
Bertero, V.V. University of California	Structural Design Implications of Recent Seismic Research Results	\$152,900 FY76	1/1/76 18	67
Biggs, John M. Massachusetts Inst. of Technology	Seismic Resistance of Present Concrete Panel Buildings	\$64,200 FY76	10/1/75 12	67
Brune, James University of California	A Strong Motion Seismograph Array in Northern Baja, California-Northwestern Sonora, Mexico	\$112,600 FY76	2/15/76 24	67

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Cheng, Franklin Y. University of Missouri	Investigation of the Effect of 3-D Parametric Earthquake Motions on Stability of Inelastic Building Systems	\$35,900 FY76	6/1/76 18	68
Clough, Ray W. University of California	Seismic Behavior of Structural Systems - Behavior of Complete Structures	\$303,700 FY76	3/15/76 12	68
Clough, Ray W. University of California	Seismic Behavior of Structural Systems - Behavior of Masonry Construction	\$88,100 FY76	4/1/76 12	69
Crist, Robert A. National Bureau of Standards	Workshop on Earthquake Resistant Masonry Construction	\$75,900 FY76	5/1/76 14	69
Duke, C. Martin Earthquake Engineering Research Institute	Implementation of a Procedure to Maximize the Learning from Destructive Earthquakes	\$191,500 FY76	2/1/76 36	70
Fenves, Stephen J. Carnegie-Mellon	Formulation and Expression of Seismic Design Provisions	\$23,000 FY76	5/15/76 15	82
Fintel, Mark Portland Cement Association	Study of Behavior of Structural Walls in Earthquake Resistant Structures	\$551,000 FY76	2/1/76 18	70
Freudenthal, A.M. George Washington University	Optimal Earthquake Design of Energy Production Storage and Distribution Systems	\$140,400 FY76	2/1/76 24	71
Fritz, Charles E. National Academy of Science	Development of Plans to Study the Socio-economic Effects of Earthquake Prediction	\$149,700 FY76	9/1/76 18	71
Galambos, T.V. Washington Univ.	Full Scale Tests on Eleven Story Buildings in the Pruitt-Igoe Housing Project in St. Louis	\$219,000 FY76	6/1/76 12	72
Gere, James M. Stanford Univ.	Scale Modeling and Testing of Structures for Reproducing Response to Earthquake Excitation	\$70,100 FY76	5/15/76 12	72
Grisamore, Nelson T. National Academy of Science	Support of Committee on Natural Hazards Commission on Socio-Technical Systems	\$60,000 FY76	5/1/76 12	73
Hegemier, Gilbert A. University of California	Earthquake Response of Reinforced Concrete Masonry Buildings	\$789,700 FY76	2/1/76 24	73
Helmberger, Donald V. California Inst. of Technology	Seismological Investigation of Strong Ground Motion-The San Francisco Earthquake	\$114,800 FY76	2/1/76 24	74
Housner, George W. California Inst. of Technology	Translation of Russian Book, "The Tashkent Earthquake of 26 April, 1966"	\$18,100 FY76	4/1/76 18	74

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Iwan, Wilfred D. California Inst. of Technology	Operation of the Universities Council for Earthquake Engineering Research	\$50,000 FY76	9/1/75 24	81
Jirsa, James O. University of Texas	Behavior of Reinforced Concrete Frame Elements Under Biaxial Lateral Loadings	\$392,700 FY76	10/15/75 14	74
Knopoff, Leon University of California	Statistical Investigation of Engineering Seismology	\$136,300 FY76	2/1/76 24	75
Lee, Kenneth L. University of California	Earthquake Stability of Reinforced Earth Structures	\$165,900 FY76	2/1/76 24	75
Linville, Jack, Jr. American Institute of Planners	Earthquake Disaster Mitigation as a Principle of Land Use Planning	\$204,000 FY76	1/15/76 14	76
Matthieson, R.B. United States Geological Survey	Operation of the National Program in Motion Instrumentation	\$735,000 FY76	10/1/75 12	76
McCue, Gerald M. McCue, Boon, Tomsick	Building Enclosure and Finish Systems: Design Procedures Considering Interaction of Building Components During Earthquakes	\$92,000 FY76	4/1/76 8	77
Merz, Kelvin L. Ayres & Hayakawa	Assessment of Seismic Design of High Rise Elevator Systems	\$37,800 FY76	6/1/76 6	77
Oppenheim, Irving Carnegie-Mellon	Vulnerability of Transportation and Water Systems to Seismic Hazards	\$187,000 FY76	5/1/76 24	77
Penzien, Joseph University of California	Seismic Behavior of Structural Systems Analysis and Design of Structures	\$122,600 FY76	4/1/76 12	78
Popov, Egor P. University of California	Seismic Behavior of Structural Systems Behavior of Structural Components	\$182,500 FY76	4/1/76 12	78
Roesset, Jose M. Massachusetts Inst. of Technology	Nonlinear and Coupled Seismic Effects	\$145,000 FY76	9/1/76 24	79
Rojahn, Christopher United States Geological Survey	Earthquake Engineering Project, Republic of Tadzhikistan, USSR	\$77,500 FY76	6/1/76 12	79
Seed, H. Bolton University of California	Analysis of the Seismic Stability of Earth Dams	\$173,500 FY76	2/15/76 24	80
Shah, Haresh C. Stanford Univ.	Measurement and Analysis of Vibrations of Oil Refinery Structures	\$190,000 FY76	4/1/76 24	80
Sherif, Mehmet A. University of Washington	Investigation into the Dynamic Soil Properties by Torsional Simple Shear Device	\$170,500 FY76	11/15/75 24	80

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Weiss, Lizette Association of Bay Area Governments	General Assembly on Earthquake Preparedness and Response	\$14,500 FY76	2/1/76 4	81
Wilson, Duncan M. AIA Research Coporation	Workshop on Earthquake Disaster Mitigation	\$116,100 FY76	11/15/75 16	82
Wobbeking, Bernard American Society for Engineering Education	Summer Institute on Protective Design	\$65,600 FY76	3/15/76 9	82
Wright, Richard N. National Bureau of Standards	Formulation and Expression of Seismic Design Provisions	\$34,000 FY76	5/1/76 15	82
FIRE RESEARCH				
Durbetaki, P. Georgia Institute of Technology	Prediction of Fire Hazard From Fabrics and Building Materials	\$61,500 FY 76	9/15/75 12	84
Einhorn, Irving N. Univ. of Utah	Physiological and Toxicological Aspects of Smoke Produced During the Combustion of Polymeric Materials	\$355,000 FY 76	10/1/75 21	84
Emmons, Howard W. Harvard University	Ignition and Flame Spread	\$80,000 FY 76	12/1/75 12	85
Magee, Richard S. Stephens Institute of Technology	Flammability Studies of Cellular Plastics	\$64,400 FY 76	4/15/76 12	85
Sibulkin, Merwin Brown University	Flame Spread Over Solid Surfaces	\$35,400 FY 76	8/1/75 12	86
Torrance, Kenneth Cornell University	Flame Spread Over Liquid Fuel	\$40,400 FY 76	2/1/76 18	87
Williams, Furman A. Univ. of California	Diffusion-Flame Extinction in Relation- ship to Fire Suppression	\$59,900 FY 76	9/1/75 24	87
Williamson, R. Brady Univ. of California	Fire Safety in Urban Housing	\$261,000 FY 76	11/15/75 12	88
Yang, Kwang-tsu Univ. of Notre Dame	Fire and Smoke Spread	\$80,100 FY 76	9/1/75 12	88
Zinn, Ben T. Georgia Inst. of Technology	Properties of Combustion Products From Building Fires	\$93,000 FY 76	10/1/75 12	89

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Zukoski, Edward E. California Inst. of Technology	Convective Flows Associated With Room Fires	\$43,800 FY 76	6/1/76 12	89
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SOCIETAL RESPONSE TO NATURAL HAZARDS

Frieseema, H. Paul Northwestern University	Long-Range Economic Dislocations and Other Consequences of Natural Disasters	\$45,200 FY 76	4/1/76 4	90
Haas, J. E. University of Colorado	Socioeconomic and Political Consequences of Earthquake Prediction	\$427,100 FY 76	5/1/76 15	91
Rossi, Peter H. University of Massachusetts	Research Program on Natural Disaster Recovery Processes: Relief, Rehabilitation and Preparedness	\$496,575 FY 76	5/1/76 14	91
White, Gilbert F. University of Colorado	Natural Hazards Research and Applications Information Center	\$200,500 FY 76	3/1/76 24	92

WEATHER MODIFICATION

Improved Weather Modification Technology

Fukuta, Norihiko Univ. of Denver	Development of Cloud Seeding Generators for Biodegradable Organic Ice Nuclei	\$133,100 FY 76	8/1/75 12	93
Gossard, Earl E. National Oceanic an Atmospheric Administration	Collection and Processing of Multiple Doppler Radar Data in NHRE	\$135,000 FY 76	5/15/76 14.5	94
Grant, Lewis O. Colorado State University	Testing and Calibration Program for Cloud Seeding Materials, Seeding Generators, and Nucleus-Observing Instruments	\$10,800 FY 76	7/1/75 12	94
Simpson, Joanne Univ. of Virginia	Evaluation and Design of Weather Modification Experiments	\$73,000 FY 76	7/1/75 9	94
Simpson, Joanne Univ. of Virginia	Silver Iodide Tracing in South Florida	\$15,000 FY 76	7/1/75 12	95
Warburton, Joseph A. Denver Research Institute	Silver Iodide Seeding Rates and Snowpack Augmentation	\$49,900 FY 76	7/1/75 6	95

Inadvertent Weather Modification

Auer, August H. Univ. of Wyoming	Lidar, Acoustic Sounder and Radiometer Investigation	\$52,800 FY 76	7/15/75 12	97
Auer, August H. Univ. of Wyoming	Modification of Convective Cloud Activity by an Urban Area	\$178,700 FY 76	2/1/76 14	98

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Braham, Roscoe R. Univ. of Chicago	Inadvertent Weather Modification in the St. Louis Area	\$301,800 FY 76	2/1/76 14	98
Changnon, Stanley A. Univ. of Illinois	Studies of Urban Effects on Rainfall and Severe Weather	\$311,500 FY 76	2/1/76 14	98
Hobbs, Peter Univ. of Washington	Inadvertent Weather Modification by Effluents from Coal-Fired Electric Power Plants	\$181,400 FY 76	6/15/76 24	99
Ochs, Harry T. Univ. of Illinois	Numerical Cloud Modeling: Application to Urban Effects on Precipitation	\$64,300 FY 76	2/1/76 14	98
Saxena, V. K. Univ. of Denver	Airborne Mapping of Urban Plume of St. Louis with a Cloud Condensation Nuclei (CCN) Spectrometer	\$21,700 FY 76	5/15/76 12	99
Social, Legal, and Economic Impact of Weather Modification				
Farhar, Barbara Human Ecology Research Services, Inc.	A Comparative Analysis of Public Response to Weather Modification	\$82,000 FY 76	12/1/75 15	101
Grant, Lewis O. Colorado State University	A Field Experiment to Test Hypotheses of the Reality, Characteristic, and Magnitude of Extended Area Effects from Weather Modification	\$215,700 FY 76	12/1/75 11	102
Klein, Donald A. Colorado State University	Management of Nucleating Agents Used in Weather Modification: Development of Microbial Threshold Toxicity Criteria	\$46,200 FY 76	10/1/75 15	102
Weather Hazard Mitigation				
Veal, Donald National Center for Atmospheric Research	National Hail Research Experiment	2,361,000 FY 76	8/1/75 12	104
Weather Modification in Support of Agriculture				
Grant, Lewis O. Colorado State University	An Assessment of the Present and Potential Role in Weather Modification in Agricultural Production	\$11,800 FY 76	7/1/75 9	105
Huff, Floyd A. University of Illinois	Assessment of Weather Modification in Alleviating Agricultural Water Shortages During Droughts	\$71,900 FY 76	11/1/75 18	105



