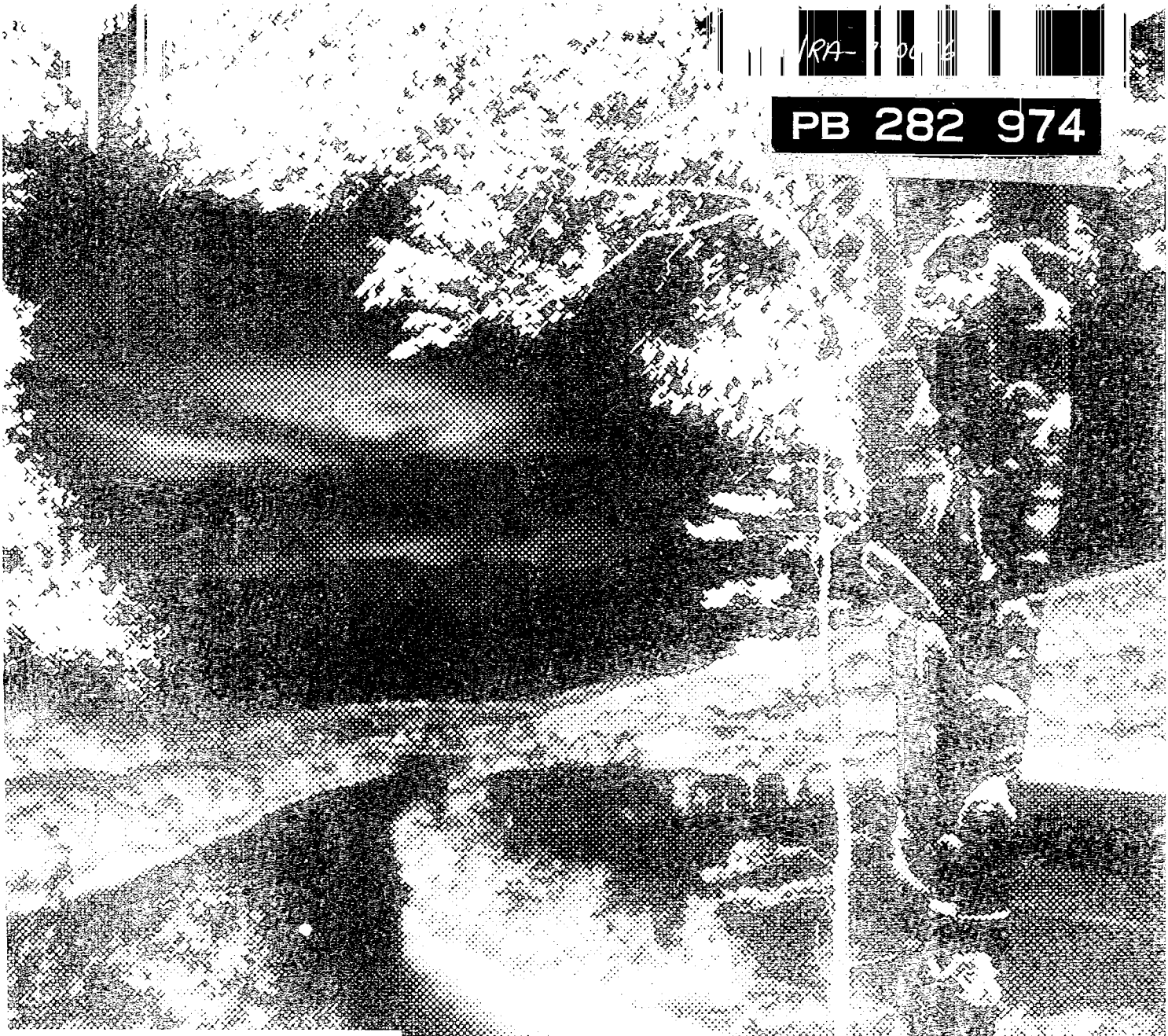

SUMMARY OF AWARDS

Fiscal Year 1977

RANN—Research Applied to National Needs

DIVISION OF ADVANCED ENVIRONMENTAL RESEARCH AND TECHNOLOGY

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

INTRODUCTION

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

RANN program objectives, determined by NSF management and advisory panels in cooperation with the Congress, are based upon specific perceived needs of the Nation. Generally, the RANN program has sought to increase the effective use of science and technology in dealing with national problems involving the public interest; to shorten the lead time between basic scientific discoveries and relevant practical application of these discoveries; to provide early recognition and warning of potential national problems; and to support applied scientific research, assessment studies and related activities directed toward the amelioration or avoidance of such problems.

Research projects funded by RANN have been subjected to peer review by the scientific community and by representative user groups. Eligibility for support depends both on scientific merit and on the projected impact of the research results on government and the private sector in inducing constructive change in policies and practices. A key to the successful application of RANN research results is the strong involvement of user group input during the planning and execution of the research. This involvement helps ensure that the problems being addressed are real. In addition, NSF places considerable emphasis on the evaluation, dissemination, and utilization of the results of this research.

In Fiscal Year 1977, RANN focused its efforts on on five major problem areas: Resources, Productivity, Environment, Intergovernmental Science and Public Technology, and Exploratory Research and Technology Assessment.

The objectives of the programs in Advanced Environmental Research and Technology (AENV) are to enhance the Nation's capability to mitigate environmental hazards, whether natural or man-caused; to ensure that this mitigation is achieved at the least possible cost; and to facilitate the effective reduction of both human suffering and government expenditures before, during, and after natural disasters.

This publication contains brief summaries of the projects funded by AENV in Fiscal Year 1977. Readers wishing information on areas currently under investigation should contact the National Science Foundation. Further information on the individual projects listed in this book should be obtained directly from the Principal Investigator.

CONTENTS

DIVISION OF ADVANCED ENVIRONMENTAL RESEARCH AND TECHNOLOGY

In Fiscal Year 1977, RANN's Division of Advanced Environmental Research and Technology was organized into two major program elements and five subelements:

MANAGING THE NATURAL ENVIRONMENT

- Chemical Threats to Man and Environment
- Regional Environmental Management

DISASTERS AND NATURAL HAZARDS

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

Research in Managing the Natural Environment was addressed to providing an improved scientific basis for public decisions about environmental problems. Research in Disasters and Natural Hazards was directed to the provision of information to facilitate the mitigation of the undesirable effects of such natural hazards as earthquakes, adverse weather, floods, and so forth.

This Summary of Awards presents brief descriptions of projects funded by AENV during Fiscal Year 1977. The Summary of Awards is organized by program and program subelement. For each research project, the problem area is described and an attempt to indicate how the research may help to solve the problem is made. An alphabetical listing of awards by Principal Investigator is included in Appendix A.

DEFINITIONS

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. All award amounts given in this document are subject to adjustment by NSF.

NOTE: The data for this report may differ from that contained in official NSF source documents, such as TAB A to the Budget and Part II of the Annual Report, which were generated from the NSF's Management Information System data base.

DIVISION OF ADVANCED ENVIRONMENTAL RESEARCH AND TECHNOLOGY*

Division Director ..... Charles C. Thiel
Deputy Division Director ..... Marvin E. Stephenson
Senior Scientist ..... H. Kenneth Gayer
Senior Engineer ..... Michael P. Gaus
Administrative Assistant ..... Dorothy F. E. Dooren

Managing the Natural Environment

Chemical Threats to Man and Environment

Program Managers
Richard A. Carrigan
Farley Fisher
Carter Schuth

Regional Environmental Management

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

Disasters and Natural Hazards

Earthquake Engineering

Program Managers
Frederick Krimgold
S. C. Liu
John B. Scalzi

Societal Response to Natural Hazards

Program Managers

William A. Anderson
George W. Baker

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

*As of December, 1977

Managing the Natural Environment

The program element MANAGING THE NATURAL ENVIRONMENT aims to provide an economically and ecologically sound scientific basis for mitigating man-caused threats to natural environment in ways that are compatible with other social goals. Through its subelements, the program attempts to identify, understand, and contribute to the reduction of contamination problems arising from the manufacture and use of chemical products and the mining and processing of metal ores, and supports continued research on land use, urban hydrology, waste water disinfection, and sludge management.

The program subelements in this area are:

CHEMICAL THREATS TO MAN AND ENVIRONMENT

REGIONAL ENVIRONMENTAL MANAGEMENT

CHEMICAL THREATS TO MAN AND ENVIRONMENT

The objective of the Chemical Threats to Man and Environment subelement is to focus on efforts to identify, understand, and reduce contamination arising from the manufacture, use, and disposal of chemical products and the mining and processing of metal ores. Many chemical 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 and the potential benefits of new compounds are so great that strong efforts to find better ways of assessing and reducing their hazardous effects are justified.

The objectives of this subelement are to:

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

Research support is concentrated in five areas in FY 1977:

- Airborne Contaminents
- Environmental Assay Methodology
- Metals and Organometallics
- Organic Chemicals of Commerce
- Program Development and Utilization

AIRBORNE CONTAMINENTS

The purpose of the Airborne Contaminents program is to identify, characterize, and quantify contaminents produced from atmospheric precursors of man-made and natural origin.

Field Studies of Biologically Produced Atmospheric Sulfur Compounds; *Alan R. Bandy*; Drexel University, Philadelphia, Pa. 19010; $87,700 for 12 months beginning May 15, 1977

Worldwide emissions of volatile sulfur compounds of biogenic origin are commonly believed to exceed the total flux of sulfur dioxide released to the atmosphere as a result of human activities. Unlike anthropogenic sources, which emit mostly sulfur dioxide, biogenic sources are believed to contribute hydrogen sulfide, dimethyl sulfide, and minor amounts of other sulfur compounds. Like sulfur dioxide, the latter sulfur carriers seem likely to oxidize in the air to form sulfuric acid or some other particulate sulfate. These sulfate forms are believed to be hazardous to human health.

This project addresses the question whether the biogenic emissions believed to be dominant on the global scale are also significant for the production of airborne sulfate particulates in regions impacted by anthropogenic sources of sulfur dioxide, like coal- or oil-burning plants. The research will be done by gas-chromatographic analysis of estuarine and oceanic waters and the overlaying air in an urban environment (Norfolk, Virginia) and in a pristine area (Wallops Island, Virginia). Samples will be analyzed for hydrogen sulfide, sulfur dioxide, methyl mercaptan, dimethyl sulfide, carbon disulfide, and carbonyl sulfide. Meteorological observations will be made as aids to the identification of sources. Surface emission rates for marsh, shallow bay, and ocean will be estimated by calculations of the gas flux across a water-air interface using the method of Liss and Slater (Nature, *247*, 181 (1974)).

Hydrogen Sulfide and Reduced Forms of Sulfur in Air; *Robert S. Braman*; University of South Florida, Tampa, Florida 33620; $68,300 for 12 months beginning July 1, 1977

Recent research has shown that hydrogen sulfide, if present in very 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. Airborne sulfate particles are believed to be a prime factor for adverse health effects. If, then, biogenic sources are important contributors to the ambient levels of particulate sulfate in the air of certain regions, the relative significance of the anthropogenic sources, like power plants, would have to be reevaluated. The question is especially interesting for urbanized coastal regions where sea salt in tidal waters can account for sulfate intrusion, and where sewage can also be a significant contributor of dissolved sulfate that could be reduced to hydrogen sulfide.

It has not been possible to resolve this question because there has existed no accurate field method for measuring the low ambient levels of sulfur compounds in air. The research is aimed at developing convenient field methods having sensitivity well below ambient levels, so that reliable quantitative measurements can be obtained. This is necessary in order to arrive at reliable quantitative estimates of the natural biogenic contributions of hydrogen sulfide and other volatile sulfur compounds for comparison with man-made sources of atmospheric sulfur, such as combustion sources of sulfur dioxide. The ultimate goal is

to provide methodology to help assess the relative contributions of natural and man-made precursors of toxic airborne sulfate particulates.

Analytical techniques to be evaluated include absorption of gaseous species in metal-coated beads with subsequent high-temperature expulsion into suitable detection systems, and selective retention and expulsion of certain sulfur species in gas-chromatographic columns. For solid particulate materials, experiments will be done by heating in inert gases, by acid treatments, by solvent extraction, and by heat treatment in the presence of hydrogen gas.

Included in the research objectives are the development of parallel methodologies for water, sediments, and airborne particulates. These analyses are needed to supplement the measurements of gaseous sulfur compounds in the air so as to round out the total cycle of airborne sulfur.

Quantitative Electron Microprobe Analysis of Individual Airborne Particles; *Peter R. Buseck*; Arizona State University, Tempe, Arizona 85281; $206,900 for 24 months beginning January 1, 1977

A large fraction of air pollutants in urban areas consists of solids. There is a pressing social need to understand the nature of such air pollutants. This requires a knowledge not only of their bulk composition, but also of the variety, size, and composition of the individual particles themselves. The study of such individual particle compositions will provide critical information regarding the sources of particulate pollution, the chemical and physical properties of airborne particles, and the changes these particles undergo in the atmosphere.

Despite this, most public health agencies and air pollution research groups currently analyze particulates only in terms of bulk concentrations. Only in a relatively few studies has there been an attempt to characterize the chemical type of individual particles.

The goal of the proposed research is to investigate the chemical composition of the individual submicron particles, and to relate this composition to sources and the chemical and physical transformation processes these particles undergo. The research program is designed to refine correction procedures developed by this research group, coupling scanning electron microscope-energy dispersive X-ray analysis with electron microprobe analysis; characterize the major types of inorganic airborne particles in a desert metropolitan area (Phoenix); pinpoint contributions from various area emission sources by comparison of individual particle analysis from ambient and source samples; and investigate the nature and extent of particle coating and agglomeration.

Global Atmospheric Measurements Experiment on Tropospheric Aerosols and Gases (GAMETAG); *Douglas D. Davis*; Georgia Institute of Technology, Atlanta, Georgia; $279,100 for 12 months beginning January 15, 1977

Using the NCAR (National Center for Atmospheric Research) Electra as a sampling platform, a global sampling effort will be initiated which will involve the measurement of over 50 atmospheric species and meteorological parameters on a simultaneous basis. Recognizing both the importance of chemically coupled atmospheric species and the strong interaction between chemistry and meteorology, the GAMETAG (Global Atmospheric Measurements Experiment on Tropospheric Aerosols and Gases) program is to be a joint effort among meteorologists, cloud physicists, and atmospheric chemists. Project GAMETAG calls for a seven-year project which is to be divided into two phases, of two and five years duration. Phase I of the project, the objective of this grant, will have as its primary objective the elucidation of the importance of the hydroxyl free radical to tropospheric chemistry. In addition, there are two secondary objectives for Phase I: (1) an assessment of the global tropospheric budgets for halocarbons, ozone, and sulfur, carbon, and nitrogen species; and (2) a minor effort aimed at assessing the levels and types of natural tropospheric aerosols.

At least two major GAMETAG flights per year are scheduled. These flights during the first two years of the program are expected to span a global latitude range of 75°N to 55°S and a longitude range of 165° to 30° in the western hemisphere. The general sampling plan for GAMETAG will include representative transit flights into Polar, Tropical, and Transition air masses which have been modified both by continents and oceans and by large scale ascent and descent.

Improved Sensitizing of Laser Absorption Techniques for Atmospheric Pollutant Monitoring; *Richard S. Eng*; Laser Analytics, Inc., 38 Hartwell Avenue, Lexington, Massachusetts 02173; $211,500 for 12 months beginning August 15, 1977

During the past several years, systems based on differential absorption of laser radiation have been developed for the detection of molecular pollutants. Advanced laser systems of the future are expected to have widespread application in atmospheric research, modeling, and surveillance, and will undoubtedly yield a new class of highly sensitive, fast-responding instruments for monitoring and process-control applications involving gases of considerable interest to both government and industry. At the present time, however, detection sensitivity is several orders of magniutude poorer than the fundamental limit, and only a few strongly-absorbing molecular species in the atmosphere can be monitored with adequate sensitivity.

The objective of this research project is to identify those factors limiting sensitivity and develop ways to overcome them. Semiconductor diode lasers will be used extensively since they span the entire infrared "fingerprint" region of the spectrum and have already been employed in several pollutant-monitoring systems. The research plan envisions a two-phase program. Phase I, to be completed during the first year, and addressed in the present project, will be concerned with stabilization of laser output power, mode selection, control of amplitude variations associated with laser tuning, and the effects of atmospheric turbulence. Techniques to minimize the adverse influences of these effects will be developed, based on laboratory and field work, with a goal of at least one order of magnitude improvement in sensitivity over the present state-of-the-art. Phase II will involve testing and evaluation of an operational long-path monitoring system, and comparison with conventional monitors in order to verify accuracy and reliability.

Sources, Transformations, and Chemical Nature of Atmospheric Pollutants; *Glen E. Gordon*; University of Maryland; $393,300 for 12 months beginning September 1, 1977

This is a continuation of work 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 of this project 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 steelmaking, 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. Studies of rainfall pH will attempt to correlate the acidity of rain with the chemistry of power plant emissions.

Aircraft sampling will be continued to elucidate the factors controlling the appearance of ozone bulges in power plant and industrial plumes by coordinating measurements of ozone, hydrocarbons, nitrogen oxides, carbon monoxide, humidity, condensation nuclei, and temperature.

Attainment of these objectives will help to resolve problems faced by regulatory authorities in their efforts to control emissions within limits allowing

acceptable levels of pollutants in ambient air. Many things can be done, and many operating parameters can be adjusted to control emissions, but practical considerations dictate that choices must be made in the light of relative benefits to public welfare, availability of resources, economics, and political pressures. Among the factors subject to control are the siting of power plants and incinerators, fuel composition, plant design and operating parameters, stack height, flue gas cleanup technology, and selective operating restrictions during stagnant air episodes. The proposed research is designed to yield data necessary for evaluating these and other factors as to their impact on ambient air quality, and as to the opportunities they may afford to regulatory authorities for choosing among control strategies.

Aerosol Characterization in Real Time; *Robert K. Gould*, AeroChem Research Laboratories, Inc., P.O. Box 12, Princeton, New Jersey 08540; $113,800 for 12 months beginning September 22, 1977

This research project is aimed at developing an atmospheric aerosol analysis technique capable of operating in either a continuous mode or as an individual particle analyzer. The instrumentation to be designed will provide information on particle mass and composition. To accomplish these measurements, an aerosol beam will be separated from the gaseous constituents and rapidly vaporized in a high-temperature cell. A pressure sensor will be used to estimate particle mass. Mass spectrometric techniques will be used to measure particle composition. The development techniques are expected to be capable of measuring several aerosol properties.

One area of expected application is the measurement of particle composition (averaged over all particles) without the need for concentration by integration collection techniques. Another area of interest concerns the ability to measure concentrations of a given compound (or a few compounds) on a particle-by-particle basis.

The research effort to be pursued will include construction and testing of the instrument components and an evaluation of the advantages and limitations of the developed techniques as they apply to specific areas of atmospheric aerosol science.

Technology Transfer of Zeeman Atomic Absorption Technique for Environmental Trace Analysis; *Tetsuo Hadeishi*; Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720; $99,700 for 12 months beginning August 1, 1977

To understand the sources, transport, and fate of hazardous chemical elements in the environment requires the capability to measure routinely trace quantities of them in large numbers of biological and environmental materials. A very high proportion of all such analyses are now done by atomic absorption spectroscopy because of the great sensitivity of this method to trace amounts of a number of elements. A disadvantage of conventional atomic absorption is the necessity to spend considerable time and much care in preparing the samples (e.g., leaves, animal tissues, etc.) for the final measurement step, introduction into the flame atomizer of the apparatus. The Zeeman Atomic Absorption Spectrometer (ZAA) avoids the prior chemical preparation by volatilizing the sample in a furnace directly into the optical path, correction for background being made by using Zeeman-shifted spectral lines as probes of the background light absorption.

This award provides for tasks necessary to effect the final transfer to users of a technique developed under a prior AENV award. Under the earlier project, the technique has been developed for mercury, lead, cadmium, zinc, arsenic, selenium, copper, and silver with the use of electrodeless discharge lamps capable of operating in the magnetic field that produces the Zeeman splitting of spectral lines. The technique is being routinely applied to biological samples, oil-shale processing residues, and waters of high salt content.

A recent breakthrough in the design of a magnetically confined lamp will be extended to additional chemical elements of interest to a variety of users. Data will be obtained on sensitivities, lamp lifes, and reliability. An operating manual will be prepared.

Diode Laser Multi-Pollutant Ambient Air Monitoring; *Robert T. Ke*; Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, Massachusetts 02173; $60,000 supplement effective January 25, 1977

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.

Pollutant 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.

Measurement of Sulfur Dioxide Oxidation on Particulate Surfaces; *Volker A. Mohnen*; State University of New York at Albany, Atmospheric Sciences Research Center, E. S. 319, 1400 Washington Avenue, Albany, New York 12203; $203,700 for 24 months beginning May 15, 1977

The objective of this program is to develop and evaluate procedures for investigating the mechanisms and importance of sulfur dioxide oxidation on the surface of solid particulate matter of natural and anthropogenic origin. Sulfate formation on well characterized particle and reference surfaces will be studied using molecular beams of sulfur dioxide, oxygen and water. Auger electron spectroscopy and mass spectrometry will be used to measure the rate of product formation. It is anticipated that reaction rates and orders can be determined for a variety of surfaces during the course of this work. Surfaces to be examined include carbon, oxides of vanadium, oxides of iron, and particulate matter collected from ambient air, power plant stacks, and laboratory flames.

Remote Measurement of Air Pollutants; *Edward R. Murray*, SRI International at Stanford University; Menlo Park, California 94025; $165,000 for 12 months beginning August 1, 1977

Both in the study of air pollution problems and in the routine measurement of air pollutants for control and enforcement purposes, there is a great need for instruments that can 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. In order to make measurements of that type with present-day technology, it would be necessary to establish a network of tens or hundreds of expensive point monitors around the area in question and, to obtain vertical measurements, to fly a plane equipped with monitors back and forth over the area. These approaches are expensive and difficult as the equipment needed at each station is expensive and the data from each station must be telemetered to a central collection station or technicians must be employed to circulate about the system to collect data. Further, such a system usually requires a great deal of expensive maintenance and some data are usually lost because of station malfunctions. Clearly there is a need for reliable remote sensing methods to replace the kinds of area-wide sampling techniques available today.

The objective of this project is the development of laser methods for remote measurement of atmospheric levels of gases such as sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), ethylene (C_2H_4), and ammonia (NH_3). These techniques are needed for monitoring ambient levels of gases in polluted air and for obtaining average concentrations integrated over kilometer (or longer) pathlengths to provide data for testing pollutant dispersion models. The work employs the differential absorption laser-radar (DIAL) technique whereby light transmitted from a laser source is back-scattered from atmospheric particles or from topographic targets (like a hillside). The light beam is tuned to a wavelength strongly

absorbed by a molecule of interest. From the time delay between the sending and receipt of the returned back-scattered signal pulses, one can determine gas concentrations at various distances along the path. The concept has been tested for measurement of SO_2 and O_2 in the ultraviolet and of NO_3 in the visible spectrum.

Under the present grant the investigators will demonstrate the performance of the system under different pollutant-gas levels and variable meteorological conditions. The technique will be extended to the infrared to explore the advantages of this spectral region for detecting a wider variety of gases and for potentially greater detection sensitivity. Special attention will be given to NH_3 and O_3 in the infrared.

The Role of Primary Particulates in Urban Air Pollution; *Tihomir Novakov*; Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720; $222,500 for 12 months beginning October 1, 1977

The atmosphere is degraded by suspended particulates consisting of solid particles and microscopic liquid droplets. Some of these particles, like wind-blown dust, fly-ash, and soot, are the *primary* particulates directly emitted into the atmosphere by pollutant sources. Others, the *secondary* particulates, are formed right in the atmosphere by chemical reactions of precursors emitted in gaseous forms by sources. Still others are primary pollutants that have been chemically modified after entering the atmosphere. Visibility reduction is the most conspicuous result of atmospheric pollution. Far more significant than visibility reduction, however, are the effects of airborne particulates on human health. In particular, airborne particulate sulfate of unspecified chemical form has been associated with the incidence of respiratory ailments like emphysema and asthma.

Strong evidence exists which suggests that significant quantities of airborne sulfate are carried on the surfaces of primary carbon particles (soot), where the sulfate is formed by the carbon-catalyzed oxidation of gaseous sulfur dioxide. Although we do not yet have a quantitative assessment of the relative importance of the carbon-borne sulfate in ambient air, evidence for its significant role is sufficiently strong to justify research on primary carbon production because of the human health implications of airborne sulfate, quite aside from the adverse effects of airborne carbon on visibility. In addition to the effect on sulfate formation, there is the further effect of carbon on the formation of certain exotic nitrogen compounds on carbon surfaces.

The first objective of this project is to assess the contribution of primary carbon (soot) emissions to the degradation of visibility through urban atmospheres. The visibility-degrading effect of primary carbon is compared with that of the secondary carbonaceous particulates formed by the oxidation of hydrocarbons in the atmosphere. A second objective is to define the roles of primary carbon in mediating the chemistry of the gaseous sulfur and nitrogen compounds in polluted air. The speed of the carbon-catalyzed oxidation of sulfur dioxide will be determined to help assess the significance of sulfate production on carbon particle surfaces and to gauge the importance of this process for the generation of hazardous airborne particulate sulfate. A parallel study is devoted to describing the surface-chemical forms of nitrogen compounds produced on carbon surfaces by reaction with atmospheric ammonia and nitrogen oxides. Polycyclic aromatic hydrocarbons associated with soot particles are investigated to determine their reactivity to nitrogen dioxide under practical conditions occurring in polluted air. This approach is designed to explore possibilities of the formation of unsuspected carcinogens in urban air.

New methodology is being studied for measuring the atmospheric burden of primary carbon by applying the optical attenuation of a laser beam by a filter carrying less than a monolayer of collected airborne particles. Raman spectroscopy is applied to the measurement of graphitic soot. Techniques for probing the chemistry of surface reactions on carbon include ESCA (electron spectroscopy for chemical analysis), infrared spectroscopy, wet chemical analysis, and x-ray fluorescence.

Study of Chemistry of Atmospheric Particulates; *Tihomir Novakov*; Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720; $132,647 supplement beginning October 1, 1976

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 adsorption 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.

Chemical Transformations in Photochemical Smog and Their Application to Air Pollution Control Strategies; *James N. Pitts*; Statewide Air Pollution Control Center, University of California, Riverside, California 92502; $352,000 for 12 months beginning February 2, 1977

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 experimentally validated model for chemical transformations into photochemical 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 misture. 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, propane and n-butane. Progress has begun on the formulation of practical mechanism for an aromatic (toluene) photooxidation system, for which little kinetic and mechanistic data is available. This has been achieved in a closely coupled program between modeling and smog chamber groups. The second major objective is to accomplish the detailed characterization of particulate pollutants in both ambient and simulated atmospheres, with emphasis on hydrocarbon aerosol precursors, trace nitrogenous compounds, and gas-to-aerosol conversion processes. Exploratory studies will be done on indoor-outdoor aerosol relationships.

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.

The Role of Solar Ultraviolet Radiation in the Formation of Hydroxyl Radicals in the Trosposphere; *F. Bach Sellers*; Panametrics, Inc., 221 Crescent Street, Waltham, Massachusetts 02154; $41,900 for 12 months beginning March 1, 1977

The reaction of the hydroxyl radical with various trace gases has been hypothesized as fundamental to a complete understanding of tropospheric chemistry. For example, the atmospheric concentrations, lifetimes and distributions of methane, carbon monoxide and sulfur dioxide are believed to be largely controlled by the hydroxyl radical. The dominant source of the hydroxyl radical in the troposphere is photolysis of ozone by solar ultraviolet radiation to produce atomic oxygen, which then reacts with water to produce the radical. Because ultraviolet flux is highly variable in the troposphere, it is of fundamental importance that it be measured simultaneously with the various important constituents.

This program is designed to provide accurate airborne ultraviolet flux measurements in the 280-400 nm wavelength region. The flux measurements will be made from the National Center for Atmospheric Research aircraft simultaneously with the chemical and meteorological measurements of the NSF supported program entitled "Global Atmospheric Measurements on Tropospheric Aerosols and Gases" (GAMETAG). Present planning on project GAMETAG calls for a seven-year program that is to be divided into two phases of two and five years duration. Panametrics will be supported for only the first phase of this program, with decisions the second phase being largely dependent on the success of Phase I. This first phase of the larger project will have as its primary objective the elucidation of the importance of the hydroxyl free radical to tropospheric chemistry in both clean and perturbed atmospheres.

Application of Computer Graphics to Air Quality Data Analysis; *Alvin H. Vanderpol*; Meteorology Research Inc., 464 West Woodbury Road, Altadena, California 91001; $159,200 for 24 months beginning September 1, 1977

This research proposal is aimed at developing statistical procedures which will enable researchers to probe large air quality data bases in a cost-effective manner. The research will lead to techniques by which scientists, unfamiliar with statistical procedures, can ask specific questions of large data bases of varying quality and expect to obtain useful information or insight.

These procedures will be developed and tested using two existing European data bases which have not yet been analyzed in detail. These two data sets, from the European Air Chemistry Network (EACN) and the Long Range Transport of Air Pollutants (LRTAP) study, will be probed to determine whether they will yield useful information on the relationship of SO_2 emissions, air mass transport, and sulfate concentrations in Europe. The results of these studies will be directly applicable to several ongoing or planned U.S. regional scale studies of sulfur transport and conversion.

The procedures to be developed will utilize powerful but little known existing statistical techniques which are especially suited for analysis of "real" data bases. These techniques are relatively insensitive to the occasional stray data points common in air pollution data.

ENVIRONMENTAL ASSAY METHODOLOGY

The objective of the Environmental Assay Methodology program is to develop advanced instrumentation and analytical methodology for the collection, identification, and quantification of specific compounds in environmental media.

A Water Pollution Monitoring Laser Optical System; *Silverio P. Almeida;* Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061; $10,300 for 2 months beginning August 1, 1977

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 to scan automatically and count the types and numbers of various diatoms in a given sample.

Coherent spatial filtering techniques are employed. 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 by 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.

This supplementary award provides for the acquisition of additional varieties of diatom species and the preparation of specimens for their inclusion in the collection of optical spatial filters used in the laser holography system. Work will also be continued on an advanced optical system for bypassing the intermediate preparation of a photographic image of the diatoms, on the computer simulation of diatoms, and on a white-light illumination system.

Effects of Pollutants on Gills of Fresh Water Fishes; *Paul O. Fromm;* Michigan State University, Department of Physiology, East Lansing, Michigan 48824; $27,600, 12 months beginning July 1, 1977

Gills represent that tissue or organ of fishes which is maximally exposed to water-borne pollutants. Continuous ventilatory activity insures that the concentration of any toxicant present in the aquatic environment is maintained at the respiratory surface. It is reasonable to believe that a study of the action of pollutants on fish gills will provide valuable information relative to the impacts of man's activities on the aquatic environment.

The primary objective of this project is to develop the isolated perfused gill preparation as a model to study the effect of selected pollutants on fish. The overall project will consist of three main divisions: (a) experimental investigation of the permeability properties (flux of water across) isolated perfused gills and the effect of pollutants on same; (b) a study of the salt transport capabilities in gills exposed to pollutants and (c) biotransformation of pollutants by gills during transit of materials from the ventilate to the blood vascular space.

Immunological Studies of Cadmium and Zinc Binding Proteins; *Justin S. Garvey*; Department of Biology, Syracuse, New York 13210; $109,100 for 24 months beginning July 1, 1977

A number of metals are known to cause deleterious human health effects at moderate and high doses. For example, lead from paint and mercury used as seed coatings have been the causitive factors in many human illnesses and deaths. These well-known cases have raised suspicion that all heavy metals and related metalloids may have adverse human health effects. Cadmium has been shown to be a renal toxin, and arsenic and selnium have long been known to be acutely toxic. However, little is known about the long term low-level toxicity of the heavy metals. Studies have been and are being conducted in laboratory animals to determine this, but it is difficult to extrapolate the results to humans. Regulatory agencies charged with the responsibility of protecting human health and the environment depend on epidemiological studies as well as animal test results when setting allowable limits, standards, and tolerances for the heavy metals. However, epidemiological studies are extremely expensive and are further complicated by a lack of quantitation of exposure levels by the involved individuals. Epidemiological studies would be less expensive and more reliable if better diagnostic techniques for exposure were available. The research sponsored by this grant seeks to accomplish this goal for cadmium and zinc exposure.

Metallothioneins are metal binding proteins which are synthesized by an organism in response to exposure to certain divalent metals, i.e., cadmium, mercury, zinc and silver. The production of metallothionein is an indication of exposure to heavy metals. Identification of the specific metallothionein can be used to determine the exact metal of exposure. Quantification of the protein produced can be used to estimate the dose. A radioimmunological technique is being developed to measure exposure to the specific antisera against the metallothioneins. These antibodies are then used as immunological reagents to study the subtle differences in the proteins as well as to visualize the metallothioneins in the cells and tissues of the experimental animals. Extracts from blood plasma, urine and selected tissues are being used to investigate the feasibility of a radioimmunoassay for quantitating exposure to the metals.

Cytogenetic Effects of Mutagens and Mitotic Poisons of Mammalian Cells; *T. C. Hsu;* University of Texas, M.D. Anderson Hospital and Tumor Institute, Houston, Texas 77030; $73,400 for 12 months beginning January 15, 1977

Cancer authorities estimate that a large percentage of cancer is caused by environmental factors. An unknown and possibly large factor is exposure to manufactured organic compounds or their degradation products in the environment—pesticides, plastics, food additives, etc. Undoubtedly, some chemicals pose unreasonable hazards in their manufacture, processing, transportation, and use. On the other hand, there are chemicals with lifesaving abilities and others which add significantly to productivity and the quality of life. But which chemicals are the hazardous ones? There is an urgent need for quick, inexpensive and reliable tests for screening chemicals for adverse health effects. Conventional tests in laboratory animals are accepted as applicable to the human experience, but there are not adequate resources, trained personnel, or time to exhaustively test the thirty thousand or more commercial chemicals in use in the United States annually. New, rapid techniques are needed for screening chemicals for their potential to cause mutations so that those with the highest potential can be extensively tested and the risk assessed in order that intelligent regulatory decisions can be made concerning the use of such chemicals. Several test systems using bacteria are in wide use but the simplicity of the bacterial mechanisms are obscuring possible effects to humans.

It is the purpose of this project to use mammalian cells as test systems. A protocol is being developed for the rapid screening of chemicals for their ability to cause chromosome breaks or otherwise interfere with mitosis in mammalian cells both in cell culture and *in vitro*. In addition, attempts are being made to refine a technique for visualizing premature condensed chromosomes so that background abnormality rates for genetic diseases can be estimated. An investigation

will also be initiated to assess the feasibility of using male, mammalian meiosis as a test system for environmental mutagens. And finally, investigation will be made using selected chemicals which cause "dominant lethals" in the Chinese hamster to ascertain the mechanism of this process.

METALS AND ORGANOMETALLICS

The purpose of the Metals and Organometallics program is to research the effects of organometallic compounds on human health and on ecosystem structure and function.

Sources of Lead in Children; *Paul B. Hammong;* University of Cincinnati, Cincinnati, Ohio 45267; beginning August 1, 1977; $5,800 for 3 months

This award seeks to develop techniques for assessing the sources of excessive lead exposure in young children via the route of oral ingestion of non-food materials.

For any potential source of lead, it is not enough to know its lead concentration in order to assess properly its degree of hazard. It is equally important to know the amount which children might consume or inhale. With regard to inhalation, the limits are reasonably well-known. Inhalation of air is a continuous, obligatory process which is proportional to the metabolic demands of the individual. This appropriate air sampling studies combined with the usual measure of internal exposure, reflected as concentrations of lead in blood (PbB), have provided a reasonable estimate of air lead hazard. But the patterns of oral intake of non-food items (pica) by children are imprecisely known. Until they are known it will remain virtually impossible to assess the hazard of these substances. The objective of this investigation is to establish how frequently children eat excessive amounts of lead, and to define the environmental milieu in which this activity occurs.

It is assumed that children who eat excessive amounts of lead are to be found among those with elevated PbB's. It is further assumed that elevated fecal lead excretion will occur subsequent to elevated lead ingestion. Although the absorption of lead is no doubt variable and is known to be as high as 50 percent in young children, even this outside figure provides for enough residual fecal lead to allow at least gross estimates of oral lead intake to be made.

The procedures which have been undertaken and are leading to the accomplishment of this objective are enumerated as follows: (1) identification and enrollment of subjects into the project cohort; (2) procurement of stool samples; (3) investigation of home environment; and (4) analytical procedures for sample analysis including origin of the sample lead content by source. Funds provided by this award are being used to complete analyses of lead in the environmental and fecal samples taken during studies of body burden clearance rates for children who have been relocated into low lead hazard areas.

An Interdisciplinary Study of Environmental Pollution By Lead and Other Metals; *Gary L. Rolfe;* University of Illinois at Urbana-Champaign, Institute for Environmental Studies, Urbana, Illinois 61801; $7,700 for 6 months beginning May 1, 1977

The general objectives of this project were 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 in urban systems of particulates with possible associated health hazards to which humans are subjected.

The original goal of the project 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 were completed and formed the basis for two final research objectives: determination of the current

or potential effects on productivity of both agricultural crops and urban vegetation impacted by the use of lead in gasoline; and determination of the urban distribution of lead and characterization of lead-containing particulates in urban systems to which humans are subjected.

Risk/benefit methodology was applied to 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 has been disseminated by project research reports, publications in the scientific literature, presentations at scientific meetings, and personal interaction with project investigators and scientists and/or decisionmakers 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.

This supplemental effort is concerned with testing and evaluating a computer-based model which is designed to predict how lead-induced stresses in agriculturally important plants may affect crop yield.

The Environmental Flow of Cadmium and Other Trace Metals; *Kenneth J. Yost;* Institute of Environmental Health, Purdue University, West Lafayette, Indiana 47907; $216,500 for 12 months beginning January 1, 1977

This award provides support for a continuation of work under a previous NSF grant.

The overall objective of this project is to provide technical data and information which will contribute to the national formulation of emission/effluent standards that will adequately project the environment while minimizing the economic impact of these standards on the metals industries. Specifically, 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.

During this period of support detailed analyses of emissions from steelmaking activities, principally the coke oven and basic oxygen furnace operations, will be carried out. For the electroplating industry, research will center on the improvement of waste treatment systems to control metal discharge in plant effluents. The environmental impact of heavy metals released by these industries will be assessed by determining the response of terrestrial ecosystems within the zone of elevated exposure. The source emission data and the environmental response data are being integrated into computer-based models which will yield scenarios of environmental impacts for various heavy metal dispersive use patterns. This information is intended to form the basis for the establishment of regulations relating metal emissions to acceptable ambient standards of quality.

ORGANIC CHEMICALS OF COMMERCE

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

Effects of Chemical and Physical Properties of Organic Compounds on their Biodegradation; *Martin Alexander;* Cornell University, Department of Agronomy, Ithaca, New York 14853; $140,000 for 12 months beginning February 1, 1977

The objectives of this research program are to develop data that would facilitate the prediction of the behavior, fates, and effects of organic chemicals in the environment. This would allow the chemical industry and regulatory agencies to predict which chemicals from among the tens of thousands of commercial chemicals should receive priority attention for investigation and testing.

The specific goals of this research project are to establish principles regarding biodegradation. It focuses on the biodegradation of individual organic compounds and mixtures of chemicals of environmental importance. Individual organic compounds are being 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. Since municipal and industrial wastes are often blended prior to treatment, it is important to establish principles of biodegradation regarding biodegradation for complex mixtures. Thus the project seeks to determine the effect of utilizable nutrients and structural analogs of potential pollutants on their rate of biodegradation in mixtures and the role of cometabolism in biological decomposition of mixtures of chemicals entering natural ecosystems. Chemicals for study include halogenated alkanes and benzenes, chlorinated benzoates and various substituted benzoic acids.

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. The development of hazard prediction capabilities based on the structure and properties of the chemicals is an expressed need of local and Federal regulatory agencies.

Chemodynamic Studies on Bench Mark Industrial Chemicals; *Cary C. T. Chiou;* Oregon State University, Environmental Health Sciences Center; Corvallis; Oregon 97331; $4,000 supplement beginning March 10, 1977

During the past three decades there has been an enormous increase in the amount and number of chemicals used by modern society. This situation is a result of the productivity of the synthetic chemists in responding to man's desire for a higher standard of living. Thus, we have a continuing increase in the production and use of drugs, food additives, pesticides, and industrial chemicals. The proliferation of chemical usage has elicited concern over the long-range effect of those materials on man and his environment. Many of these chemicals have become widespread environmental contaminants and are known to have detrimental health effects.

In order systematically to identify presently used or new compounds that are likely to cause widespread environmental problems, one needs to have better knowledge of the environmental behavior and toxicological properties of several classes of synthetic organic compounds. In this project, several physical and chemical properties of a number of model compounds representing several classes of industrial chemicals will be measured in order to provide data needed to correlate the environmental behavior of compounds with their chemical and physical properties. This type of correlation is needed in order to develop reliable predictive models of the environmental behavior of as yet untested compounds.

Identification of Mutagenic Organic Compounds in Environmental Samples; *Barry Commoner;* Washington University, Center for the Biology of Natural Systems, St. Louis, Missouri 63130; $199,900 for 12 months beginning July 1, 1977

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 percious heritage, and deterioration in gene quality can result in a corresponding decrease in the quality of life. Clinically recognizable genetic diseases currently affect about six percent 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 for mutagens. 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.

This project has several objectives related to the problems discussed above. First, investigators are working on improvements of the *Salmonella* test, which is a much more rapid screening tests for mutagenic chemicals than the traditional slow and expensive animal tests. Second, they are applying this test to a large number of chemicals already known to be carcinogenic or non-carcinogenic to determine its reliability. Third, they are examining environmental samples for the presence of chemicals that give positive results, indicating the presence of mutagens. Once positive mutagenic tests are obtained, the specific mutagenic chemical can be identified using various chemical and physical techniques.

The investigators are also determining the pathways of organic carcinogens from their origins in water and air to man to estimate the total human exposure to carcinogens.

N-Nitroso Derivatives of Pesticides and Other Chemical Formulations; *David H. Fine;* Thermo Electron Corp., Waltham, Mass. 02154; $301,500 for 12 months beginning December 13, 1976

Nitrosation is a chemical reaction in which a nitrogen-to-nitrogen bond is formed between an amine nitrogen and the nitrogen of nitrite ion. The resulting chemical is called a N-nitrosamine. Although no epidemiological evidence links N-nitrosamine exposure to cancer in humans, many nitrosamines that have been tested in animals have been shown to be carcinogenic. There are N-nitrosamines that have been shown to induce cancers after a single exposure. Considerable regulatory concern has been exercised over N-nitrosamines in human food, i.e., smoked and cured meats. N-nitrosamine contamination of chemical formulations, as found by the research funded by this grant, has been shown to be several million times greater than in foods.

The possibility of nitrosation of pesticides in the environment was first shown by researchers at the Environmental Protection Agency's laboratory at Athens, Georgia, in 1975. They showed that atrazine, one of the most widely used corn herbicides, could be nitrosated at environmentally attainable conditions of temperature and acidity. This finding is particularly significant in that atrazine is usually applied to agricultural soils which also receive heavy treatments of nitrate fertilizers and/or liquid ammonia. In addition, levels of atrazine in the range of several parts per million have been found in some drinking waters in the U.S. Atrazine is not the only pesticide that could theoretically be nitrosated in the environment. It is but one of a widely used class of triazine herbicides. If amines (including the triazines and other pesticides) can be nitrosated in the environment, there may be a serious human health risk which has been previously ignored.

The objectives of the study are to complete the investigation of the nitrosation of pesticides in the environment (particularly in soils) as originally proposed, and to estimate the extent to which N-nitrosamines occur as contaminants in consumer products and in materials to which industrial workers are exposed. The need for a survey of nitrosamine contamination emerged in the study of the nitrosation of pesticides under the original grant when the investigators analyzed the pesticide formulations for possible contaminants in order to assess background nitrosamine levels. The startling results of this survey led them to investigate other consumer and industrial products for contamination. Much congressional, public and government interest accompanied these results when they were made available by NSF to concerned government agencies, manufacturers of the products, a congressional hearing, and the press. This will include a survey of a variety of consumer and industrial goods for N-nitrosamine contamination. Confirmation of the results will be by mass spectroscopy and comparison with authentic samples of the nitrosamines. The magnitude of human exposure to nitrosamines is needed in order to assess the role of these chemicals in the causation of human cancer. The survey to be conducted under this grant will provide information on the most likely sources of human exposure. This information will assist a number of regulatory agencies, e.g., the Environmental Protection Agency, Consumer Product Safety Commission, National Institute of Occupational Safety and Health, Food and Drug Administration, in quantitating the risk associated with exposure to these compounds.

Fates of Industrial Synthetic Organic Chemicals: A Case Study; *Ronald A. Hites*; Massachusetts Institute of Technology, Cambridge, Massachusetts 01239; $197,400 for 12 months beginning July 1, 1977

The environmental hazard caused by various synthetic industrial organic compounds is now well known. Pesticides, polychlorinated biphenyls, chloro-fluoromethanes, tetrachloro-dibenzodiozane, 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, 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 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 or 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.

Characterization of Aquatic Organics and Complexes; *Walter J. Maier*; University of Minnesota, Minneapolis, Minn. 55455;$206,700 for 12 months beginning June 15, 1977

Many organic compounds are capable of forming complexes with transition metals and other elements. The complexes may have different properties from the uncomplexed metal with respect to movement through soil and water and across membranes. In some cases the complex could increase the rate of absorption of the metal; in others, it might inhibit absorption. Some of the metals subject to complexation are considered toxic (e.g. mercury, cadmium); others e.g., iron, manganese, chromium, copper are essential micronutrients which can be toxic if present in excess. Industrially synthesized compounds of concern in this regard would be the high-volume chelating agents such as nitrilotriacetic acid and ethylenediaminetetraacetic acid and others which can exhibit binding potential. What are the relative effects of these materials as compared to known natural complexing agents such as the humic and fluvic acids?

Intensive utilization of land and water resources coupled with the proliferation of new chemicals has resulted in an accumulation of organic and inorganic constituents in nearly all natural waters. A significant fraction of these constituents are detrimental to public health and aquatic ecosystems. However, the available information about aquatic organics is inadequate for the formulation of sound control policies, remedial action, and effective but economical monitoring programs.

The objective of this project is to characterize aquatic organics in the Upper Mississippi River as related to identity, chemical-physical properties, source-related behavior, transport, and metal interactions. Water samples are being obtained from the river and major inflows consisting of precipitation, subsurface seepage, surface runoff and municipal-industrial effluents. Initially, aquatic organics are sepatrated by molecular size and elemental composition, and subsequently fractionated into hydrophobic and hydrophilic classes from which acidic, neutral, and basic compounds are separated and concentrated. Techniques such as high pressure liquid chromatography, gas chromatography-mass spectrometry, and chemical ionization mass spectrometry are being used to intensively characterize and identify organic components in these fractionated samples.

Chemical Oxidation Processes in Aquatic Environments; *Theodore Mill*; Stanford Research Institute, 333 Ravenswood Avenue, Menlo Park, California 94025; $7,970 Supplement, Effective November 26, 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 chemicals 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 is concentrated 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.

A secondary goal is to develop improved experimental procedures for testing the degradability of organic compounds under simulated natural conditions.

Exploratory Study of Exposure of Migrant Workers to Pesticides and Pesticide Residues; *Clarence B. Owens*; Florida Agricultural and Mechanical University, Tallahassee, Florida 32307; $67,600 supplement

This award provides supplemental funds to a previous AENV grant. Among agricultural workers, migrant field workers are most at risk of exposure to a combination of adverse elements which may effect their health and their productivity. These elements include not only potential exposure to a greater variety and higher dosage of pesticides but socio-environmental factors related to housing, health, and nutrition. During the past five years, several states along the Atlantic Coast migrant stream have reported incidents of pesticide-related illness among migrant farm workers. The causative factors are not known but apparently there are a number of variables that can singly or synergistically interact with other variables to cause illness. The principal factors associated with conditions relating to the health of workers should be isolated if meaningful safety standards are to be initiated for migrant workers. These analyses should also provide insight on the potential human health risk to those populations exposed to much lower levels of pesticides.

The project, which is jointly supported by the National Science Foundation and the U.S. Environmental Protection Agency, is a field investigation of migrant worker exposure to pesticide and pesticide residues. The major objective is to ensure agricultural worker health and safety in the area of pesticide exposure. The project team has traveled with migrant crews harvesting agricultural crops on the Atlantic Coast from Florida to the southern New England states over an eleven month harvest cycle. During this time data on such factors as health, education, housing conditions, incidence of ill-health and pesticide related illness, and amounts and types of pesticide usage have been collected.

This award will provide assistance necessary to complete the analysis of collected data and the preparation of special reports describing the results and conclusions of this work for a variety of user groups concerned with production agriculture and human health.

The University of Houston, the University of Texas, and the University of Iowa are participating in this project through contractual arrangements with Florida Agricultural and Mechanical University.

Socio-Behavioral Responses to Chemical Hazards; *Enrico L. Quarantelli*; Ohio State University, Disaster Research Center, 127-129 West 10th Avenue, Columbus, Ohio 43201; $188,600 for 12 months beginning June 1, 1977

Chemical disasters represent a serious threat to populations in the United States today. Tens of thousands of different chemicals are produced in this country each year and new chemicals are being developed at

a rapid rate. This creates the potential for major problems in the storage, transport, use and disposal of such products. It is also likely that chemical disasters will increase in both frequency and magnitude in the future.

In spite of the increasing threat to chemical disaster, little social science research has been conducted on this hazard. This study focuses on the socioeconomic and political factors related to the adjustment of communities to chemical disasters. The research will involve three principal tasks: extensive exploration of organization and community preparations for sudden chemical disasters in vulnerable localities; in-depth study of the emergency time responses and problems in catastrophic events, major accidents, acute hazardous episodes and severe chronic events of a chemical nature; and longitudinal examination of selected cases of recovery from episodic and recurrent chemical disasters. As the study moves from one phase to another findings will be reviewed with potential users. The study should result in the identification of policy options for mitigating the impact of chemical disasters and the identification of the implications of similarities and differences between natural and chemical disasters for planning, policy, operations and research on chemical disasters. Policy implications of the study will be disseminated to potential user groups throughout the course of the three-phased project, and will not await the completion of the study.

An Investigation Into the Chemistry of the UV-Ozone Water Purification Process; *Erick Leitis*; Westgate Research Corp., Los Angeles, Calif. 90025; $94,800 for 12 months beginning May 15, 1977

Empirical research has demonstrated a synergistic effect in the simultaneous action of ultraviolet (UV) light and ozone in decomposing organic materials in very limited classes of organic wastes. The detailed chemical and photochemical mechanisms accounting for this synergism are not known. The success of the process in dealing with a few organic chemicals by trial-and-error methods suggests that it could be widely applied to the decontamination of industrial process waste streams and to the purification of drinking water.

For wide application, however, cost would be more of a factor than was the case in the specialized applications for which the process has been developed. This is why it is necessary to understand the detailed chemical mechanisms through which UV light and ozone exert their effects. To make the most economic application of the process to any given combination of organic chemicals, it will be necessary to know the sequence of chemical and photochemical processes by which the synergism is achieved. An understanding of the reaction pathways and of their relationships to one another, along with data on the detailed kinetics and the effects of operating parameters, will provide the requisite guidance for the engineering design of the most effective and most cost-effective systems. Such knowledge will allow one to estimate for which waste-disposal and water-purification problems the UV-ozone process is likely to be practical.

The objective of this research is to determine what these mechanisms are for representative organic molecules, and what factors control their action. The ultimate purpose of the research is to gain an understanding of the mechanistic details sufficient to enable the design of applications of the process to a variety of chemicals in waste streams or in drinking water. Experiments on model organic chemicals in water solution will involve exposure to UV light during, before, and after ozonation; treatment with reagents that generate OH radicals or single O_2 for diagnosing reaction mechanisms; and reaction product analysis by resin preconcentration or solvent extraction followed by gas- or liquid-chromatography and mass spectroscopy. Various process parameters will be varied, e.g., UV and ozone dosage, and acidity/alkalinity (pH).

Cancer Mortality in an Urban-Industrial Environment: A Planning Study; *Kenneth J. Yost*; Purdue Univerisity, Institute of Environmental Health, Pharmacy Building, West Lafayette, Indiana 47907; $38,800 for 12 months beginning May 1, 1977

The purpose of the study is to assess whether quantitative relationships exist between gradients of exposure to airborne carcinogens typical of an urban-industrial environment and cancers of multiple sites in humans.

This project is investigating the incidence and prevalence of cancer in human populations located in the heavily industrialized, urbanized area surrounding the southern rim of Lake Michigan in an effort to determine whether cancer mortality gradients at the census tract level can be shown to be related to the exposure gradients of airborne carcinogens. The study area, which contains petrochemical plants as well as possibly the largest steel producing complex in the world, has been shown to have both high ambient air levels of known and suspected carcinogenic compounds, and a significantly higher than average mortality rate from cancer of the respiratory, genitourinary, and gastrointestinal tract systems in humans.

The fundamental hypothesis being tested is that airborne carcinogens are causative factors in the incidence of cancer of the skin and respiratory, genitourinary, and gastrointestinal tract systems. The testing of this hypothesis will be accomplished by determining the history of multiple-site cancer mortalities in the study area census tracts. The resulting mortality rates will be combined with existing data on indices of air pollution, such as total suspended particulates, to determine whether or not a presumptive relationship between these factors can be established.

PROGRAM DEVELOPMENT AND UTILIZATION

The objective of Program Development and Utilization for the Chemical Threats to Man and Environment subelement is to assist in the development of and assessment of program initiatives and priorities; to promote the cohesiveness of the overall program effort by supporting interproject communication; and to assist in the effective utilization of research results and program findings.

Eleventh Annual Conference on Trace Contaminants in Environmental Health; *Delbert D. Hemphill*; University of Missouri-Columbia, Columbia, Missouri 65201; $15,100 for 12 months beginning June 1, 1977

The Eleventh Annual Conference on Trace Contaminants 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 system.

The purpose of these Conferences is to explore the effects on man and ecosystems of trace amounts of organic and inorganic chemical substances. The Conferences examine the occurences of these substances in enivironmental media, biota, and foods, and the processes by which they are transported through environmental pathways or produce their effects on living forms and ecosystems. These conferences form part of an overall interdisciplinary approach necessary to understand the complexity of environmental and ecological problems and the methods for their control.

An Evaluation of Toxicological Information Relevant to Future Testing Requirements for Hazardous Chemical Substances and Mixtures; *John C. Kolojeski*; Clement Associates, Inc. Washington, D.C.; $142,793 for three months beginning April 1, 1977

With the passage of the Toxic Substances Control Act (PL 94-469), on January 1, 1977, the problem of premarket testing for the determination of the hazardous nature of new chemical substances and mixtures as well as existing materials in current, widespread use has become a regulatory issue. The provisions of the Act established an eight member Interagency Advisory Committee to the Administrator of the U.S Environmental Protection Agency. The Committee is to advise the Administrator of those chemical substances and mixtures which ought to require further testing relevent to a determination of their associated risk of injury to human health or the environment.

This award is a continuation of an NSF contract and is to provide technical assistance to the Interagency Advisory Committee by: (a) providing appropriate information on exposure and health and environmental effects for a large number of manufactured chemical substances and mixtures; (b) consulting with the Committee during its review of the data provided; (c) providing support to the Committee in the selection of those chemicals affecting health and environment for which further testing appears to be appropriate; and (d) providing support to the formulation of the Committee's recommendation to the Administrator of the U.S. Environmental Protection Agency in accordance with the specifications of the Act.

Information Support Services for Chemical Threats to Man and the Environment Program; *Robert H. Ross*; Oak Ridge National Laboratory, Information Center Complex, P.O. Box X, Oak Ridge, Tennessee 37830; $150,000 for 12 months beginning July 1, 1977

The Information Center Complex of Oak Ridge National Laboratory is providing a variety of information support services to the NSF-RANN program on Chemical Threats to Man and the Environment intended for the broad community of users of the information generated by program research. The services include: (1) the preparation of overview documents summarizing current literature on halogenated organic compounds; focusing on the organohalides of strategic environmental and human health concern; (2) the publication and distribution of a bimonthly abstract journal and newsletter covering all research results published by the Chemical Threats program grantees; (3) the annual publication of the Chemical Threats Directory of program participants; (4) the management of a technical information system file; and (5) the operation of an environmental response and referral center which provides literature searches, bibliographies, summaries of information and replies to specific questions requested by the community of researchers, governmental agencies, industrial organizations and interested individuals concerned with the environmental and human health aspects of trace contaminants.

Symposium on Terrestrial Microcosms and Environmental Chemistry; *James M. Witt*; Oregon State University, Department of Agricultural Chemistry, Corvallis, Oregon 97331; $62,500; 12 months beginning June 1, 1977

Thousands of chemicals in everyday use protect health, increase agricultural production, provide improved shelter and clothing, and, more generally, raise levels of comfort and convenience. Yet these gains simultaneously have led to outcries against real, imagined, and suspected impacts of certain chemicals such as pesticides and other toxic substances. Concern about increased cancer mortality, loss of wildlife, loss of productivity of agricultural and forest lands, and loss of aquatic productivity have generated legislation and regulatory processes which in turn have increased awareness of some of the difficulties we face (e.g., loss via pesticide contamination of the non-target salmon of the Great Lakes as a human food resource). Simultaneously, world population pressures and diminished resource bases have intensified demands for maximal agricultural productivity and optimal health measures and land use.

Two approaches to evaluation of environmental hazards created by these chemicals have been proposed and employed to varying degrees. The first has been termed the "Benchmark" approach. The data from specified physical, chemical, and toxicological tests for a candidate chemical are compared to "benchmark data" for typical chemicals of different classes for which environmental behavior is known and for which impacts have been assessed in the field. Alternatively the evaluation might take the form of comparison of mathematical models of environmental fate and effects of candidate and "benchmark" chemicals.

A second approach has employed laboratory model ecosystems or "microcosms." The comparative behavior and effects of chemicals in these more complex systems in relation to comparable field experience may provide predictive insight into problematic chemicals in advance of actual use.

A conference and workshop entitled "Symposium on Terrestrial Microcosms and Environmental Chemistry" will be held at Oregon State University during the period of June 13-17, 1977 to address critical questions regarding these approaches with a view toward producing a protocol for use by industry and regulatory agencies and sharpening the research focus necessary to achieve that end.

The objectives are to review the state-of-the-art of terrestrial microcosm technology; to develop a provisional protocol applying terrestrial microcosms and chemical benchmarks to predicting environmental hazard of industrial chemicals and pesticides; to determine the research needs for development of improvement of that protocol; and to provide a forum for wider knowledge and constructive criticism of laboratory microcosms and environmental chemistry benchmark evaluative processes.

REGIONAL ENVIRONMENTAL MANAGEMENT

Research in Regional Environmental Management is designed to enhance man's ability to deal effectively with regional environmental problems. Support is focused on the identification and analysis of environmental problems of selected regions and their component interrelated factors, including economics, growth, resource availability, social, institutional, and organizational as well as physical factors. The research is user-oriented and is designed to produce information of value to the planning and management of regions or resources to achieve maximum benefit with minimum environmental disruption. A continuing effort to coordinate the activities of and exchange information among investigators, Federal, State, and local government agencies, and industry is maintained.

The objectives of this subelement are to:

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

Research support is concentrated in six areas in FY 1977:

- Environmental Risk Evaluation
- Land Use
- Regional Environmental Systems Evaluation and Synthesis
- Regional Policy and Decisionmaking
- Residuals Management
- Urban Hydrology

ENVIRONMENTAL RISK EVALUATION

The Environmental Risk Evaluation program constitutes a response to the Nation's need to know and understand those natural events and human activities capable of harmful environmental consequences.

Application of the Entropy Law to Evaluations of Pollution Control Alternatives; *Richard Greeley*, The Mitre Corporation, Metrck Division, 1820 Dolley Madison Boulevard, McLean, Virginia 22101; $39,000 for 12 months beginning July 15, 1977

This is a new award intended to test a concept for quantifying the environmental effect of alternative pollution control technologies. Recognition of the finite nature of the physical environment generates the need to direct greater attention to measures of the efficiency and flexibility of environmental activities and processes. Entropy measure derived from thermodynamics and statistical mechanics can provide insight into the degree of disorder and irreversibility associated with each major real world activity.

Successful development of these measures will facilitate a fuller, more systematic calculation and comparison of the environmental and distributional consequences of quite different pollution control systems. These systems have a variety of energy, material, resource and environmental requirements and impacts over time.

This award will develop and test the use of entropy measures and estimates as applied to systems for controlling the emission of sulphur oxides. Results will be compared to other more conventional methods for evaluating alternatives to determine insights and limitations. Successful completion of this investigation would provide a foundation for subsequent Federal studies and could lead to the development of a useful new type of environmental analysis.

Development and Testing of Risk-Benefit-Cost Analysis for Policy Formulation; *Ivars Gutmanis*; Sterling Hope Corporation, P.O. Box 19406, Washington, D.C. 20036; $154,000 for 12 months beginning September 1, 1977

This is a new award focusing on the development of policy tools to provide a basis for systematic analysis and management of high consequence/low probability events. Current policy aids such as risk-benefit-cost analysis have provided primarily technical, aggregate data to policy makers and little in the way of systematic information on component impacts and alternative utility functions and expectations. The result is that current analytical aids have been found deficient in their relevance to operational policy choices.

This effort attempts to improve the policy relevance of risk-benefit-cost analysis by developing quantitative and qualitative procedures for addressing the impacts of risks, benefits, and costs on relevant population subgroups associated with alternative policies. With the cooperation of the Department of Transportation, this improved tool will be tested on the consideration of alternative liquid natural gas policies currently under consideration. Both improvement in a policy tool and a significant test of its use are expected as results of this award.

Identifying, Evaluating and Managing Environmental Risks—Part I; *Roger E. Kasperson,* Department of Government and Geography, Clark University, Worcester, Massachusetts 01610; $265,900; for 17 months beginning August 1, 1977

This award intends to structure, clarify, and improve upon the current management of environmental risks. The responsibility for recognizing and managing natural and technological hazards has grown without coordination in a variety of agencies and public bodies. There is no coherent, effective policy for assessing risks and managing hazards.

This project is to be closely coordinated with one at Decision Research, a branch of Perceptronics, Inc., located in Eugene, Oregon. Together these research teams plan to: 1) develop one structural taxonomy of technological hazards based on physical and biological principles, and one social/psychological taxonomy based on people's perceptions of hazards; 2) analyze alternative concepts of "acceptable" risk; 3) develop improved methods for communicating facts about hazards and risk management; 4) map the hazard management process; and 5) integrate the above by relating risk acceptance and risk management efforts to the structural and psychological characteristics of the hazards.

By using laboratory, case study, and analytical procedures, the multi-disciplinary teams expect to provide an overview of hazards and hazard management, systematic conceptual tools for identifying (and perhaps predicting) hazards, broader bases for judgment of what is acceptably safe, identification of blockages in hazard management, and improved ways to communicate difficult hazard concepts. (See also, SLOVIC, Paul)

Identifying, Evaluating and Managing Environmental Risk—Part II; *Paul Slovic,* Decision Research, A Branch of Perceptronics, Inc. 1201 Oak Street, Eugene, Oregon 97401; $208,300 for 17 months beginning August 15, 1977

Guaranteeing public safety through the management of natural and technological hazards has become a major concern of government. Because this responsibility has grown without coordination in a variety of agencies and public bodies, we have today no coherent, effective policy for assigning risks and managing the hazards that face us. A variety of problems have arisen as a result. These include laws and regulations with inconsistent dictates, laws that are too strong to be met or too weak to afford protection, agencies with overlapping mandates, conflicts between different philosophical approaches to risk management, and conflicts between the public, industry and government. From previous research and reviews of problems faced by risk assessors and environmental managers under current mandates, four major areas have been identified and will be addressed by this proposed effort. These areas are: hazard indentification, acceptability of risk, communication of risk information, and the societal management of risk.

This project is to be closely coordinated with one at Clark University. Together these research teams plan to develop one structural taxonomy of technological hazards based on physical, biological principles, to develop one social/psycological taxonomy based on people's perceptions of hazards, to analyze alternative concepts of "acceptable" risk, to develop improved methods for communicating facts about hazards and about risk management, to map the hazard management process, and to integrate the above by relating risk acceptance and risk managment efforts to the structural and psychological characteristics of the hazards. By using laboratory, case study, and analytic procedures, the multidisciplinary teams expect to provide an overview of hazards and hazard management, systematic conceptual tools for identifying (and perhaps predicting) hazards, broader bases for judgements of what is acceptably safe, identification of blockages in hazard management, and improved ways to communicate difficult hazard concepts. (See also KASPERSON, Roger)

LAND USE

The objective of the Land Use program 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 determine land use impacts on selected governmental policies and on private activities; determine physical, socio-economic, and environmental effects of various land uses; determine problems, effects, and effectiveness of particular land use policies, decisionmaking processes, and management programs and techniques in achieving environmental and socioeconomic goals; and evaluate and demonstrate the capability of selected technologies for improving land use planning and management.

An Air Quality Model of Agricultural Field Burning in Oregon's Willamette Valley; *E. Wendell Hewson*; Department of Atmospheric Sciences, Oregon State University, Corvallis, Oregon 97331; $70,600 for nine months beginning November, 1976

The Livermore Regional Air Quality (LIRAQ) model, developed for the greater San Francisco Bay area, is being tested for applicability to the air pollution problems associated with agricultural field burning in the Willamette Valley of Oregon.

The model is being used to help select postulated time and area strategies for burning grass seed fields such that the resulting air pollution can be minimized. The potential advantage of the model is its ability to calculate smoke concentrations throughout the Valley that will result from burning at specific sites and times for a variety of selected meteorological conditions.

An Air Quality Model of Agricultural Field Burning in Oregon's Willamette Valley; *Charles D. Craig*; Air Resources Center, Oregon State University, Corvallis, Oregon 97331; $110,400, 12 months beginning July 27, 1977

The grass seed industry in Oregon's Willamette Valley currently produces 70 percent of the Nation's annual grass seed. Current practices use field burning after harvesting as the primary mechanism of field sanitation and pest and disease control. Field burning is both effective and economical; however, the resultant air pollution problems have generated public concern and resentment about the practice. While this particular problem is very localized in nature, burning for sanitation and waste disposal purposes is conducted in several areas of the country as a cost-effective agricultural and forestry practice. The development of effective strategies to minimize the air pollution potentials associated with these practices would be important to several areas of the country and to the agricultural and forestry concerns currently using field and slash burning as a means of product production and protection.

This research project is concerned with the evaluation of smoke management strategies to minimize air pollution resulting from such field burning as experienced in the Willamette Valley. To accomplish this objective, the Oregon State University research team is applying the Livermore Regional Air Quality (LIRAQ) model to evaluate the degree of air pollution potential to be expected under different burning procedures and meteorological conditions.

This grant provides for completion of work related to the generation of data required for model use in the Willamette Valley. During the summer burning season, meteorological data is being collected and coded for use with the LIRAQ model. Subsequently, various burning strategies are being evaluated through the use of the LIRAQ model. Qualitative evaluation of the model credibility is possible through the assessment of pollution data collected during the burning season.

Land Use Dilemmas and Public Policy: An Assessment of Research Needs; *Michael F. Brewer*; Academy for Contemporary Problems, 2030 M Street, N.W., Washington, D.C. 20036; $24,900 for 4 months beginning February, 1977

Over the last decade nationwide concern and debate developed over the issue of how land is used, its relationship to overall quality of life, and whether and how land use should be controlled and managed. In the last five years in particular there have been numerous new policies, laws and decisionmaking processes adopted at all levels of government in response to perceived land use problems. During this period there has also been an extensive investment by both the public and private sectors in applied research related to land use problems and solutions. Most of this public policy and research activity has been based on perceptions of the late 60's and early 70's of what constituted causes and solutions of land use problems. Given the passage of time and the significant level of research and policy action during that time period, there appears to be a significant national need for a review of the status of land use issues and an assessment of future research needs.

The purpose of this award is to review the status of land use issues and to determine the likely need for land use research over the next decade. Specific research questions include the following: 1) what is the current state of land use issues, of public policy and planning practice, and of our knowledge concerning causes and solutions of land use problems; 2) what are likely to be the most important land use issues facing the Nation in the next decade; 3) what important knowledge gaps exist related to these issues; 4) what is the role of research in meeting any national need identified; and 5) how can such research best be accomplished.

The project objective is to be accomplished through a process designed to obtain broad involvement of individuals and organizations representing the research community, public policy officials, practicing professionals, and private sector decisionmakers. This award is for a four month first phase effort to develop the design and detailed plan for conducting the proposed analysis.

Local Land Use Development Management Through Capital Improvements Programming; *James E. Hoben*; U.S. Department of Housing and Urban Development, Washington, D.C. 20410; $80,000 for 12 months beginning September 21, 1977

This award amends an existing interagency agreement between the U.S. Department of Housing and Urban Development (HUD) and the National Science Foundation (NSF). The original agreement provided for joint-HUD-NSF support of a research project to be initiated by HUD through a contract awarded in a competitive process. The contract was awarded to the American Society of Planning Officials with the research objective of assessing the theory and current local government practices concerning coordination of capital investments with land use and development management policies.

To date, the contract has completed the following: a) a review and analysis of existing literature; b) a reconnaissance of local governments; and c) preparation of a report for local government, presenting the results of the literature review and reconnaissance. The purpose of the amendment is to provide for eight case studies of local government practices and for an assessment of how Federal aid programs affect local government capital investment decisions.

Analysis of the Adoption and Implementation of Community Land Use Regulations for Flood Plains; *Janice R. Hutton and Dennis S. Mileti*; Woodward-Clyde Consultants, Environmental Systems Division, 3 Embarcadero Center, San Francisco, California 94111; $208,300 for 12 months beginning August 15, 1977

It has been estimated that flooding in the United States causes an annual average loss valued at approximately two billion dollars, with an estimated 22,000 communities subject to flood hazard. In recent years, many public officials and citizens have come to believe that regulation of land use in flood plains was the one technique that had the greatest potential for reducing both average flood loss and long run catastrophe potential. Despite the flood hazard and the insurance incentives, some communities have failed to adopt and implement land use controls for flood plains. To date there has been insufficient study to provide policy officials with a meaningful explanation as to why some communities initiate land use controls and others do not. Such information is vital to determining whether land use controls are a viable means of mitigating the Nation's flood hazard.

The objective of this research is to determine what factors affect the adoption and implementation of community land use regulations for flood plains. This objective will be achieved through a two phase project. This award provides funds for phase one which involves 1) the development of a conceptual framework and methods for analyzing a community's decision to adopt and implement flood plain controls, and 2) preliminary tests and refinement of the framework and measurement methods.

Part A, Collaborative Research on an Analysis of the Implementation of State Land Use Policy; *Daniel A. Mazmanian*, Department of Government, Pomona College, Claremont, California 91711; $83,900 for 18 months beginning July 1, 1977

In the last decade numerous State laws have been enacted to regulate certain land uses considered to be of more than local significance. Frequently, the enactment and implementation of such laws have been quite controversial, with intense debate over whether they were necessary and what their positive and negative effects would be. Increasingly, it has been recognized that many factors can affect the implementation of a law and whether it has the effects intended in its enactment. To date, there has been insufficient systematic study of existing land use regulatory laws.

The purpose of this project is to develop an improved understanding of the factors that affect implementation of land use regulatory laws, so that policy officials are better able to analyze and predict the implementation problems and requirements related to alternative land use policies and laws. The research involves three major tasks: 1) development of a conceptual framework; 2) testing of the conceptual framework through a case study of the implementation of the 1972 California Coastal Zone Conservation Act; and 3) evaluation of the framework for application to other laws. The project will be conducted as collaborative research in conjunction with the University of California at Davis.

Collaborative Research on Assessment of Man's Activities in the Lake Powell Region—Studies on Physical Limnology, Geochemistry, and Sedimentation; *Robert C. Reynolds, Jr.;* Dartmouth College, Department of Earth Sciences, Hanover, New Hampshire; $4,600 for 6 months beginning June 1, 1977

The Lake Powell Project has studied the scientific and social effects of the lake and its surrounding regions since 1971. Field activities and data gathering terminated during the 1976 season, and the principal investigators are writing integrated reports in which the results of the studies are applied to specific topics or problems, and conclusions are drawn concerning the functioning of the broader lake system and probable future changes.

During the period of active field work, Lake Powell was in a filling mode; that is, lake level was rising at varying rates. Models developed during the study were aimed at ascertaining the probable condition of the lake under steady-state conditions at design level (3700 feet). However, due to drought conditions, it seems apparent that the lake must be drawn down excessively in order to meet energy demands and downstream obligations for water delivery.

The volume will be low during the summer, and this could change established patterns of circulation and oxygenation. The spring run-off will be low, perhaps 25% of normal. The spring run-off is important in nutrient supply, thermal control, and for the introduction of polyphenols that limit calcite precipitation. The excessive drawdown by the end of the summer will allow the emergence of bank storage waters, the possibility of important slump and rockfalls, and the growth of the tamarisk stranded above the previous summer's high water line. In short, the apparent steady-state functioning of the system will be altered quantitatively and perhaps qualitatively. This situation presents a unique opportunity to test the validity of existing models, and to gain insight into the probable functioning of the lake system should drought conditions persist or intensify in the southwest. The most important period for examination of the lake encompasses the spring run-off and the season in which the lake has maximum use by visitors.

A careful study will be made of temperature, conductivity, dissolved oxygen, polyphenol content, and pH. Echo sounding data will be obtained from which newly deposited sedimentary piles will be detected and mapped. Biological activity in the lake will be monitored by measurements of net primary productivity, chlorophyll, and phosphorous levels. The spread and growth of tamarisk at key points along the shoreline will be measured and mapped.

Part B: Collaborative Research on an Analysis of the Implementation of State Land Use Policy; *Paul A. Sabatier,* University of California, Davis, Division of Environmental Studies, Davis, Calif. 95616; $59,600 for 18 months beginning July 1, 1977

In the last decade, numerous State laws have been enacted to regulate certain land uses considered to be of more than local significance. Frequently, the enactment and implementation of such laws have been quite controversial, with intense debate over whether they were necessary and what their positive and negative effects would be. Increasingly, it has been recognized that many factors can affect the implementation of a law and whether it has the effects intended in its enactment.

The purpose of this project is to develop an improved understanding of the factors that affect implementation of land use regulatory laws, so that policy officials are better able to analyze and predict the implementation problems and requirements related to alternative land use policies and laws. The research will involve three major tasks: development of a conceptual framework; testing of the conceptual framework through a case study of the implementation of the 1972 California Coastal Zone Conservation Act; and evaluation of the framework for application to other laws. The project is being conducted as collaborative research with separate grants to Pomona College and University of California—Davis. Successful completion of the research will contribute to development of a systematic body of knowledge that will enable policy officials to estimate the implementation problems and requirements related to alternative public policies.

An Assessment of Conflicts Between Federal Resource Lands and Adjacent Non-Federal Lands; *William E. Shands;* Conservation Foundation, 1717 Massachusetts Avenue, N. W., Washington, D. C. 20036; $43,400 for 6 months beginning August 1, 1977

There currently are approximately 738 million acres of "public lands" owned by the Federal Government and located throughout the 50 States in both urban and rural settings. Approximately 450 million acres are administered by the Bureau of Land Management (BLM), 187 million acres are national forests, 32 million acres are national wildlife refuges, and 31 million acres are national parks. The forests, parks, wildlife refuges and some of the BLM lands are considered of national significance primarily for their recreational and renewable resource values. It has long been recognized that the establishment, management and use of these Federal lands can have significant impacts on adjacent non-Federal lands. Similarly, there has been concern that the nationally significant values of the Federal lands may be adversely impacted by adjacent non-Federal land use. To date, there has been insufficient systematic study of these

issues and concerns from a nationwide perspective.

The purpose of the proposed research is to provide an overview on the nature, scope and magnitude of conflicts between certain Federal resource lands and adjacent non-Federal lands, as well as to provide an overview of potential mechanisms for conflict resolution.

The specific Federal lands as the subject of the project will be those considered to have high recreational and renewable resource values; i.e., national parks, national forests, national wildlife refuges and certain lands administered by the Bureau of Land Management. The issue assessment will be designed to include the perspectives of Federal, State and local government, as well as non-governmental interests. Specific research objectives include identification of current adjacent lands problems, trends and policy issues; identification and assessment of current Federal efforts which seek to prevent or resolve conflicts; identification and assessment of potential solutions to conflicts, including institutional, legal, training and technical assistance; and identification of priority needs for research, information and education.

This project is funded with assistance from the Bureau of Outdoor Recreation, Bureau of Land Management, Council on Environmental Quality, National Park Service, U.S. Fish & Wildlife Service, and the U.S. Forest Service.

Assessment of Enforcement and Compliance in State Land Use Regulation; *Nelson M. Rosenbaum;* Urban Institute, Washington, D. C. 20036; $243,600 for 24 months effective August 15, 1977

Over the past decade, State governments have begun to assume a major role in regulating land use of certain "critical environmental areas" such as wetlands, shorelands and coastal zones. To date, 12 States have adopted wetland regulatory programs, and 15 States have adopted shoreland or coastal regulatory programs. It has been increasingly recognized that after enactment these laws may face numerous implementation problems which influence their effectiveness. The effectiveness of enforcement programs to ensure compliance with the regulatory laws is of major concern. Yet, enforcement and compliance with State land use regulatory laws have not been subjected to systematic investigation.

The purpose of the proposed research is to provide an improved understanding of the enforcement and compliance problems related to State regulation of wetlands and shorelands. This project has three specific objectives: to analyze the nature and strength of existing State wetland and shoreland enforcement programs; to estimate the effect of enforcement programs on compliance with regulatory standards and requirements; and to assess means of organizing State wetland and shoreland enforcement programs. Project objectives will be achieved through a survey and analysis of States' enforcement programs and through conduct of case studies.

Assessment of Programs for Public Participation in State Land Use Decision-Making; *Nelson M. Rosenbaum;* Urban Institute, Land Use Center, Washington, D. C. 20037; $9,150 for 5 months beginning January 1, 1977

The purpose of this award was to provide funds for disseminating the results of research under a prior NSF grant. The objective of the original grant was to develop a conceptual framework for the design and evaluation of programs for public participation in land use decision-making and to conduct a comparative evaluation of the relative effectiveness of public participation programs in six states. The research results will be presented in formats appropriate for utilization by four different groups: (1) administrative officials in State, regional and county government, (2) legislators, (3) citizen groups, and (4) researchers.

REGIONAL ENVIRONMENTAL SYSTEMS EVALUATION AND SYNTHESIS

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

Evaluation and Testing of NSF-RANN Sponsored Land Use Modeling Projects with Ohio as a Test Case; *Oscar Fisch;* Department of City and Regional Planning, Ohio State University, Columbus, Ohio 43212; $174,900 for 15 months beginning August 15, 1977

This award is to be substantively coordinated with the core RANN modeling assessment project being conducted by Brian Mar of the University of Washington. The related Mar project has proceeded in its assessment of 18 RANN projects. It has been found that few projects have participated in final stage efforts to test the utility of transferring computer model tools to new settings. Since utilization is an essential RANN objective, this effort seeks to provide opportunities for extending uses of products and in addition will enable Mar project personnel to monitor and document attempted transfer processes.

The first step in this utilization project is to refine first estimates of user needs and potentially useful RANN models in a series of workshops. Personnel from three regional planning commissions and the Ohio State team will screen these and move toward the selection of four models or components with the potential for replacing less adequate tools. Previously developed Ohio models will be used as bases for comparison in this process. These models will be adapted for Ohio utilizing existing data and comparative testing by the regional users.

Final reports will document the screening and transfer process and assess the prospects for extending the use of the selected RANN tools within Ohio and elsewhere.

Environmental Communications to Water-Oriented Communities; *John E. Gannon*; University of Michigan, Ann Arbor, Michigan 48109; $35,800 for 15 months beginning October 1, 1977

This project addresses the problem and need of the Research Applied to National Needs (RANN) program to communicate the results of the research which it supports to various user groups, including the general public.

The goal of the project is to communicate to environmental decisionmakers in Northern Michigan and other relevent regions information resulting from a RANN supported project concerning the environmental impact of human activity in Northern Michigan's Inland Water Route Region.

The project will package and communicate, for policymakers in the public and private sectors, the results of RANN Grant No. GI-34898, (Ecological and Sociological Determinants of Land Use Decisions), through workshops, media dissemination and the mailing of written materials concerning environmental problems and options in the lake region of Northern Michigan.

Assessment of Selected RANN Regional Environmental Systems Modeling Projects: Transfer and Comparability Testing; *Brian W. Mar;* Department of Civil Engineering, University of Washington, Seattle, Washington 98105; $53,500 for 2 months beginning June, 1977

This award is a supplement to a previously awarded NSF grant. The primary purposes of the previous award were to assemble, analyze, and synthesize the major developments of selected computer modeling oriented projects sponsored by NSF's Research Applied to National Needs program (RANN). Emphasis was to be placed on an assessment of transfer and utilization strategies and experiences.

At present, several significant long-term RANN projects lack analyzable transfer testing experience as well as objective reviews of their utility. This award is expected to correct these deficiencies and produce the minimal data base needed to evaluate the transfer and utility aspects of these projects. It is doing so by supporting, monitoring, and evaluating three utilization workshops during the spring and summer of 1977. The three were selected on the basis of need and opportunity.

REGIONAL POLICY AND DECISIONMAKING

The Regional Policy and Decisionmaking Program conducts research to determine the effects and effectiveness of a variety of growth management policies, laws, and programs vis-a-sis 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.

Analysis of Positive and Negative Aspects of Time Extensions in Environmental Decision Making; *Gunter Schramm*; University of Michigan, School of Natural Resources, Ann Arbor, Michigan 48109; $106,400 for 11 months beginning July 1, 1977

In the last decade, there has been growing concern about the time span involved in making important decisions on environmental quality and natural resource development. One concern is that time "delays" may result in negative effects, such as increased cost or shortage of services and resources or continued exposure of society to hazards of pollution. On the other hand, it is argued that time delays can result in gains to society, such as more thorough consideration of alternatives, recognition of changed values, and improved concensus on decisions.

The purpose of the proposed research is to develop an improved capability of analyzing the positive and negative values of time in environmental and resource decisions. This purpose will be achieved through a two-staged project. Stage I will have several specific objectives: to develop an analytical method for measuring the magnitude and distribution of social, economic, and environmental gains and losses associated with time "delays"; and to assess the feasibility of empirical testing of the analytic methods. Assuming successful completion of Stage I, the Stage II objective would be to test the analytic methods in order to provide decisionmakers with an improved method for determining the positive and negative aspects of time extensions.

RESIDUALS MANAGEMENT

The objective of the Residuals Management Program is to synthesize residuals management strategies for minimizing environmental risk. Coupled with the need for solutions to problems of residuals management are recovery of potential resources from waste constituents and investigation of the possible reuse of waste waters.

Mechanism of Virus Inactivation in Soils Injected with Municipal Wastewater and Treatment Plant Sludges; *P. C. Cheo;* The California Arboretum Foundation; The Los Angeles Arboretum, 301 N. Baldwin Avenue, Arcadia, California 91006; $39,000 for 12 months beginning May, 1977

Intensive application of sludge to land has recently emerged as an attractive alternative despite serious questions of its effects on soil including the fate of viruses that may survive for sufficiently long periods of time to present risk to human and plant life that contacts infected soil or its products. Assessment of environmental risk and its management is an important consideration in determination of the acceptability of soil application of these sludges. This in turn will require determination of the rate and the mechanism of inactivation of pathogenic viruses. Knowledge of the latter can be applied to improve the efficiency of physical and chemical methods for virus inactivation and provide an insight into the degree of risk and potential for change when sludges are applied to agricultural soils.

The objective of this research is to investigate the mechanism(s) of anit-viral activity in soil and assess its significance and applicability to current trends toward utilization of land for management of municipal wastewater treatment plant sludges. Preliminary laboratory experiments with the tobacco mosaic virus have indicated that bacteria normally found in soil may be responsible for inactivation of plant viruses. Experiments are being performed to characterize the anti-viral factors in soils of different composition and type and to correlate the viricidal effect with other physical and chemical properties of the soil. Field-plot experiments are being conducted to determine the inactivation capacity of soil toward the tobacco mosaic virus. The research is being conducted in cooperation with the Los Angeles County Sanitation District as part of a program to determine effects of application of municipal wastewater treatment plant effluents and sludges on ornamental trees, shrubs, and ground cover.

Conversion of Municipal Wastewater Treatment Plant Residual Sludges into Earthworm Castings for Use as Topsoil; *Jack E. Collier;* Collier Worm Ranch, 2022 Cabrillo Court, Santa Clara, California 95051; $9,700 for 12 months beginning July 15, 1977

The objective of this research is to determine the feasibility of utilizing earthworms to accelerate the stabilization of municipal wastewater treatment plant sludges. In cooperation with the San Jose Water Pollution Control Plan, tests plots have been established to culture earthworms in the plant's residual sludges. Experiments are being directed toward determination of optimum worm density, rate of reproduction, intake and retention of heavy metals and comparative plant growth in worm castings. Heavy metal concertrations being determined in earthworms and castings include silver, cadmium, copper, nickel, lead, and zinc. This project is being coordinated with research by Dr. Roy Hartenstein at the University of

New York who is studying the effects on the soil ecosystem of applying sludge to land. The coordinated research is also aimed at investigating utilization of soil invertebrates in stabilization, decontamination and detoxification of sludges.

Synthesis of a Municipal Wastewater Sludge Management System; *Charles Finance*; Media Four Productions, 6519 Fountain Avenue, Hollywood, California 90028; $49,700

This is an award to provide supplemental support for the production of a 27-minute film on municipal sludge management. The film describes current sludge processing and management concepts that are the subject of research at the Massachusetts Institute of Technology, Universities of New Hampshire, Delaware and Texas-San Antonio, Colorado State University and the State University of New York-Syracuse. The film will be utilized in the synthesis and communication of a management concept for sludges that is based upon disinfection with high energy electrons and pipeline transport to a management site where it will be injected into the upper six inches of topsoil. Monitoring procedures for the process and site are presented in the context of the need to provide information that can be used to assess the environmental impact of this sludge management concept.

Utilization of Waste Heat from Power Plants in Aquaculture; *Carlos R. Guerra;* Public Service Electric and Gas Company, Research and Development Department, 80 Park Place, Newark, New Jersey 07101; $527,100 for 24 months beginning September 30, 1977

This is an award for the continuation phases of a planned three year experiment which is to determine the technical and economic feasibility of utilizing heat remaining in condenser cooling water at power generating stations for culturing edible animals. An aquaculture facility at the Public Service Electric and Gas Company (PSE&G) at the Mercer County electrical power generating site is being used in research being conducted by PSE&G, Trenton State College and Rutgers University personnel. The aquatic species being evaluated are freshwater shrimp and rainbow trout.

The American eel and striped bass are also being evaluated as alternative secondary species to the freshwater shrimp. Long Island Oyster Farms, Inc. is assisting in an evaluation of the feasibility of the program and the New Jersey Department of Agriculture's Division of Rural Resources is studying the adaptation of agricultural facilities to the production of fingerling trout. The research is responding to the need to evaluate approaches to the management of cooling water that will utilize the residual heat constructively rather than discharging the heat in a way that could adversely affect regional environmental quality.

Utilization of Waste Heat from Power Plants in Aquaculture; *Carlos R. Guerra;* Public Service Electric and Gas Company, Newark, New Jersey 07101; $198,232 supplement beginning September 1, 1976

The objective of this award is to initiate a proof-of-concept scale evaluation of utilizing thermal discharges from cooling of condensers at power generating stations to culture edible aquatic animals. An aquaculture facility utilizing Delaware River water, heated in the condensers of the Public Service Electric and Gas Company's Mercer Generating Station at Trenton, New Jersey is being used for the sequential culture of freshwater shrimp from May through October and rainbow trout from November through April. Wastes from the processing of other foods are being investigated for their potential in reducing aquaculture-feed costs. The objective of this research is to confirm the technical feasibility of the concept and its commercial feasibility concentrating upon process reliability, reproducibility and product acceptability. Subcontracts for portions of the research plan have been awarded to Trenton State College (Dr. A. Eble)

and Rutgers University (Dr. A. Farmanfarmaian). Nutritional factors being studied at physical factors influencing intestinal absorption of food and potential pollutants such as coal, chlorine and heavy metals. The Trenton State College effort is concentrated on improvement in management procedures including field application of nutritional data, intensification of culture techniques and brood stock management. Under subcontract, Long Island Oyster Farms, Inc. is assisting in evaluation of commercial feasibility and the New Jersey Department of Agriculture's Division of Rural Resources is studying adaptation of agricultural facilities to production of fingerling trout.

Control of Heavy Metal Content of Municipal Wastewater Sludges; *C. Frederick Gurnham*; Gurnham and Associates; Inc. 223 West Jackson Boulevard, Chicago, Illinois 60606; $110,900 for 18 months beginning May 15, 1977

The objective of this research is to determine the feasibility of controlling the amounts of heavy metals in municipal wastewater treatment sludges by regulations directed toward restricting or eliminating their entry into the collection system. Emphasis in this study is on non-industrial sources of metals. Two essentially residential communities served by the Metroplitan Sanitary District of Greater Chicago are being studied to characterize the kinds and amounts of metals contained in their wastewaters and treatment plant sludges. One of the communities is served by a combined and the other by a separate sanitary wastewater collection system. For those metals determined to be of significance with regard to quality of the sludges, actual sources are being determined and compared to calculated amounts based upon review of known discharges to the collection systems.

Results will be utilized to make recommendations for reducing the amounts of significant metals to acceptable levels by regulations directed at the sources. An experiment is planned during this study to evaluate the effectiveness of the procedures that are expected to result from this research.

Utilization of Soil Invertebrates in Stabilization, Decontamination and Detoxification of Residual Sludges from Treatment of Wastewater; *Roy Hartenstein;* College of Environmental Science and Forestry, State University of New York, Syracuse, New York 13210; $111,700 for 12 months beginning March, 1977

This is a continuation of research initiated under a previous grant. The objective is to determine the role of soil invertebrates in the stabilization of municipal wastewater treatment plant sludges that are managed by placement on agricultural land. Organisms being evaluated include several species of earthworms and nematodes. Representative sludges are being studied to identify response of the test organisms, a factor which may limit the rates of application of sludges on soil. The metabolism of soil organisms is being studied in laboratory and field plots by measurements of carbon dioxide, methane, hydrogen sulfide, dimethylsulfide, oxygen and nitrogen. Sludges are being characterized by presence, amount and kind of carbohydrates, ash, humus content and carbon to nitrogen ratio.

The study of transfer and dilution of heavy metals in soil by actions of earthworms includes tracing the fate of cadmium, chromium, copper, lead, zinc and mercury. The roles of earthworms as potential inactivators of viruses and as vectors of microorganism transfer through soils with emphasis on nitrogen fixation, denitrification, oxidation and reduction of sulfides are also being investigated.

The results of this research are expected to provide a basis for more efficient utilization of land application as a management concept for municipal sludges.

Effect of Infrared Radiation on Compaction of Municipal Wastewater Sludges; *Stephen C. Havlicek and Robert S. Ingols*, Engineering Experiment Station, Georgia Institute of Technology, Atlanta, Georgia 30332; $21,900 for 12 months beginning June, 1977

The objective of this research is to determine the optimum conditions under which infrared radiation results in the compaction of activated sludge, identify the active factor(s) responsible for compaction, char-

acterize associated effects such as disinfection/sterilization and evaluate the effect on other physical properties of the sludges. A small bench-scale apparatus at the Macon, Georgia municipal wastewater treatment plant is being used to conduct these investigations which include the identification of the most effective and efficient wavelength of infrared radiation and best means for acheivement of effective exposure to the source.

The physical properties of sludges being used to characterize their change in quality after exposure to infrared radiation include the sludge volume index, comparative resistance to filtration, compressibility and viscosity. Studies also include determination of the effects of pH, temperature, detention time, mixing and the presence and amounts of dissolved oxygen and inorganic substances on the compaction phenomenon.

Application of Sequencing Batch Reactors for Treatment of Municipal and Industrial Wastewater; *Robert L. Irvine;* Department of Civil Engineering, University of Notre Dame, Notre Dame, Indiana 46556; $76,800 for 12 months beginning June 17, 1977

This is a renewal of research currently in progress which has the objective of the investigation of controlled, unsteady-state processes for treatment of domestic and industrial wastewaters to attain a higher degree of reliability and consistency of performance than is practically possible using conventional contitinuous, steady-state methods. Emphasis is being placed on the potential use of sequencing batch reactors in biological wastewater treatment processes which, in continuous steady-state systems, respond unreliably and inconsistently to variations in wastewater characteristics.

The expected advantages of the controlled periodic method of operating treatment plants include benefits resulting from equalization of strength, quiescent sedimentation and modular construction. An added advantage is the ability to retain total control over final discharge until the quality of the effluent has been determined, compared with standards, and subjected to further treatment if quality is found not to meet discharge criteria. Laboratory-scale studies using synthetic wastes and combining equalization, organic carbon removal and quiescent sedimentation in the same fill and draw system, are being utilized to verify design procedures which will be tested using municipal wastewater as received at the University of Notre Dame pilot plant. Cost comparisons with conventional continuous-flow concepts are being made.

A workshop/conference is planned for June of 1978 to review the draft of a design manual for sequencing batch reactors based upon results of this research.

Agricultural Value of Irradiated Municipal Wastewater Treatment Plant Sludges; *Mary Beth Kirkham;* Department of Agronomy, Oklahoma State University, Stillwater, Oklahoma 74074; $87,800 for 24 months beginning April, 1977

The objective of this research is to determine the change in availability of plant nutrients contained in municipal wastewater treatment plant sludges irradiated with high energy electrons. The effects of sludge application rate and soil type are being evaluated in greenhouse studies and field-plot tests. The amounts of plant nutrients and heavy metals are being determined in sludges, soils, and plants grown on soils that have had sludges applied to them. Field-plot tests are being conducted in cooperation with Dr. William J. Manning at the Waltham Suburban Experiment Station, University of Massachusetts.

Sludges that have been disinfected by treatment with high energy electrons are being obtained from the Metropolitan District Commission's Deer Island Wastewater Treatment facility in Boston. Plants being used in greenhouse studies include cucumber, potato, sweet corn, tomato, several edible-root crops, leafy vegetables, alfalfa and wheat. Initial field-plot experiments will be limited to corn. Analyses are being performed on roots, stems, leaves, and grain to determine differences in nutrient and metal uptake rates and concentration. Results are expected to be utilized in determining the feasibility of using irradiated sludges to fertilize agricultural land.

Feasibility of Eliminating Discharges of Pollutants from Cooling Towers; *Jack V. Matson;* Department of Civil Engineering, University of Houston, Houston, Texas 77004; $53,200 for 24 months beginning May 18, 1977

Discharges from recirculating water in cooling systems using wet cooling towers for dissipation of heat to the local air comprise a relatively large fraction of the industrial wastewater discharges to natural waters. These discharges may contain chemical substances added to the recirculating water for slime and corrosion control. They also contain concentrated constituents of the original and make-up waters. Of the technical approaches presently available, only lime-softening has the apparent potential of eliminating all discharges of pollutants to natural waters by 1985, a target date for this control program.

The objective of this research is to determine the feasibility of using the lime-softening process to remove excess dissolved substances from water circulating in a cooling system. This permits reuse of the treated water as a coolant and eliminates the need for the discharge of pollutants to surface or ground waters. The specific technical factors that are being investigated include the effects of original source water quality and the size of the recirculating system on the performance of the process. The effect of loss of solids lost to local air and their impact on air quality is being evaluated as is the processing of residual sludges for safe handling and disposal. Recarbonization and mineral addition are being compared to determine the better method for adjustment of the hydrogen ion concentration to reduce the rate of corrosion. The economic feasibility of the process is being assessed for comparison with technologically equivalent alternatives to management of cooling water.

Disinfection of Enteric Viruses by Use of Energized Electrons; *Theodore G. Metcalf;* Department of Microbiology, University of New Hampshire, Durham, New Hampshire 02824; $35,000 for 12 months beginning July 1, 1977

The presence of viruses in municipal wastewater, their separation and then concentration in treatment plant sludges where they remain viable presents a potential contamination problem to the land or water into which these sludges may be placed. The objective of this research is to determine the effectiveness of high-energy electron radiation as a method for the inactivation of enteric virus pathogens that are contained in municipal wastewater treatment plant sludges. The results obtained in prior studies at the Metropolitan District Commission's Deer Island Wastewater Treatment Plant in Boston are being verified and compared with results obtained during simulation of routine operation of the electron beam unit under normal plant operating condiitions.

This project is coordinated with research directed by John G. Trump at the Massachusetts Institute of Technology. Virus-inactivation studies are being conducted on digested and undigested sludges from primary treatment of wastewaters. The observed capability of ferric-iron and aluminum ions to improve the effectiveness and efficiency of the radiation dose delivered is also being characterized. Virus-inactivation studies are being conducted on digested and undigested sludges from primary treatment of wastewaters. The capability of ferric-iron and aluminum ions to improve the effectiveness and efficiency of the radiation dose delivered is also being characterized.

Utilization of Cypress Wetlands for Management of Municipal Wastewater Treatment Plant Effluents; *Howard T. Odum,* University of Florida, Center for Wetlands, Gainesville, Florida 32611; $91,500 for 24 months beginning June 1, 1977

The objective of this project is to complete studies of the response of cypress wetlands to their use for conservation of the nutrient and water content of effluents from municipal wastewater treatment plants. This is a continuation of research previously initiated with the joint support of the National Science and Rockefeller Foundations and coordinated with research under direction of Dr. Flora Mae Wellings, Florida Depart-

ment of Health, who is assessing the fate of viruses. Results of this research over a period of three years indicate that cypress dome-wetlands have the capability of conserving water by returning treated wastewater to subsurface formations after removing its content of nutrients, heavy metals and remaining bacteria and viruses. This continuation research is being directed toward final observations to determine the growth response of trees and understory vegetation to the application of wastewater. The research is being coordinated with an NSF Grant to Boyle Engineering, Inc., for an engineering assessment of the feasibility of using cypress wetlands to achieve the objectives of advanced treatment for municipal wastewater. A joint workshop is scheduled to be held during 1978.

Water Quality and Health Significance of Bacterial Indicators of Pollution; *Wesley O. Pipes;* Department of Biological Sciences, Drexel University, Philadelphia, Pennsylvania 19104; $32,500 for 12 months beginning June 1, 1977

Analysis of indicator organisms is substituted in routine assessment of water quality because of the relative difficulty and cost of determining the presence and number of pathogenic organisms in water. While the data in general have presumptive significance, attempts to translate the presumption of risk into a more quantitative assessment of relative risk have the potential of establishing a better basis for making decisions on such matters as management of wastewater and sludges, quality of bathing and drinking water, efficacy of treatment and location of treatment facilities for water and wastewater treatment.

The objective of this project is to conduct a workshop that will critically review the current state of knowledge regarding the significance of bacterial indicators related to their use in the assessment of water quality and relative risk associated with its use. The workshop is to be preceded by preparation of draft reports on recovery and identification of indicator organisms, statistical analysis and interpretation of numberical data, water quality significance of indicator organisms and public health significance of their presence and count. The workshop includes representation from local, regional, State and Federal agencies with responsibilities for establishing criteria for wastewater treatment plant effluents, siting of treatment facilities, recreational and other contact uses for receiving waters and management of wastewater treatment plant sludges.

The final report is planned to identify research needs and their prioritization to improve the basis for assessment of risk to public health that is associated with the presence of indicator organisms and their absolute and relative numbers in water.

Potential Health Risk Associated with Injection of Residual Domestic Wastewater Sludges into Soils; *Bernard P. Sagik;* The University of Texas at San Antonio, College of Science and Mathematics, San Antonio, Texas 78285; $89,300 for 12 months beginning August 1, 1977

The intensive application of municipal wastewater treatment plant sludges to soil is considered to be an attractive disposal alternative, despite questions of long term sludge effects on soils, potential adverse effects on health, and technical limitations of the application process. While sludge application appears to have advantages of economy, technical superiority and more acceptable esthetic and environmental impact, pathogenic organisms removed from wastewater are concentrated in residual sludges.

The objective of this project is to assess potential risks to human health from the application of sludges from municipal wastewater treatment plants to land. Virological criteria for the selection of appropriate land application sites to minimize risk are being developed as are recommended procedures for monitoring of the sludge management sites. Soil properties which affect virus survival and transport that are being studied include pH, cation exchange capacity, types of cations present, soil texture and structure. The release characteristics of viruses from soils to which sludges have been applied are being studied, as they may be affected by total precipitation, its intensity, frequency and duration. A conference on assessment of potential risks relating to the use of land for management of municipal wastewater treatment plant sludges will be conducted in December of 1977. A workshop during the planned second year of this research will review a draft of recommended criteria for selection and monitoring of sludge injection sites to minimize health risk associated with potential virus contamination of 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, University Park, Denver, Colorado 80210; $20,000 for 4 months beginning September 2, 1977

Advancements in technology have contriubted to making large scale production of fuel from oil shale more feasible and the need for new sources of energy has focused attention on obtaining oil from oil shales. Whether retorted externally or *in situ,* processing results in large quantities of spent carbonaceous ash residuals which will contain residual volatile organic matter and polycondensed organic material (POM) with a potential for polluting air and water on a scale commensurate with the scale of processing, adversely influence the compaction of the residual ash and provide a source of organic contaminants and inorganic salts potentially capable of contaminating surface and ground water. This research is directed toward providing information needed for management of residual spent shale to minimize environmental impact. This award is in accord with an interagency agreement with the U.S. Energy Research and Development Administration, No. EE-77-28-3233.

Land Management of Subsurface-Injected Wastewater Liquid Residuals; *James L. Smith;* Colorado State University, Department of Agricultural Engineering, Fort Collins, Colorado 80521; $15,400 for 5 months beginning April 1, 1977

The objective of this supplement is to continue the supplement evaluation of the feasibility of direct injection of municipal wastewater treatment plant residual sludges into soils. The supplemental award will facilitate the preparation of a design for an integrated sludge management system combining injection into soil and disinfection using high energy electrons for a specific site. The conceptual design will be utilized to further develop a systematic approach for evaluation of potential injection sites that will lead to their acceptable operation. Environmental criteria, site-specific information, personnel qualifications and recommended monitoring procedures for the integrated concept will 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.

Use of Wetlands for Management of Pond-Stabilized Domestic Wastewater; *Jeffrey C. Sutherland*; Williams and Works, Inc. 611 Cascade West Parkway S.E., Grand Rapids, Michigan 49506; $6,400 for 4 months beginning April 1, 1977

The objective of this project is to assess the feasibility of utilizing freshwater wetlands in combination with pond-stabilization to achieve regional wastewater management objectives. This engineering/feasibility study is being coordinated with research underway at the University of Michigan, the objective of which is to complete a field-verification of wetland ecosystem models constructed during a three-year study of peat wetlands in the Houghton Lake Wildlife Research Area, Roscommon Township in Michigan.

This supplemental award provides for the coordination of this research with analogous NSF supported studies being conducted by the Boyle Engineering Company of Orlando, Florida in cooperation with the University of Florida. The objective of the Florida studies is to determine the feasibility of using cypress dome wetlands for management of wastewater treatdome wetlands for management of wastewater treatment plant effluents for conservation of nutrients and reuse of water. The coordination activities will assist in the development of plans for a cooperative conference during 1978 to discuss findings, their applications and further research needs.

High Energy Electron Irradiation of Wastewater Liquid Residuals; *John G. Trump;* Department of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139; $70,000 supplement, beginning May 1, 1977

This is an award in accord with interagency agreement with the U.S. Environmental Protection Agency, No. EPA-IAG-D7-01036.

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 (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 on complex organic substances including polychlorinated biphenyls (PCB) and organic pesticides are being studied using raw and digested primary sludges, influent wastewater and treatment effluent. Biochemical and physical performance information 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 systems and engineering data essential for design, operation and maintenance are being determined.

High Energy Electron Irradiation of Municipal Wastewater Liquid Residuals; *John G. Trump*; Massachusetts Institute of Technology; Department of Electrial Engineering, Cambridge, Massachusetts 02139; $285,000 for 12 months beginning September 1, 1977

The technical and economic feasibilities of disinfecting liquid municipal wastewater residuals with high energy electrons are being evaluated at the Deer Island Wastewater Treatment Plant of the Metropolitan District Commission (Boston). The radiation source is a 50 kilowatt, 850,000 volt electron accelerator, capable of delivering radiation doses from 100,000 to one million rads as the material flows through in a wide, thin stream. Studies include effects of radiation on bacterial and viral disinfection, parasitic deinfestation, sludge dewatering characteristics, decomposition of polychlorinated biphenyls and organic pesticides contained in digested and undigested sludges, influent wastewater and final effluent. Modes of utilization in existing and new wastewater treatment systems and engineering data essential for design, operation of research in which the influence of dose, dose rate, oxygen availability and the presence of competing and synergistic materials were evaluated utilizing a 3 MeV electron accelerator located at the MIT High Voltage Research Laboratory. During the prior award period, preliminary tests were conducted with the Deer Island unit as a guide to the current research plan which is emphasizing disinfection of undigested sludge. Results have continued to indicate that a dosage of 400,000 rads will be adequate for sludge disinfection. This research is coordinated with an award to the University of New Hampshire (T. G. Metcalf) and includes participation by MIT Departments of Chemical Engineering (E. W. Merrill) and Food Science-Nutrition (A. J. Sinskey).

Ferrate Ion Disinfection of Municipal Wastewater; *Thomas D. Waite;* Department of Civil Engineering, Northwestern University, Evanston, Illinois 60201; $108,200 for 19 months beginning March 1, 1977

The search for new methods to disinfect water and wastewaters as alternatives to the use of chlorine is an important national need since the discovery that chlorine treatment may produce chlorinated organic substances that are potentially toxic and carcinogenic. Ferrates are potentially a replacement for chlorine. Like chlorine, ferrates appear to be strong oxidants and good disinfectants. Unlike chlorine, ferrates are unstable and decompose to insoluble ferric hydroxide and oxygen on standing in water. This leads to the interesting possibility that the ferrate decomposition product (ferric hydroxide) can perform an additional useful function by coagulating suspended colloidal matter and thus clarifying the water during the detention period.

The objective of this research is to investigate the feasibility of using sources of ferrate ions for disinfec-

tion of municipal wastewater. Work is underway to establish the disinfection properties of the ferrate ion in the presence of soluble and suspended organic substances within a range of temperatures that is characteristic of those encountered in treatment of water and wastewater.

URBAN HYDROLOGY

The Urban Hydrology program 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 process; (*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.

Consumer Response to Urban Drought in Central California; *William H. Bruvold;* School of Public Health, University of California, Berkeley, California 94720; $37,500 for 12 months beginning June 1, 1977

The two major objectives of this research are *1*) to assess consumer attitudes toward, and evaluation of, residential water conservation programs adopted by selected water districts in nine Bay Area counties of California and *2*) to compare effectiveness of various water conservation programs mounted by selected Bay Area water districts after accounting for differences in residential water restrictions and consumer beliefs between districts. Thse and other objectives of the research will be accomplished by use of scientific sampling procedures to select 100 respondents per district, personal interviews with respondents guided by a polished schedule, and employment of experienced field interviewers to conduct the survey research.

The project is working in conjuction with the project awarded to Teknekron, under the leadership of Mark Hoffman. The Bruvold award is working on the consumer response to urban drought; its alternatives and consequences

Hydrometeorological Studies Addressing Urban Water Resources Needs; *Stanley A. Changnon, Jr.;* Illinois State Water Survey, Box 232, Urbana, Illinois 61801; $236,700 for 12 months beginning April 19, 1977

The growth of our cities has resulted in regional water resource problems created by these largely unplanned developments. The enormous sprawl of some American cities has frequently encompassed not only natural drainage basins but often has resulted in the need for the development of complicated engineering works necessary to serve the needs of the city that altered drastically the natural drainage paths and water balance. The design and operations of these sophisticated and complex urban water systems have become major engineering, management, and environmental problems.

The 1972 Amendment to the Water Pollution Control Act has placed strong emphasis on urban water runoff as a source of pollution and stresses the need for the acquisition of better and more practical urban storm water management schemes. The main concern in the optimization of the design and operation of urban sewer systems and other hydraulic structures is the collecting and analyzing of precipitation data.

The objectives of this project, in keeping with this concern, are to: *1*) develop an operational rain prediction-monitoring system using a combination of radar

and rainguage data for design of hydrological systems; *2*) develop a real-time rain analysis methodology to enhance the operational effectiveness of the waterworks; *3*) assess the effects of a large lake coupled with a highly urbanized and industrialized area on the regional weather; and *4*) establish methods for the transference of the results of this research project to other cities. Chicago is to be used as the model city.

Water Pollution and the Urban Economy; *Alan S. Cohen;* Argonne National Laboratory, 9700 Cass Avenue, Argonne, Illinois 60439; $143,000 for 12 months beginning February, 1977

This project is designed to develop a set of economic models to predict the effects of environmental actions and to apply the models to policy options for the Chicago region. In this project, major attention is being given to water pollution control programs.

This project continues the joint research of a group of investigators of the University of Chicago and a group from the Argonne National Laboratory, both of which are being supported by other Foundation grants. They are working on the development of a set of physical, spatial, economical and administrative response models. The benefits and cost of alternative water pollution control policies as well as incentive-type control strategies are being evaluated with these models. The hydrological-water quality data on an urban basin system, located in the Chicago area together with meteorological data and land use information is being used, after calibration and validation of the models to analyze three types of policies: *1*) user charges and other tax measures; *2*) consolidation of wastewater treatment; and *3*) land use controls (related to nonpoint sources of pollution).

New approaches in the development of methods for assessing benefits of water pollution abatement and in incentive analysis are being presented.

The Impacts of Nutrient Loading and Atomospheric Contaminants on the Water Quality of Lake Tahoe, California-Nevada; *Charles Goldman;* Institute of Ecology, University of California, Davis, California 95616; $85,700 for 12 months beginning June 1, 1977

Land disturbances, localized increases in anthropogenic atomospheric pollutants, and changes in the quality of the water receiving increased amounts of pollutants are produced by the development of watersheds through various land-use policies. Nutrient enrichment from surrounding watersheds, caused by these changes, could possible produce the eutrophication of lakes. Inputs from watersheds are directly responsible for this process as well as indirect sources such as air-borne particulate matter, solutes in rain and snow, groundwater runoff, and surface runoff.

Lake Tahoe is in danger of becoming eutrophied by these processes due to the extensive urbanization of this area and its relationship to the lake's watershed. Hence, Lake Tahoe provides excellent conditions for the research being done in this project. The principal objective of this research is to determine and measure the impact of air-borne contaminants from dry and wet precipitation on the surface and into Lake Tahoe.

Results from this project will provide, together with data already gathered through extensive research, a better understanding of the linkage between atmospheric, terrestrial, and aquatic systems. The possibility of obtaining a mass balance of chemicals like nitrogen, sulfur and other nutrients provides the means to test water quality and management models for lakes under development. New methodologies are to be developed to measure the impact of imported nutrients into the lake as well as the utilization of the periphyton community as a bioindicator of localized nutrient loading impact on water quality of the littoral zone. These techniques will be applicable to the analysis of other lakes and will help in the establishment of water quality control policies.

An Analysis of Urban Drought: A Case Study of the San Francisco Bay Area; *Mark Hoffman;* Teknekron, Inc., 2118 Milvia Street, Berkeley, California 94704; $341,200 for 12 months beginning July 1, 1977

Drought is a natural hazard that is usually aggravated by man's activities. The onset of drought is very slow as is the recovery of the system. The interrelated short-and long-term consequences are still not well understood, nor have been well measured. Now the Western United States is facing such an event, especially in the northern section of California. The management of drought in the urban environment is dependent on political, economical, legal, technological and social constraints and the impacts of adopted short-and long-range policies can be far-reaching.

The objective of this project is to provide guidelines and recommendations to help the formulation and adoption of more efficient, equitable, and effective strategies for drought-management in the urban system by local and state decisionmakers. The objective will be achieved by: a) a historical analysis of the origin and evolution of California's complex water system; b) a detailed description of how water resources are managed in the Bay Area; c) a hydrological analysis of the drought's severity, including an examination not only of measurable phenomena but of drought-prediction techniques and decisionmaking in the face of uncertainty; d) an analysis of how state and local water authorities have responded to the drought; e) an impact analysis of consumers' responses to the drought and to drought policies; and f) an analysis of the results of the five preceding tasks.

The results from this research will be highly transferable to other urban areas. Since no other major study on the subject has been conducted at the same time of the drought occurrence, nor with the same approaches, it will also be of great interest to suppliers, agencies and users to gain information in the midst of the event.

Portions of this project pertaining to the study of consumer response are being carried out under a separate grant by W. H. Bruvold of the Univerisity of California at Berkeley.

Water Pollution and the Urban Economy; *George S. Tolley;* University of Chicago, Department of Economics, Chicago, Illinois 60637; $155,000 for 12 months beginning February 1, 1977

This research's objective is the development of methods to assess the benefits and costs of alternative water pollution control polices. It also provides techniques to conduct policy studies that will aid environmental decisionmakers and planners. The present project continues the joint research of a group of investigators of the University of Chicago and a group from Argonne National Laboratory supported by NSF grants on the development of a set of physical, spatial, economical and administrative response models. The benefits and costs of alternative water pollution control policies as well as incentive-type control strategies are evaluated with these models. The hydrological-water quality data on an urban basin system located in the Chicago area, together with meteorological data and land use information is used after calibration and validation of the models to analyze three types of policies: user charges and other tax measures, consolidation of wastewater treatment, and land-use controls (related to nonpoint sources of pollution). New approaches in the development of methods for assessing benefits of water pollution abatement and incentive analysis are presented.

Conference on Drought Research Needs—December 5-9, 1977; *Vujica M. Yevjevich;* Colorado State University, Fort Collins, Colorado 80521 $47,000 for 12 months beginning June 15, 1977

From the beginning of history, drought has had severe and sometimes catastrophic effects on vital activities of man.

The effects of drought are felt through various impacts on agriculture, urban water supply, industrial supplies, pollution control, navigation, power production, recreation, and other activities. Pressure for higher standards of living and an increasing world population continuously requires more food, materials, energy, industrial output and services. The inevitable result is an increasing demand for the available water resources, and water shortages of drought proportions have enormous impacts on the economies of both developed and developing regions. Droughts and

floods are the extremes of hydrologic phenomena.

Flood damages to society are much more visible and sudden than drought damages but in modern times, this situation has been somewhat changed due to the pressure on limited water resources.

At present drought is a critical problem for water resources conservation, development, and pollution control programs in many regions of the United States. Understanding the drought phenomenon and finding the best set of drought control and/or alleviation measures for each water user and each region are challenging and urgently needed tasks.

The objective of this project is to organize and hold a multidisciplinary and interdisciplinary conference aimed at carrying out an improved assessment and formulation of research needs in the area of drought. Specific objectives of the conference are: to define areas of most needed drought research subjects, especially from the point of view of general policy for drought control; to outline in specific terms the topics needed to be investigated for each of the broader subjects chosen; to outline detailed subjects of urban drought problems, especially those concerned with domestic and industrial needs, public services and in general the non-agricultural sectors; to identify those drought problems which are interrelated and the interactions between the urban and agriculture sectors during drought conditions; to outline a scheme for future, long-term research on droughts (5-10 years); to define areas of investigation needed in drought control technologies and policies and their impacts on both the individual and combined water users; and to outline feasible alternatives of coordinating drought research efforts with organizations and individuals in the U.S. and worldwide.

A conference report will be produced from the meeting and will be given the widest possible distribution.

DISASTERS AND NATURAL HAZARDS

The program element DISASTERS AND NATURAL HAZARDS seeks methods and techniques that can provide the most cost-effective protection for man and his works from loss of life, injury, property damage, social dislocation, and economic and ecological disruption caused by natural hazards and disasters.

The program subelements in this area are:

EARTHQUAKE ENGINEERING

WEATHER MODIFICATION

SOCIETAL RESPONSE TO NATURAL HAZARDS

EARTHQUAKE ENGINEERING

Earthquakes are potentially the most devastating of natural disasters. In the Federal government, the NSF/RANN has lead responsibility for earthquake engineering and associated problems, and the U.S. Geological Survey has lead responsibility for earthquake prediction, control, and hazard identification. RANN's Earthquake Engineering subelement supports a broad basic and applied research program addressing all aspects of engineering, geotechnical geology, social and behavioral sciences, and other disciplines aimed at developing methods and procedures for the mitigation of earthquake disasters. RANN and USGS programs are coordinated through several mechanisms, including the USGS Advisory Committee, the RANN Interagency Coordination Panel, the Interagency Discussion Group on Disaster Mitigation, and several committees of the National Academy of Sciences.

The research supported by this subelement is designed to answer the following questions: How vulnerable are various structures to damage or failure through seismic activity? How can design, planning, and public policy reduce this vulnerability? How can technical information best find its way through the maze of building codes, regulations, and established architectural and engineering practices to actual decision-makers?

The objectives of this subelement are to:

- Develop economically feasible design and construction methods for building earthquake resistant structures;
- Develop procedures for integrating information on seismic risk with ongoing land use processes;
- Develop an improved understanding of the social and economic consequences of individual and community decisions on earthquake related issues; and
- Develop and present information in useable forms to potentially affected com munities seeking to reduce their vulnerability to earthquakes.

Research is concentrated in three areas in FY 1977:

- Design
- Policy
- Siting

DESIGN

The objective of the Design program of Earthquake Engineering is to bring together information from the basic physical and natural sciences and to consider function, economic constraints, and performance requirements for the life of a structure with regard to the structure's performance under earthquake conditions. This involves formulation of loadings, studies of the behavior of materials and elements under dynamic loading, formulation and development of conceptual and mathematical representations for structural systems, and validation of design procedures through observation and tests on real structures.

Building Configuration and Seismic Design: *Christopher Arnold*; Building Systems Development, Inc., San Francisco, California 94111, $199,400 for 18 months, beginning July 15, 1977

Increasing concern for seismic safety and recent drastic increases in building costs focus attention on the need to ensure that structural costs are held to a minimum consistent with meeting the intent of the building design. Building configuration—size, shape, number of floors—is at present usually a response to a number of specific issues, such as site size and shape, planning and building codes, user requirements and cost. Structural design is generally a secondary concern in the determination of basic configuration. As provision for seismic resistance becomes an increasing component of structural costs, it becomes imperative that structural engineers not be confronted by building configurations that are prohibitively costly to make seismically resistant. To date, little work has been done on systematically relating architectural configuration issues to seismic design. As a result, the seismic design implications of building shape are not well understood by architects. At the same time, requirements of functional planning that may cause the architect to choose building configurations that are not structurally optimal are not well understood by engineers.

The general objective to which this research is directed is that of determining the extent to which seismic design and building configuration are related within a context of construction cost, design difficulty, safety and building use. This study is aimed at providing a systematic body of knowledge, and a useful methodology, that will help close the gap between the architects' and engineers' understanding of each others' role. The project uses joint architect/engineer teams. Architectural investigations will concentrate on analyzing the planning and configurations of buildings in a generic way to a range of common occupancies (housing, educational, office, health, etc.). Relationships between building use, planning, and overall configuration will be established.

Structural analysis will focus on defining architectural characteristics important from a structural viewpoint. Architectural configurations will be examined for their cost and appropriateness as seismic design solutions for a set of assumed soil conditions, various ground motions, and intensities. The project's final product will be a set of guidelines for architects, engineers, and others involved in the building process. The report will form the basis for sound and economical seismic design.

Seismic Resistance of Precast Concrete Panel Buildings; *James M. Becker*, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139; $252,000 supplement beginning 12/20/76

This project continues at an advanced stage the preliminary work completed under an initial project. The original project included a survey of the current practices in the seismic design of large scale precast con-

crete panel buildings, an examination of the problems of analytical modeling, and preliminary parametric studies using response spectrum model analysis.

The modeling approach developed in the previous study indicated the need for more realistic representations of the overall range of structural behavior of precast concrete panel buildings. Such representations to be developed in this project include the study of nonlinear, inelastic response of both connection areas and panels and consideration of the overall response (three dimensional aspects) of the entire structural system under study.

Interim reports will be issued describing the various modeling effort and the parametric studies. A final comprehensive report will be issued at the completion of the study indicating final research results and recommendations.

Stability of Structures Under Static and Dynamic Loading—International Colloquim May 17-19, 1977; *Lynn S. Beedle*; Lehigh University, Fritz Engineering Laboratory, Bethlehem, Pennsylvania 18015; $17,000 for 12 months beginning February 15, 1977

The structural problems of buildings, bridges, and their components are international in scope. Since extensive research activity is currently underway in many countries, it is important that professionals from around the world meet to discuss these problems. This grant will provide support for an International Colloquium on the Stability of Structures Under Static and Dynamic Loading to be held in Washington, D.C. during the period May 17-19, 1977.

The objective of this colloquim is to bring together experts and researchers in the area of static and dynamic stability of structures to discuss their latest research results and relate them to improved methods of design for building bridges and other structures subjected to dynamic earthquake and wind loadings. Through the colloquium, the basis for formulating stability design criteria can be exposed for discussion, discrepancies can be pointed out, potential structural problems can be recognized, and experience in the use of design rules may be shared. Effective approaches for bringing currently used design rules and procedures into better agreement will be considered, further needed research will be identified, and information will be assembled for use in the formulation of new design specifications.

Close cooperation between the design and research communities of Europe, Japan and the U.S. will help improve present design methods. This International Colloquim provides unique and highly expedient means of achieving this goal. The colloquim has the professional endorsement of the European Convention for Constructional Steelworks, International Association for Bridge and Structural Engineering, Columns Research Committee of Japan, as well as the U.S. Structural Stability Research Council, which is responsible for organization of the colloquium.

Papers presented at the conference, together with discussions will be published in a book of proceedings. These proceedings will be widely distributed to researchers and practitioners.

Seismic Resistance of Fossil-Fuel Power Plants; *John L. Bogdanoff*; Purdue University, Lafayette, Indiana 47907 $127,300 supplement

This project will concentrate upon the determination of the dynamic behavior of large fossil-fuel steam power generating plants when subjected to earthquake forces. The results of this research may be used to establish design guidelines and procedures to ensure the earthquake resistance of the principal components of power plants. These guidelines and procedures form the basis for the development of seismic code provisions and recommendations for the design and construction of fossil-fuel steam power generating plants. At present there are no generally accepted design procedures similar to those for the design of buildings available to the industry and professional engineers engaged in the design of power plants.

This project will continue to investigate, analytically and experimentally, the behavior of the principal components of power plants: furnace-boiler, steam and feedwater piping systems, coal handling equip-

ment and conveyor systems, cooling towers, and stacks. Results of this research will be used to recommend improvement in design for the earthquake resistance of old and new plants, recommend a policy on spare parts to be available in the event of a disaster, recommend design quidelines and procedures, develop simplified computer codes, and recommend design provisions.

Safety Evaluation of Buildings Exposed to Earthquakes and Other Catastrophic Environmental Hazards; *Boris Bresler*; University of California, Department of Civil Engineering. Berkeley, California, 94720; $98,000 for 12 months beginning March 15, 1977

This project will study the problem of attempting to predict the potential damage which could occur to an existing structure when it is subjected to a catastrophic event such as an earthquake, severe windstorm, etc. Methods and criteria for assessing potential damageability in existing structures with respect to abating these potential hazards and to minimizing losses and the cost of rehabilitation will be developed.

In considering damageability, three general types of damage will be distinguished:

- Local damage—limited to one or several typical elements;
- Global damage—overall damage in a particular event related to the total building; and
- Cumulative damage—overall damage resulting from a series of events such as a strong earthquake followed by fire or by a series of aftershocks or some other combination of normal and castastrophic events.

Damageability of structural and nonstructural elements will be considered in conjunction with the strength and ductility of structures. Methods for assessing damageability and for developing damageability indices will be worked out. Based on the development of damageability indices using results from case studies, an attempt will be made to synthesize redamageability of structures by relatively simple means suitable for routine application. Such information will not only be useful in assessing the degree of hazard for existing structures, but will also be useful in guiding preventive rehabilitation programs and in improving the seismic design of new buildings.

Earthquake Response of Dams Including Hydrodynamic and Foundation Reactions; *Anil K. Chopra*; University of California, Berkeley, Berkeley, California 94720; $70,400 for 12 months beginning November 1, 1977

The basic purpose of this research investigation is to develop reliable and effective techniques for earthquake analysis of dams including effects of hydrodynamic and foundation interaction, and a fundamental understanding of the effects of interaction and their significance in the response of dams to earthquake ground motion. Dams of three types: concrete gravity, concrete arch, and earth are included.

Procedures for including hydrodynamic and foundation interaction effects in analysis of response of dams to earthquake ground motion will be formulated. Computer programs will be developed to implement these procedures for numerical evaluation of earthquake responses. A systematic series of analyses will be performed to establish the significance of interaction effects in the earthquake response of dams.

The developments and results expected from the proposed investigation will enable better evaluation of the response of dams to earthquake ground motion, thus improving our capability to assess the safety of existing dams and of designs proposed for dams to be constructed.

Energy Absorption Characteristics of Structural Systems Subjected to Earthquake Excitation; *Ray W. Clough*, University of California; Berkeley, California 94720; $103,000 for 0 months beginning December 8, 1976

The program of activities includes testing of structural components such as reinforced concrete beams and beam columns, reinforced concrete beam and column assemblies, and reinforced concrete frames with spandrel walls. The moderate size earthquake simulator will be used to verify, extend and modify analytic understanding of the earthquake response of steel rigid and braced frames, reinforced concrete bare

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

Structural Loads Analysis and Specification; *C. Allin Cornell*, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139; $275,600 for 0 months beginning January 5, 1977

The purpose of this award is to support the continuing research to develop a practical, unified approach to the analysis and specification of structural loadings, including extreme value loads (e.g., earthquake) and continuous loads (e.g., live load, wind). The study will have three purposes: (*1*) to develop a relatively simple, unified set of probabilistic models which represent the random characteristics of loads; (*2*) to develop and study alternative codifiable treatments of loading and load combination specifications and (*3*) to carry out the supplementary basic research that these developments require. The way in which various loads can be combined to achieve a design load condition will be investigated. The effectiveness of alternative deterministic code formats, e.g., a community load factor, split factors, partial factors, etc., applied to characteristic values or application versus success in meeting particular stated objectives, e.g., equal risk exceeding the design values. New concepts in load models will be reported and clarification of principles and applicability will be provided. The feasibility of new loading specification formats based more directly on these probabilistic models will also be investigated. With a common load model, it may be possible to develop some relatively simple unified scheme of formulas or charts ot provide more accurate assessments of the risk of a given combination of values or the design combination for a given risk.

Implementation Planning for Seismic Design Provisions for Buildings; *Charles Culver*; National Bureau of Standards, Gaithersburg, Maryland 20234; $63,700 for 6 months beginning July 15, 1977

In 1974, the National Science Foundation and the National Bureau of Standards as part of the Cooperative Federal Program on Building Practices for disaster Mitigation undertook a project with the Applied Technology Council of California to develop nationally applicable comprehensive seismic design provisions reflect the current state of the art in earthquake engineering in a form adaptable for implementation by standards organizations, model code groups, Federal agencies, and other regulatory groups. Approximately 90 professionals throughout the United States representing the design professions, the university research community, and regulatory groups including the model codes and State and local building officials participated in developing the provisions.

This project will develop a plan to implement the nationally applicable Comprehensive Seismic Design Provisions as tentatively proposed. The objective of the project is to facilitate adoption of provisions by regulatory and standards groups, and acceptance and use of the technical criteria by practicing professionals throughout the United States. Considerations involved in planning the program and the types of participants are discussed. A procedure involving participation by the appropriate organiztions will be developed in order to engage the assistance and cooperation of all the organizations involved with construction of buildings. A coordinated effort is required to facilitate this implementation and maximize the potential benefits associated with use of the design provisions. The project includes the development of a framework or plan for the effort to implement the design provisions.

Prediction of Earthquake Resistance of Structures; *Rudolph F. Drenick*; Polytechnic Institute of New York, 333 Jay Street, Brooklyn, New York 11201; $75,600 for 12 months beginning November 15, 1976

This project continues the research on the development of a "minimax" method for reliable structural design. When a structure is designed for earthquake resistance, the first major problem is to select an appropriate time history of ground acceleration as the design load. One way is to select the worst possible excitation from a class of admissible functions for the specific structure under consideration. The theory of worst or "critical" excitation and methods of analysis for elastic structures have been developed in the previous studies. The objective of this project is to convert the critical excitation method into a fully implemented design tool.

A linear method has been fully developed, and a non-linear method has been partially developed. Both methods have been applied to a limited number of test designs in previous studies. Studies will be conducted to develop design charts, computational aids, and computer programs in forms which the practicing engineer can use to design structures based on the critical response theory established.

This project is directed at the full implementation of the developed methods for elastic structures, and will complete the development of the theory, method, and design methods for inelastic procedures. Research tasks to be carried out include selection of basis excitations, development of critical response spectra, incorporation of critical excitation method into selected dynamic analysis program, establishment of procedures for the choice of representative design variables, and analysis of inelastic structures. Results will be provided to researchers and design engineers for practical application.

Structural Connections in Industrial Installations Subject to Earthquake; *George C. Driscoll*, Lehigh University, Fritz Engineering Laboratory, Bethlehem, Pennsylvania 18015; $90,500 for 18 months beginning January 15, 1977

This project will study problems of structural connections of equipment located in industrial facilities which could be subjected to earthquakes. Such connections may occur within the equipment or may attach the equipment to the structure or foundation. A study will be performed to identify the types of functions of connections, will group them into general classes, and will examine current codes and specifications for the design and construction of such connections. Methods for assessing loadings on connections will be summarized and recommendations will be offered with respect to the best methods currently available which could be used at a practical economic level. Typical connections currently available will be examined to initially assess their potential performance under earthquake loading. A report will be prepared summarizing the results of the study, and should be of value in assessing the present adequacy of equipment connections for earthquake loadings.

Summer Institute for Architectural Design for Earthquake Disaster Mitigation; *John P. Eberhard*, AIA Research Corporation, 1735 New York Avenue, Washington, D.C. 20006; $77,400 for 6 months beginning April 15, 1977

"Architects & Earthquakes: A Primer" was developed by the AIA/RC under a grant from the National Science Foundation to provide architects with a better understanding of earthquakes and to emphasize the importance and effect of their design decisions for seismic conditions. In order to efficiently and directly disseminate the Primer and other important research information to the architectural profession, AIA/RC will organize, administer and conduct a one-week summer institute. The Institute will be held for approximately fifty architectural faculty, who in turn will relay this gained knowledge to the profession in their locale, to academic curricula, and to students.

The objective of the institute will be to develop an awareness and actual application of useful knowledge in the design of buildings to resist seismic forces. This effort will ultimately result in building designs which

reflect safety features to mitigate the effects of earthquakes by reducing loss of life and property damage.

The one-week summer institute curriculum will cover four broad areas: seismology/soils, structural engineering, environmental systems, and nonstructural building design. Curricula will be designed using the latest research information to teach causes of earthquakes, effects upon soils and structures, and resultant effects upon nonstructural building elements. Participants will learn how architectural design considerations and decisions affect the seismic performance of buildings.

An expert in each field of activity will serve as faculty for the institute and will be responsible for preparation of the course materials (written and visual) and presentation of the current practices for his area of expertise.

It is planned that the staff and facilities at the Berkeley Earthquake Engineering Research Center and Stanford University John A. Blume Center be utilized for demonstration purposes.

Formulation and Expression of Seismic Design Provisions; *Steven J. Fenves*, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213; $29,000 for 0 months beginning January 31, 1977

The National Bureau of Standards and the Applied Technology Council (ATC) are currently conducted an NSF-funded project on the development of comprehensive seismic design provisions. A preliminary draft of the design provisions has been released to a wide range of professional, business and industrial groups. The 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 objective of this project is to assist the ATC project to the maximum extent possible in the preparation of the final document, to provide documentation of the logic of the final text by publication of the formal representation of the provisions embodied in the ATC's final report. A systematic study of the ATC draft will be undertaken to insure that the basic consistency of provisions are truly reflected in the final document. This documentation will provide a reference for those who adopt and update the Design Provisions.

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; $151,500 supplement

The imminent demolition of thirty or more eleven-story apartment buildings of relatively contemporary construction provides a unique opportunity to subject buildings to dynamic excitation simulating earthquake loading from which much data can be gained for deriving realistic design criteria for earthquake resistive structures. 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 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; *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 expertise of several organizations is to be utilized on one or more buildings in the Housing Project. Because the buildings are slated for demolition in the near future, and are of relatively contemporary reinforced-concrete frame construction, their availability

for testing presents a unique opportunity to expand the understanding of the behavior of full-scale structures under dynamic loading conditions relative to lateral forces experienced during an earthquake event.

Earthquake Resistant Design of Braced Steel Frame Structures; *Subhash C. Goel*; University of Michigan, Ann Arbor, Michigan 48109; $141,200 for 12 months beginning August 1, 1977

Braced multistory steel frame structures have gained popularity among engineers in recent years because they are stiffer and more economical than unbraced frames. Bracing members are considered to be effective earthquake-resistant elements because they provide necessary stiffness to prevent non-structural damage due to moderate shaking, and are a source of energy dissipation during severe earthquake motions. The need for an understanding of the cyclic inelastic response of braced frame structures is not limited to earthquake resistance, but also to tornado winds and sea storms. The hysteresis behavior of bracing members is quite complex because it is influenced by buckling and yielding. Thus the computation of realistic inelastic dynamic response is more difficult for braced frames than for unbraced frames.

This project will perform an analytical study of braced frame systems subjected to earthquakes. Practical structural configurations will be investigated to determine their advantages and disadvantages utilizing an improved understanding of bracing behavior. Based upon these and past studies, design recommendations will be formulated and analytical procedures for the design of earthquake resistant braced frame structures will be developed.

An analytical and experimental study of the hysteresis behavior of steel members subjected to combined cyclic bending and axial forces will be conducted. The results will help define the conditions under which the bending action is a primary effect and axial force is a secondary effect. The case when buckling dominates the member behavior and bending is secondary will also be investigated, as well as the intermediate range of conditions under which the member behavior may be significantly influenced by both types of action. The experimental program will be conducted to verify the theoretical results and to develop an understanding of the mechanisms and limits of failure for these types of members.

Computer Program Documentation for Technology Transfer; *Phillip L. Gould*; Washington University, St. Louis, Missouri 63130; $10,790 for 6 months beginning October 1, 1976

A comprehensive investigation of hyperbolic cooling tower shells has been conducted for the past few years at Washington University under NSF sponsorship. Efficient and powerful computer programs for the high-precision finite element analysis of rotational shells were developed and implemented. A major part of this work deals with the development of a program called SHORED for the dynamic response to cooling towers under earthquake and wind loadings. The program, which is developed for the analysis of arbitrarily loaded (static and dynamic) thin shells of revolution, is extremely efficient and powerful.

This award is to provide documentation of the program to effect the transfer of technology to potential users. High-quality theoretical and users' manuals for the SHORED computer program will be developed, as well as a complete list of available programs. The manuals will be prepared utilizing the technical papers and reports prepared in conjunction with the work on the NSF research grant supported by the Engineering Division. The capabilities will be generalized somewhat to include such items as layered shells and discontinuous meridians which are of interest to a number of potential users. The finished program will be tested using problems documented in the literature. The complete documentation will be included in the computer library of the National Information Service of Earthquake Engineering for wide distribution. The potential users include practicing engineers, designers, and professionals in private industry and government agencies.

It is expected that the documented program will be utilized primarily for the seismic analysis of rotational shells, particularly hyperbolic cooling towers, an important component in power plant complexes.

Conference on the Repair and Rehabilitation of Buildings; *Robert D. Hanson*; University of Michigan, Ann Arbor, Michigan 48109; $22,900 for 12 months beginning February 1, 1977

There is a need to collect and synthesize the available information on techniques and procedures to repair, strengthen and rehabilitate older buildings, those damaged by natural or man-made causes, and those which have been constructed in the past before seismic considerations were required.

Although existing information is available, it is distributed throughout the literature and research publications. It is important to analyze and disseminate the information to the public and to the total construction industry.

A conference will be conducted to assess the current practices and determine future research. Published proceedings will include technical papers and future research needs.

Seismic Resistance of Concrete Slab to Column and Wall Connections; *Neil M. Hawkins*; University of Washington 98105; $228,800 for 0 months beginning February 9, 1977

This grant will continue research which was concerned with the strength of reinforced concrete slab-to-column and slab-to-wall connections subjected to strong dynamic loads.

In the next stage of the work reversed cyclic loading tests will be conducted on approximately 29 specimens representative of connections at exterior columns and walls, corner columns and walls, and frames. The specimens will be subjected to statically applied, reversed cyclic loadings having varying ductility demands.

The experimental phase of the project will continue to be supported by a vigorous analytical program. That program has two parts. The first concerns the development of mathematical models capable of predicting the experimentally observed results.

The second part of the analytical program concerns the development of appropriate procedures based on the experimental data for predicting the theoretical seismic response of typical flat plate structures. During 1975 a procedure was developed that predicts well the monotonic loading response measured in the interior column connection tests and is readily extendable to frames incorporating flat plates. In this continuation, that procedure will be extended to reversed cyclic loading and dynamic response prediction.

Earthquake Induced Bond Deterioration of Reinforced Concrete; *Neil M. Hawkins*; University of Washington, Seattle, Washington 98105; $52,400 for 12 months beginning March 15, 1977

This project will be continued on studies of bond deterioration in reinforced concrete structures subjected to earthquake loadings. Immediate objectives will be to conduct calibration experiments for collation of reinforcing bar stress-slip relationships with the development of internal cracking and acoustic emissions, and to use these results for a variety of experiments simulating practical connection details. In the first phase of the study approximately eight specimens will be tested to various levels of failure and then examined using a variety of methods, from non-destructive to sawing, to determine the degree of bond deterioration. Both straight and hooked bars will be studied. In the second phase of the project analytical studies will be undertaken and additional tests will be conducted with progressively increasing reversed-cycle loading using both conventional and light-weight concretes. All of these studies have the long-range goal of the development of practical techniques to assess the degree of bond deterioration in a structure surviving an earthquake and the development of improved design methods and regulations for new reinforced concrete structures.

Effects of Damage from Strong Earthquakes; *George W. Housner*; California Institute of Technology, Pasadena, California 91104; $292,500 for 12 months beginning February 1, 1977

This research project is the third year of a 3-year program and addresses the problem of hazards posed to structures by potentially destructive earthquakes. An annual construction investment in excess of $15 billion is being made in the highly seismic regions of the United States, so that during the next 20 years some $300 billion worth of new construction will be exposed to the possibility of very strong ground shaking, and should be designed for optimum safety and economy.

The objective of this research project is to develop useful techniques for the analysis of non-linear structural response to earthquake ground shaking, to use these techniques to obtain insight into the actual behavior of structures during earthquakes, and ultimately to develop practical methods for the control of damage to structures vibrated beyond the elastic range. To accomplish this objective, the proposed research will be undertaken in three areas: theoretical analyses of the vibration of nonlinear structures; analysis of the behavior of real structures and structural elements subjected to earthquake loads; and the development of methods for assessing the degree of damage that structures will sustain in the event of very strong ground shaking.

Contribution of Floor Systems to Earthquake Resistance of Steel and Concrete Building Frames; *Ti Huang*, Lehigh University, Bethlehem, Pennsylvania 18015; $105,100 for 12 months beginning November 1, 1976

The objective of this research project is to develop improved design guidelines for floor systems of multistory buildings to resist earthquake forces. This study will investigate and evaluate the contribution of several types of floor systems to the earthquake resistance of structural frames. The response of floor systems under earthquake loading is not properly considered in the present design practice for building structures, because of the lack of information concerning the seismic behavior of various floor systems. The study will examine the behavior of floors subjected to pulsating loads and will develop design guidelines which will take the floor system contribution under repeated loading into full consideration.

Both analytical and experimental investigations will be included in this project. The study will cover several types of floor systems frequently used in steel and concrete buildings. Testing of typical floor system panels will provide information leading to the identification of design parameters controlling the behavior of floor systems. A computerized parametric study will be used for the generation of data and development of design guidelines suitable for incorporation into design codes.

Research Initiation—Strengthening of Reinforced Concrete Columns for Earthquake Resistance; *Lawrence F. Kahn*; Georgia Institute of Technology, Department of Civil Engineering, Atlanta, Georgia 30332; $20,000 for 18 months beginning April 1, 1977

The objective of this investigation is to determine the adequacy of various methods of strengthening and repairing reinforced concrete columns for improved earthquake resistance. Five full-sized reinforced concrete columns will be strengthened and subjected to reversed cycle, earthquake type loads. Four strengthing techniques will be investigated which involve wrapping the existing column with steel bars or bands to increase the area of shear reinforcement. One column will be initially tested without any strengthening system; then it will be repaired using an epoxy injection method, strengthened and retested. The test results should demonstrate which method is superior for increasing the ductility and shear resistance of existing columns. This initial research will lead to design guidelines for improving the earthquake resistance of existing structures and will spotlight additional areas of research required in the general area of a seismic rehabilitation.

Prestressed Walls for Damping Earthquake Motions in Buildings; *W. O. Keightley*; Montana State University, Bozeman, Montana 59715; $37,300 for 24 months beginning November 1, 1976

This research is intended to contribute to the reduction of human life and economic losses due to building collapse or building damage caused by excessive building sway during earthquakes. The research will investigate a method for reducing the amplitude of building sway.

Earthquakes, tornadoes, hurricanes and explosions are examples of extreme dynamic loadings which could occur on various structures. Under such loadings it is necessary for the structure to absorb the sudden input of energy with an acceptable level of damage and without developing excessive dynamic motions in the structure. This project will investigate the feasibility of using segmented prestressed concrete elements in structures to absorb energy from dynamic loads through Coulomb friction in addition to inherent viscous damping. Mobilization of this additional energy absorption mechanism has great promise for limiting dynamic motions and reducing damage in structures. The energy absorbing elements could serve as interior partitions in a structure and be built in as a normal part of the construction. Analytical studies will be made for a representative wall panel and laboratory tests will be carried out to determine needed parameters and verify analytical predictions. Factors such as residual displacements after energy absorption will be studied.

Seismic Safety Design for Police and Fire Stations; *Earle W. Kennett*; AIA Research Corporation, Washington, D.C. 20006; $196,800 for 13 months beginning January 1, 1977

The purpose of this project is to explore, define, and record seismic design considerations to be used by the architectural and public safety professions in the architectural design, construction, and operation of police and fire stations which are classified as emergency public safety facilities in post-earthquake recovery activities.

The project will analyze police and fire stations to: (1) identify specific architectural damage patterns and failures which have occurred to police and fire stations during past moderate and major earthquake events; (*2*) identify and assess their present and anticipated architectural program requirements; (*3*) identify their special architectural and public safety requirements for seismic safety design; and (*4*) develop specific prototypical, architectural design alternatives for earthquake damage mitigation.

Structural Response Under Random Wind Loading; *Y. K. Lin*; University of Illinois, Urbana, Illinois 61801; $41,200 for 12 months beginning June 15, 1977

One of the dynamic natural hazards to man-made structures is a strong gusty wind environment. Large deflections and structural instability can be caused by gusty wind under certain unfavorable loading conditions. The problem of structural response to wind loading is complex, and belongs to the general category of fluid-solid interaction. The problem is nonlinear due to the change of initial wind velocity by the presence of the structure, and is random due to the existence of turbulence in the velocity field.

The conventional treatment of the problem is often insufficient. It is based on simple equivalent static forces and on deterministic modeling of the complex dynamic loading and response process. More sophisticated analysis is required to improve the understanding of behavior of structures subjected to the random aerodynamic forces generated by winds. Although the use of the theory of stochastic processes in dynamic system analyses can be traced back much earlier, the concepts of stochastic stability have not been applied to wind-loaded structures to date. The objective of this project is to establish a mathematical theory for structural response to random gusty wind in the along-wind and across-wind directions, to apply stochastic stability concepts to solve the wind induced structural instability problem, to investigate the vortex pattern of wind and its effect,

and to demonstrate the application of the research results in the analysis and design of actual building and bridge structures. The research will provide a basis for improved design practice for structures under wind conditions.

United States—Republic of China Cooperative Research in Earthquake Engineering Part II; *Le-Wu Lu*; Lehigh University, Bethlehem, Pennsylvania 18015; $25,400 for 12 months beginning April 15, 1977

This cooperative research program in the field of earthquake engineering between the United States and the Republic of China, is under the sponsorship of the United States—Republic of China Cooperative Science program, which is administered jointly by the National Science Foundation and the National Science Council. The cooperative program is devided into two parts, Part I, a program between the University of California, Berkeley (UCB) and the National Taiwan University (NTU) and Part II, a program between Lehigh University (LU) and the National Taiwan University. The objective of this cooperative program is to study these fundamentally import subjects in both "siting" and "design" areas and to obtain useful technical information which will benefit both countries.

This project between LU-NTU deals with earthquake resistance and strengthening of concrete buildings with foundation settlement and partial structural damage. This problem has become a major concern to engineers because of the increase in height of the new buildings. Both analytical and experimental studies will be conducted to investigate the earthquake response and the strength, stiffness, and damage characteristics of such structures in an effort to develop useful information to improve engineering design and practices.

Seismic Behavior of Multistory Masonry Structures; *Hugh D. McNiven*, University of California, Berkeley, California 94702; $102,000 for 12 months beginning April 1, 1977

Masonry construction is used extensively in this country and throughout the world for housing and office buildings. Due to lack of shear strength and moment resistance as compared with steel and reinforced concrete structures, masonry structures are more vulnerable to strong ground shaking during earthquakes.

To reduce the potential loss of life and property damage associated with masonry structures due to earthquakes, research will be performed to gain better understanding of the seismic behavior of masonry structures and to develop improved design methods of such structures.

The principal subject of this experimental work is the seismic shear resistance of window piers in multistory masonry buildings. Both single and double pier test program and diagonal splitting tests will be conducted to study the stiffness and strength of the piers and their parametric variation. Correlation studies of test data will be performed, and the behavior of typical spandrel girders in multistory construction will also be investigated.

The purpose of the analytical research effort is to correlate the experimental results with predictions of various mathematical models. Work during the project period will be aimed toward further refinement of modelling techniques to better represent masonry as a periodic material, and also toward evaluation of effective material properties which may be used in the design of masonry structures.

The results will be directed to the attention of building officials, designers, and code bodies for the development of more sophisticated techniques of seismic design and code specifications.

Reliability of Existing Buildings in Earthquake Zones—Part II; *Hugh D. McNiven*; University of California, Berkeley, California 94720; $50,000 for 24 months beginning June 17, 1977

One of the most important research tasks in Earthquake Engineering is to develop a capability for predicting the behavior of structures during an earthquake. An equally important task is to develop

means by which existing buildings in earthquake zones can be appraised in terms of how they might respond during an earthquake.

This project is addressing this latter risk, that is, the development of a realistic method to evaluate the seismic reliability of existing structures. The method consists of (1) constructing mathematical models truly representing the linear and nonlinear behavior of building structures by performing shaking tests and utilizing the System Identification techniques, (2) establishing the "limit states" or "failure criteria" of structures, and (3) determining the reliability of structures by subjecting the structural models to a family of earthquake excitations.

The project requires a joint effort by the University of California, Berkeley and Purdue University. Berkeley's effort will be in the development of mathematical model by the System Identification approach and testing the physical frame models on the shaking table. Purdue's effort will be on the formulation of reliability criteria and the analysis of test results in terms of damage probability and other probabilistic response measures.

The proposed research represents a workable first step in gaining insight into the seismic reliability problems of existing structures. This research will provide the basis for formulating effective and realistic counter measures to mitigate damage and losses associated with non-engineered existing buildings in seismic areas.

Seismic Effects in Liquid Storage Tanks; *William A. Nash*; University of Massachusetts, Department of Civil Engineering, Amherst, Massachusetts 01002; $42,400 for 12 months beginning November 15, 1976

Liquid storage tanks are found throughout urban areas. The types of tanks to be studied here are those that are placed on the ground with foundation attachments. Such tanks are used for storage (such as petroleum products and water), processing (such as water treatment, sewerage handling and chemical processing), and the storage of corrosive and explosive materials (such as acids and chlorine). Failures of large liquid storage tanks have been observed in several recent earthquakes: the 1964 Niigata caused the failure of an empty petroleum storage tank. The 1964 Alaskan Earthquake caused the collapse of seven oil tanks, one of which released 750,000 gallons of aviation fuel. During the 1971 San Fernando a 1.75 million gallon wash water tank associated with the Joseph Jensen Filtration Plant developed significant yeilding although it did not collapse. The tank was half full at the time. A number of petroleum storage tanks exhibited "elephant foot" damage and might have failed if the earthquake had been of longer duration.

This study will be oriented toward developing rational design criteria for slab-supported liquid-filled containers subject to seismic excitation. The dynamic response of a partially filled cylindrical tank excited by transverse and/or vertical motion will be investigated. This includes the buckling patterns in the upper portion of the container above the liquid and the portion below the free surface. The uplift effect of lower extremity of the tank at the juncture with the base slab will be investigated. The effect of sloshing liquid impinging upon the tank top and the effects of tank prestressing will be studied. Experiments will also be conducted to supplement the analytical studies. Results will be presented in the form of easily used computer programs to permit comprehensive design of earthquake-resistant tanks.

Seismic Behavior of Structural Systems; Analysis and Design of Structures; *Joseph Penzien*; University of California, Berkeley, California 94720; $70,000

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 structures through advanced experimental 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.

Considerable effort is needed in these analytical areas to increase the reliability of controlling seismic damage according to acceptable criteria. This project, which is one of four independent programs on "Seismic Behavior of Structural Systems," by the University of California, Berkeley, undertakes the following research tasks: (1) Analytic Studies of Building Response, (2) Soil-Structure Interaction Effects in Building Response, (3) Development of Nonlinear Structural Analysis Techniques, (4) Probabilistic Studies of Seismic Response, and (5) Analytical Method for Design.

The broad objectives of this project is to develop improved seismic analysis capabilities and to apply them in the structural design to achieve increased reliability of controlling seismic damage and costs.

The United States-Japan Cooperative Research Program on Large-Scale Structural Systems; A Planning Study; *Joseph Penzien*; University of California, Berkeley, California 94720: $20,000 for 24 months beginning July 15, 1977

Traditionally, engineers have relied heavily on theory and computers to develop concepts for design of structures resistant to earthquake forces. Many of these concepts have evolved from post-inspections of earthquake damage and laboratory simulations. As beneficial as these concepts are, many factors cannot be evaluated by inspection or small scale tests. The results of these small scale tests could be verified by full size structural tests to evaluate the time behavior in a structural system. A program to extend the tests to full size structures to determine the parameters which can not be evaluated otherwise would be most desirable and beneficial to the engineering profession.

This project is to develop an effective research program on large-scale tests of structural systems. A task committee will be established under the U.S.-Japan Panel on Wind and Seismic Effects, U.S.-Japan Natural Resources Program, to ensure an effective research program of maximum benefit to both countries within the constraints of the sponsoring government agencies.

Seismic Behavior of Structures: Analysis and Design; *Joseph Penzien*; University of California, Berkeley, California 94720; $186,600 for 12 months beginning May 15, 1977

As a direct result of recent experimental and correlative analytical studies, new nonlinear hysteretic models of structural members and components are emerging which must be accommodated by mathematical models of complete structural systems. These complete models should also include elements which realistically represent the influence of soil-structure interaction. For many systems the seismic excitation traditionally applied in one-dimensional form should be prescribed in a meaningful three-dimensional form. These additional features of mathematical modeling will, of course, require modifications and improvements in the present method of nonlinear seismic analysis.

To provide a better understanding of seismic performance and modes of structural failure, the improved seismic analysis capabilities which have resulted from experimental and correlative analytical studies on structures should be applied to complete structural systems such as buildings. Also, methods of synthetic design should be developed and applied to ensure a proper balance between total cost (including earthquake damage and repair costs) and safety.

Considerable effort is needed in these analytical areas to increase the reliability of controlling seismic damage according to acceptable criteria. This project

is to continue the research support under Grant NSF/ENV 76-04264 on the following research tasks: Analytical studies of Building Response, Soil-Structure Interaction Effects in Building Response, Development of Nonlinear Structural Analysis Techniques, Probabilistic Studies of Seismic Response, and Analytical Method for Design.

The broad objective of this project is to develop improved seismic analysis capabilities and to apply them in the structural design to achieve increased reliability of controlling seismic damage and costs.

Symposium on Structural Engineering and Mechanics; *Karl S. Pister*; University of California, Berkeley, Department of Civil Engineering, Berkeley, California 94720; $20,000 for 12 months beginning May 15, 1977

This project will consist of a Symposium which will bring together a group of distinguished teachers, researchers and practicing engineers specializing in various areas of structural engineering and structural mechanics to present critical appraisals of the current state of knowledge and the needed developments in education and research to support professional practice related to analysis, design, and construction of structures. The objective will be accomplished by a careful selection of speakers who will be invited to prepare survey papers in the interrelated areas of teaching, research, and professional practice supporting analysis, design and construction of structures. Emphasis will be placed upon those fields related to the mitigation of the natural hazards of earthquake, wind, and fire. Papers will be organized along the following lines: 1. Professional preparation—undergraduate and graduate curricula and research experience, continuing education for the professional. 2. Fundamental research in mechanics, materials, structural methods, and numerical analysis. 3. Applied research with design orientation.

The theme of the Symposium will be developed by sixteen invited speakers and the lectures will be published in the form of a Symposium Proceedings. A limited number of papers may also be solicited for publication only.

Seismic Behavior of Structural Systems—Behavior of Structural Components; *Egor P. Popov*, University of California 94720; $125,000 supplement beginning November 9, 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*) incorporate the experimental results into the mathematical modeling development efforts; and *3*) correlate the experimental results with calculated results and develop broadened capabilities for analyzing the inelastic behavior of structural components under seismic conditions.

Study tasks included in this project are: an evaluation of the ducility and load resistance of simple K-braced frames/wall systems; assessment of the behavior of reinforced concrete beams and beam/column components; and 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 modelings of structural components. 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.

Seismic Behavior of Structural Components; *Egor P. Popov*; University of California, Berkeley, California 94720; $220,000 for 24 months beginning April 1, 1977

This project is to continue research supported under a prior NSF grant on seismic behavior of structural components. The objectives of this project are to conduct advanced experimental and analytical studies of the behavior of structural components subjected to earthquake excitation. A total of five study tasks are included in this project. They are: 1) Braced steel frames—to evaluate the ductility and load resistance of simple K-Braced frames; 2) Reinforced concrete walls and infilled frames—to develop practical methods for earthquake design of combined ductile frame and infilled frames/wall systems; 3) Reinforced concrete ductile frame—to obtain additional knowledge on the behavior of reinforced concrete beams; 4) Reinforced beam-column—to finalize appropriate models for beam and beam-column components; and 5) correlation computer programs—to develop and apply 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 components. 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 for analysis and design of earthquake-resistant steel and reinforced concrete structures.

Earthquake Resistance of Steel-Concrete Composite Floor Systems; *Max L. Porter and Lowell F. Greimann*; Iowa State University, Ames, Iowa 50010; $199,400 for 30 months beginning October 15, 1976

The objective of this project is to determine the behavioral and strength characteristics of composite steel deck slab diaphragms as related to design considerations for lateral loading from earthquakes, wind or other dynamic forces. The research emphasizes in-plane shear due to lateral loads resulting from earthquake loading. Tests are to consider failure mode, static strength, cyclic strength (low number of cycles), damping, and stiffness characteristics of composite floor slabs sujbjected to in-plane shear and in-plane shear in conjunction with gravity loads. The effects of continuity of the floor slabs are also to be investigated. The composite floor slab investigation will consider the composite strength of the steel-deck slab without stud shear connectors as well as with connectors. To determine the effect of stud shear connector strength on shear-bond strength, a series of one-way slab element tests is planned. An evaluation of the significant parameters affecting in-plane shear strength of composite slabs is to be made.

Achieving the above objectives will provide information necessary for a more realistic design of buildings subjected to lateral loads, particularly those buildings designed by the staggered truss concept. Some of the earthquake design problems concerning the response characteristics of composite floor diaphragms not now known will be investigated.

Effects of Earthquake Motions on Reinforced Concrete Buildings; *Mete A. Sozen and W. C. Schnobrich*; University of Illinois, Urbana, Illinois 61805; $240,200 supplement beginning February 2, 1977

This grant will support the second phase of an experimental study of the mechanisms of energy dissipation in slender multi-story reinforced concrete structures subjected to strong ground motion, with a view to the development of simple but realistic design methods or earthquake resistance.

The immediate objective of the study is to investigate the interaction between wall and frame systems in the nonlinear range of response.

The scope of the work includes: tests of four small-scale story structures incorporating walls and frames, development of an analytical model to simulate the measured response-histories, and studies of the data jointly with the results of frames and walls acting independently obtained from previous tests, to lead toward an improved understanding of energy-dissipation mechanisms in complex reinforced concrete structural systems. Tests will be carried out using the University of Illinois Earthquake Simulator.

Research Initiation—Nonproportional Damping of Interaction Systems Subjected to Earthquake Motions; *David T. Tang*, SUNY at Buffalo, Department of Civil Engineering, Buffalo, New York 14214; $20,000 for 18 months beginning April 1, 1977

This research aims at exploring the concept of employing measured damping data in the computation of seismic response of interactions systems. The study is prompted by the argument that for an interaction system, energy dissipation capacity of the structures may be modeled more realistically using small damping ratios rather than the arbitrarily high values usually considered in an analysis.

For a 3-story steel frame structure tested on a shaking table, a foundation-structure system can be established to simulate a soil-structure interaction system with lumped rocking spring and damper impedances. Damping ratios for the structure observed during the vibration tests will be used in an exact formulation for equations of motion. Through a series of dynamic analyses, foundation damping required to render good correlation between the computed and tested results will be identified. With the damping property known for the system, the performance of other commonly used damping models will be evaluated. This will include models based on weighed modal dampings, composite dampings as well as the condition where the damping matrix is formulated with truncated coupled normal coordinates. The study is intended to demonstrate that although it is small, typical measured damping capacity could be employed in a more rational formulation of damping models for interaction systems.

Earthquake and Wind Response of Segmentally Constructed Hyperbolic Natural Draft Cooling Towers; *Chi C. Tung*; North Carolina State University, Department of Civil Engineering, Raleigh, North Carolina 27607; $84,600 for 18 months beginning March 1, 1977

Reinforced concrete hyperboloid natural draft cooling towers have been used frequently in connection with power plant facilities in recent years. The construction of large reinforced concrete cooling tower is expensive and time consuming. Preliminary investigation has shown that a segmental construction technique can be successfully applied with consequent savings in cost and construction time. The prefabricated segments are assembled on site and prestressed in the circumferential and meridional directions. Since the prestress effectively prevents flexural cracks in concrete, the energy absorption capacity of the structure is greatly reduced. Furthermore, during construction, after the post-tensioning forces are applied but before grouting is performed, the prestress acts to alter the stiffness and hence the dynamic behavior of the structure. Under the combined actions of the horizontal and vertical components of strong motion earthquakes, the safety of the segmentally constructed prestressed cooling tower must be carefully investigated.

The investigation will involve the following objectives:

- Review possible procedures for segmental construction;
- Improve static design and analysis methods;
- Carry out experimental investigations of static structural behavior;
- Develop dynamic analysis and design methods for segmental prestressed construction;
- Carry out experimental investigations of dynamic structural behavior; and
- Develop recommendations for design guidelines for segmentally constructed cooling towers.

Evaluation of Seismic Safety of Buildings; *Erik H. Vanmarcke*, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139; $106,000 for 12 months beginning January 15, 1977

The objectives of this research are as follows: To evaluate and compare the possible ways of representing the predicted ground motion and the associated (three) methods of seismic analysis, each utilizing a different representation of the ground motion: (1) time-integration analysis, using one or more real or artificial earthquake motions; (2) response spectrum approach utilizing modal analysis and an envelope of possible ground motion effects on one-degree oscillators; and (3) random vibration analysis in which

the entire problem is treated statistically. In all cases there are uncertainties both in the specification of input and the evaluation of the computed response. Within the profession there is disagreement as to which of the three approaches is most appropriate for design purposes. Although the emphasis will be on linear analysis, nonlinear systems will also be considered. The aim is to identify and fill in gaps of knowledge as needed to accomplish the principal objective, which is, to establish procedures to determine the overall safety provided by seismic design, considering the variability in both the prediction of ground motion and in structural analysis and design. The study is expected to yield valuable practical information on the required variation in load factors to provide a consistent seismic safety by different procedures, and also on the effect of load factors on safety.

Shear Transfer in Thick-Walled Reinforced Concrete Structures Subjected to Seismic Loading; *Richard N. White*; Cornell University, Department of Structural Engineering, Ithaca, New York 14850; $81,500 for 12 months beginning April 1, 1977

This research study is directed toward improved design procedures for thick-walled reinforced concrete structures subjected to earthquake loadings. A well-publicized example of this type of structure is the secondary containment vessel of a nuclear power plant. The horizontal accelerations of an earthquake produce large horizontal shearing forces in the vessel that must be transmitted across very fine cracks in the reinforced concrete. A rational and not unduly conservative design method for determining the number, size, and position of steel reinforcing bars in the vessel, in conjunction with the quality and thickness of the concrete, requires a complete understanding of the very complicated actions induced in the concrete and steel during the earthquake loading.

The project will continue research on the shear transfer mechanism in cracked concrete reinforced with large reinforcing bars which was previously supported by an NSF grant. The research includes laboratory studies, development of analytical models and the development of improved design methods for reinforced concrete structures. The laboratory studies will utilize uniaxially tensioned and biaxially tensioned specimens with cyclic shear transfer. Future work will involve the incorporation of nonlinear, degrading shear stiffness characteristics into the dynamic analysis program. From the analytical model and supporting experimental data an engineering model of the cyclic shear transfer will be developed to provide design methods for the steel reinforcing bars in concrete structures carrying combined tension and cyclic shear.

Summer Institute on Multiprotection Design; *B. Wobbeking*; American Society for Engineering Education, 1 Dupont Circle, Washington, D.C. 20036; $72,000 for 10 months beginning May 15, 1977

The objectives of the summer institute program are to orient and qualify fifty selected architectural and engineering faculty participants to teach college and university students, as well as practicing architects and engineers, the technical aspects of the analysis design methods concerned with protection against natural hazards such as earthquakes, fires, winds and other environmental effects including noise, energy, and nuclear radiation.

The environmental engineering aspects of protective construction on shelter habitability and the design of structures to resist blast pressures, and combinations of these effects will be included in the course content.

The final objective is the utilization of research results expressed in the course by the faculty of practicing architects and engineers and disseminated through local classes conducted by the attendees of the Summer Institute.

Collaborative Research: Formulation and Expression of Seismic Design Provisions; *Richard N. Wright*; National Bureau of Standards, Gaithersburg, Maryland 20234; $51,000 for 0 months beginning January 17, 1977

The National Bureau of Standards and the Applied Technology Council (ATC) are currently conducting an NSF funded project on the development of comprehensive seismic design provisions. A preliminary draft of the design provisions have been released to a wide range of professional, business and industrial groups. The 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. A systematic study of the ATC draft will be undertaken 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. This documentation will provide a reference for those who adopt and update the Design Provisions. The study will also provide alternate organization of the provisions to accommodate specific categories of users from various Federal, state and local regulatory agencies and model code organizations.

Reliability of Existing Buildings in Eaerthquake Zones—Part I; *James T. P. Yao*; Purdue University, Lafayette, Indiana 47907; $50,000 for 24 mos. beginning July 1, 1977; ENV 77-05290

One of the most important research tasks in Earthquake Engineering is to develop a capability for predicting the behavior of structures during an earthquake. An equally important task is develop means by which existing buildings in earthquake zones can be appraised in terms of how they might respond during an earthquake.

This project is addressing this latter task, that is, the development of a realistic method to evaluate the seismic reliability of existing structures. The methods consists of (1) constructing mathematical models truly representing the linear and nonlinear behavior of building structures by performing shaking tests and utilizing the System Identification techniques, (2) establishing the "limit states" or "failure criteria" of structures, and (3) determining the reliability of structures by subjecting the structural models to a family of earthquake excitations.

The project requires a joint effort by the University of California, Berkeley and Purdue University. Berkeley's effort will be in the development of mathematical model by the System Identification Approach and testing the physical frame models on the shaking table. Purdue's effort will be on the formulation of reliability criteria and the analysis of test results in terms of damage probability and other probabilistic response measures.

The proposed research represents a workable first step in gaining insight into the seismic reliability problems of existing structures. This research will provide the basis for formulating effective and realistic counter measures to mitigate damage and losses associated with non-engineered existing buildings in seismic areas.

POLICY

The objective of the Policy program of the Earthquake Engineering subelement is to develop an increased understanding of the role of local, State, and Federal units government in earthquake active and risk zones. This requires an understanding of the protective measures which can be adopted, including disaster preparedness planning, land use planning, insurance, building standards and codes, and relief and rehabilitation. In addition, public information and education efforts need to be developed and evaluated so that relevant knowledge can be effectively disseminated to the public and to user groups.

U.S.-Southeast Asia Joint Symposium on Engineering for Natural Hazards Protection to be held in Manila, Republic of the Philippines, in September 1977; *Alfredo H. Ang*; University of Illinois-Urbana, Urbana, Illinois 61805

The National Science Foundation provided support through this award for U.S. engineers who participated in a symposium on engineering research related to natural hazards. The symposium was jointly sponsored by NSF and the National Science Development Board of the Philippines. Although U.S. and Philippine engineers shared organizational responsibilities and were the primary participants, other Southeast Asian engineers involved in natural hazard engineering research were invited to participate in the meetings. The symposium sessions included a review of present technologies which allow structures to withstand earthquakes, severe windstorms and flooding; discussion of unsolved problems in this subject area; identification of hazards of special concern in Southeast Asia; and examination of opportunities for cooperative research where facilities, expertise and field testing conditions could be shared between U.S. and Southeast Asian investigators.

Tall Buildings and Urban Habitat: Impact of the Urban Environment and Planning for Natural Disasters; *Lynn S. Beedle*; Lehigh University, Fritz Engineering Laboratory; Bethlehem, Pennsylvania 18015; $224,200 for 12 months beginning March 15, 1977

As the world's exploding population becomes more urbanized, the concentration of people living and working in tall buildings has increased. Over the past five years a growing wealth of information has been developed and collected under the auspices of the Council on Tall Buildings and Urban Habitat (formerly the Joint Committee on Tall Buildings). The material which has been collected so far is unique in its variety of topics and is significant in terms of the depth to which existing problems are examined. This wealth of material collected through the Council on Tall Buildings must be made available to a broad group of decisionmakers that includes and goes beyond those normally involved in building design.

The purpose of this research program is to develop effective utilization/implementation strategies and techniques and to apply them; to continue the development of a systematized data base and information center; to initiate studies into methodologies for evaluation of proposed and existing high-rise construction; and to redefine and stimulate critically needed research. As part of the implementation effort various code, standard and regulation groups will be ap-

proached through the unique combination of industry, government and university members of the Council to identify areas of codes, standards and regulations which can be improved, to place information and data in forms suitable for use by these groups, and to provide a feedback loop to persons who are leaders in developing new practices and research information.

National Information Service for Earthquake Engineering; *Ray W. Clough*; University of California, Earthquake Engineering Research Center, Richmond, California 94804; $117,262 supplement beginning January 2, 1977

The purpose of this project is to collect and organize all the research information currently available on earthquake engineering and related areas. This will provide an opportunity to collect, and assess information from many different sources and will at the same time create a single source for researchers in the field to use to obtain information from a comprehensive collection. This collection will be geared to meet the needs of both academic researchers and design engineers. The computer program distribution service how has a total of 26 programs, each fully developed and suitable for use in professional engineering offices. Many new programs will be added to the library and will be made available for distribution as they are developed. The Earthquake Engineering Research Library will consist of reports (both published and unpublished), site visit records, data collected from various seismic regions, an abstracting service, and will generate a technical journal directed to the needs of earthquake engineers.

Eight specific utilization activities will be supported: (1) development of an Earthquake Engineering Research Library, (2) publication of the *Abstract Journal in Earthquake Engineering*, (3) NISEE/application and dissemination of computer programs, (4) publication of International Journal, (5) U.S. Japan Cooperation, (6) transfer of specializing information (7) providing educational opportunities for practicing engineers in the field of earthquake engineering, and (8) Publicity.

Inflationary Changes in Construction Costs Created by Earthquake Damage: Implications for Government Policy; *Harold C. Cochrane*; Colorado State University, Department of Economics, Fort Collins, Colorado 80523; $52,500 for 12 months beginning March 1, 1977

In recent years seismologists, earthquake engineers, and social scientists have increasingly turned their attention to earthquakes and the Nation's other hazards. The potential for inflation following disasters has not, however, been systematically investigated by the scientific community. Thus, estimates of the economic impact of earthquakes and other hazards may be inadequate because, while damage losses are taken into account, losses resulting from building inflation are not. For example, several simulation studies have been conducted on potential damage in future earthquakes in San Francisco and Los Angeles, Estimates of damage from a major earthquake in Los Angeles range as high as $25 billion; however, such a disaster could also lead to a major discrepancy between available construction resources, including equipment and manpower, and what is required to rebuild the city in a timely fashion. Serious price dislocations could result from shortages in these resources following a damaging earthquake, thus increasing economic losses.

This study focuses on the potential for inflation following moderate and major earthquakes. It will have an impact on public policy by determining whether the implementation of building codes and land use guidelines helps to reduce losses from inflation as well as losses from the direct physical impact of earthquakes. It this proves to be the case, the study will provide additional support for the utilization of earthquake-proofing techniques and land use management plans.

The research is divided into two twelve-month phases. In the first phase, an inflation model will be tested with moderate and major disasters that have occurred over the past fifteen years in the United States. In the second phase, earthquakes of varying magnitudes which could occur in the Los Angeles

area will be simulated, their potential inflationary impact in the Los Angeles area determined, and alternative policies which could reduce the anticipated price changes will be assessed.

Building Futures Forum—The Importance of the Built Environment to the Quality of American Life; *Robert M. Dillion*; National Academy of Sciences, Washington, D.C. 20418; $10,000 for 6 months beginning June 1, 1977

This grant will provide partial support to prepare a postconference proceedings for the Building Research Advisory Board 1977 Building Futures Forum on "The Importance of the Built Environment to the Quality of American Life" was held in Washington, D.C., on April 28, 1977. The conference included the following major topics:

- Measuring and understanding the health, social, and economic impacts of the existing built environment on individuals and institutions,
- Assessing how people feel about the built environment by examining where and in what they choose to support, and
- Determining ways in which the built environment might be modified and new facilities built to ameliorate any perceived deficiencies and satisfy and identified needs and desires.

National Information Service for Earthquake Engineering—California Institute of Technology; *George W. Housner*; California Institute of Technology, Pasadena, California 91104; $140,842 supplement beginning March 2, 1977

This grant will continue the National Information Service for Earthquake Engineering (NISEE) at the California Institute of Technology. The NISEE provides a data base for earthquake engineering in the United States and has been of particular value to engineers in the western part of the country. The Caltech Earthquake Engineering Research Library together with the Strong Motion Records Data Bank form the nucleus of the activity. Copies of reports, recorded accelerograms and digitized card decks and magnetic tapes are distributed. Earthquake engineering information is provided to engineering offices, Government agencies, and earthquake research organizations.

This award will enable NISEE to make available a unique earthquake engineering library (approximately 10,000 items) and the most comprehensive strong earthquake recordings data file existing in the world (approximately 500 accelerograms and digitized data of acceleration, velocity and displacement). The library and the data files are housed in the same building as the California Technology Earthquake Engineering Research Laboratory and are used for research by EERL personnel as well as being made readily available to practicing engineers and to other research organizations.

Seismic Safety Preparedness by Local Governments in California; *Dean E. Mann*; University of California, Santa Barbara, Santa Barbara, California 93106; $110,400 for 12 months beginning June 1, 1977

Earthquakes are a major threat in California. Recent estimates suggest that earthquake losses in the state could reach as high as $20 billion and thousands of deaths by the end of the century. Thus, government officials in California are faced with the need to develop seismic safety measures including regulations which govern the construction and location of structures, minimize property damage and human loss from earthquakes, and also prepare a response to a community-wide disaster in the aftermath of a serious earthquake. This study focuses on California because it is a seismically active area, and the state has taken some steps which offer significant opportunities to understand seismic safety planning.

In California communities and those in other areas of the country, the need for seismic safety must compete with other interests. Very real incentives exist for local governments to avoid enactment or enforcement of stringent earthquake related laws. However, little systematic research has addressed this important issue. Such research offers the possibility of substan-

tial policy payoff. This project is designed to investigate the principal sources of resistance to earthquake mitigation planning at the local level. Four communities in California, two with recent earthquake experience and two without, will be examined to ascertain sources of resistance to adequate seismic safety planning. In addition to local decision makers, the involvement of the national, state and regional governments in local planning will also be examined. This study will provide officials at all levels of government and in the private sector with an improved understanding of social, political and economic incentives for action or inaction and alternative strategies for overcoming resistance to effective seismic safety planning.

United States—Republic of China Cooperative Research in Earthquake Engineering Part I; *Joseph Penzien*; University of California, Berkeley, California 94720; $47,500 for 12 months beginning May 18, 1977

This cooperative research program in the field of earthquake engineering between the United States and the Republic of China is under the sponsorship of the United States—Republic of China Cooperative Science Program which is administered jointly by the National Science Foundation and the National Research Council. The cooperative program is divided into two parts, Part I, a program between the University of California, Berkeley (UCB) and the National Taiwan University (NTU) and Part II, a program between Lehigh University (LU) and the National Taiwan University. The objective of this cooperative program is to study these fundamentally important subjects in both "siting" and "design" areas and to obtain useful technical information which will benefit both countries.

The UCB-NTU program is separated into two subject areas: (*1*) "Attenuation, Intensity, and Characteristics of Strong Ground Motions," and (*2*) "Seismic Response of Embedded Structures". In the first study area available data from both countries will be used to study the attenuation laws, the maximum accleration and other ground motion characteristics in order to find common features, correlations and discrepencies. In the second study area a hybrid mathematical model consisting of finite element representation for near field of foundation and continuous representation for far field will be developed to study the soil-structure interaction of both rigid and flexible structures during earthquakes.

Research Program on Natural Disaster Recovery Processes: Relief, Rehabilitation and Preparedness; *Peter H. Rossi*; Social and Demographic Research Institute, Department of Sociology, University of Massachusetts, Amherst, Massachusetts 01002; $367,550 for 14 months beginning May 15, 1977

Since its inception, this nation's response to the victims of natural disasters has been relatively generous. Disaster mitigation and preparedness programs have been revised and increased in number in the last half of this century, for both domestic and foreign disasters. A major revision occurred in May, 1974. This legislative action was largely based on humanitarian considerations and best administrative judgements, rather than findings from appropriately designed projects employing modern systematic research methods and techniques.

Cost information on Federal expenditures for both domestic and foreign disaster relief is incomplete. At state and local government levels in the U.S., as well as in the private sector, cost information is also incomplete. The processes of recovery which these programs are supposed to promote have never been empirically described and evaluated by modern research procedures. The mix of U.S. disaster mitigation and preparedness programs on all levels has never been systematically analyzed or evaluated with alternatives proposed.

This award focuses on the development of sound empitical data on the nation's relief, rehabilitation, and preparedness programs and the operation of these programs in state and local areas most at risk to floods, hurricanes and tornadoes. The first part of the study, based on an analysis of census tract data for the period 1960-70 for all standard metropolitan statistical areas in the U.S., will provide a comprehensive study of the social and economic impacts of major disasters in these cities caused by four types of hazards; floods, hurricanes, tornadoes, and earthquakes. Data from this work will be used to inform

and develop the data gathering instruments for the second part of the study. The second part is designed to: *1*) examine at state and community levels variation in response to mitigation and preparedness programs; *2*) provide an empirically based descriptive account of the decisionmaking process at state and local levels as it bears on the formulation and implementation of disaster policies; and *3*) identify barriers to policy or program changes and obtain accounts of past and recent experiences with various programs.

Policy related aspects of all project findings are to be explored by mission agency representatives and scholars from the academic community.

Community Response to Earthquake Threat in Southern California; *Ralph H. Turner*; University of California, Los Angeles, 405 Hilgard Avenue, Los Angeles. California 90024; $299,100 for 12 months beginning November 15, 1976

The scientific community is on the verge of developing the capability of predicting destructive earthquakes. In anticipation of this, there is a need to understand how people will respond to predictions so that effective public policy can be developed. This research attempts to meet this need by focusing on the community response to the Mojave Uplift along the San Andreas fault and other possible premonitory signs of a destructive earthquake. A sample survey of 1600-1800 residents of Los Angeles County will be conducted, periodic follow-up telephone interviews, direct monitoring of the mass media, and interviews with public and private leaders. The research will produce a history of community response to a prediction or near prediction, identify people's reception and understanding of reports of earthquake danger, coping steps they are willing to take, extent of their altruistic concern for others, their disposition to cooperate with hazard reduction programs, the process by which people decide about these matters, and the patterns of changing community response.

Cost-Benefit Risk Analysis of Research Budgeted for Hazard Mitigation; *John H. Wiggins*; J. H. Wiggins Company, 1650 South Pacific Coast Highway, Redondo Beach, California 90277; $40,900 for 5 months beginning October 1, 1977

The purpose of this project is to prepare a summary report on an Assessment of Risk to Structures From Natural Hazards, and to disseminate this information to the public in such a manner that it can be understood thouroughly and its implications digested with regard to national, State and local needs.

The research study examined the possible effects of nine natural hazards (earthquakes, expansive soil, landslides, river flood, storm surge, tsunami, tornado, hurricane, and severe winds) with regard to possible economic losses to building structures and loss of life from the present to the year 2000 taking into account potential damage loss reductions if information developed by research could be used to produce damage mitigations. It was concluded that potential annual damage to building structures only under 1970 conditions and in terms of 1970 dollars exceeds 5 billion dollars per year and that substantial reductions in loss could be realized through research. It was also concluded that all hazards must be considered collectively for optimum mitigation purposes, rather than individually.

SITING

The Siting program of Earthquake Engineering provides research support for the elucidation of the physical basis of earthquake energy generation and the transmission and propagation of the generated shock waves through various geologic and soil conditions. This includes studies of such mechanisms as settlement, loss of bearing capacity, embankment or slope instability, and soil liquifaction. Siting is also concerned with the impact of earthquake ground motion on structures and the development of criteria and guidelines for the mitigation of earthquake impacts on the built environment.

Simulation of Strong Earthquake Motion with Explosive Line Source Arrays; *G. R. Abrahamson*; Stanford Research Institute, Menlo Park, California 94025; $95,000 for 8 months beginning November 15, 1976

This project is intended to develop a technique to simulate spatially and temporally the motion which occurs in soils during an earthquake. Research will develop controllable explosive line sources and conduct experiments to determine whether the sources produce the effects predicted, and will analyze how close the results come to the design earthquake motions being simulated.

An explosive method consisting of a planar array of verticlal line sources with the required control and versatility to test *in situ* structures at strong earthquake levels will be developed. Key features of the line sources are that the frequency content of the earth's motion can be controlled by throttling the explosive gases from a charge canister within each source, the duration of the simulated earhhquake motion can be controlled by delayed multiple detonations, either within each line source or between groups of line sources; a minimum amount of explosive is required because the array produces plane waves originating close to the structure rather than spherically diverging waves originating from point sources; and, they are resusable. Tests will be performed over a range of simulated earthquake motions extending to levels high enough to observe not only vibration modes but also to explore potential damage mechanisms. Test will be conducted in a sand pit to veritfy that the experimentally induced motions are as predicted for the particular array.

The immediate application of the results of this project is the *in situ* testing of nuclear reactor models and prototypes (or obsolete reactors). The technique will also have application to the mcuch broader subject of soil-structure interactions in general, including those in pipelines, powerlines, dams, bridges, and tunnels.

Seminar on Earthquake Design Criteria, Structural Performance and Strong Motion Records; *M. S. Agbabian*; Earthquake Engineering Research Insitute, Oakland, California, $33,300 for 12 months beginning May 15, 1977

Practicing engineers, building officials, and government project officers whose responsibilities include the safe design of structures that range from single story residential or industrial buildings to complex facilities such as dams, power plants, and bridges, exercise their engineering judgement by depending not only on mathematical analyses but also on experience gained from investigating facilities that have been exposed to actual earthquakes.

Strong motion records are the data obtained from field laboratories. The input is an actual earthquake.

Processing and interpreting such data is essential for engineering decisions that will prevent loss of life and minimize damage during future earthquakes.

Regional seminars will be conducted in the Pacific Northwest, the Midwest, and the East Coast. Engineers in the entire United States will be able to attend and will have the opportunity to understand the state-of-the-art in earthquake criteria and structural performance. The seminars will bring together distinguished lecturers and practicing engineers, with a program that is utilization-oriented. The seminars will also disseminate research results with emphasis on practical applications.

There will be ten lectures, sequenced to develop the methodology for obtaining earthquake criteria and for conducting structural performance analyses using the interpretation of strong motion records and earthquake damage as basic resources. Seminar topics will include: Regional Geology and Seismicity, Introduction of Dynamics of Structures, Strong Motion Instruments, Stations, and Networks, Structural Design, Geotechnical and Learning from Earthquakes.

Underground Lifelines in a Seismic Environment; *M. L. Baron*; Weidlinger Associates, 110 East 59th Street, New York, New York 10022; $42,170 supplement beginning February 16, 1977

Lifelines supply and distribute essential services and functions to communities (energy, communications, transportation, water). These systems in seismic areas are vital to the health and safety of the communities they serve, and also represent nearly one-haf of the total investiment in structures. The safeguarding of these services is, therefore, clearly in the national interest.

At present, there are only rudimentary provisions in a few building codes regulating the planning, design and contstruction of underground lifelines. A major reason for this is the almost complete abscence 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 risk and optimalization studies to the planning, design and construction of lifelines structures.

The research will concentrate on underground water distribution lifelines. Specific tasks include a survey of existing underground lifelines; development of appropriate seismic input; methodology development for modeling and analysis; methodology application of real systems; and, risk and decision analyses of lifeline systems. The results of this research will be presented as design aids, guides, and specifications to be utilized by legislative and policy-making bodies, building code officials, utilities, planners, engineers, and the construction industry.

Partial Support of the Committee on Seismology; *Joseph W. Berg*, National Academy of Sciences, 2101 Constitution Avenue, N. W., Washington, D.C. 20418

This award provides partial support to the Committee on Seismology of the National Research Council. The activities of the Committee will include the preparation and publication of reports on trends and opportunities in seismology and on predicting earthquakes, and the operations of the United States Government seismograph network. New initiatives will be taken to conduct an in-depth review of research and funding of earthquake prediction efforts in the United States. The Committee will also study: the earthquake related problems associated with power plant site selection; problems having significant implications for public safety and welfare including earthquake prediction and control, geothermal energy, earthquake engineering, rock mechanics, geodesy, geological hazards, land-use planning, ocean-bottom seismology, state of stress in the earth's lithosphere, and off-shore geological explorations.

Earthquake Waves in Soil Deposits; *Ahmet S. Cakmak and Attila Askar*; Princeton University, Princeton, New Jersey 08540; $64,500 for 12 months beginning December 15, 1976

Local soil conditions can significantly influcence earthquake ground motions and therefore the intensity of earthquakes. Conventional methods for the analysis of soil behavior, site effects, and soil-structural

interaction effects under earthquakes treat the soil medium as a one dimensional shear beam or series of discrete mass-spring-dashpot systems, or as a two-dimensional layered system. However, the geological configuration and the material properties of local soil deposits are very rarely determined with sufficient accuracy. Therefore, the material property and the site geometrical uncertainties can introduce significant errors in analyses.

This project is to conduct analytical study on the investigation of seimsmic wave propagation in a random soil medium. The objective is to develop a stochastic representation and modeling of soil deposits. The stochastic (stochastic means time-dependent and random) properties of a medium introduce not simple corrections over the predictions based on a deterministic, homogeneous medium, but rather account for physical phenomena that are totally absent in the former. For elastic seismic waves, these are an effective damping as characteristic of the scattering of waves, changes in the frequency-wave dispersion relation, the coupling of shear and volumetric waves, the energy transfer between these modes, and changes in the mean square values of the various physical quantities. All of the changes cited above due to the presence of inhomogeneities effect the energy, displacement, velocity and acceleration spectra. For soils, either between the source and site or the bedrock to surface, the various inhomogeneities can be modeled as a stochastic system. The objectives of this project are to study the stochastic representation of soil deposits, to develop modeling techniques for treating the soils as random media, to analyze the nonlinear waves propagating in layered media, and to provide better and more reliable estimates for various ground motion parameters which are important factors in design practice.

Propagation charcteristics of waves and the effects of stratification will be studied aiming at the prediction of acceleration, velocity, displacement, and energy spectra of strong motion earthquakes. The results will be used to provide reliable and accurate assessments of the effects of soil-structure interaction.

Laboratory and Numerical Simulation of Near-Field Earthquake Ground Motion; *Gerald A. Frazier and James N. Brune*, University of California, San Diego, LaJolla, California 92093; $127,800 for 12 months beginning October 1, 1976

This research program is aimed at defining the basic character of earthquake ground motion within the zone where damage to civil structures is likely to occur, using physical and numerical modelling techniques. The complex physical processes involved in earthquakes are dynamic and vary spatially in a manner that is not easily characterized. Engineers and seismologists have developed some understanding of individual processes that occur during an earthquake, but nobody has succeeded in combining the various processes to simulate earthquake ground motion on the computer. This is not an impossible task, just a difficult one. The preliminary results indicate the problem, with all its intrinsic complexities, appears solvable. Also, with an improved understanding the limited strong motion data can form a basis for extrapolation to anticipated earthquakes.

The major objective of this project is to continue the research on the characterization of earthquake ground motion in terms of fault proximity, fault type, and intervening earthquake structure by numerical computations and laboratory experiments. Results from spontaneous shear ruptures in foam rubber have provided new information on rupture mechanics and the focusing of wave energy in the direction of rupture. The efficiency of a three-dimensional finite element method for modelling crack-induced waves has been demonstrated by accurately reproducing analytical results for a growing circular crack and by simulating surface motions in the laboratory experiments. New results obtained using computer methods concerning surface contours of maximum particle velocity during an earthquake, response spectra as a function of distance and direction from a strike-slip earthquake, and seismic amplification curves for a three-dimensional sedimentary deposit will be used in this research. This project is intended to further calibrate the computer methods for modelling actual earthquakes, to simulate ground motion under a variety of conditions, and to produce rules for characterizing ground motion which are suited to the needs of design engineers.

Processing and Analysis of Oroville Earthquake Aftershock Ground Motion Records; *Thomas C. Hanks*, U.S. Geological Survey, Reston, Virginia 22092; $114,000 for 12 months beginning March 1, 1977

The U.S. Geological Survey and the California Institute of Technology will jointly conduct a two year investigation of the remarkable set of strong-motion accelerograms and continuously recording seismograms taken in the course of the aftershock sequence of the Oroville, California earthquake. The Oroville aftershock accelerograms constitute a data set without precedent in the history of seismology. It is intended to exploit this remarkable data set in detail, both with conventional studies of peak ground motion characteristics, seismic source parameters, and lateral variations of the upper crust in the epicentral region and with a special effort to model complete ground motion time histories with more powerful waveform synthesis techniques.

The SEB/USGS will process 100 aftershock accelerograms, analyze data in terms of ground motion parameters, body wave spectra, seismic source parameters, and perform studies on synthesis of ground motion time histories. The CIT will process long-period data in terms of velocity and displacement time histories for 40 seismograms, analyze data for the elasto-dynamic response of half space to faulting motions, and generate synthetic motion histories. The ground motion modeling study will be carried out jointly by USGS and CIT. Close coordination between USGS and CIT will be maintained to maximize the research productivity. The developed model should predict ground motion over the frequency band of engineering interest and a wide range of magnitudes. The results will be published in a four volume series format and made available to the earthquake research community.

Processing and Analysis of Oroville Earthquake Aftershock Ground Motion Records; Part II; *Donald V. Helmberger*, California Institute of Technology, Pasadena, California 91104; $39,800 for 12 months beginning March 1, 1977

This project is a joint program between the Seismological Engineering Branch of the U.S. Geological Survey (SEB/USGS) and the California Institute of Technology (CIT). The objective of the research is to utilize a remarkable set of strong-motion accelerograms and continuously recorded seismograms taken in the aftershock sequence of the Oroville, California earthquake of 1975, to develop an improved model to predict local ground motion time histories which could occur due to an earthquake. The SEB/USGS will process 100 aftershock accelerograms, analyze date in terms of ground motion parameters, body wave spectra, seismic source parameters, and perform studies on synthesis of ground motion time histories. The CIT will process long-period data in terms of velocity and displacement time histories for 40 seismograms, analyze data for the elasto-dynamic response of half space to faulting motions, and generate synthetic motion histories. The ground motion modeling study will be carried out jointly by USGS and CIT. Close coordination between USGS and CIT will be maintained to maximize the research productivity. The developed model should predict ground motion over the frequency band of engineering interest and a wide range of magnitudes. The results will be published in a four volume series format and made available to the earthquake research community.

Earthquake Ground Motion Modeling for Central United States; *Robert B. Herrmann*; Saint Louis University, St. Louis, Missouri 63103; $79,900 for 2 months beginning March 1, 1977

The need of proper input for the earthquake resistant design of structures built in the central and eastern United States is very real and immediate. Earthquake resistant design criteria for buildings and other fixed civil works located in the central United States have not been developed to a level consonant with the associated damage potential due to the relative infrequency of damaging earthquakes in the region. At present the Department of Housing and Urban Development, the Nuclear Regulatory Commission, the Army Corps of Engineers, the Veterans Administration and other agencies require seismic input into their structural design. As a consequence, input data from other source regions, which are known to be un-

representative of actual conditions in the central and eastern United States, are being used for lack of anything better. Thus, in some cases, structures may be under-designed, at risk to their occupants, and others over-designed, with consequent economic waste.

The present design techniques use either the maximum possible earthquake to affect the site or a statistical estimate of the risk of exceeding a particular acceleration, velocity, or intensity level at the site. The point to be questioned in the present design technique is the applicability of applying the correlation between intensity and acceleration as obtained from western United States data, to the eastern and central United States.

The object of the proposed research is to provide improved earthquake ground motion predictions for events located in the central United States. The objectives of the research will be met by establishing new empirical relations for use in the central United States for predicting maximum ground velocity, displacement, acceleration and expected duration as a function of earthquake magnitude, epicentral distance and focal depth and by the synthesis of theoretical ground motion time histories for a variety of focal mechanisms, source depths, epicentral distances and earthquake source spectra shapes. The expected consequence of this research will be an improvement in the seismological input to the earthquake-resistant design problem. At present there is an urgent need for such studies in this part of the United States as more cities are considering earthquake risk in their building codes and as more federally supported and regulated structures are being built in the region.

Third U.S. National Conference on Wind Engineering Research, February 26-March 1, 1978; *Bernard M. Leadon*; University of Florida, Gainesville, Florida 32601; $29,600 for 12 months beginning June 1, 1977

Wind engineering may be described as the rational treatment of interactions between wind in the atomospheric boundary layer and man and his work on Earth's surface. A rational treatment of wind effects requires a synthesis of knowledge from the traditional fields of fluid mechanics, meteorology, mechanics of structures, physiology, and psychology. Although aerodynamics is of central importance to the evolving discipline of wind engineering, applications for the most part are non-aeronautic in nature. Atmospheric transport of air pollutants; wind effects on buildings, structures, and man; and modification of the wind environment by urban developments, topography and vegetative cover are important examples of interactions with which the wind engineer must work. The wind engineer's task is not only to minimize damage to life and property caused by adverse wind effects but also maximize human comfort and economy of design by utilization of beneficial wind effects.

During the last decade concern about wind effects has intensified. This award will provide support for the Third U.S. Conference on Wind Engineering, to be held in Gainesville, Florida. This Conference will provide opportunity for the presentation of research activities and preliminary research findings; stimulate discussion and interaction between research workers active in complementary subject areas; develop lines of communication and cooperation between research engineers and scientists; and identify areas of research which require greater effort for development of wind engineering to meet national needs. Tentative subject areas which speakers will be invited to discuss include boundary-layer winds, severe storms, wind effects on structures, wind loading on glass, and air-pollution control. A report of presentation summaries and recommendations for research will be issued.

Dynamic Response of Three-Dimensional Rigid Foundations; *Juan Enrique Luco*; University of California, San Diego, La Jolla, California 92093; $45,000 for 12 months beginning January 1, 1977

The dynamic force-displacement relation for embedded foundations plays an important role in the study of the dynamic response of foundations, and the soil-structure interaction during dynamic loads such as wind and earthquakes. Most of the information during dynamic response of embedded foundations is re-

stricted to the case of external loads and does not allow a complete analysis of the soil-structure interaction problem under earthquake excitation. To do so it is necessary to determine the dynamic response of the foundation to seismic waves propagating through the soil.

The objective of this study is to establish a complete formulation of the soil-structure interaction problem for earthquake excitations and to develop practical methods of evaluating the interaction effects.

The dynamic response of a variety of rigid embedded foundations to external forces and moments and, in particular, the response to obliquely incident plane seismic waves will be analyzed in detail.

The dynamic response of three-dimensional embedded foundations to two types of excitation: harmonic external forces and moments, and seismic excitation represented by non-vertically incident plane waves with harmonic time dependence, will be analyzed.

In the model under consideration, the three-dimensional foundation will be assumed to be rigid and embedded in a layered visco-elastic half-space representating the soil. Two different types of boundary conditions will be considered: welded contact between the foundation and surrounding soil, and lateral separation between the foundation and the soil.

Expected results include the evaluation of the effects of the bonding at the soil-foundation interface and effects of the type of seismic excitiation on the foundation response.

The research will lead to a complete formulation of the soil structure interaction problem and to simple, practical methods for evaluating the interaction effects.

Soil-Structure Interaction with Arbitrary Seismic Environment; *John Lysmer*; University of California, Berkeley, California 94720; $41,300 for 24 months beginning June 1, 1977

The site response problem and the soil-structure interaction problem are fundamental to proper design of earthquake-resistant structures. In the past few years considerable research activity in these areas has taken place. However, most current approaches to the site response problem assume that the seismic environment in the neighborhood of the structure consists of vertically propagating S- or P-waves. While there is evidence to suggest that this is a reasonable assumption for design purposes, it is also one of the most controversial aspects of current discussions of the validity of seismic analyses. Many researchers and practitioners have argued that earthquake motions in the ground consist of much more complicated motions involving surfaces waves and inclined body waves and that these wave patterns must be considered in the analysis. However, at this date, no generally applicable method has been developed which includes such wave forms in the subsequent soil-structure interaction. The soil-structure interaction problem has proved to be very complicated and expensive to investigate because of the large extent and unusually complicated geometry of various types of structures and their foundations. Many different methods of analysis have been proposed. However, with the exception of a few cases involving simple geometrics and S-waves, all published methods for soil-structure interaction analyses are limited to the case of a seismic environment which consist of propagating S- or P-waves and there is a very real need to investigate other types of motion.

The objective of the proposed research program is to develop a method for evaluating the seismic response of civil engineering structures on layered sites with a complicated seismic environment. This environment may consist of an arbitrary combination of surface waves and inclined S-and/or P-waves. Currently, no method exists for solving this problem and research in this area is of great interest to the engineering design profession. The objective of this project is to develop a theory and a finite element code, CREAM (Complex Response Earthquake Analysis Method), which can evaluate the seismic response of structures to an arbitrary seismic environment which may consist of surface waves, inclined S-waves, inclined P-waves, or a combination of these. The program CREAM will be developed with special attention to its later application by the practicing profession and will as such be fully documented and verified.

Post-Earthquake Land Use Planning; *George G. Mader*; William Spangle and Associates; 3240 Alpine Road, Portola Valley, California; $213,200 for 24 months beginning August 15, 1977

After a damaging earthquake has occurred, economic, social, phychological and political pressures coalesce to foster rebuilding as rapidly as possible. Often this leads to restoring areas, buildings, and services to their pre-earthquake conditions without regard for site or structural hazards revealed by the earthquake. If properly planned and carried out, reconstruction following an earthquake can greatly reduce risk from future events. In highly developed areas it may provide the only realistic opportunity to significantly reduce future seismic risk.

The objective of this project is to determine procedures by which government, particularly local government, can respond after an earthquake with a rebuilding program based on carefully prepared land use plans responsive to seismic hazards. An interdisciplinary team of experts in the fields of geology, structural engineering, and city planning will investigate post-earthquake land use planning and reconstruction that followed three recent earthquakes (San Fernando 1971, Santa Rosa 1969, and Alaska 1964) with the objective of identifying impediments to sound post-earthquake land use planning. The team will also develop a series of recommendations for model post-earthquake planning procedures, programs and regulations. For each earthquake event the following tasks will be performed. Structural damage and geologic phenomena of the earthquake will be identified and a range of post-earthquake land use planning options will be postulated. Land use will be reviewed to determine to what extent the foregoing identified land use options were recognized. A determination will be made of why less than optimum land use decisions were made and what would have been necessary to encourage or permit better post-earthquake land use pattern to include seismic safety as well as other considerations. Other earthquakes of potential value to the study will be identified and briefly evaluated. Planning responses to other types of disasters will be reviewed to determine what applications might be made to post-earthquake planning and reconstruction. A conference will be held to present the recommendations to users and decision makers.

Seismic Engineering Program; *R. B. Matthiesen*; U.S. Geological Survey, Menlo Park, California; $840,000 for 12 months beginning October 1, 1976

A five year project for continued operation and development of a national program in strong-motion instrumentation and data management was initiated in October of 1974 through an interagency agreement between the NATIONAL Science Foundation (NSF) and the United States Geological Survey (USGS). As indicated in the agreement, the objectives of the program are to develop a national network of strong-motion instrumentation, and maintain this network, and to process, manage, and disseminate strong-motion data.

This award is a continuation of the NSF-supported Seismic Engineering Program of Strong-Motion Instrumentation and data management. The objectives of the program are to record strong ground motions and the response of representative types of structures during potentially damaging earthquakes and to disseminate this data and information about the sites and structures to external users in earthquake engineering research and design practice. The program is divided into three projects: network design, network operations, and data management. The network design project is completing a basic plan for a nationwide strong-motion instrumentation network; the network operations project has brought about a more efficient operation of the existing network; whereas the data management project is working toward improved information retrieval and data processing methods while disseminating the available data and information about the program. The results obtained are presented in Seismic Engineering Program Reports that summarize the preliminary data and information obtained each quarter, in Strong-Motion Data Reports that present more detailed data processing and analysis and through technical reports and papers resented or published in appropriate meetings and publications.

Research Initiation—Behavior of Buried Conduit Structures Subjected to Seismic Loading; *Jack Rosenfarb*, Drexel University, Department of Civil Engineering, Philadelphia, Pennsylvania 19140; $840,000 for 12 months beginning October 1, 1976

In this research a laboratory investigation will be undertaken on the seismic behavior of buried conduit-type structures such as pipelines and tunnels. The soil-structure interaction response as characterized by measured strains and displacements will be determined for dynamically scaled models placed in a soil bin which will be attached to a shake table and will be programmed to undergo simulated earthquake acceleration-time histories. The test program will be designed to assess the effects of structure flexibilities as influenced by conduit geometry, material, and connection restraint conditions. These factors will be studied as a function of the surrounding soil type and the nature of the seismic loading.

The Dynamic Response of Anisotropic Clay Soils with Application to Soil-Structure Analysis; *Adel S. Saada*; Case Western Reserve University, University Circle, Cleveland, Ohio 44106; $68,200 for 12 months beginning November 15, 1976

In recent years a number of studies have been made to determine the response of soils to various dynamic loadings. Nuclear explosions subject the soil to a single loading and unloading with a very high peak stress; on the other hand, rotating machinery, radar towers, vehicular traffic, earthquakes, and conventional explosions involve relatively small vibrations. In the design of foundations and underground structures for steady state and transient dynamic loads, the representative values for the critical soil properties are generally difficult to obtain. Among those soil properties are the moduli and the damping factors of the various layers. For the same layer those properties can vary very widely because of their dependence on such parameters as the states of strain and stress of the soil, its fabric, the amplitudes and frequencies of the dynamic loads, the number of cycles, and other factors.

This project is to study the dynamic response of clays under cyclic loading at various inclinations of the principal stresses on the axis of rotational symmetry. Experiments involving low frequency cyclic loadings will be conducted using a special pneumatic analog computer. High frequency experiments and the determination of the dynamic moduli and damping ratios of the clays will be conducted using a specially designed "Long-Tor Drnevich resonant column" device which allows the specimens to vibrate in the torsional and longitudinal modes, independently or simultaneously, inside a triaxial cell. The directional behavior of both types of clay under cyclic loading, their moduli, and their damping ratios will be studied for a spectrum of water contents, degrees of anisotropy, amplitudes, and frequencies of loading.

The influence of material properties thus determined will be studied using finite element techniques, applied to embankments, earth dams, and other structures subjected to earthquakes and various dynamic loadings. Probabilistic techniques will be applied to model the variance of soil-structure response due to these loadings. The variance of soil properties will be estimated from laboratory tests and from assumed distributions of soil variability in the field.

Soil Dynamics Delegation to the People's Republic of China; *Marshall L. Silver*; University of Illinois-Chicago Circle, Department of Materials Engineering, Chicago, Illinois 60680

To learn more about the practice of soil dynamics and earthquake engineering in the People's Republic of China, a delegation of 13 scientists from academic institutions, government, and industry visited China for three weeks during the summer of 1977. On visits to institutions and field sites in Peking, Harbin, Nan King, Wu-Han/Hankow, Kunming, Kweiling, and Canton, the delegation (*1*) studied the nature of research presently under way, (*2*) inspected facilities and equipment available for research, (*3*) learned about the types of procedures being used to design soil deposits and soil structures to withstand earthquakes (*4*) studied the type and magnitude of soil instability that has resulted from modern earthquakes, and (*5*)

discussed ways of continuing a dialogue and the exchange of technical information. The leader of the delegation was Dr. Marshall Silver of the University of Illinois at Chicago Circle.

Probability Distribution of Extreme Wind Speeds; *Emil Simiu*; National Bureau of Standards, Center for Building Technology, Washington, D.C. 20230; $69,800 for 12 months beginning July 15, 1977

Improved code provisions on the design of structures for wind loads are a prerequisite for achieving more rational and economical designs. To develop such provisions, improvements are necessary in the practical application of the probabilistic approach to the definition of design wind speeds. Probabilistically defined design wind speeds are obtained from estimated cumulative distribution functions (CDF) of the largest yearly wind speeds. The justification for a probabilistic approach to the definition of design wind speeds is that it ensures a certain degree of consistency with respect of the effect of the wind loads upon structural safety. This is true in the sense that, all other relevant factors being equivalent, if appropriate mean recurrence intervals are used in design, then the probabilities of failure of building in different wind climates will, on the average, be the same.

The objectives of this research are to improve the capability for using a probablistic approach to specify design wind speed by studying the following questions:

- What type of probability distribution is best suited for modeling the probabilistic behavior of extreme winds?
- What is the effect of the magnitude of sampling errors in the estimation of the DCF's of the largest yearly wind speeds?
- What errors are associated with the quality of data?
- Can extreme wind climate estimates be made on the basis of short-term data?
- What is the applicability of the approach to extraordinary wind climates?

Because a part of this research will utilize micrometeorological data with the associated task of estimating and reducing micrometeorological adjustment errors, this part of the research will be carried out at the National Climate Center of NOAA.

Induced Seismicity at Nurek Reservoir, Tadjikistan, USSR; *David W. Simpson*; Columbia University, Lamont-Doherty Geological Observatory, Palisades, New York 10027; $81,900 for 12 months beginning December 15, 1976

Earthquakes with magnitudes near 6 have occurred near five large reservoirs, resulting in millions of dollars of property damage, structural damage to dams, the loss of more than 200 lives and injuries to thousands of persons. Throughout the world, over 100 large dams are now under construction or in the planning stage, at least some of which are likely to cause induced activity. The potential for a major disaster is obvious, yet scientists are just beginning to understand this type of seismic activity.

The objective of this joint US-USSR project is to study the induced seismicity at Nurek Reservoir, Tadjikistan, USSR where extensive seismograph stations have already been in operation since 1955 and where detailed data are available on pre-impounding conditions near the reservoir. The changes in the rate of seismic activity related to the filling of reservoir and other aspects of the seismic regime will be investigated. A model which can be used to predict the times of greatest potential for increased seismicity will be tested and used to generate practical information for the safety construction and operation of the reservoir.

Workshop on Research Priorities for Geotechnical Earthquake Engineering Applications; *Kenneth H. Stokoe, III*; The University of Texas, Austin, Texas 78122; $45,100 for 9 months beginning March 30, 1977

Research projects on geotechnical earthquake engineering are now in progress nationally and internationally. Various U.S. and foreign universities and institutions are conducting research which includes the many diverse areas of geotechnical engineering, including soil dynamics, stability problems related to

soil structures and soil response to earthquakes, site effects, etc. Because of the importance and diversity and the need for improved geotechnical design criteria, there is a need to identify future research priorities and ensure closer coordination between researchers and users.

This project will develop a workshop on geotechnical earthquake engineering to achieve the following purposes: to establish liaison between the various researchers in the field; to assess the present knowledge and to review the research results to date; to evaluate the research accomplishments as applied to the development of improved earthquake design criteria; and to determine needs and priority for future research.

The proceedings of the workshop will be published as a public report and distributed to professional community through NTIS and other channels. The proceedings will include technical papers on current practice, current research, and recommendations for future research accompanied by summaries of the panel discussions. The results will be used to plan research programs which will be a benefiit to the users, such as practicing engineers and architects, building officials, model code groups, regulatory agencies. This project involves the joint efforts of the University of Texas and the National Bureau of Standards. A companion but separate award has been made to the National Bureau of Standards in support of this work.

Feasibility Study of Using High Explosives to Simulate an Earthquake; *George E. Triandafilidis*; The University of New Mexico, Albuquerque, New Mexico 87131; $83,600 for 16 months beginning October 15, 1976

Analytical methods are now and must remain the prime basis for the design and analysis of engineering structures subjected to the effects of earthquakes. It is practically and economically impossible to test every structure under every potentially damaging environment. However, experimental data are needed to verify current design techniques and/or to provide the basis for new or improved techniques, fully analytical or semi-empirical. Such data must come from actual or simulated earthquakes.

Simulation sources include field shaking machines, shake tables, and explosions, either nuclear or high explosive. Field shaking machines are limited by low levels of input energy and, as a result, low vibration levels and limited affected regions. Shake tables are very useful because they are able to reproduce ground shaking from past or projected earthquakes with a high degree of precision. The major limitations of shake tables are size (similitude is required to extrapolate to prototype size structures), some limitaition on maximum displacement, and almost a complete inability to simulate effects on soil and soil-structure systems. This last limitation is very serious.

The behavior of underground conduits, subways, mines, earth dams and retaining structures are only a few of the numerous important problems which are not satisfactorily resolved by current understanding and testing technieques and which cannot be evaluated with shake tables. The Russians have been considering earthquake simulation with explosions for some time and the need in the United States is strongly emphasized by the conclusions of a recent National Academy of Engineering Workshop on the Simulation of Earthquake Effects on Structures. The Panels on Building Structures and Special Structures recommended study and development of explosive methods and the Panel on Soils, Rocks and Foundations, in particular, recommended the establishment of a national test site where ground shaking is created by explosives. The steering committee of the workshop concluded that "a much more detailed study of its (explosive simulation) technical and economic feasibility is required."

Although nuclear explosions provide a significant potential simulation source, high explosives are preferable because they offer less environmental, safety, and cost problems and greater flexibility in both charge size and configuration as well as geologic stratigraphic features, because nuclear events in the continental United States are restricted to the Nevada test site. The possibility of utilizing explosives in combination with various enhancement techniques, such as energy focusing, boundary relief, mass emplacement, sequential firing and energy coupling-decoupling has also not received adequate treatment.

This project will conduct a computer simulation study encompassing the following two objectives:

- Based upon analytical calculations and existing empirical data, to assess the technical feasibility of

using explosives to simulate the effects of earthquakes on engineering structures; and

- Based upon the simulation criteria and cost parameters, to assess the economic feasibility of using explosives to simulate the effects of large-scale earthquakes.

Automatic Digitization of Accelerograph Records; *Mihailo D. Trifunac*; University of Southern California, Los Angeles, California 90007: $80,000 for 24 months beginning October 1, 1977

It is essential to gain knowledge of ground motion in order to develop and verify the theories on soil amplification, microzonation, and structural design pro cesses. It is further essential to develop improved instrumentation for earthquake ground motion data collection and processing.

An automatic digitization system consisting of a rotating drum scanner and a complete computer interactive system has been built at the University of Southern California. This capability will provide an accurate, convenient and fast way to digitize accelerograph film records. Such a system will significantly extend the life of mechanical-optical type accelerograph systems and permit continued exploitation of the simplicity and reliability of this accelerograph type.

To implement such a system for the maximum usage for both conventional analog instruments and the upcoming digital recorders, it is necessary to develop a new generation of standard processing methods. The project represents such an effort and will develop full data acquisition and processing capabilities to provide the most reliable, accurate and economic means for strong-motion studies. In addition the project will also provide clues for such questions as whether the planned instruments for future networks should go digital or remain analog.

Seismic Vulnerability, Behavior and Design of Underground Piping Systems; *Leon R. L. Wang*; Rensselaer Polytechnic Institute; Troy, New York 12181; $63,800 supplement beginning January 5, 1977

Damage of water and sewage distribution systems during earthquakes can cause severe problems in public health and fire fighting and result in substantial loss of property, human injury and fatality. Most earthquake engineering research has concerned itself with building type structures, nuclear power plants, dams, and towers. Only limited informaition is available on the seismic resistance of underground distribution systems.

The traditional design procedures for underground piping for water/sewer distribution systems, are based on a static soil-structure interaction load/strength relationship. Sewer pipe is designed to resist external loads while water distribution systems are also subject to internal pressures.

Existing water/sewer distribution systems, if conservatively designed for static loads, may or may not be able to resist a small or moderate earthquake. This project intends to develop a systematic way of assessing the adequacy of existing water/sewer distribution systems, determining the vulnerability of the systems to earthquake damages and studying the cost-effectiveness of new designs to various magnitudes of earthquakes. A total of five analytical tasks on the dynamic analysis of beam-grid system, vulnerability, parameteric, and cost effectiveness studies of water/sewer systems will be conducted. These studies will lead to new design methodologies and recommendations for improving present design details for both new and existing systems.

Earthquake Strong-Motion Instrument Development and Array Design; *Francis T. Wu*; State University of New York, Binghamton, New York 13901; $41,400 for 12 months beginning May 15, 1977

The gathering of strong motion data has been until recently performed by the fixed station technique. Only in rare cases is there an array suitably located to record strong motions systematically around fault. Also, until recently the timing on records was not tied to real time; thus it has been difficult to decipher the precise nature of recorded waves and to generalize the obtained results for future earthquakes, since the contributions of the source and of the path can not be easily separated.

The technology of seismic recording has advanced recently. It is now possible to record data digitally using a self-contained portable system; use a "pre-trigger" digital loop to retain the complete strong motion data, including the triggering signal; use a low-drain accurate crystal clock for coordinated time; and use non-linear amplifiers to increase the dynamic range of the recording system.

In this project two such new systems to increase the efficiency of ground motion data recordings will be studied. Optimum design of local and regional instrument arrays will be investigated to minimize total cost and maximize return. The objectives of this project are threefold: to develop more efficient strong-motion instruments with wider dynamic range and versatility, to develop criteria for reliable and cost-effective network design, and to study the dynamic seismic source mechanism by using near field data. This information could be incorporated into theoretical simulation of propagating faults, which would be essential in detailed seismic risk analysis and microzonation in regions with active faults.

Workshop on Research Priorities for Geotechnical Earthquake Engineering Applications; *Felix Y. Yokel*; National Bureau of Standards, Washington, D.C. $20,800 for 8 months beginning April 1, 1977

Various U.S. and foreign universities and institutions are conducting research which includes the many diverse areas of geotechnical engineering. Geotechnical earthquake engineering research provides basic data on design forces and site engineering provisions fundamental to the proper design of earthquake-resistant structures. In order to improve current conventional practice, future research priorities must be identified and closer coordination between researchers and user needs to be established.

This project is developing a workshop on geotechnical earthquake engineering to achieve the following purposes: to establish liaison between the various researchers in the field; to assess the present knowledge and to review the research results to date; to evaluate the research accomplishments as applied to the development of improved earthquake design criteria and to determine needs and priority for future research. A two-day workshop will be held at the University of Texas at Austin for the purpose of obtaining and synthesizing the best professional options concerning the topic of research needs in geotechnical earthquake engineering applications. The workshop will consist of a series of direct group discussions among small numbers of specially invited experts who have agreed to come and to share their opinions and experience. These experts will represent all pertinent fields related to the workshop theme. The ultimate result of the workshop will be a final public report summarizing and synthesizing the expressed opinions in order to establish research priorities in the earthquake geotechnical engineering area.

The proceedings of the workshop will be published as a public report and distributed to professional community through NTIS and other channels. The proceedings will include the technical papers on current research, and recommendations for future research accompanied by summaries of the panel discussions. The results will be used to plan research programs which will be a benefit to the users, such as practicing engineers and architects, building officials, model code groups, regulatory agencies. This project involves the joint effort of the University of Texas and the National Bureau of Standards. This work is in conjunction with the University of Texas at Austin.

Simple Shear Behavior of Fine Grained Soils Subjected to Earthquake and Other Repeated Loading; *Thomas F. Zimmie*; Rensselaer Polytechnic Institute, Troy, New York 12181; $54,400 for 15 months beginning October 15, 1976

When soils fail under earthquake loading the result can be catastrophic. Failures can occur in large earth structures such as slopes and earth dams, and also in foundations. When soils are under earthquake loading, stress is increased due to accelerations which lead to a reduction in the soil strength or shearing resistance. This loss of shear strength under repeated loading is called liquefaction, and is usually applied to the behavior of coarse-grained noncohesive materials. As a result, research has been concentrated on the dynamic response of sands and other noncohesive soils rather than fine grained silts and clays. The behavior

of fine grain soils under earthquake and similar loading is not as clear cut as in the case of the noncohesive soils. Soil behavior, whether static or dynamic, is largely a consequence of pore pressure intensity changes resulting from load application. Because of the differences in permeability between sands and clays, there is quite a difference in behavior between these types of soils. If a sand does not fail because of earthquake loading, it will probabily not fail at all, since the strength will quickly return to normal as time goes on. In the case of clay soils, because of the pore pressure changes, the adverse effects of the earthquake can remain for a long period of time: several months or even years. Failure, if not immediate, can occur a long time after the earthquake. From a practical standpoint, a failure such as this may not appear to be connected with the past earthquake.

The behavior of fine grained soils during earthquakes is not yet clearly understood, and further research is urgently needed. The objective of this research is to understand the behavior of fine grained soil under repeated loading. A theoretical model for strength change of these soils under loads such as earthquakes will be developed. The effects of frequency of loading and load repetition on the behavior of fine grained soil will be investigated. The experimental test results obtained from simple shear tests and triaxial tests will be compared and correlated.

Results of this research will impact on several activities having high national priority, including earthquake engineering, submarine landsliding and construction, ocean engineering, and the construction industry.

WEATHER MODIFICATION

In 1959 the Foundation initiated a basic research program to develop an understanding of the mechanics of weather modification. This program developed a core of knowledge about atmospheric physics and convective cloud dynamics to the extent that, when RANN was formed in 1971, the area was considered ready for application. RANN has built upon this scientific base, broadening it to include the social sciences, and has developed specific program objectives. 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 with regard to the modification of natural weather patterns and the impact of this modification on society.

The objectives of this subelement are to:

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

Research support is concentrated in four areas in FY 1977:

- Inadvertent Weather Modification
- Societal Implications of Weather Modification
- Weather Modification Technology and Evaluation
- Weather Hazard Mitigation

INADVERTENT WEATHER MODIFICATION

The objective of the Inadvertent Weather Modification program 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 and precipitation.

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.

Inadvertent Weather Modification in the St. Louis Area; *August H. Auer, Jr.*; Department of Atmospheric Sciences, University of Wyoming, Laramie, Wyoming 82071; $65,000 for 9 months beginning July 15, 1977

Project METROMEX (Metropolitan Meteorological Experiment), the experiment to determine how a large urban-industrial area can significantly change the weather, has been operating in the St. Louis area for the past six years. 1976 was the final year in the field collecting data. Although the final METROMEX report is due in the near future, the analysis of the large amount of data collected will continue for some time.

The overall goal of the University of Wyoming with METROMEX has been to make comparative observations of urban and non-urban environments to determine processes responsible for differences in boundary layers, wind fields and convective cloud behavior as a result of urban-induced changes in heat, moisture, and aerosols.

The following objectives are to be studied to continue the analysis of METROMEX data and maximize the results to be obtained from the data collected. First, ascertain the role of anthropogenically altered land use on weather. Second, derive heat, moisture, and turbulent fluxes within the boundary layer of urban and rural environments in the St. Louis area. Third, develop power-law relationships for modeling wind speed and direction changes with height for airflow across an urban area and its suburbs. Finally, investigate solar radiation effects on the urban atmosphere.

The Effects of Urban-Industrial Emissions on Downwind Weather Patterns; *Roscoe R. Braham, Jr.*; Department of Geophysical Science, University of Chicago, Chicago, Illinois 60637; $146,000 for 6 months beginning April 1, 1977

The University of Chicago Cloud Physics Group made a valuable contribution to aerosol, cloud and precipitation studies in Project METROMEX which has been completed recently. METROMEX was a five year field study on the effect of a large metropolitan area (St. Louis) on summer rainfall and other weather conditions. Limited measurements by the University of Chicago Group and others indicate that a metropolitan complex also alters condensation and ice nuclei and cloud microstructure in the winter. These urban weather effects may produce low-intensity modulation of weather over large regions extending far downwind, sometimes more than 100 km. from urban sources.

This is a three-year study of anthropogenic modification of atmospheric parameters in a regional setting during winter weather conditions. The field phase is based near Muskegon, Michigan, and centers around measurements made from ground-based cloud physics

equipment and from an NCAR airplane. Emphasis is upon the study of clouds and cloud sensitive nuclei within downwind plumes from Milwaukee and/or Chicago contrasted with similar measurements outside these plumes.

A secondary effort involves the continuation of numerical modling of urban cumulus clouds and of urban boundary layer dynamics. The modeling work integrates previous measurements of summer cloud modification in the St. Louis area and also provides a basis for developing model simulations of the present field observations.

Causes and Impacts of Urban Influences on Precipitation; *Stanley A. Changnon*; Illinois State Water Survey, University of Illinois, Urbana, Illinois 61801; $237,000 for 18 months beginning July 1, 1977

Past research of urban effects on summer weather in the St. Louis area has enumerated abnormal features in thermal, moisture, airflow, precipitation, and severe weather patterns. Initial hypotheses explaining the causes of these abnormalities have been presented in interim Metromex reports.

The primary foucus of this research is to solidify and build on the Metromex findings of urban effects on inadvertent weather modification. The work includes an expanded analysis and integration of the St. Louis case studies, further studies on impacts and utilization, and the analysis of a large available date base in Chicago for comparisons to the St. Louis results. These results provide validation data for simulation models currently being developed for urban area weather. The Chicago/St. Louis comparisons together with the simulation models will be the basis for the next major step in studying inadvertent weather modification in urban areas. The expanded impact and utilization efforts are important in establishing a basis for future policy issues dealing with inadvertent weather modification.

This research focuses on four major efforts: *1*) intensive studies of selected cases of St. Louis data to further sharpen hypotheses explaining the abnormalities defined to date; *2*) analysis of the extensive weather data base available for the Chicago region and comparing and integrating the results of the St. Louis and Chicago studies to sharpen urban weather hypotheses and test the transferrability of concepts derived for St. Louis; *3*) economic and institutional response studies of the impacts of the precipitation abnormalities and the precipitation-related pollutants in the region of urban modified weather; and *4*) dissemination of key results to local, regional, and national groups affected by altered weather.

Workshop on Extended Area Effects of Weather Modification; *Robert D. Elliott*; North American Weather Consultants, 600 Norman Firestone Road, Goleta, California 93017; $30,800 for 6 months beginning July 15, 1977

There is increasing evidence that the effects of intentional weather modification programs may extend over much broader geographic areas than for which the operations are planned. Extensive post hoc analyses of downwind data from previous weather modification experiments throughout the world have shown that precipitation increases of 15 percent to more than 100 percent may occur in areas up to several hundred kilometers downwind of intended target areas in winter projects. The results of summer projects are less clear and both increases and decreases in precipitation are implied.

These results have important national relevance both with respect to augmenting water supplies and for evaluating the socio-economic-political impacts of weather modification. Precipitation enhancement from cloud seeding projects may be much more effective than was previously expected. Effects over large areas may in turn influence broader-scale atmospheric processes and systems. Conflicts may arise between groups since more heterogeneous interests are affected. Adverse interactions may occur among ongoing weather modification programs.

A workshop is being held to define the importance of extended spatial and temporal effects of weather modification and to prepare guidelines and priorities for future research. Specific objectives of the workshop are to: *1*) synthesize and evaluate the evidence for extended area effects, for both intentional and inadvertent weather modification; *2*) assess the societal

implications of extended area effects; and *3*) develop hypotheses and establish priorities for future research aimed at scientific understanding and socioeconomic implications.

A Field Experiment Design to Determine the Extended Area of Effect from Wintertime Cloud Seeding; *Lewis O. Grant*; Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado 80521; $399,700 for 15 months beginning June 1, 1977

One of the most serious public issues in weather modification concerns the downwind effects of attempts to modify precipitation in a given region. This has led to recently publicized inter-state conflicts between Idaho and Washington over rights to atmospheric moisture. The Colorado State University team has recently completed a four-year study of data from downwind areas of a large number of previous weather modification projects. Results have shown precipitation changes from 15 to 100 percent in areas up to several hundred miles downstream of intended cloud seeding target areas. From these data, past experiments at Climax, Colorado, and recently completed physical studies, a preliminary experimental design was developed for an extended area field experiment in Colorado.

This study is developing a field experiment design for determining the effect of wintertime cloud seeding for extended areas downwind of primary targets in the Rocky Mountains. A preliminary design is being refined by computer model simulations of airflow, cloud and precipitation processes and by field measurements which clarify the physical hypotheses to be tested in the experiment. Tracer and modeling studies are being used to optimize the siting of seeding generators and precipitation measurement networks. The discriminative capabilities of radar and aircraft instruments are being tested for their use in physical studies.

Due to the important societal implications of the extended area effects, societal concerns are being included in the overall experimental design. A societal task group is participating in the design study to develop a plan for the societal studies needed to complement the physical science experiment, including integrated studies involving economics, sociology, political science, law, and the environmental sciences.

Third Workshop on Inadvertent Weather Modification; *George D. Robinson*; The Center for the Environment and Man, Inc., 265 Windsor Street, Hartford, Connecticut 06120; $42,000 for 6 months beginning April, 1977

Inadvertent changes in weather resulting from man's activities in industrialization, urbanization, commerce and agriculture have become a growing environmental concern. Metromex and several other inadvertent weather effect studies are presently nearing completion.

This workshop can provide a timely synthesis of these recent research advances and provide an important basis for the planning of future projects in inadvertent weather modification.

The purpose of this workshop is fourfold:

1) Assess the current knowledge of inadvertent weather effects;

2) Determine the unsolved problems, both general and specific to various regions of the United States;

3) Assess methods and resources required to attack these problems; and

4) Establish research priorities based on scientific understanding and socio-economic implication.

The product of this workshop will be an assessment and planning document useful to the development of research programs in advertent weather modification at the National Science Foundation and other Federal agencies.

Statistics and Origin of Haze in the Central United States; *George D. Robinson*; The Center for the Environment and Man, Inc., 275 Windsor Street, Hartford, Connecticut 06120; $49,600 for 12 months beginning July 1, 1977

The increasing role of fossil fuel in federal energy policy raises the concern of serious regional and larger scale impacts on the environment through alterations in the weather and climate. The increasing incidence of haze and its apparent industrial origin makes it one of the most important concerns in inadvertent weather modification. There are preliminary indications that plant growth and crop yield may be affected. Haze of industrial origin in the central United States can deplete solar radiation reaching the ground by five to ten percent and reduce surface air and ground temperatures by one or two degrees Celsius.

This research is investigating the frequency, intensity, nature and origin of atmospheric haze in an area in the midwest, and the reduction of avilable solar energy at the earth's surface by this haze. Joint statistics of visual range, stability of the lower atmosphere, and cloud type and amount are being studied. This allows the estimation of the attenuation coefficient and scale height of the haze, and computation of the depletion of solar radiation. Validating evidence is being sought in the records of recent air quality programs in the St. Louis area.

In addition to the statistical studies, a simple air quality model, previously developed by the investigators, is being used to investigate the origin of the haze and the proportion of sulfate to other particles. Validation of the model is sought in the air quality records of the Environmental Protection Agency.

The results will provide an important step in understanding the characteristics and impacts of industrial haze and will provide a basis for further research on these problems.

Development of an Acoustic Sounder Network for Air Pollution and Land Use Application; *Phillip B. Russell*; Department of Atmospheric Physics, Stanford Research Institute, Menlo Park, California 94025; $11,800 for 6 months beginning June 15, 1977

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

This project is evaluating the application of a network of acoustic sounders for reliable, unattended and continuous observations of mixing depth over the San Francisco Bay Area. This project is developing analysis and interpretation techniques for deriving mixing depths and other information; evaluating the utility of the acoustic sounder for measuring mixing depths; and disseminating data and methodology to appropriate land use planning agencies and air pollution monitors.

Study of Urban Boundary Layer Processes Using a Three Dimensional Hydrodynamical Model; *Fred M. Vukovich*; Research Triangle Institute, Research Triangle Park, North Carolina 27709; $28,000 for 12 months beginning September 1, 1977

The application of theroretical models to the observations made by the Metropolitan Meteorological Experiment (METROMEX) field project is an important step in understanding the processes which produce urban effects on weather and are necessary to test the transferability of METROMEX results to other areas. This recently completed field study of urban weather has collected an extensive set of urban weather data, including unique measurements in the urban boundary layer. The primary objective of this

project is to study the boundary layer processes in the city of St. Louis using observed data to examine and to improve the ability of a three-dimensional primitive equation model to characterize those processes. The observational data include surface and upper air measurements of temperature and wind collected by aircraft and Doppler radar systems as well as standard techniques. In a few cases, airborne turbulent observations are also available.

Results of this study will yield a better understanding of dynamic processes in the urban boundary layer and will improve parameterizations of planetary boundary layer processes.

SOCIETAL IMPLICATIONS OF WEATHER MODIFICATION

The thrust of the Societal Implications of Weather Modification program 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.

The Legal Implications of Inadvertent Weather Modification: METROMEX and the Law; *Ray J. Davis*; School of Law, University of Arizona, Tucson, Arizona 85721; $30,000 for 15 months beginning February 15, 1977

Urban produced weather changes over and downwind of the city of St. Louis have been identified in the research results of Project METROMEX. Marked increases in cloudiness, summer rainfall, and hail have been found in a 1500 square mile area east of St. Louis. The more intense and polluted urban rains lead to 15 percent more runoff, a 100 percent increase in local flooding, and more stream and groundwater pollution.

Project METROMEX identified these weather changes. However, there is also a need to define the social, legal, and economic impacts of these weather abnormalities. This research is to determine the legal implications of inadvertent weather modification and provide an additional perspective to Project METROMEX. Although there have been previous studies of intended weather modification law and air quality control law, there has been no prior examination of the legal ramifications of unintentional weather changes. This research may be helpful in the planning of future research in inadvertent weather modification. The facts, issues, and laws are being examined to ascertain what constraints there are on making public policy as it relates to inadvertent weather modification, and what options are available to deal with those constraints.

A series of working papers on key areas of concern is being prepared which will be compiled and then reviewed by METROMEX scientists, city and state regulatory officials in the St. Louis area, Federal agency administrators, and member of the legal profession in the development of a final research product.

A Comparative Analysis of Public Response to Weather Modification; *Barbara C. Farhar*; Human Ecology Research Services, Inc., 855 Broadway, Boulder, Colorado 80302; $56,600 for 9 months, beginning March 9, 1977

Public acceptance of weather modification activities is a critical aspect of both research and operational programs. Past organized opposition has been effective in terminating ongoing projects and in enacting highly restrictive state legislation for the regulation of weather modification projects. Public acceptance of a program may, at least in part, depend upon timely management decisions. Past research has established basic hypotheses associated with acceptance and rejection of weather modification in the United States.

This research builds on the results of seven years of sociological study of public response to an decision processes involved in weather modification. Data have been collected by both individual surveys and community level information monitoring. Emphasis is being given to an extensive four year sampling program in South Dakota, although citizen interview surveys have been conducted in six states and community activities have been monitored in twenty-four states. Analyses could yield both descriptive information on social re-

sponse to weather modification in South Dakota and testing of hypotheses concerning acceptance and rejection processes. Successful validation of the hypotheses together with response patterns could provide the framework for the development of a casual model of the acceptance/rejection process. Management recommendations are to be derived from an evaluation of those factors which are influenced by policy choice.

METROMEX: Social Impacts of Inadvertent Weather Modification: A Comparative Study; *Barbara C. Farhar*; Human Ecology Research Services, Inc., 855 Broadway, Boulder, Colorado 80302; $60,300 for 13 months, beginning February 10, 1977

Urban-caused weather changes downwind of St. Louis have been identified in Project METROMEX, a six-year field program currently being completed. In addition to defining and explaining the urban-industrial causes of abnormalities in summer precipitation and other weather parameters, the program also seeks to define the socio-economic impacts of these weather abnormalities.

This study examines the social impact of the weather abnormality, including such questions as the level of awareness of area residents about the abnormality, adjustments made to changed weather patterns, and the behavior of relevant organizations with regard to the identified weather effects. A comparative case study design is to be used, comparing a community (or township) in the area affected most heavily by the weather abnormality with a match community upwind. Samples of residents and potentially affected organizations are to be interviewed in each community. Both statistical and descriptive data analysis are to be carried out on the focused interviews and unobtrusive data collected from various documents and reports.

Adjustments to the weather abnormality are to be measured and alternate public policy options are to be identified. These results will be applicable to the planning of future research on inadvertent 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 80251; $12,400 for 6 months beginning January 5, 1977

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 modfication 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.

This supplemental funding supports a workshop during November 1976 at Vail, Colorado, jointly sponsored by the Bureau of Reclamation, Department of Interior and the National Science Foundation. A group of experts is being assembled to assess possible ecological impacts of nucleating agents used in weather modification. Utilization of the results of this meeting is expected to be in the following areas: *1*) the preparation of environmental impact statements by the Federal agencies and other weather

modifiers, and *2*) the formulation of research requirements and preliminary plans to investigate important facets of the program still needing study.

Management of Nucleating Agents Used in Weather Modification: Development of Microbial Threshold Toxicity Criteria; *Donald A. Klein*; Department of Microbiology, Colorado State University, Fort Collins, Colorado 80523; $28,000 for 9 months, beginning February 10, 1977

A major environmental issue in cloud seeding is the impact of seeding agents on the surrounding ecosystem. The primary use of heavy metal compounds, particularly silver iodide, underlies this concern. Previous studies have been sporadic and generally directed toward high impact, short-term effects. This award represents an ongoing effort to substantiate longer-term cloud seeding effects through a combination of laboratory, test plot, and operational generator site studies.

Project activities are concentrating on soil and aquatic microbial ecosystems, since these trophic levels have been found to be the most critical for accumulation of such agents. It is also concentrating on the location of ecologically important mineralization processes which may be sensitive to the presence of these materials.

The methods being used 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. Laboratory analyses of potential new agents, including silver iodide-titanium oxide mixtures and silver iodide-ammonium iodide mixtures are also being carried out.

WEATHER MODIFICATION TECHNOLOGY AND EVALUATION

The objective of the Weather Modification Technology and Evaluation program is to develop specific supporting weather modification technologies with emphasis on precipitation augmentation.

Assessing Midwest Cloud Characteristics for Weather Modification; *Bernice Ackerman*; Illinois State Water Survey, University of Illinois, Urbana, Illinois 61801; $98,000 for 12 months beginning July 15, 1977

As droughts in the Midwest have become more frequent and the realization has grown that the relatively favorable climate for agriculture may become progressively worse in the future, the pressures for weather modification have increased over the past few years. There are however, major uncertainties surrounding the capacity to modify conventive clouds, the dominant rain producers during the critical production periods for crops.

This research is to compile and analyze sample statistics of variables which are important in cloud development and precipitation processes, and their modification as a function of mesoscale and macroscale atmospheric conditions. It is determining the relationships and synthesizing the results of the analysis of the interior cloud variables and other cloud parameters, environmental conditions and observed rainfall. It is also investigating in the Midwest the capability to predict results from the one-dimensional models used for cloud seeding operations.

The research involves the analysis of *in situ* cloud observations from aircraft in combination with radar, rainfall, special radiosonde and other supporting measurements. Particular emphasis is placed on bulk cloud condensate and its partition between cloud and precipitation water. Multiple soundings are to be used to determine the effects of space-time separation between cloud and sounding location on the validity of model predictions of maximum cloud growth.

Utilization activities include widespread dissemination of the results to the user community, such as various governmental agencies, commercial cloud seeders, farm groups, and others.

Laboratory Studies of Organic Ice Nuclei for Cloud Seeding; *Norihiko Fukuta*; University of Utah, Salt Lake City, Utah 84112; $48,600 for 12 months beginning October 1, 1977

The objective of this research is to characterize the nucleation and decay properties of two organic nucleants being developed as a substitute for silver iodide for use in cloud seeding. Metaldehyde and 1.5 dihydroxynaphthalene exhibit excellent seeding properties and have advantages over silver iodide such as: *1*) low cost and long term availability, *2*) minimizing the downwind effect, and *3*) eliminating the potential ecological effects of the heavy metal silver.

The research includes two laboratory studies: *1*) the evaporation and/or decay of organic smoke particles, the basis for the decreased downwind effects of cloud seeding, and *2*) the "vapor activation" ice nucleation by metaldehyde, and the behavior of the resutlant double plate and vaned ice crystals which may provide the opportunity for fast and efficient nucleation because of the unusually rapid ice crystal growth.

Testing and Calibration Program for Cloud Seeding Materials, Seeding Generators, and Nucleus Observing Instruments; *Dennis M. Garvey and Lewis O. Grant*; Department of Atmospheric Sciences, Colorado State University, Fort Collins, Colorado 80521; $78,500 for 15 months, beginning July 1, 1976

The objective of this grant is to provide a standard facility for comparing the output from ice nucleation materials, cloud seeding generators, and ice-nucleus measuring instrumentation. This facility supports weather modification activities worldwide, but especially the weather modification community in the United States.

The Cloud Simulation and Aerosol Laboratory is maintained by the Colorado State University as a testing and comparison facility to support weather modification and cloud physics research. Major utilization of the facility is by Federal agencies and the commercial cloud seeding community. For example, most of the tesing and calibration now underway is in support of Project Stormfury (hurricane modification) Oceanographic and Atmospheric Administration in support of Project Stormfury (hurrican modification) and the Florida Area Cumulus Experiment for precipitation augmentation. The Department of the Interior, Bureau of Reclamation High Plains Experiment will conduct a major testing and calibration program in the near future. The facility has and will continue to provide support for the several National Science Foundation research efforts in this area. The commercial cloud seeding industry also tests and compares its seeding generators at the facility.

The Generation and Use of Cirrus Clouds as a Tool for Weather Modification; *William A. Gray*; Department of Atmospheric Sciences, Colorado State University, Fort Collins, Colorado 80521; $70,000 for 18 months beginning July 15, 1977

The objective of this research is to explore the feasibility of artificicially generating cirrus clouds, to numerically model and observe the influence of cirrus on mesoscale weather, and to study the amount and diurnal variation of natural cirrus clouds to determine whether mesoscale weather modification by artificially produced cirrus clouds in feasible.

The effort consists of an observational research program utilizing infrared data from satellites, data from the Global Atmospheric Research Program Atlantic Tropical Experiment and from the Northwest Pacific, and cirrus cloud versus surface temperature data over the United States. The second portion of the study consists of numerical modeling of the effects of cirrus clouds on the troposphere and mesoscale weather using two and three dimension models currently in operation. Possible means of producing cirrus clouds include seeding saturated layers of the upper atmosphere, jet aircraft condensation trails positioned so as to spread throughout cold moist layers of the upper atmosphere, or injecting carbon black into the atmosphere with the heating resulting from solar energy absorption producing the cirrus cloud.

Operational Cloud Seeding Evaluation Techniques; *Paul Schickedanz*; Atmospheric Science Section, Illinois State Water Survey, University of Illinois, Urbana, Illinois 61801; $116,000 for 18 months beginning July 1, 1977

One of the continuing problems in weather modification is the evaluation of operational cloud seeding programs, those modification efforts carried out on a day-to-day basis without benefit of randomization or other statistical design features to facilitate evaluation. In fact, most of the weather modification activities carried out around the world are operational efforts, and most of the data available for evaluating weather modification are nonrandomized. Thus, if it were possible to develop statistical tools for evaluating operational weather modification results, the amount of data available for such work would be considerably expanded from the present data base of statistically randomized experiments.

Another problem in the evaluation area is the unpredictability and large natural variability of precipitation. How can the effect of weather modification activities be determined if what would have happened in absence of modification efforts cannot be specified?

The objectives of this research are to develop and test evaluation techniques for operational weather modification programs. The award is *1*) developing statistical-physical methods for evaluation of operational seeding programs; *2*) evaluating an adequate number of operational programs to test the techniques; *3*) planning efforts for future activities regarding the evaluation of operational weather modification programs, and *4*) insuring the transfer of research findings and results to the user community, such as various governmental agencies, commercial cloud seeders. farm groups and others.

Evaluation and Design of Weather Modification Experiments; *Joanne Simpson*; Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia 22903; $149,900 for 21 months; beginning December 17, 1976

There are a number of weather modification cloud seeding experiments being conducted around the country, each attempting to evaluate the results of the seeding treatment applied. This research involves the statistical evaluation of data to determine the effect on precipitation of dynamic seeding of cumulus clouds over southern Florida, and the transfer of this technology to other geographic areas. The data used is from the National Oceanographic and Atmospheric Administration Florida Area Cumulus Experiment (FACE).

Cumulus clouds and cloud systems produce about three-fourths of the world's rainfall. The FACE data includes (and at other levels using radiosondes and radar measurements) including temperature, pressure, humidity, naturally occurring nuclei, precipitation, radar echo intensity and motion, wind direction and speed, and cloud parameters such as height of the base and tops, motion and coverage.

Evaluation will be accomplished using the combined tools of model simulation, classical and Bayesian statistics, and physical theory and observations. Various major hail experiments are also being assessed, not only for evaluation techniques used, but for seeding procedures, operational techniques, etc. with the results to be provided to the National Hail Research Experiment (NHRE) at an early date to assist in the redesign of the NHRE. Ice nuclei data from both NHRE and FACE are being analyzed, and new silver iodide data is being collected and analyzed. The improved statistical methods being developed will be utilized in the design and evaluation of major weather modification experiments for hail suppression and precipitation augmentation.

Hail Suppression Seeding Technology: An Assessment Based on Silver Content in Rain and Hail; *Joseph A. Warburton*; Desert Research Institute, University of Nevada, Reno, Nevada 89507; $55,900 for 12 months beginning March, 1977

One of the most important questions in weather modification is related to the effectiveness of the seeding technique. Does the silver iodide released actually get to the right location in the clouds in sufficient concentration at the proper time to glaciate the mositure and influence the precipitation? In large thunderstorms which may produce hail, the precise time and location of the silver iodide in the cloud may be extremely important in the formation of hail embryos. In 1973, the most recent year for which complete information has been analyzed, hail damage in the United States to crops was $680,000,000 with additional property damage bringing the total to over three quarters of a billion dollars.

The overall objective of this research is to analyze the National Hail Research Experiment data already collected to establish the role played by the silver iodide nuclei, the effectiveness of the seeding techniques utilized, and determine where the seeding material went.

The objective is being achieved by means of a detailed analysis of the silver content of the precipitation, both rain and hail, collected in hail suppression experiments, the radar data, the aircraft seeding data, and the radiosonde data. These analyses are correlated with the storm analyses accomplished by other participants to determine the trajectories and history of the seeding material injected into the storms.

WEATHER HAZARD MITIGATION

The objective of the Weather Hazard Mitigation program 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 extent to which hail suppression might be accomplished economically on an operational basis.

National Hail Research Experiment; *Donald Veal*; National Center for Atmospheric Research, Boulder, Colorado 80302; $2,006,000 for 12 months beginning October 1, 1976

In the United States the annual loss due to hail storms is over three quarters of a billion dollars. While economic incentive to reduce damaging hail has long existed, it was not until the early 1970's that a definite 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 research objectives of NHRE are: *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 study of economic, social, environmental, and legal impacts to assess costs of a hypothetical hail factors relevant to the ultimate implementation of an operational hail suppression program.

A large field research program (not a randomized seeding experiment) was carried out in northeast Colorado during the summer of 1976. Planned observations of storms by a network of Doppler radars and several aircraft including the armored T-28 aircraft carrying greatly improved insturuments, together with a variety of more convential measurements, represent a major advance in the ability of NHRE to test hypotheses regarding storm processes and modification by direct observations. Analysis of the data collected will continue. Following sufficient progress in the development of hailfall covariates and classification variables, and better information about seeding location, amount, effectiveness, and timing, an improved randomized seeding experiment will be designed.

SOCIETAL RESPONSE TO NATURAL HAZARDS

The broad objective of the Societal Response to Natural Hazards subelement is to evaluate recent and ongoing disaster-related programs of mission agencies at the Federal, State, and local levels and in the private sector. This subelement is designed to support research to understand and evaluate the benefits and costs of different combinations of adjustments to natural hazards and disasters: prediction and warning, disaster preparedness, physical protection, land use management, insurance, and relief. Research is also aimed at finding commonalities between adjustments to different hazards.

The objectives of this 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; and
- Design, develop, and test alternative approaches to enable society to prepare for, respond to, and recover from disasterous events.

A Longitudinal and Cross Cultural Study of the Post Impact Phases of a Major National Disaster: The February 6, 1976 Guatemalan Earthquake; *Frederick L. Bates*; Department of Sociology, University of Georgia, Athens, Georgia 30602; $144,925 for 12 months beginning June 1, 1977

For many years the United States and other national societies, impelled by humanitarian and other considerations, have responded generously to the plight of both domestic and foreign disaster victims. U.S. disaster policies are based largely on humanitarian values, common sense, and conventional wisdom. The United States has a substantial amount of research opportunities to study the social impacts of floods, tornadoes, and hurricanes, but is lacking in the areas of earthquakes because of their sporadic occurence in the United States. Hence, there is a need for research in other countries on the social impacts of earthquakes.

This project is focused on a comprehensive, in-depth longitudinal study of the short-and long-range socioeconomic effects of a major disaster on a national society: the February 4, 1976 Guatemalan earthquake. This tragic disaster provides a unique research opportunity to study: *1*) the impact of an earthquake on a nation and its society; *2*) the effects of the costly U.S. Government and private sector disaster relief on the impacted society and its recovery processes; *3*) the manner in which the U.S. relief was coordinated with similar responses from more than 30 other countries; and *4*) the effects of the earthquake and the relief efforts on the U.S. sponsored development programs in Guatemala.

The findings and rcommendations from this study are designed to serve two major functions: *1*) to prompt and facilitate the reconsideration of past and present U.S. Federal and private sector foreign disaster programs, especially in Latin America; and *2*) to aid the U.S. in preparing policies and programs for the societal impact of its next major earthquake, a low probability, high risk national catastrophe.

Search and Rescue Missions in Natural Disasters and Remote Settings; *Thomas E. Drabek;* Department of Sociology, University of Denver, Denver, Colorado 80208; $261,300 for 24 months beginning September 1, 1977

Searching for and rescuing potential disaster victims is a primary activity in post-disaster situations. Many search and rescue activities are also carried out in wilderness settings. This 24 month study is to provide an initial empirical data base on search and rescue missions in disaster and remote settings which can be related to relevant policy issues. Three objectives are to be pursued. First, seven field studies of search and rescue missions are to be conducted: five following large natural disasters and two within remote areas. Interviews are to be a primary source of data in these field studies, including some conducted with local and state officials and members of informal groups. Second, an assessment of search and rescue demand and capacity levels is to be made in two different states. Third, a major dissemination effort is to be made to maximize the utilization of findings by potential user groups, including those at the local, state and national levels. Workshops and other presentations are to be made and major publications are being prepared which will be distributed to user groups.

Community Response to Natural Hazard Warnings; *Robert K. Leik*; Department of Sociology, University of Minnesota, Minneapolis, Minnesota 55455; $177,500 for 12 months beginning May 15, 1977.

Based on sustained and adequate research findings, man's technological ability to evaluate, predict, and monitor some natural hazards, such as hurricanes and to some degree earthquakes, has increased significantly over the last few decades. However, as the nation's major disasters continue to demonstrate, there has not been a comparable growth in man's ability to predict and control the response of individuals, families, organizations, and communities to the disaster warning which the above technology enables the mission agencies to disseminate. Support for research on the human and social components of warning response systems has been infrequent and inadequate.

Prompt and appropriate responses of these components to disaster warnings are essential if lives are to be saved, injuries minimized and property losses reduced. This three year project provides information on how families and organizations in the community at risk to hurricanes, tornadoes, floods and earthquakes perceive, prepare for, make decisions on, and respond to disaster warnings. The project's research questions are designed to clarify how warning responses are related to: *1*) content and timing of message; *2*) interorganizational relations; *3*) incogruity between normal and emergency relations; *4*) predisaster planning; *5*) individual decisions; and *6*) social and economic constraints. The pilot phase of the project involves development and pretesting of interview data from households and organizations in four communities. Controlled laboratory experiments are an integral part of the project. First experiments determine the adequacy and appropriateness of questions to be asked in field interviews. Later experiments are to aid in the interpretation of this field. Communities, households and organizations are being studied prior to each hazard season, and will be studied after a warning/impact has been received.

State Government Policy Options for the Utilization of Earthquake Prediction Technology; *Hirst Sutton*; Council of State Governments, 1225 Connecticut Avenue, N.W., Washington, D.C. 20036; $177,500 for 12 months beginning January, 1977

Historically, the catastrophic and dramatic concequences of earthquakes have generally made these disasters especially newsworthy. However, man's scientific understanding of the causes of earthquakes has increased significantly during the last twenty years. More recently, some scientists have advanced the claim that precise and reliable earthquake prediction would soon be a reality. National and international interest in this important claim has attracted the attention of other scientists and public officials who are concerned with the social, economic and legal implications of earthquake predictions.

Basic earthquake research and the development of earthquake prediction technology is largely the responsibility of the U.S. Geological Survey. Planning for and responding to earthquakes and earthquake prediction is largely a state and lcoal matter. There are still many unresolved social policy and program questions to be quickly attached and resolved if the emerging prediction technology is to be a positive tool for man and society.

This award presents a plan for focusing attention on the prediction problem at state and local levels. It contains a plan for arriving at alternative courses of action. The project staff is to perform these tasks by convening a general conference of state and other public officials for the purpose of informing the conferees and exchanging views on such related matters as the state of the art of earthquake prediction, and responsibilities and procedures for issuing earthquake warnings. Prior to the conference, three select committees are to be established: *1*) state attorney generals, to address legal questions and possible present or future needs for state legislation; *2*) state planning officials, to give special attention to mitigation opportunities and recovery programs; and *3*) state directors for disaster preparedness, to examine operational issues related to earthquake hazard warning and response.

Policy position papers will be drafted and submitted for consideration to organizations with related responsibilities. Products from this relatively modest project will produce programs designed to deal with the first credible earthquake prediction before it is issued.

Disaster Knowledge and Beliefs and Emergency Planning; *Dennis E. Wenger*; Department of Sociology, University of Delaware, Newark, Delaware 19711; $34,300 for 12 months beginning June 1, 1977

People can be expected to react to disasters partially on the basis of the knowledge and beliefs they possess about such events. Thus, it is crucial that residents of disaster-endangered communities possess a realistic understanding of disaster situations. This is particularly true of officials in emergency-relevant organizations who have the responsibility for disaster planning. If such persons do not have a realistic perspective on the disasters which their communities face, this could be reflected in their disaster plans and preparations and render them less useful.

This research is important because it is to make a systematic assessment of the knowledge and beliefs held by residents and emergency officials in three disaster prone communities and determine the extent to which such understandings do enter the disaster planning process. Additionally, this project is to determine the source of public knowledge about disaster situations; that is, to what extent it comes from interpersonal contacts, the mass media, or public education programs.

There are at least two major public policy implications of this research. First, by identifying the possible types of misinformation held by residents of disaster threatened communities, as well as gaps in their knowledge, this project can increase an understanding of the kinds of disaster related information the public needs most. Second, by identifying how disaster knowledge is acquired by the public, the project can increase an understanding of how to disseminate disaster related information. The project will result in specific recommendations to officials in emergency organizations regarding these kinds of policy issues.

APPENDIX

The Division of Advanced Environmental Research and Technology—FY 1977 Awards*

Principal Investigator/ Institution	*Title*	*FY 1977 Amount**	*Effective Date/Award Duration*	*Page*
	MANAGING THE NATURAL ENVIRONMENT			
	CHEMICAL THREATS TO MAN AND ENVIRONMENT			
	Airborne Contaminents			
Alan R. Bandy Drexel University	Field Studies of Biologically Produced Atmospheric Sulfur Compounds	$87,700	5/15/77 12 months	7
Robert S. Braman University of South Florida	Hydrogen Sulfide and Reduced Forms of Sulfur in Air	$68,300	7/1/77 12 months	7
Peter R. Buseck Arizona State University	Quantitative Electron Microprobe Analysis of Individual Airborne Particles	$206,900	1/1/77 24 months	8
Robert L. Byer Stanford University	(See Edward R. Murray)			
Douglas D. Davis Georgia Institute of Technology	Global Atmospheric Measurements Experiment on Tropospheric Aerosols and Gases (GAMETAG)	$65,000	1/15/77 12 months	8
Richard S. Eng Laser Analytics, Inc.	Improved Sensitivity of Laser Absorption Techniques for Atmospheric Pollutant Monitoring	$211,500	8/15/77 12 months	9
Glen E. Gordon University of Maryland	Sources, Transformations, and Chemical Nature of Atmospheric Pollutants	$393,300	9/1/77 12 months	9
Robert K. Gould AeroChem Research Laboratories, Inc.	Aerosol Characterization in Real Time	$113,800	8/15/77 12 months	10
Tetsuo Hadeishi Lawrence Berkeley Laboratory	Technology Transfer of Zeeman Atomic Absorption Technique for Environmental Trace Analysis	$99,700	8/1/77 12 months	10
Robert T. Ku Lincoln Laboratory/MIT	Diode Laser Multi-Pollutant Ambient Air Monitoring	$60,000	1/25/77	11
Volker A. Mohnen State University of New York at Albany	Measurement of Sulfur Dioxide Oxidation on Particulate Surfaces	$231,100	5/15/77 24 months	11
Edward R. Murray Stanford University	Remote Measurement of Air Pollutants	$167,000	8/1/77 12 months	11

* 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)

Principal Investigator/ Institution	*Title*	*Amount/ FY of Award*	*Effective Date/ Duration*	*Page*
Tihomir Novakov University of California Lawrence Berkeley Laboratory	The Role of Primary Particulates in Urban Air Pollution	$222,500	10/1/77 12 months	12
Tihomir Novakov Lawrence Berkeley Laboratory	Study of Chemistry of Atmospheric Particulates	$132,637	10/1/76 12 months	13
James N. Pitts University of California, Riverside	Chemical Transformations in Photochemical Smog and Their Application to Air Pollution Control Strategies	$350,000	1/1/77 12 months	13
F. Bach Sellers Panametrics, Inc.	The Role of Solar Ultraviolet Radiation in the Formation of Hydroxyl Radicals in the Troposphere	$37,200	3/1/77 12 months	14
Alvin H. Vanderpol Meteorology Research, Inc.	Application of Computer Graphics to Air Quality Data Analysis	$159,200	9/1/77 24 months	14

CHEMICAL THREATS TO MAN AND THE ENVIRONMENT

Environmental Assay Methodology

Silverio P. Ameida Virginia Polytechnic Institute and State University	A Water Pollution Monitoring Laser Optical System	$10,300	8/1/77 2 months	15
Paul O. Fromm Michigan State University	Effects of Pollutants on Gills of Fresh Water Fishes	$27,600	7/1/77 12 months	15
Justin S. Garvey Syracuse University	Immunological Studies of Cadmium and Zinc Binding Proteins	$109,100	7/1/77 24 months	16
T. C. Hsu University of Texas—M. D. Anderson Hospital and Tumor Institute	Cytogenetic Effects of Mutagens and Mitotic Poisons on Mammalian Cells	$73,400	1/15/77 12 months	16

Metals and Organometallics

Paul B. Hammond University of Cincinnati	Sources of Lead in Children	$5,800	8/1/77 3 months	18
Gary L. Rolfe University of Illinois at Urbana-Champaign	An Interdisciplinary Study of Environmental Pollution by Lead and Other Metals	$17,700	5/1/77 6 months	18
Kenneth J. Yost Institute of Environmental Health, Purdue University	The Environmental Flow of Cadmium and Other Trace Metals	$216,500	1/1/77 12 months	19

Principal Investigator/ Institution	*Title*	*Amount/ FY of Award*	*Effective Date/ Duration*	*Page*
	Organic Chemicals of Commerce			
Martin Alexander Cornell University	Effects of Chemical and Physical Properties of Organic Compounds on their Biodegradation	$140,000	2/1/77 12 months	20
Cary C. T. Chiou Oregon State University	Chemodynamic Studies on Bench Mark Industrial Chemicals	$4,000	3/10/77 12 months	21
Barry Commoner Washington University	Identification of Mutagenic Organic Compounds in Environmental Samples	$199,900	7/1/77 12 months	21
David H. Fine Thermo Electron Corp.	N-Nitroso Derivatives of Pesticides and Other Chemical Formulations	$301,500	12/13/76 12 months	22
Ronald A. Hites Massachusetts Institute of Technology	Fates of Industrial Synthetic Organic Chemicals: A Case Study	$197,400	7/1/77 12 months	22
Walter J. Maier University of Minnesota	Characterization of Aquatic Organics and Complexes	$206,700	6/15/77 12 months	23
Theodore Mill Stanford Research Institute	Chemical Oxidation Processes in Aquatic Environments	$7,990	6/1/76 24 months	23
Clarence B. Owens Florida Agricultural and Mechanical University	Exploratory Study of Exposure of Migrant Workers to Pesticides and Pesticide Residues	$67,600	6/1/76 0 months	24
Enrico L. Quarantelli Ohio State University	Socio-Behavioral Responses to Chemical Hazards	$188,600	9/1/77 12 months	24
Eriks Leitis Westgate Research Corp.	An Investigation Into the Chemistry of the UV-Ozone Water Purification Process	$93,600	5/15/77 12 months	25
Kenneth J. Yost Purdue University	Cancer Mortality in an Urban-Industrial Environment: A Planning Study	$38,800	5/1/77 12 months	25
	Program Development and Utilization			
Delbert D. Hemphill University of Missouri, Columbia	Eleventh Annual Conference on Trace Substances in Environmental Health	$15,100	6/1/77 12 months	27
John C. Kolojeski Clement Associates, Inc.	An Evaluation of Toxicological Information Relevant to Future Testing Requirements for Hazardous Chemical Substances and Mixtures	$142,793	4/1/77 3 months	27
Robert H. Ross Oak Ridge National Laboratory	Information Support Services for Chemical Threats to Man and the Environment Program	$150,000	7/1/77 12 months	28
James M. Witt Oregon State University	Symposium on Terrestrial Microcosms and Environmental Chemistry	$62,500	6/1/77 12 months	28

Principal Investigator/ Institution	*Title*	*Amount/ FY of Award*	*Effective Date/ Duration*	*Page*
	MANAGING THE NATURAL ENVIRONMENT			
	REGIONAL ENVIRONMENTAL MANAGEMENT			
	Environmental Risk Evaluation			
Richard Greley The Mitre Corporation	Application of the Entropy Law to Evaluations of Pollution Control Alternatives	$39,000	7/15/77 12 months	30
Ivars Gutmanis Sterling Hobe Corporation	Development and Testing of Risk-Benefit-Cost Analysis for Policy Formulation	$154,000	9/1/77 12 months	30
Roger E. Kasperson Clark University	Identifying, Evaluating and Managing Environmental Risks—Part I	$265,900	8/1/77 17 months	31
Paul Slovic Decision Research, A Branch of Perceptronics, Inc.	Identifying, Evaluating and Managing Environmental Risks—Part II	$208,300	8/15/77 17 months	31
	Land Use			
Michael F. Brewer Academy for Contemporary Problems	Land Use Dilemmas and Public Policy: An Assessment of Research Needs	$24,900	6/1/77 4 months	33
Charles D. Craig Oregon State University	An Air Quality Model of Agricultural Field Burning in Oregon's Willamette Valley	$110,400	7/27/77 12 months	32
E. Wendell Hewson Oregon State University	An Air Quality Model of Agricultural Field Burning in Oregon's Willamette Valley	$70,600	11/1/76 9 months	32
James E. Hoben U.S. Department of Housing and Urban Development	Local Land Use Development Management Through Capital Improvements Programming	$80,000	9/21/77 12 months	33
Janice R. Hutton Woodward-Clyde Consultants	Analysis of the Adoption and Implementation of Community Land Use Regulations for Flood Plains	$208,300	8/15/77 12 months	34
Dennis S. Mileti Woodward-Clyde Consultants	(See Janice Hutton)	$208,300	8/15/77 12 months	
Daniel A. Mazmanian Pomona College, CA	Collaborative Research on an Analysis of the Implementation of State Land Use Policy: Part A	$83,900	7/1/77 18 months	34
Robert C. Reynolds, Jr. Dartmouth College	Collaborative Research on Assessment of Man's Activities in the Lake Powell Region—Studies on Physical Limnology	$4,600	6/1/77 6 months	34
Paul A. Sabatier University of California, Davis	Collaborative Research on an Analysis of the Implementation of State Land Use Policy: Part B	$59,600	7/1/77 18 months	35
William E. Shands Conservation Foundation	An Assessment of Conflicts Between Federal Resource Lands and Adjacent Non-Federal Lands	$43,400	8/1/77 6 months	35

Principal Investigator/ Institution	*Title*	*Amount/ FY of Award*	*Effective Date/ Duration*	*Page*
Nelson M. Rosenbaum Urban Institute	Assessment of Enforcement and Compliance in State Land Use Regulation	$243,600	8/15/77 24 months	36
Nelson M. Rosenbaum Urban Institute	Assessment of Programs for Public Participation in State Land Use Decision-Making	$9,150	1/1/77 5 months	36
	Regional Environmental Systems Evaluation and Synthesis			
Oscar Fisch Ohio State University	Evaluation and Testing of NSF-RANN Sponsored Land Use Modeling Projects With Ohio as a Test Case	$174,900	8/15/77 15 months	37
John E. Gannon University of Michigan	Environmental Communications in Water-Oriented Communities	$35,800	10/1/77 15 months	37
Brian W. Mar University of Washington	Assessment of Selcted RANN Regional Environmental Systems Modeling Projects: Transfer and Comparability Testing	$53,500	4/15/77 2 months	38
	Regional Policy and Decisionmaking			
Gunter Schramm University of Michigan	Analysis of Positive and Negative Aspects of Time Extensions in Environmental Decison Making	$106,400	7/1/77 11 months	39
	Residuals Management			
P. C. Cheo The California Arboretum Foundation	Mechanism of Virus Inactivation in Soils Injected with Municipal Wastewater and Treatment Plant Sludges	$39,000	5/15/77 12 months	40
Jack E. Collier Collier Worm Ranch	Conversion of Muncipal Wastewater Treatment Plant Residual Sludges into Earthworm Castings for Use as Topsoil	$9,700	7/15/77 12 months	40
Charles Finance Media Four Productions	Synthesis of a Municipal Wastewater Sludge Management System	$49,640	7/18/77 4 months	41
Carlos R. Guerra Public Service Electric and Gas Company	Utilization of Waste Heat from Power Plants in Aquaculture	$527,100	9/1/77 24 months	41
Carlos R. Guerra Public Service Electric and Gas Company	Utilization of Waste Heat from Power Plants in Aquaculture	$198,232	9/1/76 24 months	41
C. Frederick Gurnham Gurnham and Associates, Inc.	Control of Heavy Metal Content of Municipal Wastewater Sludges	$110,900	5/15/77 18 months	42
Roy Hartenstein State University of New York, Syracuse	Utilization of Soil Invertebrates in Stabilization, Decontamination and Detoxification of Residual Sludges from Treatment of Wastewater	$111,700	6/1/77 12 months	42
Stephen C. Havlicek Georgia Institute of Technology	Effect of Infrared Radiation on Compaction of Municipal Wastewater Sludges	$21,900	7/1/77 12 months	42

Principal Investigator/ Institution	*Title*	*Amount/ FY of Award*	*Effective Date/ Duration*	*Page*
Robert S. Ingols Georgia Institute of Technology	(See Stephen C. Havlicek)			
Robert L. Irvine University of Notre Dame	Application of Sequencing Batch Reactors for Treatment of Municipal and Industrial Wastewater	$76,800	7/1/77 12 months	43
Mary Beth Kirkham Oklahoma State University	Agricultural Value of Irradiated Municipal Wastewater Treatment Plant Sludges	$87,800	4/15/77 24 months	43
Jack V. Matson University of Houston	Feasibility of Eliminating Discharges of Pollutants from Cooling Towers	$53,200	5/15/77 24 months	44
Theodore G. Metcalf University of New Hampshire	Disinfection of Enteric Viruses by Use of Energized Electrons	$35,000	7/1/77 12 months	44
Howard T. Odum University of Florida	Utilization of Cypress Wetlands for Management of Muncipal Wastewater Treatment Plant Effluents	$91,500	6/1/77 24 months	44
Wesley O. Pipes Drexel University	Water Quality and Health Significance of Bacterial Indicators of Pollution	$32,500	6/1/77 12 months	45
Bernard P. Sagik The University of Texas at San Antonio	Potential Health Risk Associated with Injection of Residual Domestic Wastewater Sludges into Soils	$89,200	8/1/77 12 months	45
Josef J. Schmidt-Collerus Denver Research Institute	Characterization of Contaminents in Oil Shale Residuals and the Potential for their Management to Meet Environmental Quality Quality Standards	$20,000	9/2/77 4 months	46
James L. Smith Colorado State University	Land Management of Subsurface-Injected Wastewater Liquid Residuals	$15,400	4/1/77 5 months	46
Jeffrey C. Sutherland Williams and Works, Inc.	Use of Wetlands for Management of Pond-Stabilized Domestic Wastewater	$6,400	4/1/77 4 months	46
John G. Trump Massachusetts Institute of Technology	High Energy Electron Irradiation of Municipal Wastewater Liquid Residuals	$285,000	5/1/77 12 months	47
John G. Trump Massachusetts Institute of Technology	High Energy Electron Irradiation of Municipal Wastewater Liquid Residuals	$285,000	9/1/77 12 months	47
Thomas D. Waite Northwestern University	Ferrate Ion Disinfection of Municipal Wastewater	$108,200	3/1/77 19 months	47
	Urban Hydrology			
William H. Bruvold University of California, Berkeley	Consumer Response to Urban Drought in Central California	$37,500	6/1/77 12 months	49
Stanley A. Changnon, Jr. Illinois State Water Survey	Hydrometeorological Studies Addressing Urban Water Resources Needs	$236,700	2/1/77 12 months	49

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Alan S. Cohen Argonne National Laboratory	Water Pollution and the Urban Economy	$145,000	2/1/77 12 months	50
Charles Goldman Institute of Ecology, University of California, Davis	The Impacts of Nutrient Loading and Atmospheric Contaminants on the Water Quality of Lake Tahoe, California-Nevada	$85,700	6/1/77 12 months	50
Mark Hoffman Teknekron, Inc.	A Case Study of the San Francisco Bay Area	$341,200	7/1/77 12 months	51
George S. Tolley University of Chicago	Water Pollution and the Urban Economy	$155,000	2/1/77 12 months	51
Vujica M. Yevjevich Colorado State University	Conference on Drought Research Needs—December 5-9	$49,000	6/15/77 12 months	51

DISASTERS AND NATURAL HAZARDS

EARTHQUAKE ENGINEERING

Design

Christopher Arnold Building Systems Development, Inc.	Building Configuration and Seismic Design	$199,400	7/15/77 18 months	55
James M. Becker Massachusetts Institute of Technology	Seismic Resistance of Precast Concrete Panel Buildings	$252,000	12/20/76 24 months	55
Lynn S. Beedle Lehigh University	Stability of Structures Under Static and Dynamic Loading—International Colloquium May 17-19, 1977	$17,000	2/15/77 12 months	56
John L. Bogdanoff Purdue University	Seismic Resistance of Fossil-Fuel Power Plants	$127,300	8/15/76 12 months	56
Boris Bresler University of California	Safety Evaluation of Buildings Exposed to Earthquakes and Other Catastrophic Environmental Hazards	$98,000	3/15/77 12 months	57
Anil K. Chopra University of California	Earthquake Response of Dams Including Hydrodynamic and Foundation Reactions	$67,600	11/1/76 12 months	57
Ray W. Clough University of California	Energy Absorption Characteristics of Structural Systems Subjected to Earthquake Excitation	$103,000	1/12/77 0 months	57
C. Allin Cornell Massachusetts Institute of Technology	Structural Loads Analysis and Specification	$275,600	1/5/77 0 months	58
Charles Culver National Bureau of Standards	Implementation Planning for Seismic Design Provisions for Buildings	$63,700	7/15/77 6 months	58

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Rudolph F. Drenick Polytechnic Institute of New York	Prediction of Earthquake Resistance of Structures	$75,600	11/15/76 12 months	59
George C. Driscoll Lehigh University	Structural Connections in Industrial Installations Subject to Earthquake	$90,500	1/15/77 18 months	59
John P. Eberhard AIA Research Corporation	Summer Institute for Architectural Design for Earthquake Disaster Mitigation	$77,400	4/15/77 6 months	59
Steven J. Fenves Carnegie-Mellon University	Formulation and Expression of Seismic Design Provisions	$29,000	1/31/77 0 months	60
Theodore V. Galambos Washington University	Full Scale Tests on Eleven Story Building in the Pruitt-Igoe Housing Project of St. Louis	$151,500	7/1/77 12 months	60
Subhash C. Goel University of Michigan	Earthquake Resistant Design of Braced Steel Frame Structures	$141,200	8/1/77 12 months	61
Phillip L. Gould Washington University	Computer Program Documentation for Technology Transfer	$10,790	10/1/76 6 months	61
Robert D. Hanson University of Michigan	Conference on the Repair and Rehabilitation of Buildings	$22,900	2/1/77 12 months	62
Neil M. Hawkins University of Washington	Seismic Resistance of Concrete Slab to Column and Wall Connections	$228,800	3/15/77 12 months	62
Neil M. Hawkins University of Washington	Earthquake Induced Bond Deterioration of Reinforced Concrete	$52,400	3/15/77 12 months	62
George W. Housner California Institute of Technology	Effects of Damage from Strong Earthquakes	$292,500	2/1/77 12 months	63
Ti Huang Lehigh University	Contribution of Floor Systems to Earthquake Resistance of Steel and Concrete Building Frames	$105,100	11/1/76 12 months	63
Lawrence F. Kahn Georgia Institute of Technology	Research Initiation—Strengthening of Reinforced Concrete Columns for Earthquake Resistance	$13,000	4/1/77 18 months	63
W. O. Keighley Montana State University	Prestressed Walls for Damping Earthquake Motions in Buildings	$37,300	11/1/76 24 months	64
Earle W. Kennett American Institute of Architects	Seismic Safety Design for Police and Fire Stations	$146,800	1/1/77 13 months	64
Y. K. Lin University of Illinois	Structural Response Under Random Wind Loading	$41,200	6/15/77 12 months	64

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Le-Wu Lu Lehigh University	United States—Republic of China Cooperative Research in Earthquake Engineering Part II	$21,800	4/15/77 12 months	65
Hugh D. McNiven University of California	Seismic Behavior of Multistory Masonry Structures	$102,000	4/1/77 24 months	65
Hugh D. McNiven University of California	Reliability of Existing Buildings in Earthquake Zones—Part II	$50,000	6/17/77 24 months	65
William A. Nash University of Massachusetts	Seismic Effects in Liquid Storage Tanks	$42,400	11/15/76 12 months	66
Joseph Penzien University of California	Seismic Behavior of Structural Systems	$70,000	11/1/76 0 months	66
Joseph Penzien University of California	The United States-Japan Cooperative Research Program on Large-Scale Structural Systems	$20,000	7/15/77 24 months	67
Joseph Penzien University of California	Seismic Behavior of Structures: Analysis and Design	$186,000	4/1/77 24 months	67
Karl S. Pister University of California, Berkeley	Symposium on Structural Engineering and Mechanics	$20,000	5/15/77 12 months	68
Egor P. Popov University of California, Berkeley	Seismic Behavior of Structural Systems—Behavior of Structural Components	$125,000	11/9/76 24 months	68
Egor P. Popov University of California, Berkeley	Seismic Behavior of Structural Components	$220,000	4/1/77 24 months	69
Max L. Porter and Lowell F. Greimann Iowa State University	Earthquake Resistance of Steel-Concrete Composite Floor Systems	$199,400	10/15/76 30 months	69
W. C. Schnobrich University of Illinois	Effects of Earthquake Motions on Reinforced Concrete Buildings	$240,200	2/2/77 12 months	69
Mete A. Sozen University of Illinois	(See W. C. Schnobrich)			
David T. Tang SUNY at Buffalo	Research Initiation—Nonproportional Damping of Interaction Systems Subjected to Earthquake Motions	$13,000	4/1/77 18 months	70
Chi C. Tung North Carolina State University	Earthquake and Wind Response of Segmentally Constructed Hyperbolic Natural Draft Cooling Towers	$84,600	3/1/77 18 months	70
Erik H. Vanmarcke Massachusetts Institute of Technology	Evaluation of Seismic Safety of Buildings	$106,000	1/15/77 12 months	70

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Richard N. White Cornell University	Shear Transfer in Thick-Walled Reinforced Concrete Structures Subjected to Seismic Loading	$81,500	4/1/77 12 months	71
Bernard Wobbeking American Society for Engineering Education	Summer Institute on Multiprotection Design	$72,000	5/15/77 10 months	71
Richard N. Wright National Bureau of Standards	Collaborative Research: Formulation and Expression of Seismic Design Provisions	$51,000	1/17/77 0 months	72
James T. P. Yao Purdue University	Reliability of Existing Buildings in Earthquake Zones—Part I	$50,000	7/1/77 24 months	72
	Policy			
Alfredo H. Ang University of Illinois, Urbana	U.S.-Southeast Asia Joint Symposium on Engineering for Natural Hazards Protection to be held in Manila, Republic of the Philippines, in September 1977		7/1/77 12 months	73
Lynn S. Beedle Lehigh University	Tall Buildings and Urban Habitat: Impact of the Urban Environment and Planning for Natural Disasters	$224,200	5/15/77 12 months	73
Ray W. Clough University of California	National Information Service for Earthquake Engineering	$126,000	1/12/77 14 months	74
Harold C. Cochrane Colorado State University	Inflationary Changes in Construction Costs Created by Earthquake Damage: Implications for Government Policy	$52,500	3/1/77 12 months	74
Robert M. Dillon National Academy of Sciences	Building Futures Forum—The Importance of the Built Environment to the Quality of American Life	$10,000	6/1/77 6 months	75
George W. Housner California Institute of Technology	National Information Service for Earthquake Engineering—California Institute of Technology	$140,842	3/2/77 36 months	75
Dean E. Mann University of California, Santa Barbara	Seismic Safety Preparedness by Local Governments in California	$110,400	6/1/77 12 months	75
Joseph Penzien University of California, Berkeley	United States—Republic of China Cooperative Research in Earthquake Engineering Part I	$41,560	3/15/77 12 months	76
Peter H. Rossi University of Massachusetts	Research Program on Natural Disaster Recover Processes: Relief, Rehabilitation and Preparedness	$367,550	5/15/77 14 months	76
Ralph H. Turner University of California, Los Angeles	Community Response to Earthquake Threat in Southern California	$299,100	11/15/76 12 months	77

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John H. Wiggins J. H. Wiggins Company	Cost-Benefit Risk Analysis of Research Budgeted for Hazard Mitigation	$40,900	10/1/77 5 months	77
	Siting			
G. R. Abrahamson Stanford Research Institute	Simulation of Strong Earthquake Motion with Explosive Line Source Arrays	$95,000	11/15/76 12 months	78
M. S. Agbabian Earthquake Engineering Research Institute	Seminar on Earthquake Design Criteria, Structural Performance and Strong Motion Records	$33,300	5/15/77 12 months	78
Attila Askar Princeton University	Earthquake Waves in Soil Deposits	$64,500	13/15/76 12 months	79
M. L. Baron Weidlinger Associates	Underground Lifelines in a Seismic Environment	$42,170	2/16/77	79
Joseph W. Berg National Academy of Sciences	Partial Support of the Committee on Seismology	$20,000	3/1/77 24 months	79
James N. Brune University of California, San Diego	(See Gerald A. Frazier)			
Ahmet S. Cakmak	(See Attila Askar)			
Gerald A. Frazier University of California, San Diego	Laboratory and Numerical Simulation of Near-Field Earthquake Ground Motion	$127,800	10/1/76 12 months	80
Thomas C. Hanks U.S. Geological Survey	Processing and Analysis of Oroville Earthquake Aftershock Ground Motion Records	$114,000	3/1/77 12 months	81
Donald V. Helmberger California Institute of Technology	Processing and Analysis of Oroville Earthquake Aftershock Ground Motion Records, Part II	$39,800	3/1/77 12 months	81
Robert B. Herrmann Saint Louis University	Earthquake Ground Motion Modeling for Central United States	$79,900	3/1/77 2 months	81
Bernard M. Leadon University of Florida	Third U.S. National Conference on Wind Engineering Research, February 26-March 1, 1978	$29,600	6/1/77 12 months	82
Juan Enrique Luco University of California, San Diego	Dynamic Response of Three-Dimensional Rigid Foundations	$45,000	1/1/77 12 months	82
John Lysmer University of California, Berkeley	Soil-Structure Interaction with Arbitrary Seismic Environment	$41,300	6/1/77 24 months	83
George G. Mader William Spangle and Associates	Post-Earthquake Land Use Planning	$213,200	8/15/77 24 months	84

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R. B. Matthiesen U.S. Geological Survey	Seismic Engineering Program	$840,000	10/1/76 12 months	84
Jack Rosenfarb Drexel University	Research Initiation—Behavior of Buried Conduit Structures Subjected to Seismic Loading	$14,000	4/1/77 18 months	85
Adel S. Saada Case Western Reserve University	The Dynamic Response of Anisotropic Clay Soils with Application to Soil Structure Analysis	$68,200	11/15/76 12 months	85
Marshall L. Silver University of Illinois Chicago Circle	Soil Dynamics Delegation to the People's Republic of China	$19,200	7/1/77 6 months	85
Emil Simiu National Bureau of Standards	Probability Distribution of Extreme Wind Speeds	$69,800	7/15/77 12 months	86
David W. Simpson Columbia University	Induced Seismicity at Nurek Reservoir, Tadjikistan, USSR	$81,900	12/15/76 12 months	86
Kenneth H. Stokoe University of Texas	Workshop on Research Priorities for Geotechnical Earthquake Engineering Applications	$45,100	3/30/77 9 months	86
George E. Triandafilidis The University of New Mexico	Feasibility Study of Using High Explosives to Simulate an Earthquake	$83,600	10/15/76 16 months	87
Mihailo D. Trifunac University of Southern California	Automatic Digitization of Accelerograph Records	$80,000	10/1/77 24 months	88
Leon R. L. Wang Rensselaer Polytechnic Institute	Seismic Vulnerability, Behavior and Design of Underground Piping Systems	$63,800	10/1/77 24 months	88
Francis T. Wu State University of New York, Binghamton	Earthquake Strong-motion Instrument Development and Array Design	$41,400	5/15/77 12 months	88
Felix Y. Yokel National Bureau of Standards	Workshop on Research Priorities for Geotechnical Earthquake Engineering Applications	$20,800	4/1/77 8 months	89
Thomas F. Zimmie Rensselaer Polytechnic Institute	Simple Shear Behavior of Fine Grained Soils Subjected to Earthquake and Other Repeated Loading	$54,400	10/15/76 15 months	89
	WEATHER MODIFICATION			
	Inadvertent Weather Modification			
August H. Auer, Jr. University of Wyoming	Inadvertent Weather Modification in the St. Louis Area	$65,000	7/15/77 9 months	92
Roscoe R. Braham, Jr. University of Chicago	The Effects of Urban-Industrial Emissions on Downwind Weather Patterns	$146,000	5/15/77 12 months	92

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Stanley A. Changnon Illinois State Water Survey, University of Illinois	Causes and Impacts of Urban Influences on Precipitation	$237,000	7/1/77 18 months	93
Robert D. Elliott North American Weather Consultants	Workshop on Extended Area Effects of Weather Modification	$30,800	7/15/77 6 months	93
Lewis O. Grant Colorado State University	A Field Experiment Design to Determine the Extended Area of Effect from Wintertime Cloud Seeding	$399,700	6/1/77 15 months	94
George D. Robinson The Center for the Environment and Man, Inc.	Third Workshop on Inadvertent Weather Modification	$42,000	4/1/77 6 months	94
George D. Robinson The Center for the Environment and Man, Inc.	Statistics and Origin of Haze in the Central United States	$49,600	7/1/77 12 months	95
Philip B. Russell Stanford Research Institute	Development of an Acoustic Sounder Network for Air Pollution and Land Use Application	$11,800	6/15/77 6 months	95
Fred M. Vukovich Research Triangle Institute	Study of Urban Boundary Layer Processes Using a Three Dimensional Hydrodynamical Model	$28,000	9/1/77 12 months	95
	Societal Implications			
Ray J. Davis University of Arizona	The Legal Implications of Inadvertent Weather Modification: METROMEX and the Law	$30,000	2/15/77 15 months	97
Barbara C. Farhar Human Ecology Research Services, Inc.	A Comparative Analysis of Public Response to Weather Modification	$56,600	2/1/77 9 months	97
Barbara C. Farhar Human Ecology Research Services, Inc.	METROMEX: Social Impacts of Inadvertent Weather Modification: A Comparative Study	$60,300	2/1/77 13 months	98
Donald A. Klein Colorado State University	Management of Nucleating Agents Used in Weather Modification: Development of Microbial Threshold Toxicity Criteria	$12,400	1/5/77 6 months	98
Donald A. Klein Colorado State University	Management of Nucleating Agents Used in Weather Modification: Development of Microbial Threshold Toxicity Criteria	$28,000	2/10/77 9 months	99
	Technology and Evaluation			
Bernice Ackerman University of Illinois	Assessing Midwest Cloud Characteristics for Weather Modification	$98,000	7/15/77 12 months	100
Norihiko Fukuta University of Utah	Laboratory Studies of Organic Ice Nuclei for Seeding	$48,600	10/1/77 12 months	100
Dennis M. Garvey Colorado State University	Testing and Calibration Program for Cloud Seeding Materials, Seeding Generators, and Nucleus Observing Instruments	$25,870	7/1/76 15 months	101

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Lewis O. Grant Colorado State University	(See Dennis M. Garvey)			
William A. Gray Colorado State University	The Generation and Use of Cirrus Clouds as a Tool for Weather Modification	$70,000	7/15/77 18 months	101
Paul Schickedanz University of Illinois	Operational Cloud Seeding Evaluation Techniques	$116,000	7/1/77 18 months	101
Joanne Simpson University of Virginia	Evaluation and Design of Weather Modification Experiments	$149,900	12/17/76 21 months	102
Joseph A. Warburton Desert Research Institute University of Nevada	Hail Suppression Seeding Technology: An Assessment Based on Silver Content in Rain and Hail	$55,900	8/1/77 12 months	102
	Weather Hazard Mitigation			
Donald Veal National Center for Atmospheric Research	National Hail Research Experiment	$2,006,000	11/15/76 11 months	103
	SOCIETAL RESPONSE TO NATURAL HAZARDS			
Frederick L. Bates University of Georgia	A Longitudinal and Cross Cultural Study of the Post Impact Phases of a Major National Disaster: The February 6, 1976 Guatemalan Earthquake	$144,925	6/1/77 12 months	104
Thomas E. Drabek University of Denver	Search and Rescue Missions in Natural Disaster and Remote Settings	$261,300	9/1/77 24 months	105
Robert K. Leik Univesity of Minnesota	Community Response to Natural Hazard Warnings	$260,750	5/15/77 12 months	105
Hirst Sutton Council of State Governments	State Government Policy Options for the Utilization of Earthquake Prediction Technology	$177,500	1/77 12 months	105
Dennis E. Wenger University of Delaware	Disaster Knowledge and Beliefs and Emergency Planning	$34,300	6/1/77 12 months	106