WATER RESOURCES RESEARCH GRANT PROGRAM
PROJECT DESCRIPTIONS, FISCAL YEAR 1990

Compiled by Melvin Lew and Pamela Murray

U.S. GEOLOGICAL SURVEY
Open-File Report 91—195

Reston, Virginia
1991

U.S. DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

Chief, Office of External Research
U.S. Geological Survey
Water Resources Division
424 National Center
Reston, Virginia 22092

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WATER RESOURCES RESEARCH GRANT PROGRAM
PROJECT DESCRIPTIONS, FISCAL YEAR 1990

By Office of External Research
Water Resources Division
U.S. Geological Survey

ABSTRACT

This report contains information on the 40 new projects funded by the U.S. Geological Survey's Water Resources Research Grant Program in fiscal year 1990 and on 24 projects completed during the year. For the new projects, the report gives the grant number, project title, performing organization, principal investigator(s), project duration, and a project description that includes: (1) identification of water-related problems, (2) contribution to problem solution, (3) objectives, and (4) approach. The 40 projects include 7 in the area of water transport and flow, 7 in agricultural pollution, 6 in water quality, 6 in biology, 7 in economics and management, and 7 in climate and hydrology.

For the 24 completed projects, the report gives the grant number, project title, performing organization, principal investigator(s), starting date, date of receipt of final report, and an abstract of the final report. Each project description provides the information needed to obtain a copy of the final report.

The report also contains tables showing (1) proposals received according to area of research interest, (2) grant awards and funding according to area of research interest, (3) proposals received according to type of submitting organization, and (4) awards and funding according to type of organization.

INTRODUCTION

In January 1985, the U.S. Geological Survey was assigned responsibility for administering the functions of the Water Resources Research Act of 1984 (Public Law 98-242). Section 105 of the act authorizes funds for research grants, on a fund-matching basis, to qualified individuals and groups as defined in the law. Each year an announcement is issued to solicit proposals for research support from the funds appropriated by the Congress.

In fiscal year (FY) 1985, 24 of 368 proposals that were submitted were selected for funding with the $2.543 million appropriated by Congress. In FY 1986, 43 of 299 proposals were selected for funding with the $4.767 million appropriated, in FY 1987, 34 of 273 with $4.381 million; in FY 1988, 38 of 239 with $4.381 million; and in FY 1989, 36 of 260 with $4.381 million. These projects are described in U.S. Geological Survey Open File Reports 85-687, 86-548, 88-179, 89-249, and 90-139, respectively.

In FY 1990, 250 proposals requesting $29.0 million of Federal funding ($30.3 million of non-Federal funding) were submitted in response to U.S. Geological Survey Announcement No. 7609 issued on August 8, 1989. Of this number, 40 were selected for funding with the $4.322 million appropriation (Table 1). As in previous years, proposals from academic institutions dominated the competition for grant funds (Table 2).

Section I of the report presents summaries of the 40 proposals selected for funding. Section II presents summaries of the 24 projects completed during FY 1990.

Table 1--Proposals and awards by research interest area, fiscal year 1990

Proposals

Interest Area	No.	Federal Funds ($)	Non-Federal Funds ($)	Total Funds ($)
Water Flow and Transport	63	7,271,947	7,360,912	14,632,859
Agricultural Pollution	29	3,863,379	3,967,048	7,830,427
Water Quality	59	6,413,098	6,837,966	13,251,064
Biology	31	4,208,707	4,399,629	8,608,336
Economics and Management	23	2,106,286	2,283,397	4,389,683
Climate and Hydrology	45	5,179,188	5,405,484	10,584,672
Totals	250	29,042,605	30,254,436	59,297,041

Awards

Interest Area	No.	Federal Funds ($)	Non-Federal Funds ($)	Total Funds ($)
Water Flow and Transport	7	775,660	884,930	1,660,590
Agricultural Pollution	7	909,825	951,695	1,861,520
Water Quality	6	572,306	692,871	1,265,177
Biology	6	636,797	653,651	1,290,448
Economics and Management	7	523,685	748,574	1,272,259
Climate and Hydrology	7	903,727	966,876	1,870,603
Totals	40	4,322,000	4,898,597	9,220,597

Table 2.--Proposals and awards by organization, fiscal year 1990

Proposals

Organization	No.	Federal ($)	Non-Federal Funds ($)	Total Funds($)
Academic Institutions	240	28,319,894	29,508,484	57,828,378
Non-Federal Government	4	237,780	255,021	492,801
Private	6	484,931	490,931	975,862
Total	250	29,042,605	30,254,436	59,297,041

Awards

Organization	No.	Federal ($)	Non-Federal Funds ($)	Total Funds ($)
Academic Institutions	40	4,322,000	4,898,597	9,220,597
Non-Federal Government	0	0	0	0
Private	0	0	0	0
Total	40	4,322,000	4,898,597	9,220,597

SECTION I

PROJECT SUMMARIES

FISCAL YEAR 1990 GRANTS

CLIMATE AND HYDROLOGY

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1885
PROJECT TITLE:	Paleohydrology of the Non-Glaciated Great Plains: Climatic and Geomorphologic Implications
PERFORMING ORGANIZATION:	University of Texas
PRINCIPAL INVESTIGATOR:	Alan R. Dutton
DURATION:	August 1990 to July 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.
Shallow ground-water resources beneath some parts of the Central and Southern High Plains are chronically overdeveloped, resulting in major water-level declines. Research results will be important to understanding the paleohydrologic history of the High Plains aquifer system.

2. Contribution to Problem Solution.

This research will provide fundamental insights into the hydrology and geochemistry of infiltration processes, water flow and mass transport, sensitivity of water quality in regional aquifers to changes in recharge-water composition, and paleohydrology of Quaternary recharge across the non-glaciated Great Plains and will influence conceptual hydrologic models that underlie numerical simulations of the High Plains aquifer. Ground-water conservation districts, recognizing that the truncated confined aquifers are not recharged under the modern flow system, might use the research results to improve estimates of safe yields and revise projections of the extent of overdevelopment.

3. Objectives.

The objectives of this research are to:
(a) prove whether isotopically depleted ground water beneath the southern Great Plains is "fossil" (ancient) water that is preserved owing to landscape evolution and paleohydrologic changes in the ground-water flow system;

(b) determine if the paleorecharge model based on the hydrogeology of the southern Great Plains applies to other parts of the non-glaciated Great Plains; and

(c) evaluate the implications of isotopic variations within aquifer units for late Cenozoic paleoclimatology of the continental interior.

4. Approach.

Confined ground waters that have depleted concentrations of the stable isotopes of hydrogen and oxygen, relative to waters in overlying unconfined aquifers, will be dated using radioactive isotopes such as ^{14}C and ^{36}Cl. Ground-water flow systems will be simulated with numerical models to evaluate effects of physiographic evolution and climatic change on recharge rates and patterns.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1886
PROJECT TITLE:	Impacts of Global Warming on Reservoir Systems
PERFORMING ORGANIZATION:	Georgia Technology Research Corporation
PRINCIPAL INVESTIGATOR:	Aris P. Georgakakos
DURATION:	September 1990 to September 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

Although global warming maybe several decades away, the possibility of its profound and irreversible effects are of urgent concern both to the scientific community and to the Federal Government. Among other consequences, global warming could upset several climatic variables, including rainfall, evaporation, and runoff.

2. Contribution to Problem Solution.

This project will study the potential effects of major climatic changes on watershed hydrology and water resources systems at the catchment scale. More specifically, it will determine the catchment flow processes most affected by changes in the local precipitation and evapotranspiration regimes. This investigation will provide fundamental knowledge of the scales and nature of the temporal variability of hydrologic processes at the catchment scale under various climatic forcing scenarios.

3. Objectives.

The objectives of this research are to:

(a) understand the relationship between the short- and long-term streamflow variability and the short- and long-term variability of mean areal surface air-temperature and precipitation;

(b) understand and quantify the effects of global warming on reservoir systems functions including energy generation, flood prevention, water supply, and pollution abatement through low flow augmentation; and

(c) suggest appropriate reservoir operation rule modifications to minimize the consequences of potential climate pattern changes.

4. Approach.

The approach will model the relationship of climatic variables such as surface air temperature and humidity to (1) rainfall and (2) evapotranspiration, and the relationship of watershed runoff to reservoir system outputs. These three associations will be estimated using state-of-the-science statistical-dynamic, physically-based, reservoir control models. The project will be the first to combine such models in an integrated system and assess the sensitivity of watershed and reservoir outputs to potential climatic scenarios. The approach will combine hydrologic simulation with multi-objective reservoir optimization and will explicitly consider the natural variability of climatic inputs and the uncertainty in reservoir inflow predictions. The case studies will include systems with varying features and from different U.S. regions (southwest, midwest, and west coast) to validate the generality of the research conclusions and relate output sensitivity to physical process and reservoir system characteristics

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1887
PROJECT TITLE:	Field Testing of a Small Catchment Hydrologic Model that Uses and Predicts Spatial and Temporal Information
PERFORMING ORGANIZATION:	University of Washington
PRINCIPAL INVESTIGATOR:	S. Burges
DURATION:	July 1990 to July 1993

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.
The major problem area addressed is improving the technology for predicting the hydrologic effects of land-use change (particularly urbanization) by refining and testing a newly developed hydrologic model for small catchments. The proposed work differs significantly from previous work by focusing on modeling the integrated effects of the observable and mappable spatial distribution of flow production zones within the small, zero to third order (tens to thousands of acres), catchments.

2. Contribution to Problem Solution.

The key contribution of this research is that it will allow the integrated affects of change on flow paths to be evaluated at the scale of change (acres), using a model developed for, and tested at, this small scale. Model testing will determine what types and amounts of information are needed for its use, particularly in situations where gauging has not been done previously. Once tested, the model can be used to predict locations within a basin which can supply sediment and pollutants to the channel quickly. The planned testing, under a range of hydrogeologic environments, will determine the model's applicability in different climates and landforms.

3. Objectives.

The objective is to refine and test a new hydrologic model for use in small catchments for predicting hydrologic responses resulting from land use (urbanization) change.

4. Approach.

A continuous rainfall input hydrologic model has been developed specifically for the dynamics of small catchments which includes infiltration, unsaturated and saturated subsurface flow, evapotranspiration, and surface flow. It will be recoded substantially so its land-phase outputs become inputs to " Hydrologic simulation program-FORTRAN " 's channel routing routines which will be incorporated directly into the model. The model will be reformulated also to permit use of geographic information system (GIS) compatible polygon land areas.

The model will then be tested using the extensive field data collected by Dunne and Black; (1970, An experimental investigation of runoff production in permeable soils; Water Resources Research, 6(2), p. 478-490). This will allow rigorous testing of model components under small scale field conditions. Model coefficients for physical processes will be estimated from part of the data, with the remainder used for validation.

The model will be calibrated using field mapped process zones and short-term measured rainfall and streamflow for three small catchments in King County, Washington to determine the minimum data needed for calibration. Measurements and field mapped process zones will be available for three water years; time series data not used for calibration will be used for validation. One catchment is 100 acres (zero order) with second growth forest, another is 50 acres of gently sloping pasture, the third (101 acres) is urbanized and has three years of previously measured rainfall and streamflow data. A final test will be made using existing data from a catchment in a different hydrogeologic environment. Two Agricultural Research Service experimental watersheds have been identified as potential sites; (1) the 25-acre, R-5 catchment near Chickasha, Oklahoma, and (2) Walnut Gulch near Tombstone, Arizona.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1888
PROJECT TITLE:	Hydrologic and Biogeochemical Response of Alpine Catchments to Global Change
PERFORMING ORGANIZATION:	University of California
PRINCIPAL INVESTIGATOR:	J. Melack
DURATION:	September 1990 to August 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

Seasonally snow-covered areas of the Earth's mountain ranges are important components of the global hydrologic cycle, even though they do not cover a large portion of the Earth's surface area. Many of the physical, chemical, and biological changes that may occur in alpine basins as a result of increasing climatic fluctuations will be mediated through hydrological fluxes. Understanding the links between processes at the scale of a sampling plot and these same processes on a regional scale are essential if we are to extend our understanding of hydrology and hydrochemistry to global scales.

2. Contribution to Problem Solution.

The project's contribution to solving these problems is threefold. First, data collection and process-level studies will continue on long-term hydrologic and hydrochemical records at a pristine watershed, and extend this data base to six additional watersheds. Second, modeling efforts, which will use existing records plus the new data, will result in a better understanding of the spatial and temporal variability of hydrologic patterns and processes in one alpine region - the Sierra Nevada. Third, there will result a better understanding of the links between processes at the small-catchment scale (m^2 to km^2) and these same processes at the river-basin scale (10 to 100 km^2). The approach that is used and tools that are developed will have application to other alpine regions of the United States and the world.

3. Objectives.

The objective of the research is to evaluate the potential impacts of global change on the hydrology and biogeochemistry of seasonally snow-covered alpine areas. The project will focus on the California Sierra Nevada, for which there is the most complete detailed data.

4. Approach.

The approach is to use a synergistic program of field measurements, process-level research on physical parameters, and process-oriented model research. The research divides the problem of understanding hydrologic and hydrochemical dynamics at several scales into the following steps: (1) model validation and identification of parameters that vary spatially and temporally, through process-oriented model research on existing data at the intensively studied Emerald Lake watershed; (2) increasing the understanding of physical processes at a point that the modeling work identifies as important on a watershed scale, e.g. snowmelt runoff as a function of energy flux; (3) collection of the hydrologic, hydrochemical, geologic, and biological data necessary for a regional assessment by a combination of field work and compilation of data from other agencies; (4) application of the validated model to other headwater-watersheds using the regional data base, and further testing/validation; and (5) aggregation of the watershed-level processes to a regional scale by distributing parameters spatially and temporally and identifying scale-dependent processes. This study will build on previous research and process-oriented modeling that describes the hydrology and biogeochemistry of alpine areas, through parameterization and reduction of errors in the existing Alpine Hydrochemical Model

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1889
PROJECT TITLE:	Remote Determination of Soil Moisture and Evapotranspiration from Thermal Infrared Measurements
PERFORMING ORGANIZATION:	Pennsylvania State University
PRINCIPAL INVESTIGATOR:	T. N. Carlson
DURATION:	September 1990 To September 1993

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

In order to monitor evapotranspiration and soil water content by satellite over regional-scale areas for the development of climate models and forecasts of crops productivity, it is necessary to have good models, know the values of their coefficients, and be able to apply the models using remotely sensed data.

2. Contribution to Problem Solution.

The project addresses the development of models (theory) and the application of some new ideas in remote measurement of evapotranspiration. The evapotranspiration research constitutes a continuation of our past U.S. Geological Survey-supported work on these topics. During the past two years we have made significant progress in the theoretical work (modeling the water flow through vegetation) and remote sensing (developing a method for estimating evapotranspiration and substrate water content over sparse vegetation canopies). We will use our vegetation model both as a diagnostic tool to study the differing responses of plants to water stress and, in conjunction with remote measurements, to estimate substrate (root zone and surface) soil water content and fractional vegetation cover.

3. Objectives.

The objectives of this research are to:

(a) extend our present vegetation model to model water utilization by different types of vegetation;

(b) develop and test a new method for remotely determining the fraction of vegetation cover and soil moisture at two substrate levels;

(c) use the technique from (b) and theory from (a) to determine surface evapotranspiration over partial vegetation cover (for example, scrub or desert vegetation) from U. S. National Oceanic and Atmospheric Administration satellite measurements; and

(d) explore capabilities of the model as a diagnostic tool for field measurements.

4. Approach.

Our approach is to use surface measurements to improve the parameterization of the surface temperature/moisture/evapotranspiration relationships in a model. Emphasis will be on applications over semi-arid and plains vegetation where large changes (in space and time) of surface moisture and ground temperature are normally experienced.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1890
PROJECT TITLE:	Evaluation of Evapotranspiration and Other Hydrological Responses to Climate Change Using a Planetary Boundary Layer Model
PERFORMING ORGANIZATION:	Oregon State University
PRINCIPAL INVESTIGATOR:	R. H. Cuenca
DURATION:	September 1990 to August 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

It has become apparent that changing land-use and increasing emissions of trace gases due to human activity in recent years may be influencing the earth's large-scale weather patterns. These suspected changes are based upon analysis of recent observational trends and studies of global climate using general circulation models (GCMs). Should these potentially dramatic changes in the atmosphere actually occur, they will seriously affect the hydrosphere, possibly altering the amount and distribution of evapotranspiration and surface soil moisture across the globe.

2. Contribution to Problem Solution.

This research will provide more accurate estimates and better understanding of the processes that affect surface evapotranspiration and other moisture parameters in response to large-scale weather pattern changes predicted by GCMs. Present GCMs do not contain sufficient boundary layer, plant canopy and soil physics to describe changes in local climates in response to a given change of large scale circulation patterns.3. Objectives. The objective of this research is to determine the response of the boundary layer, specifically with respect to evapotranspiration, to changes in the large-scale flow patterns as predicted by GCMs and other sources. The response of the boundary layer and soil moisture will be determined with the aid of a coupled numerical model of the atmospheric boundary layer-plant-soil system. This model has been developed at Oregon State University to emphasize atmospheric-hydrology problems.

4. Approach.

In order to further verify and improve the accuracy of output from the planetary boundary layer-plant-soil model, we will analyze evapotranspiration and soil moisture data from 1) a currently operational Oregon State University field site, 2) an atmospheric-soil hydrology project carried out in southwest France in 1985-86, and 3) three other combined meteorological and lysimeter-measured evapotranspiration data sets representing climates from humid to arid conditions over a total of 12 years. Plans also exist to use output from various GCMs, plus other scenarios of climate change, as boundary conditions for our model. Numerical iterations will determine the modeled surface response of evapotranspiration and soil moisture to various changes of global-scale circulation patterns.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1944
PROJECT TITLE:	Spatial Patterns of Hydroclimatic Variability in the Mississippi River Basin
PERFORMING ORGANIZATION:	University of Denver
PRINCIPAL INVESTIGATOR:	M. J. Keables
DURATION:	September 1990 to September 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

Much of the United States citizenry relies on the water resources of the Mississippi River Basin for agricultural, municipal, industrial, commercial, and transportational use. There is growing concern among climatologists and hydrologists of the impact of potential climate change on the hydrologic system, and in particular, the effect on surface hydrology. It is, therefore, critical that the relationship between climate and hydrology be fully investigated. Paramount to understanding climate-hydrology relationships in the Mississippi River Basin is the need to determine the spatial variability of precipitation and streamflow that occurs in response to the dominant large-scale atmospheric circulation patterns over North America.

2. Contribution to Problem Solution.

This research will identify the dominant large-scale atmospheric circulation patterns over North America and the corresponding spatial distributions of precipitation and stream discharge in the Mississippi River Basin. Results of this research will identify specific precipitation and streamflow patterns within the Mississippi River Basin which are associated with specific midtropospheric circulation patterns.

3. Objectives.

The specific objective of this project is to identify the spatial variability of large-scale atmospheric circulation patterns over the United States and the associated precipitation and streamflow patterns that resulted within the Mississippi River Basin during the period 1950-85.

4. Approach.

Hydroclimatic associations will be identified by subjecting a single circulation-precipitation-stream discharge matrix, consisting of temporally standardized monthly observations, to principal component analysis. The component loadings for the significant principal components will be mapped to identify specific regions within the Mississippi River Basin in which the precipitation and streamflow are significantly related to specific midtropospheric circulation patterns. This approach differs from previous studies in that the variance-covariance structure of the combined data will identify the circulation-hydrology associations.

ECONOMICS AND MANAGEMENT

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1891
PROJECT TITLE:	Institutional Change in Water Management: Consequences of State Trust Land Claims and Participation
PERFORMING ORGANIZATION:	University of California
PRINCIPAL INVESTIGATOR:	S. K. Fairfax
DURATION:	September 1990 to August 1993

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

State trust lands could have tremendous impact on water allocation and management at the state level, most obviously the state school lands which were granted by the Federal government to the states. The issue of whether Federal reserved water rights are attached to those lands has only been tangentially discussed.

2. Contribution to Problem Solution.

Due to the priority date of the state school grants, even the possibility of reserved water rights attaching to state trust lands must be regarded seriously. Less speculatively, the fact that managers are obligated to maximize the return to the beneficiaries of the land may force state trust managers to explore water marketing possibilities. Even the less intrusive scenarios now emerging from issues in Colorado, New Mexico, and Montana suggest that the potential role of state trust land in water management must be understood before opportunities for directing future developments are lost.

3. Objectives.

The objectives of this research are to:

(a) identify areas (geographically and substantively) in which an enhanced role for state trust lands may be anticipated;

(b) identify likely consequences of enhanced state trust lands participation; and

(c) make recommendations regarding implementation strategies and institutional structures to maximize the efficiency thereof.

4. Approach.

Almost no comprehensive data exist on state trust lands and none of state land commissioners considers their role in water allocation and management. Ongoing exploratory study of those lands in ten western states will provide the context and background data for the more detailed analysis herein. This project will use a case study approach: (1) review water market literature and water-law developments to specify the likely areas of greater participation of state trust land and land commissioners in water management and allocation; (2) conduct a state-by-state review of nascent water management programs and issues to identify both patterns and sites for representatives case studies; and (3) engage in detailed study of four cases.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1892

PROJECT TITLE: Coping with Severe Sustained Drought in the Southwestern United States

PERFORMING ORGANIZATION: Utah State University

PRINCIPAL INVESTIGATOR: L. D. James

DURATION: September 1990 to September 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

To overcome seasonal and multi-year shortages and meet projected demands for water, Federal and state governments have built massive storage and conveyance systems. The economy of the Southwestern United States has been built by establishing a water supply in a largely arid land, and many institutions have developed to support water-resources development in the area. The laws of the seven states in the region strongly protect past water development investments and management rules that have evolved for water usage. Regional water-management systems have developed and linked the water resources of the Colorado River and the Northern California Basins to serve Southern California. But, they have never had to face major drought and are not prepared to get through one. Also, increasing population and growing anthropogenic demands on land and water resources increase the potential drought severity and magnify the probable losses during a major sequence of dry years. Thus far, the dry periods of the 20th century have not matched the duration or severity of droughts in the previous four centuries as estimated from tree-ring analysis and other historical data.

2. Contribution to Problem Solution.

This research will develop a tentative severe drought contingency plan for the Colorado River Basin. Currently, no system-wide contingency plan exists.

3. Objectives.

Presently, the investigators in this project are working on Phase I of this study which is being funded by the United States Man and Biosphere Program. This grant is for Phase II of the study. During Phase II, the researchers will assess the existing coping ability of water laws, institutions, and management infrastructure in the study area; analyze the qualitative and quantitative impacts of drought on ecological, economic, social, and political sectors of the study area; and suggest potential methods of enhancing the resiliency of social and natural systems. The over-riding objective is to help clarify approaches to considering severe sustained drought (SSD) as a public policy issue.

4. Approach.

An interdisciplinary team will define the existing institutional-economic engineering system, structure some drought scenarios that are reasonable in light of probable occurrences during the last 500 years but more severe than any in the last century, assess their impacts, and evaluate alternative management strategies for minimizing the losses when such droughts occur. The results will be reviewed to identify opportunities for greater effectiveness through cooperation and the practicality for decision-makers within the existing management systems to take advantage of such opportunities. Through a hydrologic assessment, the team will define three droughts with realistic probabilities, estimate their potential economic, environmental, and social impacts, and predict likely coping responses. The team will predict impacts and responses by sector and region.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1893

PROJECT TITLE: Optimal Control of Pumping Facilities

PERFORMING ORGANIZATION: University of Arizona

PRINCIPAL INVESTIGATOR: K. E. Lansey

DURATION: September 1990 to August 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

Pumping water is an expensive service which consumes large amounts of energy. For water utilities, the pumping energy may be up to 90 percent of their energy budget. An optimal control system is needed to assist in scheduling pump operations of general water supply systems including water distribution, irrigation, and regional water supply.

2. Contribution to Problem Solution.

Development and implementation of a control system will assist water managers in making cost and energy efficient operating decisions which will satisfy demand and pressure requirements. The control system will be developed to execute on low cost personal computers and for easy implementation for a general system.

3. Objectives.

The major objective of this research is to develop a control system which consists of a long term model and an on-line updating tool to assist in determining optimal pump operations.

4. Approach.

The long term control system is a non-linear programming problem which determines the least cost pump-station head and discharges at each time step during the period of analysis. Input to this model is a continuous pump station curve derived from the available pumps defining the highest efficiency available at each pump station head and discharge. The optimal head/discharge combinations will be converted to actual operations through enumeration or dynamic programming. Since the long term decisions are based on forecasted demands which may not occur exactly, an on-line model is needed to update and maintain low cost operations in the short range. Several potential approaches will be evaluated to solve this problem.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1894
PROJECT TITLE:	Improved Estimates of Economic Damages from Residential Use of Mineralized Water
PERFORMING ORGANIZATION:	Colorado State University
PRINCIPAL INVESTIGATOR:	C. J. Makela
DURATION:	September 1990 to February 1982

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

Dissolved minerals (salinity) in household water supplies shorten appliance lives and otherwise increase costs to households in the southwestern United States and across the southern plains. The problem is of sufficient magnitude that many hundreds of millions of dollars have been or will be spent for abatement by private individuals and by government agencies. Estimates of marginal economic returns to abatement are needed for economic evaluation of specific public salinity control programs. The most recent of the few general data collection efforts on residential salinity damages was conducted in 1981. Further, different data-collecting techniques have yielded inconsistent results. Analyses also differ in their findings as to how damages vary with measures of concentration. Marginal damages have not been directly estimated in some studies, and statistical confidence limits have not been provided.

2. Contribution to Problem Solution.

Application of advances in statistical analysis and survey research procedures can improve the scientific basis for managing residential water supplies of impaired quality. These knowledge gaps will be addressed by empirical test. Improved questionnaire design and newly available econometric testing procedures will be applied. Three alternative sources or types of abatement benefit estimates, including a) willingness to pay, b) reduced costs from salinity, and c) damage estimates from appliance repair and plumbing firms will be compared. A wider range of mineral concentrations will be sampled so the non-linear damage hypothesis can be carefully tested.

3. Objectives.

The objectives of this research are to:

(a) compare and assess three alternative data collecting procedures;

(b) derive statistical measures (with confidence intervals) of marginal economic damage; and

(c) test whether damages are linearly or non-linearly related to mineral concentration.

4. Approach.

The portion of the Arkansas River Basin lying in Colorado has been chosen as the study area, because it includes headwater communities enjoying low mineral concentrations (200 mg/1) and plains area towns that experience salinity ranging up to 2500 mg/1. A mail survey of households in the Basin with a target of over 1000 respondents will be conducted. A parallel survey of at least 75 appliance repairs and plumbing enterprises will be undertaken. The individual responses on appliance life as well as willingness to pay for improved water quality will be analyzed with statistical regression procedures, including tests for functional form, so as to derive estimates of marginal damages from dissolved minerals. The alternative data sources will be compared and assessed.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1895
PROJECT TITLE:	Alternative Institutional Arrangements for Managing an Exhaustible Aquifer: An Analytical Hierarchy Process Application
PERFORMING ORGANIZATION:	Oklahoma State University
PRINCIPAL INVESTIGATORS:	R. Sharda and K. Willett
DURATION:	July 1990 to October 1991

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

The major source of irrigation waters in the Oklahoma Panhandle region is the Ogallala aquifer which has been classified as an exhaustible aquifer. Declines in ground-water levels means that irrigators will be faced with increasing pumping costs, declining well yields, and decreasing pumping efficiency. This state of affairs has resulted in proposed alternatives for managing the Ogallala aquifer.

2. Contribution to Problem Solution.

The purpose of this research is to use the analytic hierarchy process (AHP) model to evaluate alternative institutional arrangements for managing water withdrawals from an exhaustible aquifer. This research will focus on the Ogallala aquifer in the Oklahoma Panhandle region.

3. Objectives.

The objectives of this research are to:

(a) adapt the AHP as a decision making tool for selection of the optimum institutional arrangement in the Oklahoma Panhandle region for managing ground-water withdrawals; and

(b) test the validity of the developed model on various constituencies who are affected by the decisions, and then investigate differences among their choices and relative weights given the different criteria.

4. Approach.

The research tasks and methodology for this study will include the following efforts: review the relevant literature to describe the institutional structure that has evolved for ground-water resources and identify the nature of institutional changes which are likely to evolve in managing ground-water resources in the future; analyze the social aspects and distributive consequences of alternative institutional arrangements; develop representative case studies providing estimates of economic efficiency gains and the distributive consequences from institutional changes; and describe the hydrologic information needed to support alternative institutional arrangements.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1896
PROJECT TITLE:	Economic Impacts of Pesticide Regulations to Protect Ground Water
PERFORMING ORGANIZATION:	North Carolina State University
PRINCIPAL INVESTIGATOR:	L. E. Danielson
DURATION:	July 1990 to July 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

Limited assessments of the potential for pesticides to contaminate ground water have been made, but these were "first-cut" estimates and were done with limited local or regional input. Furthermore, these estimates have been criticized for excluding several hydrogeologic factors that affect pesticides (for example, soil half-life, water solubility, and sorption coefficients), and site-specific soil characteristics (for example, organic matter content, soil pH). In addition, policy makers seldom have information about the level and distribution of economic impacts of alternative policies that protect ground water by regulating or restricting the use of agricultural pesticides. This complicates or prevents efficient policies from being selected because consumer and producer policy impacts often differ greatly among alternative polices; even though they may achieve the same level of ground-water quality protection.

2. Contribution to Problem Solution.

This project will provide research results in three phases that will assist in policy development to reduce the potential for contamination. The first phase will develop estimates of the extent of pesticide use at the county level using detailed, county-based data, and will evaluate soils characteristics to estimate the potential for pesticides to reach ground-water resources as a function of soil and pesticide characteristics. The second phase will estimate the level and distribution of economic impacts of regulations that are considered to be alternative policies for reducing agricultural pesticide use. The third phase will make this information available to policy-makers to assist them in making equitable and effective ground-water policy decisions.

3. Objectives.

The overall project objective is to develop improved and expanded research-based information for ground-water policy makers. More specifically, for selected counties in the Southeast Coastal Plain, the objectives are to develop improved pesticide-use estimates at the county level, to incorporate additional hydrogeologic factors into models for estimating the potential for contamination of ground water from agricultural pesticides, to estimate the level and distribution of

economic impacts from alternative pesticide-use policies designed to reduce the potential for ground-water contamination, and to provide this information to officials responsible for ground-water quality protection.

4. Approach.

The research will include the development of an improved, more comprehensive pesticide-use database and a model to estimate the contamination potential for selected pesticides in areas of the Southeast Coastal Plain of the United States. Once the contamination-potential information is available, estimation of the economic impacts of alternative policies designed to reduce the contamination potential will be analyzed using producer and consumer economic impact models. This information will be provided to policy makers at the local, state, and national levels through publication of papers and reports, and through incorporation of results in ongoing information and education programs.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1897
PROJECT TITLE:	The Effect of Legal and Administrative Factors on Short-Term Urban Drought Management
PERFORMING ORGANIZATION:	Southern Illinois University
PRINCIPAL INVESTIGATOR:	B. Dziegielewski
DURATION:	August 1990 to August 1991

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

The legal and administrative aspects of drought management are of primary importance in the formulation and implementation of drought contingency plans. The literature suggests that water agencies are largely unaware of legal rights and obligations until after problems have arisen, may postpone action because of legal uncertainties, or may be influenced by the legal environment to adopt a reactive, crisis-management approach rather than a proactive, risk-management approach. However, many discussions are based on theoretical analyses; empirical evidence is lacking. Despite the paramount importance of this issue, little has been done to investigate the actual impacts of legal and administrative systems on (short-term) drought management and to recommend the most appropriate legal and administrative mechanisms for drought management. Thus, the basic question remains: How does the legal and administrative environment faced by an urban water-supply agency affect short-term drought management decisions? If indeed there is an influence, what is the nature of this influence? How is the range of choice affected? Do the effects vary among differing legal and administrative environments? How influential is this environment relative to other considerations?

2. Contribution to Problem Solution.

The research will determine whether and to what extent legal and administrative factors influence the adoption of short-term drought management measures by community water systems. If legal and administrative factors do affect such decisions, this investigation will indicate the nature of the factors; whether the factors serve to promote or to impede drought planning and management; which factors are of greatest concern to water agencies and why; and the relative importance of legal and administrative factors vis-a-vis various non-legal management concerns.

3. Objectives.

The objectives of this research are to:

(a) assess the legal and administrative environments in which drought management occurs;

(b) determine which legal and administrative factors were manifested during the evaluation and adoption of drought management measures and to classify them within a set of elemental legal concepts;

(c) measure the extent to which legal and administrative factors influence drought management decision making, and determine whether or not the legal and administrative environment creates a negative influence and serves to impede drought management; and

(d) quantify the importance of legal and administrative factors in drought management decision making relative to other managerial concerns (for example, consumer preferences, professional ideologies, and economic factors).

4. Approach.

A total sample of approximately 600 water supply agencies will be obtained from six states which recently have experienced drought (Alabama, California, Florida, Oklahoma, Tennessee, and Wyoming). A mail questionnaire will be administered to each of the agencies and will measure responses at normal, ordinal, and interval levels. Data will be augmented by telephone interviews with key personnel at the state or regional levels, by available legal documents and related bodies of literature, and by auxiliary correspondence where appropriate.

BIOLOGY

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1898
PROJECT TITLE:	Containment of Genetically Engineered Microorganisms after Application to Subsurface Environments
PERFORMING ORGANIZATION:	University of Idaho
PRINCIPAL INVESTIGATOR:	S. Kellogg
DURATION:	September 1990 to August 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

Contamination of subsurface environments by hazardous chemicals poses one of the most serious and well-recognized threats to ground water throughout the United States. Even if contamination of ground water is not immediate, chemicals often enter aquifers secondarily by leaching processes. Thus, it is imperative that technologies be developed to remove hazardous chemicals from soils of all types. One of the few evolving technologies with the potential to economically decontaminate subsurface environments is bioremediation, the use of natural and/or genetically engineered microorganisms to mineralize pollutants.

Many hazardous chemicals such as the polychlorinated biphenyls and chlorinated dioxins are not degraded or are degraded inefficiently by naturally available microorganisms. In such cases it may be possible to engineer efficient degraders by recombinant DNA techniques. Unfortunately, use of such genetically engineered strains in the environment may be ecologically risky. New techniques are needed that will allow use of genetically engineered microorganisms (GEMS) in remediation of contaminated soils and waters while minimizing ecological risks.

2. Contribution to Problem Solution.

This research project will develop a novel physical containment technology that will permit safe uses of GEMS in the environment. In turn, this will lead to better and less expensive methods to protect and restore ground waters threatened or contaminated by toxic chemicals.

3. Objectives.

The objectives of this research are to:

(a) develop a novel double-layered cell entrapment matrix for containment of active GEMS;

(b) determine the effectiveness of entrapment in preventing cells from entering the environment; and

(c) determine the effectiveness of entrapment in preventing genetic transfer from GEMS to natural microbes.

4. Approach.

The approach will use cell entrapment techniques to develop a physical containment system that will minimize or eliminate the risk that GEMS will become established in the environment, or that GEM DNA will be transferred to indigenous microorganisms. The purpose of research is to develop and test novel techniques for using GEMS in the environment without releasing them to the ecosystem, thus enabling GEMS to remediate ground-water and subsurface soil pollution without substantial ecological risks.

Model gram-positive (a Streptomyces sp. and a Bacillus sp. harboring an inducible phage) and gram-negative (a Pseudomonas sp.) GEMS will be entrapped within calcium alginate or agarose beads, which will then be encapsulated within a thin layer of polyurethane. This outer layer should be non-biodegradable and non-permeable to whole bacterial cells or phage particles, and by varying the pore size it can be made nonpermeable to plasmids or phages, but permeable to pollutants in the aqueous phase. The polyurethane layer should therefore prevent loss of GEMS or their genes to the surrounding environment, while permitting desirable metabolic activities. DNA released from dead cells within beads will probably be degraded by nucleases, not surviving long enough to be transferred to soil or water microorganisms; such DNA also may be strongly adsorbed to the polyurethane. This system will be tested in microcosms consisting of subsurface cores to which "sequestered" GEMS have been added. We will monitor how effectively the beads prevent losses of GEMS, and whether genetic markers are transferred from GEMS to external microorganisms. Monitoring processes will include viable plate counts, phage counts, and gene probes, including use of gene amplification by the polymerase chain reaction.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1899
PROJECT TITLE:	Determining the Role of Nitrogen-Enriched Acid Rain in Estuarine Eutrophication: The Neuse River Estuary, North Carolina
PERFORMING ORGANIZATION:	North Carolina State University
PRINCIPAL INVESTIGATOR:	H. W. Paerl
DURATION:	July 1990 to July 1993

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

Acid rain and associated dry deposition constitute a significant, yet frequently overlooked and unassessed source of biologically-available nitrogen in shallow East Coast estuaries. Preliminary estimates of atmospheric nitrogen inputs in major East Cost estuaries, including the Chesapeake Bay and Albemarle-Pamlico Sounds, range from 20-40 percent of total nitrogen loading. A basic informational and management need exists to elucidate the role that this relatively large nitrogen source plays in estuarine eutrophication, particularly in light of increasing frequencies of nuisance phytoplankton blooms and the resultant water quality degradation characterizing these waters.

2. Contribution to Problem Solution.

Research results will shape our fundamental understanding of productive/trophic impacts of atmospheric deposition in estuaries and provide urgently needed information essential for evaluating and ultimately managing these impacts on intrastate, interstate, and international levels.

3. Objectives.

The objectives of this research are to:

(a) seasonally, quantify the importance of acid and non-acid precipitation as nitrogen sources, relative to other nitrogen inputs, in the Neuse River Estuary;

(b) identify the nutritive component(s) of acid rain responsible for altering primary production and phytoplankton species compositions;

(c) examine and evaluate short-term versus long-term impacts of acid versus non-acid precipitation inputs on phytoplankton primary production and community composition in the Neuse River Estuary; and

(d) determine if short-versus long-term impacts on primary production affect and/or alter trophic (food web) characteristics and transfer in the Neuse River Estuary.

4. Approach.

Because of its location downwind of acid rain sources, its well-documented nitrogen-limited characteristics, hydrological, and biogeochemical representativeness as a shallow, commercially, and recreationally-important East Coast estuary exhibiting incipient stages of eutrophication, the Neuse River Estuary is an ideal site for examining productive and tropic impacts of atmospheric nitrogen deposition. Bimonthly, we will deploy; 1) field measurements of nutrient, physical, and biotic features, including rates of primary production, phytoplankton biomass, and community composition, 2) chemical analyses of volume-weighted wet and dry deposition inputs, 3) evaluations of other point and non-point nutrient input sources, and 4) short-term in situ bioassay and longer-term mesocosm studies to examine and assess the relative importance and roles of atmospheric deposition in estuarine eutrophication. Project objectives will be addressed along a salinity gradient extending from oligohaline to euhaline conditions. Parallel, ongoing hydrological and chemical monitoring efforts along this gradient by the State of North Carolina (Department of Environment, Health, and Natural Resources), U. S. Environmental Protection Agency (Albemarle-Pamlico Estuarine Study), U.S. Geological Survey, and individual University researchers will facilitate deriving nutrient budgets, including precise estimates of atmospheric nitrogen inputs in the Neuse River Basin.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1900
PROJECT TITLE:	Biochemical and Molecular Approaches to Analysis of Metal Exposure in Natural Populations of a Marine Mollusca
PERFORMING ORGANIZATION:	University of Maryland
PRINCIPAL INVESTIGATOR:	G. Roesijadi
DURATION:	August 1990 to July 1993

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

Measurements of physiological and biochemical responses to waterborne toxic materials are recognized as potentially useful in assessing the biological effects of toxicants for water quality management. However, their development as research and assessment tools is still at a relatively early stage. Of responses studied to date, those of the metallothioneins, a family of low molecular weight, metal-binding proteins, are considered to reflect a specific response to metal exposure, with both physiological and population-based implications. Although use of this system as a measure of metal exposure has shown promise in recent studies, technical difficulties associated with metallothionein biochemistry in many invertebrate species has delayed rapid progress in this field.

2. Contribution to Problem Solution.

This study will extend recent advances in the biochemistry of molluscan metallothioneins made in the principal investigator's laboratory to the development of specific procedures for assessing metallothionein response in natural populations of oysters.

3. Objectives.

The objectives of this research are to:

(a) develop or refine procedures for (1) sample preparation for quantitative high performance liquid chromatography (HPLC) techniques for metallothionein purification so the amounts of metals bound to specific metallothionein forms can be determined in individual oysters more efficiently, (2) quantification of the metallothionein messenger RNA using molecular hybridization probes so that the level of metallothionein induction, which reflects the expression of the genetic capability, can be determined, and (3) analysis for duplications of the metallothionein gene using molecular probes so that the adaptive significance of exposure of natural populations of oysters can be evaluated; and

(b) apply procedures above in analyzing the status of metallothionein in oysters that inhabit an environment characterized by a metal gradient and oysters transplanted to that environment.

4. Approach.

The approach involves the refinement or development of procedures to assess (1) metals bound to individual forms of metallothioneins, (2) transcriptional induction of metallothionein, and (3) amplification of the metallothionein gene and application of the procedures to populations of oysters that inhabit a metal-contaminated tributary of the Chesapeake Bay. Taken together, these measures will provide information on (1) the involvement of the proteins in binding the metals of interest (cadmium, copper, and zinc), (2) the induction of metallothionein, which is known to be a specific response to metal exposure, and (3) whether long-term exposure of oysters in the field results in selection of individuals with enhanced capabilities for metallothionein at the genomic level.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1901
PROJECT TITLE:	Effective Management of Water Resources: A Function of Geomorphology and Instream Flow Requirements
PERFORMING ORGANIZATION:	Arizona State University
PRINCIPAL INVESTIGATORS:	J. C. Stomberg and D. T. Patten
DURATION:	September 1990 to August 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems Approach.

Water resource management in the arid west is facing new challenges as the values of natural resources are being recognized and addressed in legislation. Effective techniques that allow determination of minimum flows for riparian ecosystems, and do so based on readily measurable parameters, are becoming necessary to meet these challenges.

2. Contribution to Problem Solution.

This research would lead to the development of procedures for determining ecologically acceptable levels of stream diversion, as well as for discriminating between stream reaches which are ecologically sensitive to flow reduction and those which are less sensitive (for example, stream reaches that can tolerate greater levels of flow reduction without degradation of the ecosystem).

3. Objectives.

The objectives will be to test the following hypotheses:

(a) valley geomorphology can be used as an index for determining ecologically acceptable levels of stream diversion, by determination of the ecological sensitivity of stream reaches to flow reduction; and

(b) instream flow requirements of riparian vegetation vary as a function of stream geomorphology and are quantifiably lower in constrained, bedrock reaches than in unconstrained, alluvial reaches.

4. Approach.

Using newly developed dendroecological techniques that determine instream flow needs of riparian vegetation and existing techniques for classifying stream reaches according to their hydro-geomorphology, instream flow needs will be quantified as a function of stream geomorphology. Using these data, the hypotheses that valley geomorphology can be used as an index for determining ecologically acceptable levels of stream diversion, and that instream flow requirements of riparian vegetation vary as a function of stream geomorphology will be tested.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1902
PROJECT TITLE:	Microbial Degradation of Soil-Associated Organics
PERFORMING ORGANIZATION:	Virginia Polytechnic Institute and State University
PRINCIPAL INVESTIGATOR:	J. T. Novak
DURATION:	September 1990 to February 1993

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

Contaminated soils resulting from spills, leaking storage tanks, or improper waste disposal are of concern as a source of ground-water pollutants. These soils can serve as a reservoir for organics, releasing contaminants slowly over time, and thereby causing a long-term pollution problem. Although several techniques have been successfully used to clean soils, removal of some of the soil associated organics is limited by the rate at which these materials can be removed from soil surfaces. Several investigators have reported the existence of a small but significant fraction of the absorbed material that desorbs slowly. This fraction may contribute to the ground water for years after the majority of contaminants have been removed.

The principal water related problem to be addressed in this research is to better understand the fate of organics associated with soil systems. More specifically, the bioavailability of soil associated organics will be studied, and the role of humic matter in controlling the bioavailability will be evaluated.

2. Contribution to Problem Solution.

This research should help to improve the ability to predict the fate of organics and better evaluate the potential for in-site biological remediation of contaminated soils and ground waters. While adsorption can serve as an important mechanism for mitigating the impact of sub-surface contaminants by reducing peak concentrations, it can also contribute to long-term contamination problems by retaining contaminants and providing for their slow release over time. Although biological degradation has been proposed as a mechanism for cleaning of soils, the ability of organisms to remove or enhance the removal of adsorbed organics is not well understood. It can be expected that the ability of organisms to biodegrade adsorbed organics will depend on many factors, including organic contaminant and the nature of the adsorption process. In this study, these factors will be evaluated in order to better understand the fate of organic contaminants in soils.

3. Objectives.

The objectives of this research are to:

(a) determine time dependent adsorption and desorption isotherms for three organics on soil containing varying amount of humic matter. The organics to be used will be selected from a group of commercially available radiolabeled phenols based on their degradability and adsorption properties. Soil will be obtained from a site in Virginia which has previously been used for adsorption and biodegradation studies;

(b) determine the degradation rate of soil adsorbed organics in batch systems by acclimated bacteria;

(c) determine the desorption rate of adsorbed soil organics in batch systems for comparison to rates of degradation; and

(d) determine the biodegradability of organics adsorbed to dissolved humic matter.

4. Approach.

In this research adsorption and biodegradation studies will be combined in an effort to better understand the impact of adsorption on bioavailability and the effect of microorganisms on the association of organics with soil surfaces. Radiolabeled organic compounds will be used in an effort to make better measurements of the adsorbed fractions and to account for the mineralized organics. The approach used in this study should result in better mass balances and should permit the determination of the fate and distribution of organics in soil systems.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1903
PROJECT TITLE:	Biomarkers for Redox-Active Genotoxins in Contaminated Sediments: A Mechanistic Approach
PERFORMING ORGANIZATION:	North Carolina State University
PRINCIPAL INVESTIGATOR:	R. T. DiGiulio
DURATION:	July 1990 to July 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

Sediments serve as the critical repository for most persistent contaminants in aquatic systems, and sensitive approaches for assessing the hazards posed by contaminated sediments, both to aquatic systems and human users of those systems, comprise an important need for environmental scientists and managers. Of particular concern is the occurrence of genotoxins in some sediments, which has been associated with elevated rates of neoplasia in populations of benthic animals inhabiting some contaminated systems.

2. Contribution to Problem Solution.

The methodology emanating from this research will have ramifications for evaluating the integrity of aquatic systems, as well as for assessing the potential for deleterious effects on human users of such systems. It will have very practical uses for evaluating contaminated systems, prioritizing areas for clean-up efforts, and determining the success of clean-up efforts.

3. Objectives.

The objectives of this research are to:

(a) quantify relationships between exposures to contaminated sediments and biomarkers for genotoxicity and associated indices of oxyradical generation in the channel catfish (Ictalurus punctatus) and the brown bullhead (I. nebulosus) in both laboratory and field studies;

(b) test the hypothesis that free radical intermediates play a significant role in the genotoxicities of model compounds occurring in these sediments; and

(c) from these integrated laboratory and field studies, develop a sensitive, mechanistically-based approach for monitoring genotoxic impacts of contaminants in aquatic ecosystems employing feral and caged fish.

4. Approach.

Experiments will be conducted to quantify relationships between exposures of these sediments and responses indicative of genotoxicity (^{32}P-post-labeling analysis of DNA adducts, DNA unwinding, and concentrations of 8-hydroxydeoyguanosine), oxidative stress (enhanced antioxidant enzyme activities, altered redox status, and lipid peroxidation), and hydrocarbon metabolism (ethoxyresorufin O-deethylase activities and polycyclic aromatic hydrocarbons (PAH) metabolites in bile). Initial in vitro studies will assess the abilities of representative model compounds to redox cycle and generate free radicals in hepatic microsomes as indicated by cytochrome c reduction. From these experiments, one compound will be selected for detailed investigations of free radical-mediated mechanisms of DNA damage. In the second year of the project, field studies employing both feral and caged fish will be conducted in the Buffalo River and Black Creek that will closely parallel the in vivo laboratory studies. Collectively, these integrated laboratory and field studies will provide for the creation of a sensitive and practical methodology, based on a biochemically-related set of responses, for assessing the bioavailability and genotoxic impacts of compounds widely occurring in sediments of contaminated aquatic ecosystems.

AGRICULTURAL POLLUTION

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1904
PROJECT TITLE:	Effects of Drainage and Water Table Control on Ground-water and Surface-Water Quality
PERFORMING ORGANIZATION:	North Carolina State University
PRINCIPAL INVESTIGATOR:	R. W. Skaggs
DURATION:	August 1990 to July 1993

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

Non-point source pollution from poorly drained agricultural soils is important for two reasons: (1) they comprise a significant portion of our total cropland, 25 percent nationally, 40 percent in North Carolina; (2) they are concentrated in bottom lands near creeks and rivers and in the Coastal Plains close to environmentally sensitive waters. Potential impacts of non-point sources on ground-water quality are also critical as it is the source of drinking water for over 75 percent of rural residents.

Previous research has shown that drainage and water table control practices significantly affect the rate and pathway of water draining from agricultural lands. This has led to controlled drainage methods that are now being applied as a best management practice on thousands of acres in North Carolina and neighboring Atlantic coastal states. However, present methods for predicting the effects of water management and cultural practices on pollutant loading are limited. They cannot be used to determine the best way to manage controlled drainage systems to minimize pollutant loading. Nor can the effects of changing fertilizer rates, or the timing of its application, be predicted. More importantly, more research data and a good understanding of the effects of water table management on pesticide movement and fate in the ground water and surface water of these poorly drained soils is needed.

2. Contribution to Problem Solution.

This research will provide experimental data on the effects of water table control on the movement and fate of pesticides in surface water and shallow ground water. This will fill an important void in the knowledge base. Additionally, this work will result in a high quality data set on the hydrologic and water quality response to water table control practices. These data will be used to test the reliability of existing models and will be available for the development of future models to predict the fate of pesticides, nutrients, and sediment in poorly drained soils.

3. Objectives.

The objectives of this research are to:

(a) measure and evaluate the effects of drainage and water table control practices on the movement and fate of pesticides and fertilizer nutrients to ground water and surface water in poorly drained soils; and

(b) test the reliability of selected models for predicting the fate of pollutants in ground and surface waters, and to modify and improve the reliability of those models where feasible.

4. Approach.

The approach in this study will be to conduct a well-instrumented, precisely controlled, field experiment to determine the effects of drainage and related water table control practices on ground-water and surface-water quality. The focus will be on the effects of water management practices on the movement and fate of pesticides and nutrients in shallow ground water and surface water.

The data collected in these experiments will be used to test the reliability of simulation models developed elsewhere. The most promising of these models will be modified and further developed to improve their reliability for shallow water table conditions.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1905

PROJECT TITLE: Irrigation Water Quality, Rooting Depth, and Nutrient Budgets in Citrus

PERFORMING ORGANIZATION: University of Florida

PRINCIPAL INVESTIGATOR: J. Syvertsen

DURATION: August 1990 to August 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

The loss of agricultural fertilizer to the environment, particularly nitrate pollution of ground water, is a serious concern in Florida citrus production. Citrus growers have been labeled as nitrate polluters in the absence of any data to support or refute that claim. Although depth to water table and salts in irrigation water affect nutrient uptake, there is no quantitative information on effects of poor drainage and saline irrigation water on nutrient budgets and leaching losses which contribute to the deterioration of ground-water quality.

2. Contribution to Problem Solution.

This effort will provide quantitative data on the effects of water quality and depth to water table on nutrient losses into the ground water at currently used fertilizer rates for citrus production in both Florida Ridge and flatwoods soils and provide this information to growers interested in maximizing nutrient uptake and minimizing potential ground-water contamination.

3. Objectives.

The objectives of this research are to:

(a) provide macronutrient (nitrogen (N), phosphorus (P), potassium (K)) leaching data from mature 'Valencia'orange trees:

   1. Compare trees on two rootstocks growing in Ridge sand and irrigated with three levels of salinity;

   2. Compare trees growing in flatwoods soils with fixed water tables confining roots to 0.3, 0.6, and 0.9 m of depth (Ft. Pierce); and

(b) use ^{15}N enriched fertilizer to quantify effects of (1) saline irrigation water and (2) depth to water table, on N pollution hazard, N uptake efficiency and subsequent allocation.

4. Approach.

We will study nutrient budgets using mature citrus trees growing in whole-tree lysimeters to quantify water use, nutrient uptake and leaching loss as affected by rooting depth and saline irrigation water. Irrigation and fertilizer application strategies will then be modified with respect to ground-water pollution hazards and water quality management goals.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1906
PROJECT TITLE:	Predicting Water Flow and Kinetic-Equilibrium Sorption Effects on Pesticides in Soil
PERFORMING ORGANIZATION:	Cornell University
PRINCIPAL INVESTIGATOR:	R. J. Wagenet
DURATION:	September 1990 to September 1993

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

Demands by legislative bodies and regulatory agencies often make it necessary to estimate the behavior of a chemical under field conditions without sufficient knowledge regarding the interaction of the chemical with soil surfaces, or the characteristics of its transport through the unsaturated zone. Although a number of cases of pollution by pesticides of surface and ground water have been reported throughout the United States in recent years, there remain few quantitative studies that attempt to relate the basic physical-chemical processes occurring in soils to pesticide fate. This often leads to uniformed and extreme regulatory reaction, such as the banning or imposition of severe restrictions on the use of the chemical, when alteration of its management to reduce the threat of ground-water contamination might have sufficed. Additionally, a number of otherwise effective new pesticides have not been marketed because a license for their use could not be obtained due to a presumed potential danger of pollution.

2. Contribution to Problem Solution.

Increased understanding of the key processes which influence pesticide fate in soils, such as water flow and sorption, will provide a framework within which both existing and new chemicals can be properly evaluated, thereby protecting the quality of water resources.

3. Objectives.

The objectives of this research are to:

(a) develop predictive models for the movement of pesticides based on realistic and quantitative representations of water flow in both homogeneous and non-homogeneous (macropore) soils;

(b) develop, through carefully controlled laboratory experiments, an improved and more realistic representation of pesticide sorption than is presently available for atrazine and alachlor in both surface and subsurface soils, and to incorporate this understanding in models developed in objective a; and

(c) apply the models developed in objectives (a) and (b) to field data of atrazine and alachlor movement to gain insight into the transport of these pesticides in field soils.

4. Approach.

An approach that has shown promise for a number of pesticides in further extending our ability to quantify and predict sorption in unsaturated soils, and which will be explored here, is the representation of sorption as a combination of kinetic and equilibrium processes, rather than as a simple equilibrium process. By combining consideration of spatially variable water flow and sorption, this project will provide the opportunity for improved integration of the effect of these processes upon solute transport. This will be accomplished by modifying an existing model of water flow and pesticide transport, with the integration and model testing being the third objective of this project. This objective will be achieved using the results of field experiments accomplished both in New York and as part of the Midwest Water Quality Research Initiative. Soil samples of atrazine and alachlor distribution with depth and time, along with other relevant field characterization data, will provide the test data. The adaptation and improvement of an existing, widely tested and operational simulation model of unsaturated zone leaching will be the focus of the model development, with the revised model used in data analysis.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1907

PROJECT TITLE: Preventing Pesticide Contamination of Aquifers by Best Management Practices

PERFORMING ORGANIZATION: University of Delaware

PRINCIPAL INVESTIGATOR: W. F. Ritter

DURATION: September 1990 to September 1993

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

Pesticide contamination of ground water may be decreased by reducing the amount applied, improving disposal of containers, avoiding spills, and preventing transport to ground water after application. Integrated pest management is specifically directed towards reducing the amount applied. Measures for proper container disposal have been implemented and negligence resulting in spills has diminished. However, even with these measures, ground-water pollution is still a problem, and to reduce or eliminate pesticides from ground water, best management practices that promote degradation into non-harmful products before it reaches the ground water are needed.

2. Contribution to Problem Solution.

The research deals with preventing the transport of chemicals from the surface to the ground water.

3. Objectives.

The objectives of this research are to:
(a) test management strategies that reduce pesticide transport to ground water;
(b) examine the interaction of preferential flow and management practices, both on real soils in the field and on undisturbed soil columns in the laboratory: and
(c) develop general guidelines for best management practices to protect aquifers from pesticide contamination.

4. Approach.

The research will compare the effectiveness of two existing management practices (ridge tillage and reduced tillage) with two best management practices in which the organic matter content in the soil is increased with either a cover crop of clover and rye or manure. To make the results valid over a larger geographic area, emphasis will be placed on studying the underlying mechanisms that cause the difference in losses between the management practices. For that reason, we will perform both laboratory and field experiments. The laboratory studies will give insight into why the observed difference in management practices occur.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1908
PROJECT TITLE:	Tillage and NH3 Banding Impact on Water, N, and Herbicide Movement
PERFORMING ORGANIZATION:	South Dakota State University
PRINCIPAL INVESTIGATOR:	S. Clay
DURATION:	September 1990 to August 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

In many agricultural soils, applications of subsurface banded anhydrous ammonia produce chemical conditions that are quite different than those existing in the bulk soil. Interactions between herbicide, fertilizer, and tillage technique have been largely ignored, and thus, additional research is required to define the effects of tillage and fertilizer application technique on the formation and movement of herbicide-soluble organic matter complexes in soil.

2. Contribution to Problem Solution.

The proposed research will determine the amount of nitrogen (N) and atrazine moving through soil as impacted by ridge tillage and subsurface NH_3 banding. The research can be used for risk assessment of groundwater vulnerability resulting from a commonly used tillage, fertilizer, and herbicide management system.

3. Objectives.

The objectives of this research are to investigate the effect of ridge tillage and NH_3 subsurface banding on;

(a) microhydrology;
(b) N movement;
(c) soluble organic matter movement;
(d) herbicide movement; and
(e) relationship between NO_3^- and atrazine movement.

4. Approach.

This project will have both field and laboratory components. In the field, anhydrous ammonia will be banded at the 2-leaf growth stage of corn at two rates (0 and 20 g N m^{-2}) in a ridgetill system. Atrazine, used as a model herbicide, and bromide, used as a water tracer, will be applied following the fertilizer application. Soil pH, water potentials, soil temperatures, and relative aeration will be monitored continuously in the fertilizer band and in a diagonal surrounding the band. Water

(10 cm) will be applied with a rainfall simulator immediately, 7 days, and 30 days following the atrazine application. Water draining through the soil will be collected in 2-dimensional grid samplers placed below the root zone. Each individual grid will be connected to a sample bottle and vacuum pump (-10 kPa). Water samples will be analyzed for bromide, inorganic N, soluble organic carbon and N, and atrazine. Soil cores will be taken from the soil above the grid and analyzed for the different components. Soluble organic matter in fertilizer band and extracted from soil samples will be characterized by high performance liquid chromatography. In the laboratory, atrazine adsorption and desorption isotherms will be determined under different anhydrous ammonia application rates. Data from laboratory and field experiments will be used as input parameters to validate existing models that predict NO_3-, herbicide, and water flow in soil.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1909
PROJECT TITLE:	Matrix Diffusion and Contaminant Transport in Granular Geologic Materials, with Case Study of Nitrate Transport, Salinas Valley, California
PERFORMING ORGANIZATION:	University of California
PRINCIPAL INVESTIGATOR:	G. E. Fogg
DURATION:	September 1990 to August 1993

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

Non-point source contamination of ground water, particularly from agricultural fertilizers, pesticides, and herbicides, is degrading ground-water quality over vast regions of the world, but little scientific effort has been devoted to this problem. As stated in a recent report by the Office of Science and Technology Policy with respect to non-point source contamination. (Subcommittee on Ground Water 1989),

> "Models currently are not available to account for the spatial variability and the controlling factors of complex organic [and inorganic] contaminants over broad regions. In addition, models are only currently being developed that can be used to describe the movement of chemicals from their point of origin near the land surface through the unsaturated zone and into the saturated zone."

For example, we cannot even answer the question: How much must fertilizer use be curtailed to prevent further nitrate contamination, and when would the ground-water quality recover to acceptable levels? Answering this question will require consideration of a fundamental transport process that has heretofore largely been overlooked, that is, matrix diffusion. This process involves diffusion of a dissolved contaminant from relatively high-conductivity materials into relatively low-conductivity materials and can be very significant if the surface area or interface between materials is large and the contaminant spreads over a large enough area to contact substantial portions of this interface. We submit that most geologic materials are heterogeneous, making the surface area between regions of low and high-conductivity materials vast, and in regional transport the plume(s) will encounter enough low-conductivity material to effect substantial attenuation.

2. Contribution to Problem Solution.

Several important contributions to problem solution would result from this research. (1) The first ever simulations of the matrix diffusion phenomena in realistically heterogeneous geologic materials over long time scales would provide information on the potential role of matrix

diffusion on ground-water contaminant migration. (2) Improved methods of modeling aquifer heterogeneity and matrix diffusion would be developed. (3) Improved understanding of long-term migration of nitrate in the vadose zone and aquifers of an alluvial valley (Salinas Valley) as a function of nitrate loading rates would be acquired.

3. Objectives.

The objectives of this research are to:

(a) define the role of matrix diffusion in realistically complex geologic media as a function of hydrogeologic conditions, geostatistical parameters, and length and time scales;

(b) estimate travel times through the relatively thick vadose zone of the Salinas Valley; and

(c) study long-term response of an alluvial valley aquifer system to changes in nitrate loading rates.

4. Approach.

The approach will be to generate the "realistically complex" heterogeneities with stochastic simulation methods that are conditioned with existing data and new data to be collected in this study. Geostatistical parameters for the stochastic simulations will be obtained from previous studies and from hydrologic and geologic data on the Salinas Valley. Hypothesis testing on the role of matrix diffusion in the various heterogeneity scenarios will be performed by simulating particle movement in two and three dimensions. Nitrate fluxes through the vadose zone in the Salinas Valley will be estimated using the bromide anion as an in-place tracer. Bromide was applied to parts of the valley 10 to 20 years ago when methyl bromide was routinely used as a fumigant.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1945
PROJECT TITLE:	Effect of Uniconazole on Plant Growth and Water Use
PERFORMING ORGANIZATION:	Oklahoma State University
PRINCIPAL INVESTIGATOR:	J. C. Henderson
DURATION:	September 1990 to August 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

Limited water supplies in various localities and during certain parts of the year make production and maintenance of landscape plants difficult. Utilization of drought tolerant plants or cultural practices which reduce water use is advantageous in reducing water needs, thereby conserving available moisture. Nursery producers are particularly concerned with water availability and potential rationing plans since they are not always considered an agricultural entity which is exempt from rationing. Any water conservation practice which can be implemented into existing production systems is advantageous.

2. Contribution to Problem Solution.

Results of this research would lead to cost effectiveness of nursery production in two ways. First, less pruning would be necessary to maintain desireable plants, so less labor would be needed. Second, the potential reduction in water usage by treated plants could help conserve available water for other water needs or for later use in production.

3. Objectives.

The objectives of this research are to:

(a) determine the effectiveness of foliar and soil drench applications of uniconazole on growth of three common landscape plant species;

(b) determine the ability of uniconazole to reduce water use of a predetermined woody plant species; and

(c) determine the effect of uniconazole on gibberellic acid (GA) and abscisic acid (ABA) quantities and their influence on water use of a predetermined woody plant species.

4. Approach.

This research will include screening several plant species for their growth response to uniconazole, then testing the most affected species for differences in drought tolerance. This data will be used in conjunction with ABA and GA analyses to find a possible casual relationship between biochemical activity and water use in the plant.

WATER QUALITY

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1910
PROJECT TITLE:	Soil Spatial Variability Considerations in Salt Emission and Drainage Reduction
PERFORMING ORGANIZATION:	University of California
PRINCIPAL INVESTIGATOR:	J. W. Hopmans
DURATION:	August 1990 to July 1993

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.
It is generally accepted that current and future irrigation management should focus on practices that control salinity and deep percolation losses. Excess drainage water increases salt and trace element loading to surrounding surface and ground waters. In addition, it may elevate the water table and cause water logging and salt buildup in the root zone. Moreover, in regions where a large fraction of the total water supply is used for irrigated agriculture, improved water management can save large amounts of water which can be used for other purposes. Field studies and modeling efforts are needed to reduce applied water and drainage within environmental and economic constraints.

2. Contribution to Problem Solution.

Management practices resulting from this study may prove to be an intermediate as well as long-term solution to salinity and drainage problems in irrigated fields. Success with these practices presumes that the proposed field layouts and surface irrigation designs are profitable, and significantly reduce salt emissions and drainage water.

3. Objectives.

The objectives of this research are to:

(a) determine if soil spatial variability considerations in drainage and irrigation management reduce mass emission of salts through deep percolation or drainage;

(b) analyze and simulate the influence of cracked soils on water infiltration, salt distribution and ground-water level response; and

(c) determine if the costs of the proposed irrigation management practices, including intensive soil sampling, are acceptable from an engineering and economic point of view.

4. Approach.

Research directed at improving irrigation efficiency has focused primarily on increasing the water application uniformity of irrigation systems.

Though this is important, an equally important factor is soil variability and how it affects infiltration, water storage, deep percolation and plant growth and development. The approach will combine surface irrigation with subsurface, unsaturated-saturated, water flow models. Both models will include stochastic components to simulate spatially variable characteristics of the irrigation and soil system.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1911
PROJECT TITLE:	Cation-Induced Aggregation in Humus and Its Relationship to Aquatic Organic Contaminant Transport
PERFORMING ORGANIZATION:	South Dakota State University
PRINCIPAL INVESTIGATOR:	J. A. Rice
DURATION:	August 1990 to August 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

Laboratory studies of the aggregation of aquatic humus have focused on parameters (pH, ionic strength, dissolved organic carbon (DOC), and so forth) whose limited variability in most natural freshwater environments may indicate that they are not important controls on this phenomena. It is proposed that in a natural system the presence and concentration of multivalent cations (for example, Ca^{2+}) are more important factors in determining the extent of aggregation of aquatic humus. Previous studies have shown that multivalent cations (M^{2+}) will cause aggregation on a macroscopic scale (that is, precipitation, coagulation or flocculation), but the extent of aggregation on a microscopic (colloidal) scale has not been ascertained.

2. Contribution to Problem Solution.

The information gained from these studies will provide insights into the mechanisms of hydrophobic organic chemicals (HOC)-aquatic humus binding. The conclusions of the proposed studies will be useful to those studying the fate and transport of organic contaminants in natural aquatic systems.

3. Objectives.

The objectives of this research are to test the hypotheses that:

(a) the extent of aggregation, on a microscopic scale, will vary with the M^{2+} concentration under environmental pH, DOC and ionic strengths; and

(b) M^{2+} induced aggregation of aquatic humus will solubilize relatively insoluble hydrophobic organic chemicals.

4. Approach.

The aggregation of aquatic humus as a function of the M^{2+} concentration will be monitored using small angle x-ray scattering and gel permeation chromatography. Solubilization of the HOC, as a function of the degree of aggregation of aquatic humus will be assessed using ^{14}C-labelled compounds and liquid scintillation counting.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1912
PROJECT TITLE:	Nucleophilic Reagent Effect on Mutagenic, Chlorinated Drinking Water
PERFORMING ORGANIZATION:	State University of New York
PRINCIPAL INVESTIGATOR:	R. T. LaLonde
DURATION:	September 1990 to September 1993

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

The hygienic chlorination of humic-containing drinking water and the industrial chlorination of lignin result in the formation of a family of genotoxic substances, of which MX is the most potent isolated to date. The systematic name of MX is 3-chloro-4(dichloromethyl)-5-hydroxy-2(5H)-furanone. MX is a bacterial mutagen, a mammalian cell clastogen, and a major contributor to the mutagenic activity of drinking water concentrates from three continents. MX forms an adduct with DNA. The occurrence of MX and other genotoxins of the same family is a concern because of the possible long-term carcinogenic hazard from chronic ingestion of these substances.

2. Contribution to Problem Solution.

Current and previous results point to possible relationships between the molecular structure of MX compounds and their reactivity with nucleophiles, an understanding of which is necessary for assessing compound stability, inactivation treatments, mechanisms of biochemical detoxication, and the action of the MX family of substances on DNA leading to expression of genotoxicity. Almost totally lacking from the current and previous work is the identification of products resulting from MX. Characterization of reaction products is a first step leading to an understanding of chemical reactivity. The absence of reaction product identification is the problem addressed by this research.

3. Objectives.

The objectives of this research are to:

(a) identify where MX undergoes attack by a hydride reducing agent;

(b) determine the degradation products of MX when it reacts with water or hydroxide ion;

(c) determine the products resulting from the nonenzymatic reaction of glutathione with aqueous solutions of MX; and

(d) identify MX reactions with deoxynucleosides as indicators of DNA reactivity.

4. Approach.

Reaction products resulting from the action of the nucleophiles - hydroxide ion, glutathione and deoxyquanosine - will be isolated and identified. The product profiles of complete and incomplete inactivation of MX by alkali and glutathione will be compared and the products unique to the incomplete inactivations will be assayed for mutagenicity. The foregoing experiments will be conducted to test the null hypothesis: incomplete inactivations occur because initial, rapidly formed intermediates have a measure of mutagenicity of their own that is subsequently lost at a slower rate of inactivation by the nucleophilic reagent.

Products obtained from the action of the nucleophilic reagent sodium borohydride on MX will be characterized to test the second hypothesis: reacting in solution above pH 7, MX will give products from its open-ring tautomer. This second hypothesis will be further tested in comparing the product profiles resulting from the action of water, hydroxide ion and glutathione on both MX and 4-(dichloromethyl)-2(5H)-furanone. The latter, a highly mutagenic structural analog of MX, cannot tautomerize to the open-ring form, and therefore, serves as a model of the closed-ring tautomer of MX. Finally, the products from the reaction of MX with deoxyguanosine will be characterized to complete the assessment of MX's reactivity with a range of nucleophiles pertinent to the questions of MX's stability, inactivation and genotoxic effects, and to set the stage for solutions to the more complex problems of the structural ramifications in DNA-MX interactions.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1913
PROJECT TITLE:	In-Situ Solvent Extraction for Remediation of Coal Tar Sites
PERFORMING ORGANIZATION:	Carnegie Mellon University
PRINCIPAL INVESTIGATORS:	R. G. Luthy and D. A. Dzombak
DURATION:	August 1990 to January 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

A significant environmental problem at sites of former manufactured-gas plants and other industrial and waste disposal sites throughout the country is subsurface contamination with dense, nonvolatile organic liquids. Currently, this problem is responsible for ground water contamination in many areas and is difficult to remediate by means other than excavation, an approach often not technically or economically feasible.

2. Contribution to Problem Solution.

A possible alternative to conventional subsurface contaminant recovery schemes for removal of dense, nonvolatile organic liquids such as coal tars, is in-situ extraction by injection and recovery of a suitable water-soluble solvent. In this project, the technical and economic feasibility of such a remedial approach will be investigated. In-situ solvent extraction offers the possibility of a simple, cost-effective technology for removal of long-term sources of ground-water contamination.

3. Objectives.

The objectives of this research are to:
(a) evaluate the feasibility of in-situ solvent extraction for recovery of waste tar from the subsurface at former manufactured-gas plant sites.
(b) identify and evaluate promising solubilizing agents consisting of environmentally-degradable, water-miscible, organic solvents;
(c) assess the tar dissolution process and solvent recovery;
(d) develop physical and mathematical models that can be used to assess appropriate deployments and designs for an injection/recovery system; and
e) perform preliminary engineering design/feasibility studies for cost estimation and for development of plans for larger-scale testing.

4. Approach.
Laboratory studies and engineering analyses will be employed to evaluate promising solvents (for example, alcohols, ketones), examine coal tar dissolution rates, identify appropriate hydrogeologic conditions for effective deployment, develop physical and mathematical models and conceptual designs, and evaluate costs.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1914

PROJECT TITLE: Three Dimensional Modeling of Pollutant Transport in Surface Waters

PERFORMING ORGANIZATION: Stevens Institute of Technology

PRINCIPAL INVESTIGATOR: M. Bruno

DURATION: August 1990 to August 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

The continuing degradation of many surface water bodies by contamination from hazardous and toxic substances is one of the most formidable problems facing today's environmental scientists and planners. Examples include the introduction of polychlorinated biphenyls (PCBs) into Buzzards Bay, Massachusetts, through PCB-laden bottom sediments, and the high concentrations of heavy metals in Raritan Bay, New Jersey, associated with heavy industry discharges, legal and illegal. These are just two examples which serve to highlight the seemingly endless array of water quality issues currently being addressed throughout the nation, whether in rivers and streams, the Great Lakes, or along our coastlines. In most cases, the development of remedial solutions depends on the quality of information concerning the behavior of the water-borne pollutants, including transport and mixing rates, residence times, etc. Such information is not practically obtainable from field investigations. In fact, a prediction of pollutant behavior within the water column is often required to avoid and/or alleviate potential problems.

Although this topic has attracted much attention in recent years, most investigators have, for a variety of reasons, concentrated on a two-dimensional treatment, that is, utilizing depth-averaged water velocity information and obtaining tracer concentration variations only in the horizontal plane. Obviously, such a treatment is of limited use when a situation dictates a knowledge of the three-dimensional behavior of pollutants, as would be the case for examining the vertical transport of the bottom-dwelling PCBs mentioned earlier.

2. Contribution to Problem Solution.

A three-dimensional, Eulerian-Lagrangian model of pollutant advection and diffusion will provide an extremely valuable tool in the simulation of the behavior of surface water pollutants. Information as to the transport and mixing rates of pollutants introduced to the water column will provide a key ingredient needed in the analysis by environmental scientists of the eventual fate of water-borne pollutants.

3. Objectives.

The primary goal of the research is the development of a fully three-dimensional transport model for use in the analysis of the eventual fate of water-borne pollutants.

4. Approach.

The approach will focus on the prediction/simulation of the three-dimensional behavior of water-borne tracers under the combined action of current-induced advection and turbulent diffusion. Specifically, an attempt to develop a numerical model within the framework of the Eulerian-Lagrangian method of transport modeling. This method has been applied in the two-dimensional simulation of pollution transport with very favorable results. This fact, and the stated need for three-dimensional information on pollution concentrations, would appear to make this extension of the state-of-the-art a logical and worthwhile pursuit.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1915
PROJECT TITLE:	Spreading of Oil in Ice Covered Water
PERFORMING ORGANIZATION:	Clarkson University
PRINCIPAL INVESTIGATOR:	P. D. Yapa
DURATION:	August 1990 to August 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

Oil spills occur in many surface water bodies. The magnitude of these oil spills can vary from a few hundred gallons to millions of gallons, such as the recent Valdez oil spill in Prince William Sound, Alaska. The possibility of oil spill occurrence in ice covered waters has increased in the last two decades due to increased winter navigation, oil drilling in cold climate, and the use of super tanker transport. These oil pollution problems occur in both saltwater ice and freshwater ice.

2. Contribution to Problem Solution.

The ability to simulate oil spreading is important in assisting clean-up operations, assessing the environmental impact due to accidents, contingency planning, and evaluating risks. Therefore, establishing methods to predict the spreading rates under different ice cover conditions is vital to reducing environmental damage. It is expected that the proposed study will result in a more comprehensive and more accurate formulation than those available at present.

3. Objectives.

The objective of the study is to develop equations that can be used to predict the spreading of oil in ice covered waters.

4. Approach.

First the equations will be derived for oil spreading in ice covered waters. The equations will then be verified through experiments, using oils of different viscosities, ice covers of different roughnesses, and a variety of discharge conditions.

FLOW AND TRANSPORT

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1916
PROJECT TITLE:	Spreading and Mixing of Soluble Contaminant Plumes in Self-Similar Porous Media
PERFORMING ORGANIZATION:	Utah State University
PRINCIPAL INVESTIGATORS:	M. W. Kemblowski and G. Urroz
DURATION:	September 1990 to September 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

There is a strong scientific need to investigate how the mixing process occurs in ground water, and what properties of the subsurface determine the rate of mixing. Such information can be used to understand the decrease in concentrations within the contaminant plume (which obviously cannot physically occur without mixing). Furthermore, ground-water mixing is extremely important to the analysis of subsurface chemical and biochemical processes. It is generally agreed that the biodegradation of soluble hydrocarbons occurs significantly faster under aerobic (oxygen present) conditions than under anaerobic ones. If the ground water surrounding a soluble hydrocarbon plume contains oxygen, the degradation of the plume will be considerably enhanced by the mixing of oxygen and hydrocarbon at the plume's edge. Intuitively, even if one assumes that the major mixing mechanism is in this case the molecular diffusion, the mixing process should be helped on the macroscale by the fact that the "contact surface" between the plume and ground water is highly irregular due to the subsurface heterogeneity.

2. Contribution to Problem Solution.

The plume's spreading coefficient and mixing coefficient are fundamental quantities that describe the transport and fate of soluble plumes. This research will contribute to the understanding of how these parameters relate to the statistics of log-conductivity, assuming that its distribution can be described using the concepts of fractal geometry. Thus, the relationship between the log-conductivity distribution's statistics (fractal dimensions, which may be different in different directions, and its intrinsic variance) and the spreading and mixing coefficients will be investigated. The research will take into account the finite size of the contaminant plume. It is worth noting that most of the research on solute transport in ground water has been focused on the evaluation of macrodispersity coefficients, assuming a close connection between dispersion (spreading) and mixing.

3. Objectives.

The principal objective of this research is to determine how the self-similar nature of the logK distribution influences the spreading and mixing of soluble contaminant plumes.

4. Approach.

We shall use spectral methods, stochastic analysis, and numerical and analytical modeling to solve the stochastic differential equation that governs the transport of soluble plumes in heterogeneous formations. In particular, we will analyze this process for self-similar distributions of logK. No simplifying assumptions will be made regarding the fractional dimensions of logK distribution. Specifically, we will allow the fractional dimension to be anisotropic (that is, different in the vertical and horizontal directions). Two approaches will be used to simulate the contaminants' degradation in the presence of oxygen: (1) instantaneous reaction, and (2) Monod kinetics. The numerical modeling effort will most likely utilize the finite difference method combined with the random walk approach. Fractal algorithms will be used to generate self-similar logK fields.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1917
PROJECT TITLE:	Mass Transfer of Volatile Organic Compounds and Gases Across the Capillary Fringe: Physical and Mathematical Modeling
PERFORMING ORGANIZATION:	Oregon Graduate Institute of Science and Technology
PRINCIPAL INVESTIGATOR:	R. L. Johnson
DURATION:	September 1990 to September 1993

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.
Mass transfer across the capillary fringe is a controlling factor in the subsurface transport and fate of volatile organic contaminants. Unfortunately, flow and transport within the capillary zone are very complex and not well understood. For many volatile organic compounds, it is crucial to understand the importance of mass exchange from the unsaturated to saturated zones because very small concentrations of these compounds in ground water (i.e., parts-per billion) are thought to pose health risks. Contaminants also can move from the saturated zone to the unsaturated zone and ultimately to the atmosphere, and there is increasing interest in measuring unsaturated-zone vapor concentrations as a means of detecting and characterizing underlying ground-water contamination. However, without a better understanding of the processes controlling this exchange, these and other important questions regarding ground-water quality cannot be adequately assessed.

2. Contribution to Problem Solution.

This research will examine the exchange of volatile organic compounds and gases between the saturated and unsaturated zones. It will investigate the influences of compound properties, ground-water velocity, soil-moisture profile, infiltration, water-table fluctuations, aquifer heterogeneity, and surface boundary conditions on this exchange. Both quantitative experimental data and a validated numerical model will be direct results of this project.

The large physical model studies proposed here provide an excellent research tool to complement laboratory, field and mathematical research activities. The models provide the control and flexibility available in laboratory experiments but also permit the larger distance and time scales typical of field experiments. The physical models can also be designed to match initial and boundary conditions of interest in the mathematical models.

3. Objectives.

The objectives of this research are to:

(a) examine the processes which control the movement of volatile organics and gases between the ground-water and unsaturated zones under steady-state flow conditions using large physical models;

(b) characterize how the physical/chemical properties of the compounds of interest affect the capillary-zone mass-transfer process;

(c) examine how changes in ground-water velocity influence mass exchange;

(d) examine how changes in water level affect the mass-transfer process;

(e) determine the role of infiltration in redistributing mass near the capillary fringe; and

(f) develop and validate a mathematical model which describes how the factors listed above mass transfer across the capillary fringe.

4. Approach.

Organic compounds will be introduced into the ground-water zone of a physical model, which will be operating under steady flow conditions. Vapor and ground-water samples will be collected from an array of discrete-level monitoring points. This experiment will serve as the benchmark for subsequent non-steady-state conditions. By selecting a suite of compounds with a range of physical and chemical properties it will be possible to decouple many of the processes which control mass transfer (for example, sorption and volatilization). Once the organics distribution reaches steady-state in the aquifer, the ground-water velocity will be increased, and subsequent changes in contaminant distribution will be determined. The water level in the aquifer will be lowered 0.5m, and vapor concentrations will be determined. The water level will be raised 1.0m and both vapor and aqueous-phase concentrations will be determined. Metered amounts of water, corresponding to 1-3 centimeter rain events, will be distributed over the surface of the aquifer, and changes in organics distribution will be observed. A series of lower- and higher-permeability lenses will be placed in the aquifer, and several of the previous experiments will be repeated. Data gathered during the preceding experiments will be used to construct and validate a Eulerian-Lagrangian numerical model for ground-water flow and mass transfer across the capillary fringe.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1918

PROJECT TITLE: Dispersion in Variable Density Flow

PERFORMING ORGANIZATION: Ohio State University

PRINCIPAL INVESTIGATOR: F. W. Schwartz

DURATION: August 1990 to August 1993

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

A continuing thrust of research in the study of mass transport in groundwater systems is the definition of the processes controlling mass transport. To date, there is virtually no information to establish how important density-related phenomena are in controlling concentration distributions at the field scale. The large number of practical situations in which these effects could develop (for example, contaminant plumes of all kinds, deep well injection of fluids, and evaporative concentration in regional flow situations) demands that these processes be examined critically.

2. Contribution to Problem Solution.

The research will establish when density effects on dispersion have to be considered and their relative importance as compared to other transport processes.

3. Objectives.

The objectives of this research are to:

(a) evaluate the ability of numerical models to simulate dispersion due to Rayleigh convection and local-scale variability in velocity related to interactions between density-driven flow and heterogeneities; and

(b) establish through simulation the importance of density-affected dispersion in controlling mass transport at the macroscopic or field scale.

4. Approach.

The approach is to numerically model density-affected dispersion at a field scale with realistic representations of heterogeneous aquifer systems. A necessary step in advance of this modeling is the validation of the variable density flow and mass transport model, particularly in terms of the ability of these models to simulate convective instabilities. For this purpose, we will utilize actual data already collected from a series of flow-tank experiments (Schincariol, R. A., 1989, M. Sc. Thesis, University of Alberta). These experiments involve homogeneous and

isotropic, layered, and lenticular media and a variety of different density contrasts. The overall evaluation will involve statistical and qualitative comparisons of the simulation and experimental results.

The field-scale modeling will be based on data from well characterized sites like Canadian Forces Base Borden or Cape Cod, Massachusetts, but the problems will be suitably generic. The base cases will be trials involving a fluid having the same density as the ambient ground water. Succeeding model trials will involve varying fluid density and flow velocities together with the correlation structure in hydraulic conductivity. We will frame our analysis of these results in terms of appropriate dimensionless numbers to generalize their applicability.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1919
PROJECT TITLE:	Hydrodynamic, Hydrochemical, and Hydrothermal Investigation of Bank Storage Effects in Stream-Aquifer Systems
PERFORMING ORGANIZATION:	University of Texas
PRINCIPAL INVESTIGATOR:	J. M. Sharp, Jr.
DURATION:	August 1990 to July 1991

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

Research to compare and develop methods to study and quantify the relationships between a stream and its associated alluvial aquifer is needed. Understanding bank storage, ground-water levels, ground-water flow, and solute transport in both systems is necessary for the effective management of surface-water and associated ground-water resources.

As an example, the Lower Colorado River Authority is charged with developing water resources of the Colorado River. Problems of water quality and water availability abound from the City of Austin to the Gulf of Mexico. Specific problems include chemical pollution from irrigation return flows, transport of acidic waters into surface water from flooded lignite mines, nitrate leaching beneath feedlots and landfills, and inadequate water supplies to satisfy all of the competing demands (for example, agriculture, municipal supply, recreation, and habitats).

A need for the protection and proper management of other environmentally sensitive stream-aquifer systems in other river basins exists. This need can be realized only if the relationships between the stream and its alluvial aquifer can be studied and quantified.

2. Contribution to Problem Solution.

The research focuses on techniques which can be used to study stream-aquifer relationships. Methods to quantify the exchange of water, chemical species, and heat between a river (the lower Colorado River) and its alluvial aquifer will be developed. Emphasis will be placed on the use of coupled-process digital models calibrated with hydraulic, hydrochemical, and hydrothermal field data.

3. Objectives.

The objectives of this research are to:

(a) develop a method to quantify the exchange of water, chemical species, and heat between the lower Colorado River and its associated alluvial aquifer using field data and digital simulations;

(b) determine if coupled-process digital models, calibrated with field data, are superior to existing theoretical bank storage models, and determine if coupled-process models can be used to accurately quantify bank storage effects and other problems of stream-aquifer interaction; and

(c) determine what hydraulic, hydrochemical, and thermal research tools, and what field, analytical, and numerical techniques should be used to study and quantify stream-aquifer processes in other river systems.

4. Approach.

A five-fold approach is planned. It will include the installation of several monitoring wells at several locations along the lower Colorado River; collection of diurnal and spatial data on the hydraulic, hydrochemical, and thermal variations in surface water and ground water which accompany stream stage fluctuations; interpretation of hydrodynamic, hydrochemical, and hydrothermal processes individually, using statistical techniques, analytical equations, and single-process numerical simulations; application of a coupled-process model using field data collected during natural and artificially induced river stage fluctuations; rigorous comparison between single-process and coupled-process simulations; and analysis of coupled-process models for the quantification of stream-aquifer processes in other river systems.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1920

PROJECT TITLE: Scale Variations in Ground Water-Surface Water Interactions

PERFORMING ORGANIZATION: University of Illinois

PRINCIPAL INVESTIGATOR: K. L. Prestegaard

DURATION: August 1990 to July 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.
In most humid temperate regions, overland flow is rare except during extreme storm or snowmelt events. Streamflow is generated by subsurface as well as surface processes. In most regions, we do not know ground-water and unsaturated zone contributions to streamflow nor the controls on these contributions. Yet this knowledge is essential for accurate rainfall-runoff predictions and for determining the fate of contaminants transported in ground water.

2. Contribution to Problem Solution.
The project will monitor in the field the contributions of ground-water flow to streamflow and to determine mechanisms of interactions between ground water and surface water. A main focus of this research is to determine if there are scale variations in the timing and magnitude of ground-water contributions to streamflow.

3. Objectives.

The objectives of this research are to:
(a) identify processes and areas where ground water-surface water interactions are important and to monitor variations in ground-water contributions to streamflow that occur with variations in scale and/or with season; and
(b) examine the mechanisms by which ground-water systems can respond rapidly to precipitation events and to determine the consequences of these responses to surface water flow.

4. Approach.
The approach is to monitor surface and subsurface flow processes in a small (0.5 km^2) convergent basin which is outfitted with rain gages, piezometers, tensiometers, and small weirs. Flow in the basin will be monitored during snowmelt and rainstorm events and the hydrologic characteristics of the soils will be evaluated throughout the year. Precipitation, streamflow hydrographs, ground-water discharge, and ground-water flow paths at 11 main sites in a larger (30 km^2) basin using automatic recording stream gauges, rain gauges, seepage meters, minipiezometers, and piezometers will also be monitored. The researchers will directly monitor the mechanics of the unsaturated zone and ground-water movement in the floodplains, which can be compared with the mechanics and rates of subsurface flow in headwater hillslope systems.

PROJECT INFORMATION

GRANT NUMBER: 14-08-0001-G1921

PROJECT TITLE: Using Ground Penetrating Radar to Improve Monitoring and Predicting Preferential Solute Movement in Sandy Soils

PERFORMING ORGANIZATION: University of Wisconsin

PRINCIPAL INVESTIGATOR: S. Kung

DURATION: September 1990 to September 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

Recently, field experiments conducted in Plainfield sand by the researchers demonstrated that water and solute applied uniformly to soil surfaces were funneled by interbedded and inclined soil layers into concentrated flow paths that occupied only a small portion of the soil matrix in the vadose zone and bypassed the bulk of the soil, yet, accounted for most of the transport.

Preferential flow not only invalidates currently developed models but also has a significant impact on ground-water contamination. The contamination potential of water-borne chemicals carried by preferential flow increases significantly because the flow is more concentrated and faster; hence the time available for degradation is greatly reduced. Because preferential flow carries a chemical through a very small portion of the soil matrix, total adsorption will be also greatly reduced. Moreover, because water flows through more scattered regions as it moves deeper, preferential flow invalidates current solute sampling protocol.

2. Contribution to Problem Solution.

The research will extend the understanding of the transport of contaminants in sandy soils to ground-water supplies. It will result in a nondestructive technique to classify possible flow paths in sandy soils. It also will provide an experimentally verified model for preferential flow in sandy soils and improve sampling techniques. The results will be of use to planners and engineers designing land-use plans and site regulations.

3. Objectives.

The objectives of this research are to:

(a) improve ground penetrating radar so that characteristics of the vadose zone can be accurately determined;

(b) develop monitoring techniques valid for preferential contaminant transport in the sandy soils; and

(c) construct precise models valid for complex strata with specific attention to conditions which can trigger preferential paths.

4. Approach.

In the development of characterization of the soil profile, ground penetrating radar images of large laboratory and field soil profiles will be used to map soil layers of different conductivity in three-dimensional space. Based on the three-dimensional images, monitoring schemes will be developed locating samplers in areas where the flow is concentrated. The experimental work will also focus on developing simulation models for solute transport in the presence of inclined soil layers of different conductivity. The location of the layers, the validity of the monitoring scheme, and the accuracy of the models will be verified in the laboratory by assembling layered soil profiles and in the field by infiltrating tracers (dye and bromide) and observing the distribution by excavating the site until ground water is reached.

PROJECT INFORMATION

GRANT NUMBER:	14-08-0001-G1989
PROJECT TITLE:	Hydrogeologic and Petrologic Implications of Mixing-Zone Geochemistry in a Coastal Intermediate Aquifer System
PERFORMING ORGANIZATION:	University of Virginia
PRINCIPAL INVESTIGATOR:	J. S. Herman
DURATION:	September 1990 to September 1992

PROJECT DESCRIPTION

1. Identification of the Water-Related Problems.

The intermediate aquifer system is of burgeoning importance as a water resource in southwest Florida. The aquifer system consists of three general hydrogeologic units: confining beds at the top and base that separate a water-bearing unit, in the middle, from the overlying surficial aquifer system and the underlying Floridan aquifer system. The aquifer units are primarily composed of either siliciclastic sand or carbonate rock.

In coastal areas, saltwater and freshwater mix in zones within the aquifer portion of the system. The freshwater-saltwater mixing has produced in such zones a chemically reactive environment conducive to the diagenetic processes of carbonate mineral dissolution, alteration, and precipitation. The effects of diagenesis on porosity and permeability are a major influence on the groundwater flow characteristics in hydrogeologic systems. This is currently being investigated for the deep Floridan aquifer. At present, our knowledge of the hydrogeologic and petrologic implications of mixing-zone geochemical processes in the intermediate aquifer system is limited.

2. Contribution to Problem Solution.

The study will result in detailed understanding of how porosity and permeability evolve in the mixing zone of a coastal intermediate aquifer system. The information will be used by carbonate petrologists studying the diagenesis of limestone, by hydrogeologists studying the evolution of physical characteristics of aquifers, and by ground-water geochemists studying water-rock interactions and their control on the composition of natural waters.

3. Objectives.

The objectives of this research are to:

(a) establish the hydrogeochemistry and petrology of the mixing zone in the intermediate aquifer system;

(b) quantify the chemical reactions that have yielded the current rock and water compositions in the mixing zone; and

(c) relate these hydrogeochemical processes to the evolution of the intermediate aquifer system.

4. Approach.

The coastal area of southern Hillsborough, Manatee, and northern Sarasota Counties will be the area of study because the ground-water mixing zone is found in the intermediate aquifer system. Geochemical and petrologic research techniques will be employed to characterize the ground water above, within, and below the mixing zone and the diagenetic features occurring in the aquifer rocks. This dual approach will define the precise water-rock interactions occurring in the ground-water mixing zone.

SECTION II

SUMMARIES OF PROJECTS COMPLETED

IN FISCAL YEAR 1990

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1127

TITLE: Movement of Pesticides and Nutrients into Tile Drainage Water

PERFORMING ORGANIZATION: Purdue University

PRINCIPAL INVESTIGATORS: G. E. VanScoyoc and E. J. Kladivko

START: September 1985

FINAL DATE RECEIVED: November 1989

ABSTRACT:

The objectives of this study were to determine field-scale pesticide and nutrient losses to tile drains over a 3-year period on a low organic matter, poorly structured silt loam soil (Fine-silty, mixed, mesic, Typic Ochraqualf) under typical agricultural management practices. A tile drainage spacing study was instrumented to measure water outflow rates and to continuously collect tile outflow samples on a flow-proportional basis. Two replicates of 3 tile spacings (5, 10, 20 m) were included in the study. Water samples were analyzed for all applied pesticides (atrazine, cyanazine, alachlor, carbofuran, terbufos, and chlorpyrifos) as well as major nutrients and sediment. Annual carbofuran losses in tile outflow ranged from 0.8 to 14.1 g ha^{-1}, or 0.05 to 0.94 percent of the amount applied to the soil. Carbofuran losses to tile drains were lowest for the widest tile spacing (20 m), probably indicative of greater sorption or degradation occurring during the longer travel times to the tile. Following spring pesticide application, carbofuran concentrations in the outflow increased after each new outflow event started, and they decreased as the flow event continued. Losses of all other pesticides were $\leq$ 0.06 percent of the amount applied. Annual nitrate-N losses to tile outflow ranged from 18 to 74 kg ha^{-1}, with the greatest losses occurring from the narrowest tile spacing (5 m). The study was conducted in southeastern Indiana on the Illinoian glacial till plain, and results would be applicable to many similar soils in southern Ohio, Indiana, and Illinois.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB90-129149

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1135

TITLE: The Development of Purge and Trap with Whole Column Cryotrapping for the Analysis of Ground Water Contaminated with Organic Chemicals

PERFORMING ORGANIZATION: Oregon Graduate Institute of Science and Technology

PRINCIPAL INVESTIGATOR: James F. Pankow

START: September 1985

FINAL DATE RECEIVED: December 1989

ABSTRACT:

A method has been developed for the determination of volatile organic compounds in water. It involves the direct purging of a sample to a fused silica capillary column. As they are purged, the compounds are focussed on a DB-624 column (0.32 or 0.53 mm i.d.) using whole column cryotrapping (WCC). WCC at -90 to -80 °C traps all of the purgeable priority pollutant compounds. After purging, the gas chromatograph (GC) run is started immediately. This purge and whole column cryotrapping (P/WCC) method is facilitated by the fact that water is relatively non-volatile; at 20 °C, the equivalent of only 0.9 uL of liquid water is transported to the column for every 50 mL of purge gas at the purge vessel pressure. Advantages of P/WCC include: 1) simplicity and therefore high reliability; 2) low background contamination since no sorbent traps or multiport valves are needed; 3) no need to retain very volatile compounds on an intermediate trap; and 4) very short run times.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB90-159245

PUBLICATIONS:

Pankow, J. F., 1987, Purging directly to a capillary column with whole column cryoptrapping (P/WCC) for the determination of aqueous volatile compounds: Journal of High Resolution Chromatography & Chromatography Communications,v. 10: 7,p. 409.

Pankow, J. F., 1989 in press, Technique for removing water from most headspace and purge gases containing volatile organic compounds. Application in the purge with whole column cryotrapping (P/WCC) method: Environmental Science and Technology.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1141

TITLE: Development of Methodology and Criteria for Irrigation Management under Limited Water Conditions

PERFORMING ORGANIZATION: University of Nebraska

PRINCIPAL INVESTIGATORS: Raymond J. Supalla and Derrel L. Martin

START: September 1985

FINAL DATE RECEIVED: May 1990

ABSTRACT:

How to optimally manage irrigation systems under water-limiting ground-water regulations is an increasingly common question in the Western United States. Methodologies for addressing this question were developed and applied to a Nebraska case study region. Dynamic programming was used to analyze both inter-seasonal planning decisions and intra-seasonal irrigation scheduling decisions. The optimum plan for Central Nebraska under ground-water limitations was generally to produce continuous corn at less than full irrigation. For some water-limiting conditions a permanent or short term disinvestment in irrigation systems was found to be profitable and small acreages of alternative crops emerged as appropriate in a few instances. Optimum intra-seasonal irrigation scheduling involved establishing a target marginal net return based on the planning model and then applying water to meet the target, with consideration of actual weather and the plant response in each growth stage.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB90-222308

PUBLICATIONS:

Martin,D. L., and Van Brocklin, J., 1985, The risk and return with deficit irrigation: Paper No. 85-2594, American Society of Agricultural Engineers, Winter Meeting, December.

Severin, M. A., 1988, Optimal deficit irrigation management: Unpublished M. S. Thesis, University of Nebraska-Lincoln.

Gollehon, N.R., 1987, Methodology and strategies for multi-season farm-level irrigation decisions under limited water conditions: Unpublished Ph.D. Dissertation, University of Nebraska-Lincoln.

Martin, D. L., Gilley, J. R., and Supalla, R. J., 1989, Evaluation of irrigation planning decisions: Journal of Irrigation and Drainage Engineering, ASCE, v. 115 (1) February, p. 58-77.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1279

TITLE: Evaluation and Modeling of Volatile Organic Vapor Transport in the Unsaturated Zone for Ground-water Quality Protection

PERFORMING ORGANIZATION: Utah State University

PRINCIPAL INVESTIGATOR: R. Ryan Dupont

START: September 1986

FINAL DATE RECEIVED: October 1989

ABSTRACT:

The effects of hydraulic and temperature gradients on the emissions of hazardous organic vapors from soil systems were evaluated under a variety of initial and boundary conditions. To provide necessary environmental fate input data for transport modeling, laboratory investigations were undertaken to evaluate the effects of temperature on soil liquid transport coefficients and multiphase soil distribution constants. Distribution coefficient determinations were evaluated using multiphase versus two-phase and single component versus multicomponent systems, and the feasibility and accuracy of computational methods for estimating multiphase/multicomponent distribution coefficients was investigated. The vapor diffusion coefficients of three soils were determined as a function of bulk density, liquid content and vapor composition. A computer model which accounts for the effects of hydraulic and temperature gradients on volatile solute movement in soil systems was developed, and laboratory column studies were used for model calibration and verification. Partition coefficients determined for ten volatile compounds introduced individually into batch equilibrium reactors were statistically equivalent to those determined when introduced as a mixture of ten compounds, and linear isotherms adequately described these distribution relationships over the range of volatile organic carbon (VOC) concentrations examined in this study. As temperature increased, the mass of VOCs in the air and water phases increased, while the amount in the soil phase decreased. Temperature had a negligible effect on oil phase VOC concentrations over the temperature range from 4 to 35°C. The van't Hoff equation was not valid for all coefficients of interest in the study. Soil/water, air/soil, and air/oil partition coefficients were highly correlated with both molecular connectivity indexes (MCIs) and total molecular surface area (TSA), and regression models were developed to estimate these partition coefficients from compound topological parameters. Similar relationships between topological parameters and other partition coefficients could not be developed. However, the saturated conductivity of the test soils were shown to vary with the bulk density and soil temperature. This soil temperature effect on saturated conductivity could not be explained solely by the change in viscosity of the wetting fluid with temperature.

The saturated conductivity determined in a static temperature environment was also shown to be statistically different from that measured using a dynamic temperature environment. This has significant implications when estimating hydraulic conductivity for real world situations where temperature fluctuation is the norm. Using measured transport and partition coefficients for the fine sand and the Penreco 2257 Oil, the multiphase, non-isothermal vapor transport model developed in the study accurately predicted benzene vapor flux for a subsurface injection of oil containing aromatic compounds over the first 75 hours of the simulation. After 75 hours, unknown effects (for example, biodegradation) resulted in model divergence from measured emission values.

OBTAINABLE FORM: National Technical Information Service
Order Department
Springfield, Virginia 22161

ORDER NUMBER: PB90-119736

PUBLICATIONS:

Gan, D. G., 1988, Studies of multiphase distribution coefficients and effects of temperature on partitioning of selected hazardous organic chemicals in soil systems: Thesis submitted in partial fulfillment of the MS degree in Civil and Environmental Engineering, Utah State University, Logan, Utah, 145p.

Gan, D. C. and Dupont R. R., 1989, Batch equilibrium experiments for the measurement of distribution coefficients of selected volatile organic compounds in soil systems: Accepted for publication in the Journal of Hazardous Waste and Hazardous Materials, Fall 1989 issue.

Doherty, J. D., 1989, The effect of hydraulic and temperature gradients on the vapor emissions of hazardous materials: Dissertation submitted in partial fulfillment of the PhD degree in Civil and Environmental Engineering, Utah State University, Logan, Utah. 199p.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1280

TITLE: Canal Automation Providing On-Demand Water Deliveries for Efficient Irrigation

PERFORMING ORGANIZATION: California Polytechnic State University

PRINCIPAL INVESTIGATORS: C. Burt and J. Parrish

START: September 1986

FINAL DATE RECEIVED: October 1989

ABSTRACT:

An algorithm for downstream control of sloping canals (CARDD) was refined and tested using both computer simulations and a 200 m. long physical model canal with six pools. CARDD uses independent controllers to analyze the pattern of water level changes (based upon three water level sensors per pool and controlling a setpoint at the downstream end of a pool) and computes upstream gate movements. Rules for successful CARDD implementation were determined. In simulations CARDD was transferrable between different canals with little or no modification. Large (greater than 25% of canal capacity), multiple turnout changes could be made and stability was achieved rapidly in almost all cases.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161

ORDER NUMBER: PB90-119769

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1283

TITLE: Development and Field Evaluation of a Catenary Trail-Tube System for Reducing Irrigation Water Losses

PERFORMING ORGANIZATION: South Dakota State University

PRINCIPAL INVESTIGATOR: Shu-Tung Chu

START: September 1986

FINAL DATE RECEIVED: January 1990

ABSTRACT:

Trail tube technology has the potential to minimize irrigation water losses, maximize water use efficiencies and minimize energy requirements associated with the application of water.

A theoretical analysis of the hydraulics of a catenary trail tube system was successfully completed and expressed in the form of elevation, tube flow rate, friction loss and pressure distributions along the length of a tube. The maximum deviation between theoretical and measured tube flow rates was 3.5 percent of the total flow rate, which was judged to be an excellent verification of the developed theory.

Three trail tube treatments (1.5 m, 3.0 m, 4.5 m tube spacings) and one low pressure (40 kPa) sprinkler treatment were evaluated in a field study on a silt loam soil in north central South Dakota. Water application uniformities decreased with an increase in tube spacing. Representative coefficients of uniformities were 70, 55, and 45 percent for the 1.5 m, 3.0 m, and 4.5 m sprinkler spacings, respectively. Mean runoff depths were nearly the same for the 1.5 m and 3.0 m treatments, but were about one half of the sprinkler runoff values on the corn and soybean plots. Differences in water application uniformities and surface runoff depths did not have a significant impact on corn or soybean yields.

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U.S.A.

ORDER NUMBER: PB90-165200

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1285

TITLE: Improved Methods for Regional Flood Frequency Analysis

PERFORMING ORGANIZATION: Colorado State University

PRINCIPAL INVESTIGATOR: J.D. Salas

START: September 1986

FINAL DATE RECEIVED: June 1990

ABSTRACT:

The overall objective of the research has been to develop flood frequency models and estimation methods for prediction of floods at gaged and ungaged watersheds. Several topics were studied under this project including, estimation of Pearson III model, properties and estimation of non-conventional distributions such as mixture models, and regional maximum likelihood estimation (MLE). In addition, applications to flood data in Colorado and Illinois regions were made. Population moments, moment-ratio diagrams and separation conditions of mixture and two-component product models were studied. New families of mixture of quantile models as well as estimation based on censored MLE for mixture models were developed. Likewise, moment and MLE procedures for estimating the Box-Cox transformation parameter were derived. Results based on simulation experiments indicated that regional MLE may be beneficial in estimating flood quantiles at a given site as compared to at site estimates or estimates derived by alternative least square methods, under the assumption of a reliable regional parametric structure. However, as the parametric structure becomes unreliable, the benefits of regional MLE become less apparent. Likewise, in comparing regional MLE with generalized least squares methods based on observed flood data, results indicate that both methods perform about the same.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB90-235334

PUBLICATIONS:

Boes, D. C., Heo, J., and Salas, J. D., 1987, Examining the properties of the index flood technique: AGU Fall Meeting, San Francisco, AGU Abstract, EOS, V. 70 (15), p. 325, December.

Boes, D. C., Heo, J., and Salas, J. D., 1988, Regional flood quantile estimation for a weibull model: Water Resources Research, v. 25 (5), p. 979-990, March.

Guo, X., Salas, J.D., Cunnane, C., and Boes, D. C., 1989, Mix-distribution function for flood frequency analysis: AGU Spring Meeting, Baltimore, AGU Abstract, EOS, V. 70 (15), P. 325, May.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1291

TITLE: An Automated Method for Representing, Tracking and Forecasting Rain Fields of Severe Storms by Conventional and Doppler Weather

PERFORMING ORGANIZATION: University of California

PRINCIPAL INVESTIGATOR: M. L. Kavvas

START: September 1986

FINAL DATE RECEIVED: December 1989

ABSTRACT:

A new automated method was developed in order to track and predict in short-term (15 min-2 hr lead times) the evolution of rain fields in time and space, as observed by weather radar. First the rain field was decomposed into simple, tractable elements. Then a statistical adaptive forecasting scheme was developed in order to predict the changes in each of these elements in time. The composition of these elements forms the complete rain field with respect to its spatial configuration, location and rain intensity texture at each prediction lead time. The method has been applied to the conventional and doppler digital weather radar data of rain fields. Some application results are given.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB90-138629

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1292

TITLE: The Removal of Toxic Heavy Metals from Contaminated Ground Water and Specific Industrial Wastewater by Fungal Adsorption Process

PERFORMING ORGANIZATION: University of Delaware

PRINCIPAL INVESTIGATOR: J. P. Huang

START: September 1986

FINAL DATE RECEIVED: December 1989

ABSTRACT:

The metal adsorption behavior of 12 species of fungi was investigated using batch reactors. Specific surface area and surface characteristics of the fungal biomass were determined. Two typical fungal species, Aspergillus oryzae and Saccharomyces cerevisiae were chosen for further investigation. Factors such as growth conditions, pretreatment of biomass and pH of the metal solution were thoroughly studied. The results indicate that the optimum growth condition for metal take-up by A. oryzae biomass was at the C/N ratio of 10 - 15. The amounts of Cu(II), Cd(II), Zn(II) and Ni(II) removal increased with pH. The removal of Pb(II) by fungal biomass is pH-independent. Metal-laden fungal biomass can be regenerated by acid-washing. Moreover, the acid-washing is the most effective pretreatment of biomass for heavy metal removal. The adsorption of various metals onto fungal wall can be described by either single-site or multiple-site Langmuir isotherm using both the modified Langmuir plot and the Scatchard plot. Heavy metal removal with columns packed with pelleted A. oryzae or immobilized yeast cells of sand bed was conducted. A finite difference computer model was applied to simulate the performance of these column reactors.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U. S. A.

ORDER NUMBER: PB90-138637

PUBLICATIONS:

Westman, D., Quirk, K., and Huang, J. P., 1988, The removal of Cd(II) from dilute aqueous solutions by fungal adsorbent: Proceedings, International Conference on Water and Wastewater Microbiology, 1, 61.

Westman, D., Quirk, K., Huang, J. P., and Morehart, A. L., 1988, The removal of Cd(II) from water by fungal adsorbent: Water Science and Technology, v. 20, (11), p. 369.

Westman, D., Quirk, K., Huang, J. P., and Morehart, A. L., 1988, Removal of cadmium (II) from dilute aqueous solutions by fungal biomass: Particulate Science and Technology, v. 6, p. 405.

Huang, J. P. and Morehart, A. L., 1988, The removal of Cu(II) from dilute aqueous solutions by saccharomyces servisae: Water Research, accepted for publication.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1300

TITLE: Hydrologic Information and Analyses Required for Mitigating Hydrologic Effects of Urbanization

PERFORMING ORGANIZATION: University of Washington

PRINCIPAL INVESTIGATOR: Stephen J. Burges

START: September 1986

FINAL DATE RECEIVED: September 1989

ABSTRACT:

The objectives were to characterize for gauged and ungauged catchments the pre-development hydrology and to determine or estimate the post-development hydrology and develop criteria for runoff control measures to mitigate hydrologic effects of development. Field observations combined with map and stereo aerial photograph interpretation were used to identify catchment features associated with runoff production. From these features the spatial distribution of dominant basin hydrologic processes was estimated. Hydrologic and geomorphic processes, not considered in traditional methods, that are identified by the process zone mapping procedure developed include areas of saturated overland flow, return flow, areas with significant water detention, and channel segments where sediment transport thresholds were likely to be exceeded.

Process zone maps were prepared for any proposed development configuration and differences between it and the pre-development conditions were summarized in tables, charts, and maps. Changes in drainage density, water detention volume, and quick storm response areas were associated with their respective downstream channels. Examination of the channel sections, bars, and substrate for channel segments draining relatively undisturbed and changed parts of the catchment, respectively, indicate critical channel erosion problems and erosion and deposition potential. Flow released from mitigative schemes must be constrained above the start of first order-channels if channel geometry and stream habitat are to be preserved. The method yields primarily two-dimensional zone maps and channel segments, each having several associated attributes. The information is stored most conveniently using an appropriate geographic information system (GIS).

A relatively simple spatially-distributed rainfall-runoff model for quantitative decision making was developed using the mapped extent of flow production zones as subareas within subcatchments. Upper soil (and litter) and lower soil depths are included explicitly. The hydrographs determined for subareas (twenty to thirty per one hundred hectares) provide guidance for the type and location of appropriate mitigative measures to reduce hydrologic impacts. The model needs further refinement and testing before its general applicability can be determined.

OBTAINABLE FROM:	National Technical Information Service Order Department Springfield, Virginia 22161 U.S.A.
ORDER NUMBER:	PB90-109448

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1303

TITLE: Economic and Legal Analysis of Strategies for Managing Agricultural Pollution of Ground Water

PERFORMING ORGANIZATION: Virginia Polytechnic Institute and State University

PRINCIPAL INVESTIGATORS: S. S. Batie, R. A. Kramer, and W. E. Cox

START: October 1986

FINAL DATE RECEIVED: October 1989

ABSTRACT:

The overall objectives were to identify constitutional and legal strategies for the management of ground-water quality, to design alternative state and/or federal strategies for the management of environmental risks associated with agricultural pollution of ground water, and to estimate first round impacts of farm income, land use, government revenues, and ground-water pollution levels resulting from implementation of alternative management strategies in a case study context. A comprehensive review of existing state strategies and available legal mechanisms within constitutional constraints and the federal legal frame-work was completed. These strategies were used in hypothetical scenarios to reduce nitrate pollution of ground water from dairy farms in Rockingham County, Virginia. CREAMS, a hydrology sub-model was employed to model physical relationships between changed farming practices and altered chemical leaching magnitudes. Dairy farmers were surveyed as well, and the results were used to create a mathematical programming farm model with which to estimate impacts of alternative management strategies.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB90-129131

PUBLICATIONS:

Cox, W. E. and Batie, S. S., 1988, Protecting ground water from agricultural impacts: In the proceedings of the conference on Agricultural Impacts on Ground Water, sponsored by the Association of Ground Water Scientists and Engineers, March 21-23, p. 3-9.

Batie, S. S., 1987, Institutions and ground water quality: In Larry W. Canter (ed.), Proceedings of a National Symposium on Agricultural Chemicals and Ground Water Pollution, conducted by University of Oklahoma, June, p. 22-40.

Halstead, J., Batie, S. S., and Kramer, R. A., 1988, Agricultural practices and environmental attitudes of Rockingham County, Virginia dairy farmers: results of survey: Department of Agricultural Economics Staff Paper 88-1, Virginia Polytechnic Institute and State University, January.

Diebel, P. L., Halstead, J. M., Batie, S. S., Kramer, R. A., and Taylor, D. B., 1989, An abstract: managing agricultural nitrate contamination of ground water in Rockingham County, Virginia: A policy analysis: Southern Journal of Agricultural Economics 21 (in press).

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1306

TITLE: Efficient Management of Multiple Water Sources Given a Range of Quality Levels and User Quality Requirements

PERFORMING ORGANIZATION: University of Arizona

PRINCIPAL INVESTIGATORS: A. L. Lieuwen, B. G. Colby, D. R. Davis, and W. Martin

START: September 1986

FINAL DATE RECEIVED: January 1990

ABSTRACT:

The research project consists of an institutional and economic assessment of effluent reuse in Arizona's Tucson Basin. The study area characterizes much of the urbanizing West in terms of limited and increasingly expensive water supplies, concerns with water quality, and water managers' desire to develop reliable supplies to support a growing population. The Arizona case study is particularly interesting in light of legislative mandate to reduce ground-water pumping and eliminate ground-water overdraft. Effluent reuse is perceived as a key strategy in achieving these policy objectives.

The institutional assessment of water reuse in the Tucson Basin in Arizona indicated that despite policies encouraging the substitution of effluent for native ground water, many opportunities for water reuse are precluded by existing water rights arrangements and insufficient economic incentives to switch from ground water to treated effluent. The economic assessment compares potential benefits and costs of implementing water reuse plans for Tucson area with potential benefits and costs of alternative water-supply scenarios in which similar quantities of water are provided from other sources. Alternative water sources include pumping native ground water, "reallocating" water away from low value water uses, and importing surface water and ground water from other basins. The economic analysis indicates that, at the present time, there is no economic justification for increased water reuse. Not only are reallocation and importation alternatives less costly to implement than increases in effluent use, they also save more ground water and thus go further in achieving state policy objectives. The economic assessment implies that planned increases in the use of effluent in the Tucson metropolitan area should be postponed until the costs of water reuse become more competitive with the costs of alternative water supply and ground-water conservation options.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB90-159260

PUBLICATIONS:

Lieuwen, A. L., 1989, An institutional and economic assessment of water reuse in the Tucson Basin: PhD Dissertation, Department of Hydrology and Water Resources, University of Arizona.

Colby, B. G., 1989, Alternative approaches to valuing water rights: Appraisal Journal, v. 57, p. 180-196.

Colby, B. G. and Cory, D. C., 1989, Valuing amenity resources under uncertainty: Journal Environmental Economics and Management, v. 16, p. 149-155.

Colby, B. G., 1988, Water markets, state water transfer policies and economic consequences: Recent Developments in Western Water Law, published by American Bar Association.

Colby, B. G., 1988, Economic impacts of water law--state law and water market development in the southwest: Natural Resources Journal, v. 28, p.21-37.

Martin, W. E., Ingram, H. M., Cory, D. C., and Wallace, M. G., 1988, Toward sustaining a desert metropolis: water and land use in Tucson, Arizona: Manuscript prepared by World Resources Institute Workshops on Water and Arid Lands of the West, Tucson, February 20-21, 1986. In M. T. EL-Ashray and D. C. Gibbons eds., Water and the Arid Lands of the Unites States: Cambridge University Press, London, England, p. 281-332.

Young, R. A., Hamilton, J. R., Whittlesey, N. K., Gardner, R. L., and Martin, W. E., 1988, Discussion - aggregate marginal returns from water irrigated agriculture, by Roger B. Long: Water Resources Bulletin, v. 24 (6), p. 1337-1339.

Martin, W. E., 1988, Back to the future: A willingness to play reexamined: Western Journal of Agricultural Economics, v. 13 (1), p. 112-120.

Saliba, B. C., 1987, What are water rights worth? Valuation approaches and the value of water in alternative uses: Water Marketing: Profits, Problems, and Policies in the Western United States, p. 60-97. Published by University of Denver, College of Law.

Saliba, B. C., and Bush, D. B., 1987, Water markets in theory and practice: Market transfers, water values, and public policy: Boulder Westview Press, September, 269 pages.

Saliba, B. C., 1987, Do water markets 'work'? Market transfers and tradeoffs in the southwestern states: Water Resources Research v. 23, p. 1113-1122.

Cory, D., and Saliba, B. C., 1987, Requiem for option value--the role of option value in amenity valuation: Land Economics, v. 63, p. 1-10, February.

Bush, D. B., and Martin, W. E., 1987, Discussion - The efficiency of water pricing: A rate of return analysis for municipal water departments, by Lloyd J. Mercer and W. Douglas Morgan: Water Resources Bulletin, v. 23 (5), p. 955-956.

Martin, W. E., and Bush, D. B., 1987, Discussion - Impacts of residential water reuse in the Tucson area, by Kenneth E. Foster and K. James Decook: Water Resources Bulletin, v. 23 (5), p. 961-964.

Saliba, B. C., 1986, Market transactions and pricing of water in the West: S. Shupe, editor, Water Marketing: Opportunities and Challenges of a New Era, University of Denver, College of Law.

Abe, J. M., and Saliba, B. C., 1986, Economic Feasibility of Recharge and Recovery of Imported Water in Butler Valley, Arizona: Hydrology and Water Resources in Arizona and the Southwest, v. 15, p. 87-98.

Martin, W. E., and Thomas, J. F., 1986, Policy Relevance in Studies of Urban Residential Water Demand: Water Resources Research, v. 22 (13), p. 1735-1741.

Bush, D., and Saliba, B. C., 1986, Commodity identification and price behavior in western water markets: Abstract in American Journal of Agricultural Economics, v. 68, p. 1390.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1308

TITLE: Ground-water Investigation of SO_4 Diffusion from a Cretaceous Shale Hillslope: Upper Colorado River Basin

PERFORMING ORGANIZATION: Utah State University

PRINCIPAL INVESTIGATOR: C. J. Duffy, J. J. Jurinak, S. Korom, and P. Corey

START: September 1986

FINAL DATE RECEIVED: October 1989

ABSTRACT:

This research examines the role of advection, diffusion, and dispersion in the generation and transport of ground-water salinity from hillslopes to streams of the Upper Colorado River Basin. The study coordinated field experiments and theoretical-computer experiments to gain insight into the way that subsurface salinity fronts are mobilized and transported from hillslopes of the region, and to better understand the mechanics of the ground-water system within surficial deposits which generate the observed accumulation of salinity in the Colorado River system. The field situation is that excess irrigation water from snowmelt runoff infiltrates, generates a shallow saturated zone and ultimately produces stream salinization as return flow. The following two mechanisms are proposed: (1) the formation of a shallow aquifer and accelerated displacement of salts from alluvial sediments on the lower portion of hillslopes. This displacement is a natural consequence of excess irrigation and canal seepage. (2) The diffusion of saline pore fluids from a low permeability marine shale which underlies the shallow aquifer. Since the marine, Mancos Shale, underlies most of the irrigated land of the basin, the potential for diffusive salt loading from this formation constitutes a major nonpoint source of downstream salinity.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB90-129156

PUBLICATIONS:

Duffy, C. J., Kincaid, C. T., Huyakorn, P. S., 1989, in press, A review of groundwater models for assessment and prediction o f nonpoint-source pollution: USDA conference on nonpoint source pollution.

Lee, D. H., 1988, Comparison of models for nonpoint source pollution of groundwater: M.S. Thesis, Civil Engineering, Utah State University.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1316

TITLE: An Assessment of the Relationship Between Climate and Streamflow Variability Using Water Balance Models

PERFORMING ORGANIZATION: Portland State University

PRINCIPAL INVESTIGATOR: Roy W. Koch

START: September 1986

FINAL DATE RECEIVED: March 1990

ABSTRACT:

An improved understanding of climate variability can lead to a better description of hydrologic variability with many applications. An investigation of the association of surface climate and streamflow with a global scale climate phenomenon, the El Nino - Southern Oscillation (ENSO), showed statistically significant relationships in two regions of the western United States; the Pacific Northwest (PNW) and the desert Southwest (SW). Within these regions, the strongest associations were noted in the mountainous areas and streamflow exhibited a stronger relationship than precipitation. During ENSO events, drier conditions were observed in the PNW while wetter conditions occurred in the SW. The strongest associations were observed between annual or winter season precipitation and an index of the ENSO averaged over the previous summer. Several different methods for water supply forecasting were also evaluated, including approaches which consider associations with large scale climate features. Statistical regression equations and a water balance model were applied to the problem of forecasting the annual runoff volume for the Wilson River in western Oregon. The statistical approaches were shown to be better than the water balance approach. Of the alternative statistical approaches, the equations based only on data available up to the time of the forecast produced the best results, particularly early in the forecast season. An index of the ENSO was an independent variables in several of these equations.

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Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB90-202177

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1319

TITLE: Alluvial River Bed Transport Process with Graded Material

PERFORMING ORGANIZATION: University of California, Berkeley

PRINCIPAL INVESTIGATORS: Hsieh Wen Shen and Xudong C. Rao

START: September 30, 1986

FINAL DATE RECEIVED: September 15, 1990

ABSTRACT:

A theoretical model was developed to describe the deposition distribution of solid sediment particles. This model agrees with experimental data collected from this study.

An attempt was made to search for a single representative sediment size to be applied to existing sediment transport rate predictive equations. A new regression model was developed based on a set of 1151 existing data. This model agreed with these data better than any other existing equations.

The main contribution from this study was to develop a sediment transport model for non-uniform sediment sizes based on the Einstein bed load function.

The thickness of the bed layer was found to be related to the characteristic size of a sediment mixture and the thickness of the viscous sub-layer of the flow as well. A hiding function was established by recognizing that the finer particles move faster than the coarser ones within the bed layer.

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Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB91-111559

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1474

TITLE: Treatment of Chlorophenol-Contaminated Water and Soils Using Immobilized Microorganisms

PERFORMING ORGANIZATION: BioTrol, Inc.

PRINCIPAL INVESTIGATORS: Ronald L. Crawford and Thomas J. Chresand

START: September 29, 1987

FINAL DATE RECEIVED: April 29, 1990

ABSTRACT:

A pentachlorophenol (PCP) -degrading Flavobacterium, a p-cresol-degrading Pseudomonas, and the lignin-degrading P. chrysosporium were all effectively immobilized in both alginate and polyurethane. The immobilized cells effectively degraded their target compounds, and the systems proved amenable to use in batch or fluidized bed reactors for degrading PCP or cresol contaminated water and soil. Polyurethane appears to be the immobilization matrix of choice for field application as it (a) is mechanically strong, (b) stabilizes cells for long half-lives, (c) protects cells from pollutant toxicities, and (d) in the case of PCP, acts to adsorb the contaminant and localize it in the support. Electron microscopy showed that cells were likely entrapped in small pores in the foam as opposed to being covalently linked to it. A field laboratory was assembled at a wood treating site and a 40 liter fluidized bed reactor containing foam-immobilized Flavobacterium was operated for a four week trial. The system achieved approximately 75 percent removal of PCP with a residence time of 0.5 hours, and approximately 90 percent removal with a residence time of 0.8 hours. It was determined that PCP activity in the field was due to the inoculated Flavobacterium rather than indigenous organisms growing on the outside of the foam particles.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A

ORDER NUMBER: PB90-222241

PUBLICATIONS:

O'Reilly, K. T., and Crawford, R. L., 1989, Kinetics of p-cresol degradation by an immobilized pseudomonas sp.: Applied and Environmental Microbiology, v. 55, no. 4.

O'Reilly, K. T., and Crawford, R. L., 1989, Degradation of pentachlorophenol by polyurethane-immobilized flavobacterium cells: Applied and Environmental Microbiology, v. 55, no. 9.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1483

TITLE: Large-Scale Ocean Atmospheric Variability Associated with Hydrological Extremes in Western North America

PERFORMING ORGANIZATION: Scripps Institute of Oceanography

PRINCIPAL INVESTIGATORS: Daniel R. Cayan, John O. Roads, and Jerome Namias

START: September 1987

FINAL DATE RECEIVED: July 1990

ABSTRACT:

This project centered around the effects of Northern Hemisphere atmospheric circulation on precipitation and streamflow in North America for monthly to several year time scales, and a diagnosis of numerical predictions of precipitation from the U.S. National Meteorological Center's medium and extended range model on weekly and monthly time scales.

Monthly and seasonal northern hemisphere atmospheric flow patterns provided insight in diagnosing the great continental drought over the United States during the Summer of 1988, effects of atmospheric anomalies on the record-breaking rise in the Great Salt Lake in 1981-1986, the effect of Pacific Ocean surface conditions and atmospheric circulation on streamflow variability and stream chemistry in western North America, and the identification of extreme southerly displaced North Pacific storms which cause flooding in the San Bernadino Mountains and the Mojave River watershed. To evaluate extended range precipitation forecasts (2-10 days lead), an extensive comparison of medium and extended range National Meteorological Center Model forecasts was made with observations. This work culminated in the publication of five journal articles, listed below.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB91-159400

PUBLICATIONS:

Namias, J., 1989, 1988 Spring and summer drought over the contiguous U.S.- causes and prediction: in review for publication in Journal of Climate.

Namias, J., 1989, in press, Record-breaking rise of Great Salt Lake in 1981-86 related to anomalous mid-tropospheric wind patterns: Wetter and Leben.

Cayan, D. R., and Peterson, D. H., 1989, The influence of North Pacific atmospheric circulation on streamflow in the West: Geophysical Monograph 55, p. 375-397, available from U.S. Geological Survey, MS 496, 345 Middlefield Road, Menlo Park, California 94025.

Peterson, D. H., Cayan, D. R., Festa, J. F., Nichols, F. H., Walters, R. A., Slack, J. V., Hager, S. E., and Schemel, L. E., 1989, Climate variability in an estuary: effects of riverflow in San Francisco Bay: Geophysical Monograph 55, p. 375-397, available from U.S. Geological Survey, MS 496, 345 Middlefield Road, Menlo Park, California 94025.

Enzel, Y., Cayan, D. R., Anderson, R. Y., and Wells, S. G., 1989, Atmospheric circulation during Holocene Lake stands in the Mojave Desert: evidence of regional climate change: Nature, 341, No. 6237, p. 44-48 and 21.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1486

TITLE: Managing Ground-water Pollution from Agriculture Related Sources: An Economic Analysis

PERFORMING ORGANIZATION: Oregon State University

PRINCIPAL INVESTIGATORS: S. L. Scott, G. M. Perry, and R. M. Adams

START: September 1987

FINAL DATE RECEIVED: December 1989

ABSTRACT:

Extensive use of chemicals to enhance yield and improve crop quality has played a major role in creating a highly productive U.S. agricultural system. Increased chemical use has also imposed some significant environmental costs, among which are pollution of ground water by nitrates.

This research examines the economic effects of adopting alternative strategies that reduce agricultural-related ground-water pollution from nitrates. The research involved the development and implementation of a multi-method approach which linked a farm-level linear programming crop mix model, field-level dynamic optimization models, crop simulators, and a geohydrology model of ground water nitrate movement.

The results suggest that 1) careful management of soil moisture is critical to the reduction of pollution rates, 2) some leaching is unavoidable when producing irrigated crops within the study area, 3) weather events play a significant role in explaining the existence of nitrate leachate under optimal irrigation and fertilization practices, 4) input taxes and restrictions on nitrogen application rate may not always reduce pollution rates, 5) Pigouvian taxes, appear to be the most efficient means of reducing nitrate levels, although difficult to implement, and 6) some federal government farm program provisions increase pollution rates, while others have the opposite effect.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB90-149063

PUBLICATIONS:

Perry, G. M., and Adams, R. M., 1989, Nitrite pollution of groundwater by agriculture: what can be done?: Oregon Farmer-Stockman, 112: 6-7.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1487

TITLE: Managing Public Water Supplies During Droughts

PERFORMING ORGANIZATION: University of North Carolina

PRINCIPAL INVESTIGATORS: D. H. Moreau and K. W. Little

START: September 1987

FINAL DATE RECEIVED: January 1990

ABSTRACT:

Results of two surveys of drought management in municipal water supply systems are reported in this study. One survey covered the drought in the Southeast in 1986; the other the nationwide drought in 1988. A number of case studies are used to explore the current state of practice in greater detail. The study also included the development of a risk-based drought management model, and it examined the effectiveness of drought management plans with the use of models for daily water use. Among the major findings of the surveys are: (1) 50 percent of all urban water supplies in the country were adversely affected by the drought of 1988; (2) slightly less than 50 percent of all the utilities had drought contingency plans in place before 1988; (3) less than 30 percent of the respondents in the survey had any kind of quantitative method to support making of decisions during droughts; (4) the existence of a drought policy had a positive effect on the effectiveness of conservation programs; and (5) the existence of a decision support system had a positive effect on the level of satisfaction with decisions. The case studies revealed a wide range of practices in drought management, but for the most part, municipalities are still basing plans on historical droughts. The study also shows the kinds of errors that are commonly made in estimating the effectiveness of conservation programs in the absence of appropriate models for comparing water use with conservation with what it would have been without conservation.

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ORDER NUMBER: PB90-165192

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1491

TITLE: Prediction of Ground-water Flow and Mass Transport Using Linear and Nonlinear Estimation Methods

PERFORMING ORGANIZATION: Stanford University

PRINCIPAL INVESTIGATOR: P. K. Kitandis

START: August 1987

FINAL DATE RECEIVED: October 1989

ABSTRACT:

Geologic formations are heterogeneous with respect to the properties which affect ground-water flow and transport. However, the reliability of predictions can be improved through the effective use of site-specific measurements, descriptions of the spatial structure of geohydrologic properties, and mathematical models of flow and transport. Past research has focused on methods which involve some form of linearization and consequently are applicable to small-variance cases. The applicability of this approach was evaluated through analysis and applications. A refinement was advanced, founded on the linearization of the governing equations, about the best estimates given all available measurements. This methodology is advantageous when the variance of the logarithm of conductivity is large but there are many measurements. Furthermore, this research has combined analytical and numerical methods to extend such methods to large-variability cases. Among other contributions, numerical spectral methods were advanced for the derivation of the distribution of head given the distribution of the hydraulic conductivity or transmissivity. Another contribution was the development of an approach for the estimation of head gradients. The developed methodologies can be used by modelers in calculating probabilities needed in risk analysis, in selecting sampling strategies, in assessing the degree of contamination, and in devising cost-effective and reliable management policies.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB90-119603

PUBLICATIONS:

Philips, R. D., and Kitanidis, P. K., 1989, in press, Geostatistical estimation of hydraulic head gradients: Ground Water.

Van Lent, T., and Kitanidis, P. K., 1989, in press, A numerical spectral approach for the derivation of piezometric head covariance functions: Water Resources Research.

Hoeksema, R. J., and Kitanidis, P. K., 1989, in press, Prediction of transmissivities, heads, and seepage velocities using mathematical models and geostatistics: Advances in Water Resources.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1495

TITLE: Determination of the Toxicity, Water Quality Interactions and Biomagnification of Selenium in Aquatic Food Chains

PERFORMING ORGANIZATION: University of California

PRINCIPAL INVESTIGATOR: A. W. Knight

START: August 1987

FINAL DATE RECEIVED: November 1989

ABSTRACT:

Ecological degradation of aquatic ecosystems associated with the presence of elevated concentrations of the trace element selenium has been of considerable scientific, governmental, and public concern. The increased flux of selenium into several aquatic ecosystems, due to anthropogenic activities, has resulted in death, teratogenesis, reproductive impairment, and decreased populations in fish and waterfowl communities in these systems. Our research group has completed and is continuing several investigations into the toxicity, bioaccumulation, transfer, and biotransformation of selenium in aquatic organisms and laboratory food chains. Initial studies were primarily concerned with the comparative acute and chronic toxicity, water quality interactions, and toxicological interactions of several chemical species of selenium to a variety of aquatic organisms, including two algal primary producers (Selenastrum capricornutum and Anabaena flos-aquae), three invertebrate primary consumers (Daphnia magna, Chironomus decorus, and Hyalella azteca), and a fish (Pimephales promelas). Further research was directed towards the biotransformation, transfer, and subsequent bioaccumulation of selenium in simplified laboratory aquatic food chains. Studies on the transfer, bioaccumulation and toxicity of selenium from dietary sources (algal primary producer: Selenastrum capricornutum) to consumers (aquatic invertebrates: Daphnia magna and Chironomus decorus) were conducted. The development of methodology for determining and quantifying the biochemical speciation of selenium in aquatic organisms was initiated, as was a study examining the comparative accumulation of waterborne selenium by bluegill (Lepomis macrochirus) and flathead minnows (Pimiphales promelas).

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB90-132648

PUBLICATIONS:

Davis, E., Maier, K. J., and Knight, A. W., 1988, The biological consequences of selenium in aquatic ecosystems: California Agriculture 42:18-20.

Maier, K. J., Foe, C., Ogle, R. S., Williams, M. J., Knight, A. W., Kiffney, P., and Melton, L. A., 1987, The dynamics of selenium in aquatic ecosystems: In Trace Substances in Environmental Health-XXI. Hemphill, D. D. (ed.), University of Missouri, Columbia, MO. p. 361-408.

Maier, K. J., Ogle, R. S., and Knight, A. W., 1988, Selenium in lentic ecosystems: Lake and Reservoir Management. 4(2):155-163.

Ogle, R.S., Maier, K. J., Kiffney, P., Williams, M. J., Brasher, A., Melton, L., and Knight, A. W., 1988, Bioaccumulation of selenium in aquatic ecosystems: Lake and Reservoir Management. 4(2):165-173.

Olge, R. S. and Knight, A. W., 1989, Effects of elevated foodborne selenium on the growth and reproduction of the fathead minnow (Pimephales promelas): Archives of Environmental Contamination and Toxicology, 18(6):795-805.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1499

TITLE: Sampling Strategies for Parameter Estimation in Ground-water Quality Management: Theory and Field Validation

PERFORMING ORGANIZATION: University of California at Los Angeles

PRINCIPAL INVESTIGATORS: William W-G. Yeh and Douglas M. Mackay

START: September 16, 1987

FINAL DATE RECEIVED: April 16, 1990

ABSTRACT:

The report is divided into two parts. In Part I, an optimal experimental design algorithm is developed to facilitate the planning and the optimal configuration and scheduling of a ground-water tracer test whose data are to be used to estimate model parameters. A maximal information criterion is used to select among competing designs. A zero-one integer heuristic is used to solve a simplified example for experiment configurations under a given experimental duration. The design considers the installation cost which is a function of location and depth of the observation well as well as the samples themselves. The resulting designs are intuitively reasonable. It was found that a dramatic increase in information can be obtained with an experimental budget increase in a heterogeneous example case. Part II of the report describes a two-well field test conducted to estimate the retardation of organic contaminants during transport in ground water at the Borden site, Ontario, Canada. One inorganic tracer and four organic solutes were injected for a period of 48 hours and their migration towards the extraction well monitored by 3 multi-level wells and 1 partially penetrating monitoring well. The results of this forced gradient field test are analyzed and compared with the results from a previous natural gradient experiment and associated laboratory studies of the aquifer media.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB90-222258

PUBLICATIONS:

Yeh, W. W-G., and Sun, N. Z., 1990, Variational sensitivity analysis, data requirement and parameter identification in a leaky system: Accepted for Publication in Water Resources Research.

Cleveland, T. G., and Yeh, W. W-G., 1989, Sampling strategies for transport parameter identification: Presented at the 1988 AGU Fall Meeting, December 5-9, 1988, San Francisco, California, Transactions, AGU, v. 69 (44), p. 1193, November.

Cleveland, T. G., and Yeh, W. W-G., 1990, Sampling network design for transport parameter identification: Accepted for publication in Journal of Water Resources Planning and Management, ASCE.

Cleveland, T. G., and Yeh, W. W-G., 1990, Optimal configuration and scheduling of a groundwater tracer test: Accepted for publication in Journal of Water Resources Planning and Management, ASCE.

Mackay, D., Bianchi, G., Kianajah, H., Thorbjarnarson, K., and Kopania, A., 1990, Comparison of methods to estimate mobility of organic contaminants in groundwater: UCLA Environmental Science and Engineering Technical Report No. 90-68.

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1500

TITLE: Development of an Expert System Embedding Pattern Recognition Techniques for Groundwater Pollution Source Identification

PERFORMING ORGANIZATION: University of California

PRINCIPAL INVESTIGATOR: G. T. Orlob

START: September 1987

FINAL DATE RECEIVED: March 1990

ABSTRACT:

A new methodology for the identification of unknown sources of groundwater pollution is developed. This new methodology is based on the concept of statistical pattern recognition. The statistical pattern recognition algorithm uses Bayes' Optimal Decision Rule. The function of the pattern recognition system is to statistically match an observed set of concentrations in the field with a comparable set obtained by simulating ground-water transport for various disposal conditions. In order to make the application of this methodology easier, an Expert System was developed. This Expert Systems uses the results obtained by applying the pattern recognition algorithm to select a particular set of pollution source locations and magnitudes. The Expert System also has the capability of adding measures of confidence to alternative selections of sources made by the pattern recognition system, such that these solutions can be ranked according to the subjective confidences supplied by the users. The performance of the pattern recognition system and the Expert System was evaluated for a selected study area.

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ORDER NUMBER: PB90-185927

COMPLETED PROJECT

GRANT NUMBER: 14-08-0001-G1538

TITLE: The Water Transfer Process as a Management Option for Meeting Changing Water Demands

PERFORMING ORGANIZATION: University of Colorado

PRINCIPAL INVESTIGATOR: Lawrence J. MacDonnell

START: September 1987

FINAL DATE RECEIVED: August 1990

ABSTRACT:

The West is in transition from an era of water supply development to a period of reallocation of a portion of the developed supplies to new uses. One important allocation option is the use of water transfers--transactions involving a voluntary change in the purpose and/or place of use of water under an existing water use entitlement. This study examines the water transfer law and experience in six western states: Arizona, California, Colorado, New Mexico, Utah, and Wyoming. Volume one provides a general summary of the findings from the study. It includes economic and demographic comparisons among the states, including comparisons in water use. It provides a comparative analysis of the level and types of transfers in the study states based on an analysis of all applications for water transfers submitted for state review between 1975 and 1984. It also offers general recommendations for facilitating water transfers. Volume two contains the detailed findings from the individual state studies. Included are analyses of the laws and procedures governing water transfers in the states as well as the transfer activity during the study period. Conclusions and recommendations specific to each state are presented.

OBTAINABLE FROM: National Technical Information Service
Order Department
Springfield, Virginia 22161
U.S.A.

ORDER NUMBER: PB90-274168

PUBLICATIONS:

Woodward, G., and Checchio, E., 1989, The legal framework for water transfers in Arizona: Arizona Law Review, v. 31, p. 721-744.

Gray, B., 1989, A primer on California water transfer law: Arizona Law Review, v. 31, p. 745-782.

MacDonnell, L., 1989, Changing uses of water in Colorado: law and policy: Arizona Law Review, v. 31, p. 783-816.

DuMars, C., and Minnis, M., 1989, New Mexico water law: determining public welfare values in water rights allocation: Arizona Law Review, v. 31, p. 817-840.

Davis, R. J., 1989, Utah water rights transfer: Arizona Law Review, v. 31, p. 841-864.

Squillace, M., 1989, Water marketing in Wyoming: Arizona Law Review, v. 31, p. 865-904.

MacDonnell, L., 1990, Transferring the uses of water in the West: Oklahoma Law Review, v. 43, p. 1-23.